BOARD OF WATER SUPPLY

CITY AND COUNTY OF HONOLULU
630 SOUTH BERETANIA STREET
HONOLULU, HI 96843
www.boardofwatersupply.com

October 7, 2019

Mr. Omer Shalev
EPA Red Hill Project Coordinator
United States Environmental Protection Agency
Region IX
75 Hawthorne Street
San Francisco, California 94105

and

Ms. Roxanne Kwan
Solid and Hazardous Waste Branch
State of Hawaii
Department of Health
2827 Waimano Home Road
Pearl City, Hawaii 96782

Dear Mr. Shalev and Ms. Kwan:

Subject: Honolulu Board of Water Supply Comments on Navy's "AOC SOW Section 5 Corrosion and Metal Fatigue Practices, Destructive Testing Results Report" dated July 7, 2019 and IMR's Report "Destructive Analysis of 10 Steel Coupons Removed from Red Hill Fuel Storage Tank #14" dated December 17, 2018

The Honolulu Board of Water Supply (BWS) offers the following comments on above-referenced reports. In accordance with the requirements of the Administrative Order on Consent (AOC) Statement of Work (SOW), the Navy commissioned destructive testing (DT) on Red Hill Bulk Fuel Storage Facility (RHBFSF) Tank 14. The testing included removal of ten steel liner samples (commonly referred to as "coupons") with "the primary aim of validating" non-destructive examination (NDE) results through third party laboratory testing (Navy, 2019a). IMR Test Labs (IMR) performed the DT and issued a report on December 17, 2018 (IMR, 2018), which it revised and resubmitted on June 3, 2019 as Revision 2 (IMR, 2019). The Naval Facilities Engineering Command (NAVFAC) issued a summary DT report on July 1, 2019 that included the IMR Report Revision 2 as an appendix. In this letter you will find our general remarks followed by detailed comments addressing these documents.

Please note that BWS has submitted letters to the United States Environmental Protection Agency (EPA) and Hawaii Department of Health (DOH) (collectively, "Regulatory Agencies") in the past that commented on other deliverables submitted by the Navy under RHBFSF AOC Section 5 (Lau, 2017a; Lau, 2017b; Lau, 2017c; Lau, 2017d; Lau, 2017e; Lau, 2017f; Lau, 2017g; Lau, 2017h; Lau, 2018a; Lau, 2018b; Lau, 2019a; and Lau 2019b). We are referencing these past letters as they provide context and historical perspective to our comments contained herein.

General Comments on NDE and DT

The BWS has reviewed the IMR reports (IMR, 2018; and IMR, 2019) and the Navy's DT report (Navy, 2019a) describing IMR's laboratory testing, and has itself evaluated how the DT findings compare with results of *in situ* NDE testing prior to coupon removal. This comparison is critical because backside corrosion represents a significant leak hazard in single-walled underground storage tanks with steel liners. Inspection methods to detect backside corrosion must be accurate and reliable to ensure that all locations of deep corrosion that could progress to through-wall are identified and repaired. In larger tanks such as those at the RHBFSF, more area must be checked for corrosion and, therefore, higher inspection accuracy and reliability is required to achieve the same assurance that no areas of significant corrosion will be missed. The Navy's current inspection and repair process depends on its ability to reliably detect backside corrosion-thinned areas using NDE from the inside face of the liner. The BWS has expressed, and continues to express, concerns about the Navy's ability to accurately and reliably find and repair these locations. Nothing in the IMR reports or the Navy's DT report alleviates the BWS' concerns regarding the accuracy and reliability of the Navy's NDE practices.

Moisture trapped between the outside face of the RHBFSF underground storage tanks' steel liner and concrete shell causes corrosion to form on the backside of the liner, and that corrosion progresses inward with time. Because this concealed corrosion can be neither directly observed nor prevented, the Navy's maintenance of the RHBFSF tanks is instead reliant upon being able to detect this corrosion damage indirectly using NDE methods and weld new plates over the compromised portions of the liner before the corrosion can grow through the tank wall. The nature of the RHBFSF tanks' construction and the fact that these single walled, underground tanks have already suffered and will continue to be subjected to ongoing corrosion damage amplify the importance of reliable NDE in light of the following:

- Corrosion is progressing from the backside of the steel liners, which cannot be visually inspected;
- RHBFSF tanks' 75-year-old steel liners have no corrosion protection on the backside surface; in certain locations the steel is adhered to the surrounding concrete and in other locations there are documented gaps where water can collect;
- RHBFSF tanks' ¼-inch steel liners have previously experienced through-wall penetration by corrosion; and,
- RHBFSF tanks' steel liners are the sole barriers against fuel escaping into the environment, as it has been demonstrated during previous leak events that the surrounding concrete cannot provide reliable secondary containment.

The Navy's NDE and DT direct comparison work has confirmed the BWS' concern that the Navy cannot reliably and accurately find all areas of tank wall thinning that need repair. Not only has the Navy failed to establish that its NDE techniques are sufficiently reliable, its own laboratory testing proves that the scanning is inaccurate. For instance, four of the ten coupons were determined by DT to have been thinned by corrosion to the point that repair is required (i.e., a remaining wall thickness of less than 0.160 inches) but the Navy's NDE prior to coupon removal only identified two of these locations as needing repair. In addition, the Navy's NDE identified three areas for repair which, in fact, did not need repair based on the DT results. These misidentified areas demonstrate the inaccuracy of the Navy's NDE process. Statistical analysis of the NDE versus DT results further demonstrates the extent to which the Navy is likely to miss locations in the RHBFSF tanks that should be repaired. The increased risk of fuel release associated with not properly identifying locations of significant backside corrosion has not been acknowledged by the Navy and, consequently, is not being adequately addressed.

A brief summary of BWS' more detailed findings regarding the Navy's NDE and DT efforts as part of Section 5 of the AOC process are as follows:

- Data and analysis indicate that both NDE techniques used to find areas of the RHBFSF tanks in need of repair are highly unreliable;
- The Navy has not sufficiently evaluated the Balanced-Field Electromagnetic Testing (BFET) technique specifically used for weld inspection;
- Data and analysis did not provide adequate information regarding the condition of the surrounding concrete, the condition of the reinforcing steel in the concrete, or the ability of the surrounding concrete to contain fuel leaked through the liner; and
- Data and analysis did not provide any reliable information regarding the corrosion rate that is used to determine the threshold minimum thickness for steel liner repair.

The Navy's DT work under AOC Section 5 reinforces the BWS' belief that the only reliable way to prevent fuel from entering the environment at the RHBFSF is to adopt a tank upgrade alternative (TUA) that either moves the RHBFSF tanks to a location not over our sole-source aquifer or upgrades them with secondary containment.

<u>Background on The Navy's NDE Validation Plan</u>

The Navy uses multiple NDE techniques that are designed to inspect 100% of the ¼-inch thick steel liners in the tanks. The Navy relies on the techniques to identify flaws or deterioration (corrosion-induced plate thinning, weld defects, cracks, gouges, etc.) that could grow into through-wall defects within 20 years, which would be the next scheduled inspection. The first technique used is Low Frequency Electromagnetic Technique (LFET), which is the initial step to determine the presence of backside corrosion (both general wall-thinning and pitting corrosion). LFET is used to scan the entire inside surface of each tank (the Navy's designated "screening" step). The second technique used is Phased Array Ultrasonic Testing (PAUT), which provides spot-checks to the areas identified during the screening step (the Navy's designated "prove-up" step).The Navy has set the action limit for corrosion repair at 0.09-inch corrosion or defect depth, corresponding to 0.160 inches of remaining steel liner thickness of the original (nominal) 0.25-inch thickness. If the prove-up step does not agree with the screening step, the Navy relies on the prove-up data since it is allegedly more accurate. In contrast and more concerning is that areas that are not identified as problematic during the screening step are not subject to any further evaluation. Therefore, if the screening step misses an area, the prove-up step is never performed.

In order to validate the accuracy and reliability of the various NDE techniques, and in accordance with AOC SOW Section 5.3, the Navy needed to perform destructive testing in at least one of the RHBFSF tanks:

> *"**5.3 Destructive Testing***
> *The purpose of the deliverables to be developed and work to be performed under this Section is to verify the findings of the Corrosion and Metal Fatigue Practices Report through the use of destructive testing on at least one tank at the Facility."*
> (AOC SOW, 2015)

The Navy ultimately performed the DT on Tank 14 by removing ten approximately one-square-foot areas (coupons) cut from the ¼-inch tank liner. These coupons were then sent to IMR, the laboratory the Navy used to characterize the depth of corrosion and flaws found by the Navy's NDE inspectors. This analysis is described as DT because the coupons need to be cut up in order to expose the minimum remaining wall in the plate.

Because the validity of the NDE verification process is dependent upon the methods used to select the specific tank and the portions thereof tested, it is critical to understand how the Navy approached this process. The following is a summary of the Navy's statements and discussions leading up to the selection of these ten coupons.

<u>**The Navy's 2016 DT SOW Drafts**</u>

In 2016, the Navy prepared at least two drafts of its DT SOW for discussion purposes, one on September 9, 2016 (Navy, 2016a) and another on December 23, 2016 (Navy, 2016c). The final DT SOW was issued on May 30, 2017 (Navy, 2017a).

In the September 9, 2016 DT SOW draft for discussion, it was stated that:

> *"Removal of 5 coupons is planned. Locations for selection of coupons for testing will be based on data from previous visual and NDE inspections of the tanks for selection of target areas based on reported reductions in wall thickness, corrosion, and cracking."* (Navy, 2016a)

The locations for the five proposed coupons were generally as follows: (a) one from the upper dome; (b) two from the barrel (i.e., the tank vertical walls); (c) one from the lower dome sloped area; and (d) one from the lower dome bottom plate. Further, at this time in 2016, Tank 17 was the Navy's proposed tank.

In the December 23, 2016 DT SOW draft for discussion, more details were provided regarding the Navy's plan. The Navy specifically started defining the goals and desired outcomes:

- ***Validate the results of Non-destructive examination (NDE) inspection technologies***
- *Characterize steel material*
- *Record observations/chemical characteristics of the concrete behind the liner*
- *Analyze corrosion rate calculation procedures and recommend improvements as warranted*
- *Evaluate results against current corrosion mitigation practices and recommendations for modifications/improvements to tank inspection, repair, and maintenance (TIRM) procedures and tank upgrade alternatives (TUA).* (Navy, 2016c) (emphasis added).

However, later in the document, it was stated that:

> *"As previously indicated, the* ***Navy desires to minimize the amount of destructive testing*** *on operational fuel storage tanks required to meet the requirements of the AOC."* (Navy, 2016c) (emphasis added).

To be consistent with both the letter and spirit of the AOC, the goal of the DT work should not have been to minimize the amount of testing, but rather to definitively determine whether the Navy's NDE methods are accurate and reliable for the damage mechanisms that it is assessing. If the Navy did not feel confident that it could achieve that with an operational tank, it should have pursued other options. Nevertheless, at this point the Navy was willing to increase the number of coupons to twelve from the originally proposed limited number of five:

> *"Removal of at least five but no more than 12 coupons is planned. The size of the coupons will be 2 feet by 2 feet and will include a variety of characteristics* ***(i.e. steel plate with internal/backside flaws, steel plate without flaws, and welded areas).****"* (Navy, 2016c) (emphasis added).

These proposed coupons were four times larger than the ones ultimately removed from the tanks. Even if the larger coupons were used, it would be extremely difficult to provide enough data from twelve coupons for a full statistical analysis given the range of techniques and damage mechanisms that the Navy was trying to assess. The Navy knew this as evident from its statement:

> *"Due to the huge surface area presented by the steel tank liner, acquiring sufficient number of samples for worthwhile statistical analysis of a particular tank's status and behavior with respect to corrosion (and fatigue) would be an inordinate task.*
>
> *...*
>
> *Clearly for the Red Hill Tanks, determination of the number and size of coupons must include good engineering judgement in combination with statistical methods to provide sufficient data for the planned statistical analysis."* (Navy, 2016c)

Given the limited number of coupons for DT, *any* discrepancies or misidentifications found must be considered significant. As discussed below, the Navy's attempt to dismiss the misidentifications on a case-by-case basis is not justified. Such discrepancies and misidentifications demonstrate that the NDE methods are not reliable.

It appears that the Navy also initially recognized the significance of such discrepancies and anticipated more coupon sampling would be required if the DT work did not validate the NDE. In the December 2016 draft DT SOW for discussion, the Navy stated:

> *"If more than five samples exhibit significant difference to the findings of the NDE, take five additional coupons from another tank (either Red Hill or a similar AST of approximately the same vintage) scheduled for inspection and repair."* (Navy, 2016c)

It is highly noteworthy that that DT did not support the NDE conclusions for five of the ten coupons tested. While the BWS believes that more samples would be required to fully and accurately quantify the inaccuracy of the Navy's NDE process, the high failure rate with this small number of coupons clearly establishes that the Navy's NDE process is not accurate and reliable. Clearly the Navy's DT results cannot be used as a basis for validating its NDE process or supporting a position that the single-walled RHBFSF tanks should remain above our sole-source aquifer.

The Navy's 2017 Final DT SOW

The Navy submitted its formal DT SOW on May 30, 2017 which reiterated the Navy's goal to validate the results of NDE using minimum testing on operational tanks (Navy, 2017a).

As of the Navy's 2017 DT SOW, the tank to be sampled had not been decided. Several tanks were proposed, one of which was Tank 14 and it was ultimately selected. The Navy stated:

> *"The two tanks are proposed based upon operational schedule and AOC-SOW Section 5.3 timeline, not on representative condition. The AOC-SOW Section 5.3 scope of work is to validate the non-destructive evaluation (NDE) technology, not the representative condition of the tank."* (Navy, 2017a)

While the Navy's desire to minimize disruption of operations is understandable, this desire should not be allowed to prevail over the need to characterize the accuracy of the various NDE techniques the Navy uses in its inspection and repair procedures. The BWS does not agree with the concept that the validity of the NDE technology can be assessed without consideration of the condition of the tank selected. This is an important issue as Tank 14 may not be representative of the nature and extent of defects in the steel liner of other RHBFSF tanks. The Navy has not provided any basis to establish that Tank 14 is representative of the other tanks with respect to defect type, distribution, and/or depth. Factors such as differences in the order of tank construction, local geology (lava tubes, drainage, etc.), previous inspection and repairs, welder qualifications and training, and other factors may make Tank 14 non-representative and, therefore, extrapolating the NDE-DT comparisons to other RHBFSF tanks may underestimate the potential for corrosion in other locations if those tanks have issues not present at Tank 14. Further, and as an example, if Tank 14 did not have any weld defects then there would be no validation for the ability of the Navy's NDE method to detect weld defects even though the defects might be present in other tanks.

The Navy's 2017 DT SOW refined the number of coupons and size of the coupons:

> *"Removal of at least five (5) but no more than 12 coupons is planned. The size of the coupons may be as large as 12 inches by 12 inches and will be selected **to include**, as much as practicable, **multiple indications of backside thinning, back side pitting, and linear indication flaws**."* (Navy, 2017a) (emphasis added).

The final coupons extracted from Tank 14 were indeed 12-inches by 12-inches, representing just a quarter of the area proposed in the earlier draft DT SOW documents, which indicated 24-inches by 24-inches (2-feet by 2-feet). Presumably to ensure a broad range of conditions were tested, the coupons were to include instances of backside thinning, backside pitting, and linear indication flaws. Linear indication flaws are likely associated with weld defects and should be detected with the Navy's BFET NDE technique. However, the December 2016 DT DOW draft for discussion indicated that "*steel plate with internal/backside flaws, steel plate without flaws, and welded areas*" would be included in the coupons. As evident from the final coupon selection that occurred in June 2018, no linear indication flaws were extracted. In fact, only one coupon contained an actual plate weld and it does not appear to have been selected because of the weld, the presence of the weld appears to have been by sheer coincidence. Further, that weld did in-fact contain a linear indication (as shown by the destructive testing) and thus the only weld extracted demonstrated another NDE miss.

The Navy DT SOW describes generally the different NDE methods in use at RHBFSF and the general intent as shown below (Navy, 2017a):

Table 2. Red Hill Tank NDE Process

NDE Inspection Type	Primary NDE Testing	Secondary NDE Testing
Pitting	Low Frequency Electromagnetic Technique	Traditional Ultrasonic Testing Methods
Wall Thinning	Low Frequency Electromagnetic Technique	Traditional Ultrasonic Testing Methods
Welds	Balanced Field Electromagnetic Technique	Shear Wave Ultrasonic Testing or Magnetic Particle Testing

The Navy is using LFET and the PAUT NDE methods to find areas that need repair as a result of either pitting or general corrosion. There is nothing inherently wrong in using these methods to check for wall loss; however, the Navy's DT testing has shown these techniques to be inaccurate and unreliable.

As of the Navy DT SOW, the following coupons were intended to be extracted:

- ***One coupon from the upper dome*** *just above spring line.*
- *Cut-out* ***two to four coupons from the barrel****. Coupons will be from opposite sides of the Barrel, with at least one taken from the upper part of the Barrel and one from the lower part. The lower coupon shall be taken from just above a horizontal butt welded joint between the 19.6' x 5.0' shell plates.*
- *Cut-out* ***one or two coupons from the lower dome****. Coupons are to be taken from the sloping plate in the second course up from the flat bottom plate just above a horizontal butt welded joint.*
- *Cut-out* ***one coupon from the lower dome*** *(½"* ***bottom plate****.)*
- *Cut-out* ***up to four additional coupons at random locations based on the LFET or BFET scans****.*

The Navy, however, did not follow its commitment in the DT SOW and instead selected a much less diverse range of coupons that are unlikely to be representative of the potential conditions within Tank 14 much less the conditions of all the tanks at the RHBFSF. Ultimately, the Navy extracted eight coupons from the tank barrel (i.e., the vertical walls), one from just inside the upper dome, and one from sloped section of the lower dome; shown below for the locations marked in green. The locations marked in red were identified as possible coupon locations but were not extracted. The BWS is not aware of any random locations selected based on the BFET scans specifically to assess the welds. The Navy's description of the NDE result at these coupon locations do not discuss the BFET result at all. Further, the BWS is not aware of any coupons extracted from the lower dome bottom plate.

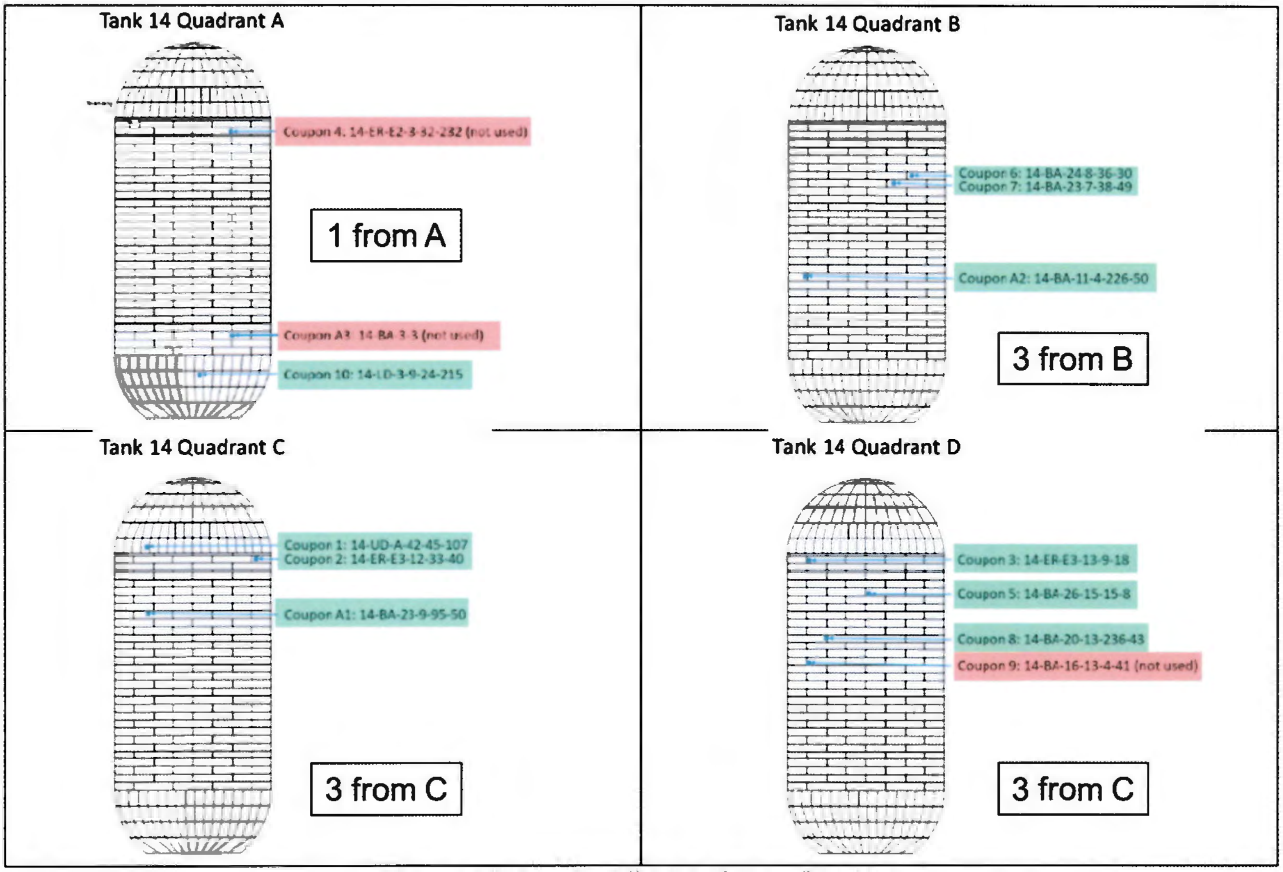

Figure 2-1 Schematic of Tank 14 Coupon Locations

Regulators' 2017 Conditional Approval of the Navy's DT SOW

On July 7, 2017, the Navy was granted conditional approval of its DT SOW. As part of the preamble to the conditions of approval, the Regulatory Agencies stated:

> *"To maximize the effectiveness of this validation, the Regulatory Agencies* ***seek full transparency in its testing, planning, design and implementation****, and suggest* ***the Navy and DLA provide transparency to external subject matter experts*** *as well."* (EPA and DOH, 2017) (emphasis added).

The approval required:

> *"2. … The Regulatory Agencies and external subject matter experts shall be given an opportunity to participate in the review of the NDE strategy, plans, data acquisition and the selection of locations and configuration for coupon sampling."* (EPA and DOH, 2017)

The BWS notes that it still has not had the opportunity to review the past NDE data for the tank that was ultimately used for selecting the coupons to comprise the DT work. For example, the associated American Petroleum Institute (API) inspection report for Tank 14 still has not been made available. However, we understand that the Navy chose the coupon sample areas such that some coupons would exhibit flaws or deterioration, and some would not.

The Navy's NDE Plan

In October 2017, the Navy drafted a NDE plan outline for the RHBFSF tanks being inspected. In the heavily redacted plan made available to external subject matter experts such as BWS, the Navy elaborated on several of the NDE methods that would be utilized. Details for the TesTex devices and methods used in the past for the RHBFSF tanks were expanded upon because the plan was to use them again. Specifically, the Navy proposed to use the TesTex TS-2000 and Falcon Mark II 2000 LFET along with the Hawkeye 2000 system BFET device. The Navy made several claims about these devices.

The LFET devices were purported to be capable of:

> [Falcom Mark II 2000] *"detect[ing] metal plate surface crack, back-side corrosion, and as little as 5% wall thinning. …100% POD at 25% wall loss on defects such as isolated pitting at a 3:1 aspect ratio."*
>
> [TS-2000] *"…sensors have diameters of only a few millimeters, tiny defects like pits can be detected, and scanning in general is in high resolution. … measure small gradual wall losses on the order of 10%, pits of diameter 0.062" (1.57mm), and vibration/fret wear of five volume percent" (Navy, 2017b)*

The BFET method was purported to be capable of:

> [Hawkeye 2000] *"…detect[ing] flaws on and immediately below the surfaces of welds. … In one pass, it can assess both sides of a butt weld… Features it can detect include porosity, slag, undercuts, and cracks. As for cracks in particular, they can be found up to 3 mm or 0.125 inch deep from the surface of carbon steel."* (Navy, 2017b)

The BWS understands that these devices were to be used for the NDE of Tank 14 prior to the DT work but the BWS has never seen any test results or documentation regarding the specific NDE instruments used.

The Navy's DT Plan

On June 1, 2018, the Navy issued its DT Plan. The plan detailed all of the steps that were going to be taken for the DT work and identified the areas from which the coupons were going to be extracted. The Navy re-iterated that a goal and desired outcome was to:

> *"Validate the results of Non-destructive examination (NDE) inspection technologies, specifically the NDE process used at Red Hill."* (Navy, 2018a).

However, the Navy at this point began to start qualifying the extent to which the equipment was going to be validated. Specifically, the Navy claimed that:

> *"Accuracy of detecting defects below the established screening criteria is less of a concern, as they are not expected to cause integrity issues before the next tank inspection based upon current, conservative corrosion rate calculation methodology."* (Navy, 2018a).

The screening criteria was 160 mils (0.160-inches) because that was the actionable wall thickness set by the Navy. Meaning, any area thinner than 160 mils needed to be repaired and any area thicker than that could be left in service. Significantly, the DT work ultimately showed that the Navy's NDE missed two of the four areas that required repair. The Navy's screening step (LFET) identified these two areas as possibly needing repair, but the Navy's prove-up step (PAUT) cleared them as being satisfactory. The DT work showed that the two areas needed repair.

The coupons for DT were selected as a result of discussion with Regulators' and certain subject matter experts:

> *"The Navy provided EPA and DOH a spreadsheet documenting the scan results from the clean, inspect and repair contract for Red Hill tank 14. These scan results provide the basis for coupon selection.* ***The final EPA/DOH approved coupon selection locations are provided in Table 1.****"* (Navy, 2018a) (emphasis added).

Further, the BWS understands that:

> *"Selection of coupon locations was* ***based on scanning data from LFET, PAUT and BFET inspections of the tank. Target areas based on*** *reported* ***reductions in wall thickness, pitting****, and* ***weld defects*** *were chosen to provide a representative sampling."*
>
> ...
>
> *"Therefore coupons were selected strategically to characterize the tank and the various NDE findings. With input from Regulators and SMEs,* ***coupons with isolated pitting, general corrosion, pitting with general corrosion, and no identified corrosion were selected.****"*
>
> ...
>
> ***"In addition coupons were selected to include areas of where no defect was indicated.****"* (Navy, 2018a) (emphasis added).

Although BFET results were purportedly part of the consideration for coupon selection, the BWS is not aware of any coupons having been intentionally selected due to a weld indication. Only one coupon actually contained a plate-to-plate weld and it showed a clear linear weld defect of the shape and size that BFET should have identified. The Navy did not address this in its final report, but, rather downplayed how it validated the BFET results when the only weld extracted contained a missed linear indication. Further, the IMR lab that performed the DT analysis was specifically not analyzing the welds when the Navy's DT Plan indicated that it should have been:

> [Navy DT Plan] *"Analyzing coupons quantitatively to validate NDE process for detecting areas without indications of: ... Non-full-penetration welds, welding discontinuities, and welding defects, including corrosion on welds."*
>
> [IMR] *"A full weld evaluation is outside the scope of this effort. The results are thus provided for information only."* (Navy, 2018a)

Finally, the Navy's DT Plan indicated that:

> *"4.3.1 NDE Validation Meets Criteria*
> *If the validation meets the accepted criteria, then the Navy will produce the Destructive Testing Results Report with no further action required.*
>
> *4.3.2 NDE Validation Does Not Meet Criteria*
> ***If the NDE validation criteria are not met, possible causes will be evaluated with input from regulators and SMEs.*** *Requirements for additional testing and the path forward will be evaluated. Possible actions could include obtaining additional coupons from representative plate material. The Destructive Testing Results Report will document any further actions as deemed necessary."* (Navy, 2018a) (emphasis added).

As will be discussed in the remainder of this letter, the DT work did not validate the NDE methods. The DT clearly showed that BWS concerns expressed since the beginning of the AOC process are valid and that the current NDE methods are insufficient for ensuring the tank integrity. The Regulatory Agencies should reject the Navy's attempt to justify the NDE inaccuracies on a case-by-case basis and require the Navy to redo the DT testing in accordance with its original SOW given that:

- The LFET screening method did not find all instances of corrosion.
- The PAUT prove-up method did not confirm the instances of corrosion and did not have an accuracy within 20 mils.
- The BFET method for weld assessment did not accurately identify linear indications and surface breaking flaws, as shown by the one coupon with a weld.
- The DT work demonstrates that the NDE methods are neither highly accurate nor highly reliable as described in the Navy's DT Plan.

<u>The Navy's DT Coupon Removal from Tank 14</u>

In June 2018, the ten steel coupons were removed from Tank 14, so that a metallurgical and corrosion analysis of the coupons could be undertaken, <u>with the primary aim of validating NDE results</u> (Navy, 2018a). As part of this, the Navy stated that a quantitative validation was to be performed based on the following:

- Backside Pitting. Prove-up measurement (pit depth) within 20 mils of actual laboratory results.

- Wall Thinning. Prove-up measurement within 5% of actual laboratory results.
- Welds. (If any identified) Detecting a surface-breaking crack with minimum width dimension of 0.025 inch. (Navy, 2018a)

Although these were the Navy's stated goals, the BWS believes that both PAUT (prove-up) and LFET (screening) should be able to demonstrate accuracy within 20 mils of actual flaw depth (as proposed by the Navy for PAUT validation) since LFET is the technique used to locate corrosion and defects, while PAUT is only intended to verify the LFET results once the defects are identified.

Furthermore, the Navy preformed CT scans (computed tomography x-ray scanning) on the 10 coupons presumably to determine the precise location of the thinnest portions on each coupon such that the metallography specimens could be cut from these locations to validate the NDE results. Neither the Navy nor the IMR reports discuss or describe how the CT scans were used to determine where the metallographic coupons should be taken. Nevertheless, BWS analysis of these scans indicate less than optimal conditions were used for the CT scanning. This could be due to a variety of factors such as a shifting coupon during the scanning. Since the Navy states "*obtaining additional data through more destructive testing does not justify the added investment in terms of time and funding*" the BWS asks that the Regulatory Agencies direct the Navy to provide the metallography specimens and coupon plate remnants such that an independent CT and metallographic analysis can be made.

Finally, although the BWS has previously expressed concern that this sample size (ten coupons) is too small to accurately quantify the reliability and accuracy of the various NDE techniques, the discrepancy between NDE and DT on this small sample clearly indicate the Navy's NDE technique is not accurate and are not reliable.

Summary Statements in the Navy's DT Report

The BWS does not agree with certain conclusions expressed in the DT report. The Navy's DT summary includes what appear to be misleading, incorrect, and/or imprecise statements regarding the comparison between the NDE and DT results. For instance, the Navy states the metallurgical analysis:

> *"[V]alidated NDE results in terms of presence or absence of indications for repair"*
>
> and
>
> *"Sufficient confidence can be placed in the NDE processes which could result in metal loss below the minimum threshold before the next inspection interval"* (Navy, 2019a).

These statements are incorrect. As discussed in this letter, the Navy's NDE:

- Did not find every area that needed repair;
- Did not identify all areas with backside corrosion occurring;
- Did not reliably establish whether an area needed repair or not;
- Did not achieve the intended thickness measurement accuracy of 20 mils for either the LFET screening step or the PAUT prove-up step; and,

- Did not sufficiently evaluate the NDE techniques used for weld flaws.

Given these results, the BWS disagrees with the Navy's conclusion that there is no need to obtain additional data and believes that without such additional data, the Regulatory Agencies must conclude that NDE is not reliable. The Navy's NDE and DT work establish that the current NDE inspection techniques do not have the required accuracy and reliability to find all (or even a reasonable percentage of) areas of the tank that need repair. Additional DT is not required to further demonstrate that the Navy's current NDE techniques are inaccurate and unreliable, nor could additional DT improve the accuracy or reliability of these methods. Improving the accuracy and reliability of the Navy's NDE process would require investment in other equipment or techniques, including additional DT to validate the accuracy of any new methods. If the Navy cannot demonstrate sufficient accuracy and reliability, then the RHBFSF tanks should be moved to a location not over our sole-source aquifer or upgraded with secondary containment.

NDE Qualitative Assessment

The summary table (Table 1) shows the DT report findings for each coupon regarding the NDE qualitative assessment and the BWS assessment of whether the DT work validates the NDE results. As is evident, on four of the ten coupons (3, 5, 6, and 8), backside corrosion was mischaracterized by NDE and thus the areas were incorrectly assessed, but the Navy did not directly address this unreliability in its report.

Table 1 – Summary of the NDE Qualitative Assessment

Coupon #	Expected Features from NDE[1]	Actual Features from Visual Inspection[1]	Qualitative NDE Validation Achieved?[2]
1	One or more backside-corrosion (BC) pits in central part of coupon	Corrosion on many parts of coupon, mostly on right half. Pitting present	**Yes**.
2	One or more BC pits in most of top half of coupon	Corrosion mostly concentrated in a 2" horizontal band. Pitting present. Portions adhered to concrete.	**Yes**; but more corrosion expected
3	Horizontal plate manufacturing flaw† running through middle of coupon, but no backside corrosion	Visible backside corrosion scattered throughout coupon. Pitting present.	**No**; missed backside corrosion of actionable depth (< 0.160-in remaining wall thickness) likely extends to beyond coupon, no manufacturing flaw

5	Horizontal laminar-type manufacturing flaw† all over coupon, but no BC pits expected	Slight corrosion on several isolated parts of coupon surface. Most of coupon was adhered to concrete.	**No**; missed backside corrosion, no manufacturing flaw
6	No indications, including BC pits thinner than 200 mils, expected	Slight corrosion on several isolated parts of coupon surface. Most of coupon was adhered to concrete. Pitting present.	**No**; missed backside corrosion and a pit of actionable depth (< 0.160-in remaining wall thickness)
7	One or more BC pits expected throughout coupon	Thick corrosion product on about 90% of coupon. Pitting present	**Yes**.
8	At center, an inclusion, or an original manufacturing flaw†, expected, with a minimum thickness of 69 mils	Slight corrosion on about 40% of coupon surface. Pitting present	**No**; missed backside corrosion, no manufacturing flaw.
10	No indications, including BC pits thinner than 200 mils, expected. If any BC is present, it would be general metal loss	No significant metal loss found. Black surface throughout coupon area.	**Yes**.
A1	One or more BC pits expected throughout whole coupon, except for left-most 1"	Concrete adhesion on top 2/3 of coupon; concrete on about 60% of bottom 1/3 of coupon. Pitting present	**Maybe**; corrosion on half of the coupon, not throughout the whole coupon, LFET over-predicted the amount of corrosion.
A2	At center, a thickness greater than 160 mils expected, otherwise, no indications. If any BC is present, it would be general metal loss	On most of coupon, from 1" from the top all the way down, slight corrosion scattered throughout surface, with concrete adhesion as well.	**Yes**.

† Manufacturing or lamination flaw not be expected to be observed on the surface of the metal
[1] Navy Destructive Testing Report (Table 4-1, p. 43, Navy, 2019a)
[2] BWS comment

Source: Site Specific Report. SSR-NAVFAC EXWC-CI-1941. "Red Hill Bulk Fuel Storage Facility Destructive Testing

Results Report, AOC/SOW 5.3.3." July 7, 2019 (Navy, 2019a).

Case-by-Case Justifications

The DT report states:

> *"Therefore, the NDE results are validated, both by DT and thorough, case-by-case analysis" (p. 61, Navy, 2019a).*

This statement is incorrect. The DT work did not confirm all the NDE results on a case-by-case basis. The two NDE methods performed by the Navy in Tank 14, LFET and PAUT, produced estimates that were not significantly correlated with the actual thickness of the coupons. In fact, at times the two NDE methods contradicted each other. For example, LFET screening identified actionable wall loss to Coupon 3 but then PAUT prove-up cleared it, meaning no repair was required. The DT work showed definitively that corrosion was present and that the area did need repair. In this case, LFET screening was correct but the supposedly more accurate PAUT failed to confirm the corrosion. Furthermore, the NDE technique reportedly used for weld inspections, BFET, does not appear to even have been evaluated in this NDE versus DT study.

The DT report also states:

> *"Every coupon area at which the contractor did not recommend repair (Coupons 6, 8, 10, and A2) was found through DT and through additional analysis not to require repair after all" (p. 61, Navy, 2019a).*

Again, this claim is incorrect. Most notably, this statement does not mention that the Navy's NDE was inaccurate with respect to Coupon 3. The Navy tries to minimize missing this repairable location:

> *"Coupon 3 destructive testing showed actionable metal loss whereas the NDE did not identify any in this exact location. ...An actionable indication was found adjacent to where Coupon 3 was cut out. During the follow-on repair process, however, the metal loss at the Coupon 3 location would have been detected" (p. 61, Navy, 2019a).*

This statement is misleading. The location of Coupon 3 needed repair and PAUT was clearly in error. The fact that an adjacent area required repair and that the corrosion under Coupon 3 might have been found through those repair efforts, is irrelevant as the goal of the NDE/DT efforts was to evaluate the accuracy and reliability of the NDE methods for specific coupon areas. The PAUT prove-up step was not only being evaluated against the qualitative findings but also against its quantitative findings. PAUT should have been accurate to within ±20 mils (0.020 inches) of the actual minimum thickness. However, for Coupon 3, PAUT reported a minimum thickness greater than 0.200 inches and the actual minimum thickness was 0.132 inches, an error more than three times larger than the Navy's stated accuracy objective.

In addition, Coupon 6 required repair but its thinned condition was missed by both LFET and PAUT. The DT report attempts to downplay this missed corrosion location as follows:

> *"Coupon 6 showed more metal loss than was predicted by the NDE and was just below the repair threshold. The destructive testing identified this to be a pit of very small volume. The NDE method used (LFET) does not always detect metal losses of very small volume" (p. 61, Navy, 2019a).*

However, the BWS disagrees with both the DT report's characterization of the corrosion pit identified at Coupon 6 and the significance of the inability of the LFET method to identify such a pit. First, both LFET methods as described in the Tank Inspection and Repair, and Maintenance (TIRM) Report (Navy, 2016b) should have detected the pitting found in Coupon 6. From the October 2016 TIRM Report, there were two LFET methods being considered:

1. The larger, TesTex Falcon Mark II 2000 device should have been able to detect the pit in Coupon 6. According to the Navy this device has a probability of detection (POD) of 100% at 25% wall loss on pits with an aspect ratio of 3:1. The deepest pit in Coupon 6 amounted to ~37% wall loss and aspect ratio of greater than 3:1 (width to depth ratio). Figure 1 shows the cross-section through the deepest pit in Coupon 6 where the size and depth of the pit is obvious.
2. The smaller, TesTex TS-2000 device should have been able to detect the pit in Coupon 6 as the Navy stated this device can detect pits with a diameter of 1.57 mm. The width of the corrosion pit in Coupon 6 was much, much wider than 1.57 mm as is shown in Figure 1.

Second, the BWS believes Figure 1 clearly demonstrates this pit cannot be described as a "*pit of very small volume.*" This figure clearly shows a broad pit of considerable volume.

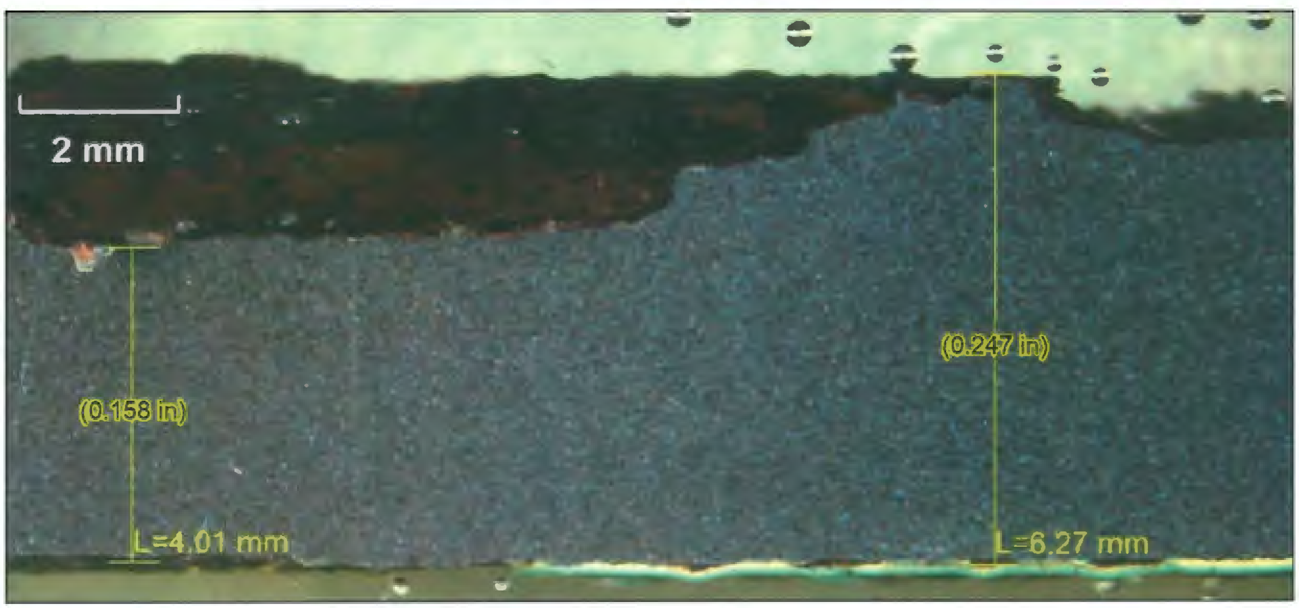

Figure 1 – Destructive Testing Cross-section from Sample 6-1

Source: Site Specific Report. SSR-NAVFAC EXWC-CI-1941. "Red Hill Bulk Fuel Storage Facility Destructive Testing Results Report, AOC/SOW 5.3.3." July 7, 2019 (Navy, 2019a).

Weld Quality

The DT report states:

> *"The NDE results did not find linear indications on any of the welds on the coupons. ... The laboratory findings are consistent with weld examination results for the entirety of Tank 14 in that linear indications were not found" (p. 60, Navy, 2019a).*

The BWS does not believe that there is a reasonable basis for such conclusions. Specifically:

1. The NDE and DT AOC/SOW Section 5 selection process did not have a sufficient number of coupons with welds to allow any meaningful conclusions regarding the ability to detect weld flaws. Only one coupon out of the ten coupons taken, Coupon 8, contained an actual plate-to-plate butt weld. Coupon 10 had an anomalous errant weld deposit, and thus should not be used for the purpose of weld evaluation.
2. The DT lab report from IMR explicitly states that it was not investigating weld quality.
3. The DT report incorrectly asserts that because no weld indications were identified in Tank 14, the welds must be good. This is a false equivalency since if BFET is inaccurate and unreliable, then no weld defects would be found even if they are present. Furthermore, BWS notes again that we do not have either the API inspection report for Tank 14 or the NDE scan data spreadsheet provided to the DOH and EPA regulators over a year ago (Navy, 2018a).
4. The DT inspection <u>did find weld defects</u>. The one coupon that actually had a weld contained a linear defect that was found by destructive testing. This lack of fusion linear weld defect is shown below.

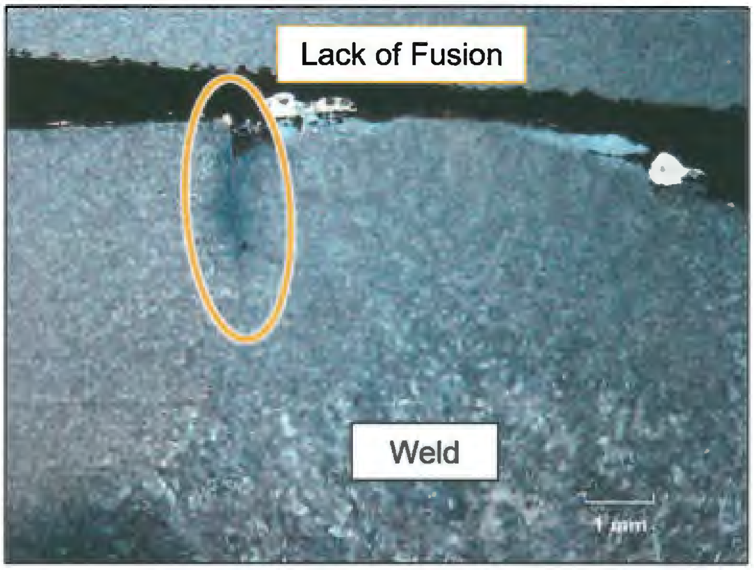

Figure 2 -- (Image from: IMR Test Labs. 2018)

Source: Site Specific Report. SSR-NAVFAC EXWC-CI-1941. "Red Hill Bulk Fuel Storage Facility Destructive Testing Results Report, AOC/SOW 5.3.3." July 7, 2019 (Navy, 2019a).

Corrosion Rates

The DT report states:

> *"The results of the destructive testing validate that the method is conservative. No changes to the corrosion rate assessment are recommended" (p. vi, Navy, 2019a).*

This claim does not appear to be supported by technical analysis and, moreover, it is contradicted by other statements in the report (*see* Navy, 2019a, pp. 52, 59, 60 and 62). For instance, the Navy implies that since corrosion has been occurring over 75 years a low corrosion rate is warranted but, on the other hand, the Navy states that "corrosion cells observed on the Tank 14 coupons could have remained dormant for many years." A shorter time span of active corrosion would significantly increase the corrosion rate over the values the Navy reported. As previously discussed by the BWS, the corrosion rates that occur to the tanks' steel liners are uncertain and the BWS does not believe there is justification to use any corrosion rate lower than about 0.004 inch/year, 4 mils/year, (Lau, 2016).

Further, the Navy has found pitting corrosion in certain areas and knows that pitting corrosion can have higher corrosion rates compared to the bulk uniform corrosion rate. Pitting corrosion is generally faster and less predictable compared to uniform corrosion. The Navy is aware of these aspects as they have previously described pitting as:

> *"Pitting, **a localized form of corrosion**, presents **a higher risk to the integrity of a Red Hill tank** steel liner than wall thinning or metal fatigue. While general external corrosion rates of the liner are low due to the passivating nature of*

> *concrete,* ***a pit caused by corrosion can occur at an accelerated rate.***" (Navy, 2017a) (emphasis added).

Despite this recognition, the Navy seems to minimize pitting corrosion as being a serious mechanism for fuel release. For example, the Navy attempts to minimize the significance of this error since the pit was "*of very small volume.*" Based on the reported LFET accuracy, the pit in question should have been found regardless of the volume. Furthermore, its miss is significant given that pitting corrosion rates can be higher and more variable than uniform corrosion rates and as such represent a risk to the tank integrity.

The DT report further states:

> *"Water moving through the subsurface .... does not affect the reinforced concrete structures because the concrete is high above the groundwater table and the surrounding geology contains many vertical passages for water drainage" (p. 59, Navy, 2019a).*

Nothing in the DT report can be reasonably construed to inform the condition of the concrete shell, the shell reinforcement, or the water/moisture environment at the shell-to-liner interface. The BWS recommended that coring or other destructive examination of the concrete shell be performed at the time the coupons were removed, but the Navy chose not to do such testing.

<u>Prove-Up Data</u>

The DT report provides a table that purports to represent a summary of the NDE and DT findings. This table, reproduced here as Figure 3 with red highlights, misconstrues the findings from PAUT prove-up. For instance, on several coupons the prove-up measurement is listed as "No prove-up" when, in fact, PAUT prove-up did occur. The column in this table is supposed to provide the minimum thickness found by PAUT, but the PAUT prove-up step cannot report a thickness when the value is greater than 0.200 inches. Therefore, just because a precise value was not reported, that does not mean that information about the coupon thickness predicted by the prove-up measurement is not available. For example, Coupon 3 has no prove-up thickness listed when it was reported from the DT plan that:

> *"Prove-up thickness (PAUT): No indication noted, so no repair recommended Horizontal indication at y = 18" believed to be a plate manufacturing flaw; PAUT prove-up determined no repair"* (p. B-4, Navy, 2018a).

PAUT prove-up cleared Coupon 3 when in fact DT indicated that this coupon had a deep defect that should have been found and repaired. Further, for Coupon 3, the Fuel Tank Advisory Committee (FTAC) November 2018 update presentation stated:

> "*Initial Indication:*
>
> - *Screening scan indicates repair is <u>necessary</u>*
> - *Prove-up scan indicates repair is <u>unnecessary</u>*
> - ***Expect lab measurements to validate NDE measurements***" (Slide 23, Navy, 2018b) (emphasis added).

The Navy's expectation was not confirmed by the DT laboratory measurements. The BWS does not believe that DT report Table 2-1 is an accurate depiction of available information, nor does it provide any reasonable basis upon which to consider the Navy's NDE techniques reliable.

Table 2-1 Tank 14 Coupon Locations

#	Row in Master Table	Overall ID	Contractor Repair No.	Region	Course	Plate	X-Coord	Y-Coord	Ind Type	Screening Measurement (in)	Prove-up Measurement (in)	Actual Minimum Thickness (in)
1	2282	14-UD-A-42-45-107	14-UD-A-42-45-107-3	UD	A	42	45	107	BC	0.147	0.112	0.208
2	2892	14-ER-E3-12-33-40	14-ER-E3-12-34-44-5	ER	E3	12	33	40	BC	0.157	0.150	0.152
3	2903	14-ER-E3-13-9-18	14-ER-E3-13-7-5-2	ER	E3	13	0-18	18	BC	0.033	No prove-up	0.131
4	2959	14-ER-E2-3-32-232	14-ER-E2-3-32-232-5	ER	E2	3	32	232	BC	0.110	No prove-up	Not used
5	3706	14-BA-26-15-15-8	14-BA-26-15-28-3-1	BA	26	15	27	8	BC	0.047	No prove-up	0.224
6	N/A	N/A	N/A	BA	24	8	N/A	N/A	N/A	N/A	No prove-up	0.158
7	3944	14-BA-23-7-38-49	14-BA-23-7-32-36-1	BA	23	7	38	49	BC	0.157	0.135	0.164
8	4300	14-BA-20-13-236-43	(No Repair)	BA	20	13	236	43	BC	0.069	0.200	0.206
9	4625	14-BA-17-13-4-41	14-BA-17-13-4-41-1	BA	17	13	4	41	BC	0.037	No prove-up	Not used
10	6492	14-LD-3-9-24-215	(No Repair)	LD	3	9	24	215	BC	0.198	0.200	0.242
A1	3962	14-BA-23-9-95-50	14-BA-23-9-94-53-2	BA	23	9	87-103	45-55	BC	0.134	No prove-up. Weld repair	0.122
A2	5176	14-BA-11-4-226-50	(No Repair)	BA	11	4	226	50	BC	0.161	No prove-up	0.248
A3	N/A	N/A	N/A	BA	3	3	N/A	N/A	N/A	N/A	No prove-up	Not used

Note: Coupons 4 and 9 were not used due to anticipated difficulties in removing them, as explained in the text of Section 2.0, so Coupons A1 and A2 were substituted for them. Coupon A3 was an alternate coupon that was not used.

Figure 3 – Table 2-1 from the DT Report (p. 4, Navy, 2019a).

Source: Site Specific Report. SSR-NAVFAC EXWC-CI-1941. "Red Hill Bulk Fuel Storage Facility Destructive Testing Results Report, AOC/SOW 5.3.3." July 7, 2019 (Navy, 2019a).

BWS Summary Comparison of NDE and DT Results

BWS has taken the information from the Navy's NDE and DT reports and summarized it in the following table. This table shows that of the ten coupons the DT showed that four coupons actually needed repair (Coupons 2, 3, 6, and A1), i.e., 40% of the coupons were in need of repair. However, the Navy's NDE only predicted that two of the four actually needed repair. That is the Navy missed 50% of the coupons in need of repair.

Table 2 – NDE and DT Summary

Coupon #	LFET Min Thickness (in)	PAUT Min Thickness (in)	Would Navy Repair?	Best Est. NDE Min Thickness[a]	DT Actual Min Thickness (in)	Does DT Support Decision?	LFET Error	PAUT Error	LFET Within 20 mils?	PAUT Within 20 mils?
1	0.147	0.112	Yes	0.112	0.208	No	-29%	-46%	No	No
2	0.157	0.150	Yes	0.150	0.152	Yes	3%	-2%	Yes	Yes
3	0.033	NR, >0.200	No	**>0.200**	0.132	No	-75%	**≥ 52%**	No	**No**
5	0.047	NR, <0.160	Yes	**<0.160**	0.224	No	-79%	**≤ -29%**	No	**No**
6	NR, >0.200	NR, >0.200	No	**>0.200**	0.158	No	**58%[b]**	**≥ 27%**	**No**	**No**
7	0.157	0.135	Yes	0.135	0.164	No[c]	-4%	-18%	Yes	No
8	0.069	NR, >0.200	No	**>0.200**	0.206	Yes	-66%	--	No	Maybe
10	0.198	NR, >0.200	No	**>0.200**	0.242	Yes	-18%	--	No	Maybe
A1	0.134	NR, <0.160	Yes	0.134	0.122	Yes	9%	--	Yes	Maybe
A2	0.161	NR, >0.160	No	**>0.160**	0.248	Yes	-35%	--	No	Maybe

NR: not recorded (per 6/1/18 DT Plan)

[a] Where thickness values are given for both screening (LFET) and prove-up (PAUT) we use the prove-up value as presumably it is more accurate. Since PAUT cannot detect plate thickness greater than 0.200-inch plate thickness could be anywhere between 0.200 and 0.250. Where PAUT is only reported as being above or below the repair threshold (i.e., 0.160) we use the LFET value if available, consistent with PAUT, and is not unrealistically small (i.e. Coupon 5).

[b] No indication noted, and no thickness reported, assumed thickness of 0.250 in.

[c] DT showed a minimum wall thickness only 0.004-in larger than the threshold.

Data Source: Site Specific Report. SSR-NAVFAC EXWC-CI-1941. "Red Hill Bulk Fuel Storage Facility Destructive Testing Results Report, AOC/SOW 5.3.3." July 7, 2019 (Navy, 2019a).

We have also plotted the actual minimum plate thickness determined from the DT against the best estimate of the coupon minimum thickness determined prior to the DT, Figure 4. To simplify, we conservatively assume the NDE-measured thickness in censored cases (i.e., the coupons for which thickness is reported as known only to be either greater or less than a specified value) were the specified bounding values. Similar analyses were also done for each NDE method treating those cases as interval-censored, and the results did not change significantly.

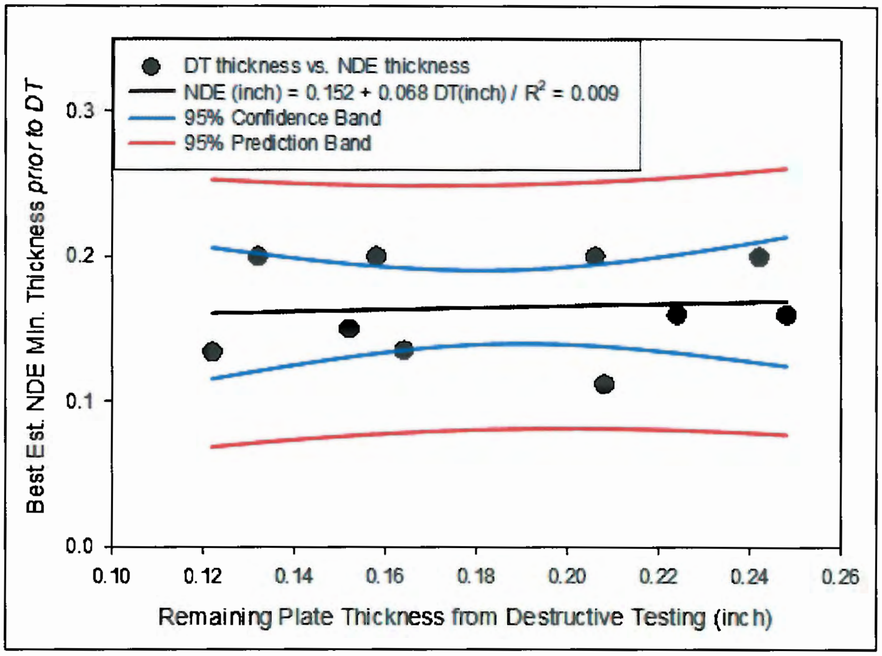

Figure 4 – Relationship between NDE thickness estimate prior to DT and the actual remaining thickness determined from DT.

Figure 4 clearly indicates the NDE techniques are neither accurate nor reliable. First, the slope (0.068) of the line drawn through the DT vs NDE data is very flat (close to zero), indicating the NDE results are essentially insensitive to actual corrosion depth. For comparison, if NDE was perfectly accurate, then the DT thickness would be equal to the NDE thickness and the slope of the line drawn through the data would be 1.0. Instead, the calculated slope is consistent with what one would expect if the NDE results were simply chosen at random without regard to the actual coupon thickness. Another indication is the coefficient of determination (R^2), which measures NDE accuracy by comparing the variation in NDE results to the residual variation after accounting for the actual coupon thickness (using the regression line). As noted in Figure 4, the R^2 value is effectively zero (0.009), indicating none of the observed variation in NDE-measured thickness is attributable to corresponding variation in the actual thickness of the test coupons.

Finally, the figure includes plots of the 95% lower and upper prediction bands, which are very broad. For example, for a coupon with an actual remaining wall thickness of 0.12 inch, with 95% probability the corresponding NDE-measured thickness will fall between 0.070 and 0.25 inch (the values at which the lower and upper bands, respectively, intersect the vertical line at 0.12 inch). The bands vary little over the range of coupon thickness studied. Thus, for any actual tank wall thickness, the NDE-measured thickness can be reasonably expected to range from effectively no damage to severe damage.

A more graphic illustration of the error in the NDE methodology is shown in Figure 5. The image on the left-hand side of Figure 5 shows the extensive backside corrosion on Coupon 3. The right-hand side of Figure 5 shows the plate's reported thinnest area in cross-section after destructively testing. While it is unclear from the DT and IMR reports, this thinned region

(0.131-inch-thick) was presumably located by CT scanning of the entire coupon. The Navy NDE predicted that this area had little to no backside corrosion.

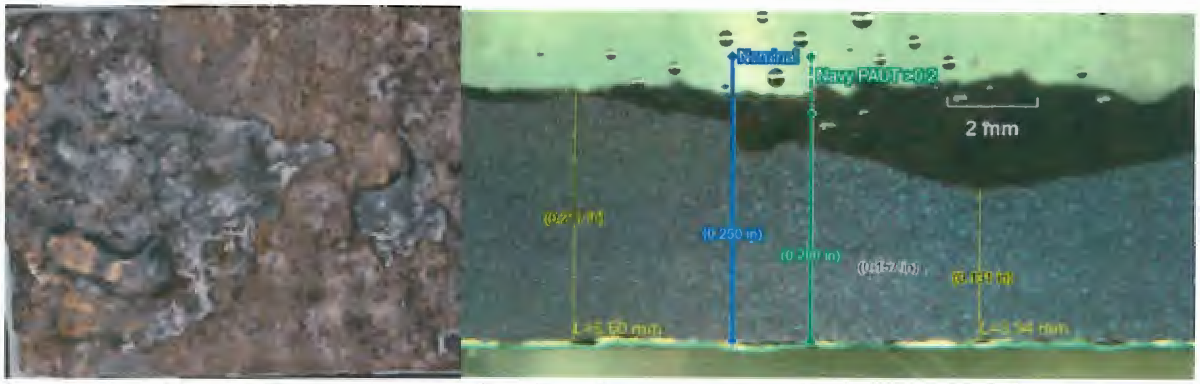

Figure 5 – Destructive Testing Cross-section from Sample 3-3.

Source: Site Specific Report. SSR-NAVFAC EXWC-CI-1941. "Red Hill Bulk Fuel Storage Facility Destructive Testing Results Report, AOC/SOW 5.3.3." July 7, 2019 (Navy, 2019a).

The thin blue-green layer on the bottom of the plate on the right-hand side of Figure 5 is the paint on the fuel wetted side of the steel liner. The blue line shows the full plate thickness of 0.250 inches. The yellow line on the left side is the actual maximum plate thickness which shows 0.217 inches thickness indicating general corrosion thinning and deeper corrosion over the back side of this steel coupon. The green line shows the thickness the PAUT found, i.e., > 0.200 inches (LFET found a remaining wall of 0.033 inches but the supposedly more accurate PAUT indicated the plate was much thicker). The actual minimum thickness found by DT was 0.131-inches as shown by the yellow line on the right side. This variation in the lengths of the colored lines illustrates how large the difference can be between the various NDE inspection techniques and the actual depth of corrosion. In this case, LFET indicated the plate was very thin, the PAUT prove-up indicated little-to-no corrosion, and the DT indicated that this location was sufficiently thinned that repair should have been triggered.

A similar figure was provided for Coupon 6 in Figure 1. The Navy's LFET and PAUT entirely missed the backside corrosion on Coupon 6, but the DT showed the minimum wall to be 0.158 inches thick. That is, DT demonstrated that this location should have been repaired, whereas both the LFET and PAUT NDE techniques indicated that the liner in this area was thicker than 0.200 inches.

The accuracy and reliability of the NDE techniques used to inspect the steel liner of the RHBFSF tanks is of critical importance as the steel liner is the only fuel-tight barrier protecting the environment. The surface area of steel liner and length of the welds to be inspected in each tank are enormous–over 1.3 acres of steel plate and several miles of welds per tank. These expanses of material to be inspected demand a much more accurate process of finding backside corrosion, otherwise many locations requiring repair will be missed. In recent testimony, the Navy reported up to 2% of the tank liners required repair (Navy, 2018c), which translates to about 1,600 square feet (tank surface is 80,000 square feet or 1.8 acres). Given the demonstrated unreliability of the Navy's NDE process (50% rate of correctly identifying areas in need of corrosion repair), the chance of missing a substantial number of corroded areas that should have been repaired is almost certain. This risk to the aquifer is simply unacceptable.

The Section 5 AOC SOW NDE and DT results reinforces BWS' belief that the only reliable way to prevent fuel from entering the environment is to move the RHBFSF tanks to a location not over our sole-source aquifer or to upgrade them with secondary containment.

Further Work on the Coupons

Following the initial issue of IMR on December 17, 2018, the Navy asked IMR to further investigate the corrosion seen on the edge on the remains of Coupon #7. IMR used CO_2 cleaning of the test sample edge. These results are provided in Appendix A of the IMR revised report. Figures A-4 and A-5 of the IMR revised report are included below to show the area of concern. The revised report Appendix A concludes:

1. No pitting was observed, as shown in Figures A-3 and A-4.
2. The rust-colored feature shown in the photographs provided to IMR on March 13, 2019 was a stain on the surface or some other artifact and not a deep pit.
3. The IMR report hypothesizes atmospheric corrosion, corrosive media attack or sectioning heat effects could have caused the observed damage in the area of concern.

BWS disagrees:

1. There was pitting observed as shown in their Figure A-4
2. It is not surprising that corrosion was not found as this area had been sandblasted.
3. The explanation that the area of concern "had been superficially altered by heat associated with sectioning or some other post-sectioning reaction (atmospheric corrosion or corrosive media attack)" is not credible. Atmospheric corrosion would be uniformly distributed along the cut surface, but the area of concern is localized. Secondly, the porosity is not consistent with heat associated with sectioning. Finally, we are unaware of any corrosive media used during coupon removal that could have locally attacked the edge in the area of concern.

Figure A-4. Detail of the sandblasted edge on 3/20/19 in the same location as shown in the picture below. The sandblasting revealed that the feature was not a corrosion pit, as shiny metal was revealed when the red-colored staining was removed. There was an unusual appearance to the edge in this location, as though the sectioned edge had been superficially altered by heat associated with sectioning or some other post-sectioning reaction (atmospheric corrosion or corrosive media attack). That alteration gave the appearance of a deep corrosion pit.

Figure A-5. The same area is shown in an image provided prior to shipping Coupon #7 to IMR (provided to IMR on March 13, 2019). What appeared to be a deep corrosion pit was actually rust-colored staining of the edge surface

Source: Site Specific Report. SSR-NAVFAC EXWC-CI-1941. "Red Hill Bulk Fuel Storage Facility Destructive Testing Results Report, AOC/SOW 5.3.3." July 7, 2019 (Navy, 2019a).

Because the area of concern has not yet been fully investigated, the BWS requests that it (and the other coupons) be made available for independent analyses. At the very least, BWS requests that these coupon remnants and metallographic mounts be preserved for future examination.

Conclusions

In summary, the Navy's NDE and DT efforts, as part of the AOC Section 5 process show:

- NDE techniques used by the Navy to find areas of the RHBFSF tanks in need of repair are highly unreliable;
- NDE techniques used by the Navy qualitatively missed four instances of backside corrosion, two of which required repair;
- PAUT prove-up reported the minimum thickness to be greater 0.200-inch or less than a 0.160-inch threshold value seven times, and three of those assessments were incorrect;
- PAUT prove-up reported precise minimum thickness values three times, and two of those did not achieve the required accuracy of 20 mils;
- Navy does not appear to have sufficiently evaluated the BFET inspection technique required for welds;
- The DT scope was insufficient to inform any of the Navy's statements regarding condition of the concrete shell, the shell reinforcement, or the water/moisture environment at the shell-to-liner interface; and,
- Navy did not provide any reliable information regarding the corrosion rate or justification not to conservatively presume a higher corrosion rate to determine the threshold minimum thickness for steel liner repair.

The Navy's AOC Section 5 SOW efforts reinforce the BWS' belief that the only reliable way to prevent fuel from entering the environment is to relocate the RHBFSF tanks away from our sole-source aquifer or upgrade them with secondary containment.

Thank you for the opportunity to comment. If you have any questions, please contact Mr. Erwin Kawata, Program Administrator of the Water Quality Division, at 808-748- 5080.

Very truly yours,

ERNEST Y.W. LAU, P.E.
Manager and Chief Engineer

CC: Mr. Steve Linder
United States Environmental Protection Agency
Region IX
75 Hawthorne Street
San Francisco, California 94105

References

ABS Group (ABS). 2018. Quantitative Risk and Vulnerability Assessment Phase 1 (Internal Events without Fire and Flooding), Red Hill Bulk Fuel Storage Facility NAVSUP FLC Pearl Harbor, HI. November 12.

Administrative Order on Consent, Attachment A, Statement of Work (AOC SOW). 2015. Administrative Order on Consent In the Matter of Red Hill Bulk Fuel Storage Facility, EPA Docket No: RCRA 7003-R9-2015-01, DOH Docket No: 15-UST-EA-01. United State Environmental Protection Agency Region 9. The Department of Health State of Hawaii. Respondents: The United States Department of the Navy and Defense Logistics Agency. September 15.

Environmental Protection Agency (EPA) and State of Hawaii Department of Health (DOH). 2017. Conditional Approval of Scope of Work for Destructive Testing Dated May 30, 2017 submitted to the Regulatory Agencies Pursuant to Section 5.3.2 of the Red Hill Administrative Order on Consent. July 7.

IMR Test Labs. 2018. Thomas N. Ackerson, P.E. and Jennifer Breetz, "Destructive Analysis of 10 Steel Coupons Removed from Red Hill Fuel Storage Tank #14", Prepared for: Solomon Resources, LLC, Kapolei, HI, Attention: Michelle Mercado, IMR Report No. 201801967. December 17.

IMR Test Labs. 2019. Thomas N. Ackerson, P.E. and Jennifer Breetz, "Destructive Analysis of 10 Steel Coupons Removed from Red Hill Fuel Storage Tank #14", Prepared for: Solomon Resources, LLC, Kapolei, HI, Attention: Michelle Mercado, IMR Report No. 201801967 Revision 2. June 3.

Lau, E. Y. W. (2016).Board of Water Supply (BWS) Comments to the Work Plans Being Developed Under the Red Hill Bulk Fuel Storage Facility Administrative Order on Consent (AOC) Statement of Work (SOW) Sections 2 through 5 and 8, May 27

Lau, E. Y. W. (2017a). Board of Water Supply (BWS) Comments Comments to the Work Plan Being Developed Under the Red Hill Bulk Fuel Storage Facility Administrative Order on Consent (AOC) Statement of Work (SOW) Section 5.3, February 13.

Lau, E. Y. W. (2017b). Board of Water Supply (BWS) Comments Pertaining to the Environmental Protection Agency (EPA) and Hawaii Department of Health (DOH) February 15, 2017 Administrative Order on Consent (AOC) Sections 2, 3, 4, 5 and 8 Meeting, March 9

Lau, E. Y. W. (2017c). Subject: Board of Water Supply (BWS) Comments to the Work Plan Being Developed Under the Red Hill Bulk Fuel Storage Facility Administrative Order on Consent (AOC) Statement of Work (SOW) Section 5.3, Letter to Mr. Bob Pallarino, EPA Red Hill Project Coordinator, Region IX, and Mr. Steven Chang, P.E., DOH Red Hill Project Coordinator, State of Hawaii, Department of Health, Honolulu, Hawaii Dated May 30, 2017, From Board of Water Supply, Honolulu, HI, June 16.

Lau, E. Y. W. (2017d). Board of Water Supply (BWS) Comments to the Conditional Approval of Scope of Work for Destructive Testing Dated May 30, 2017 submitted to the Regulatory Agencies Pursuant to Section 5.3.2 of the Red Hill Administrative Order on Consent (AOC), dated July 7. 2017, Letter to EPA and DOH, July 14.

Lau, E. Y. W. (2017e). EPA Letter Regarding: Revision to Conditional Approval of Scope of Work for Destructive Testing Dated May 30, 2017 Submitted to the Regulatory Agencies Pursuant to Section 5.3.2 of the Red Hill Administrative Order on Consent, Letter to EPA and DOH, October 16.

Lau, E. Y. W. (2017f). Approval of Red Hill Administrative Order on Consent ("AOC") Statement of Work ("SOW") Section 2.4- Tank Inspection, Repair and Maintenance ("TIRM") Procedures Decision Document and Clarifications dated September 5 2017, Letter to EPA and DOH, October 18

Lau, E. Y. W. (2017g). Red Hill Bulk Fuel Storage Facility - Tank Upgrade Alternative Decision Process Document Dated September 29, 2017, Letter to: Mr. Bob Pallarino, EPA Red Hill Project Coordinator and Mr. Steven Chang, DOH Red Hill Project Coordinator, from: Board of Water Supply, Honolulu,` October 19

Lau, E. Y. W. (2017h). Red Hill Bulk Fuel Storage Facility - Red Hill Tanks 14, 17, and 18 Non-Destructive Examination Plan (Redacted) Document Dated October 2017, Letter to Mr. Pallarino (EPA) and Chang (DOH Hawaii), November 9.

Lau, E. Y. W. (2018a). Letter to Mr. Omer Shalev, US EPA, and Ms. Roxanne Kwan, Hawaii Department of Health, Subject: Honolulu Board of Water Supply (BWS) Comments on the Red Hill Bulk Fuel Storage Facility (RHBFSF), Scope of Work for Destructive Testing Supplement - Destructive Testing Plan, Supplement to Administrative Order on Consent (AOC) and Statement of Work (SOW) Section 5.3.2, dated June 1, 2018 and Our Inspection on June 25, 2018 of Coupons Removed from Tank 14, August 20, 2018.

Lau, E. Y. W. 2018b. Letter to Dr. Bruce Anderson, Chair, Fuel Tank Advisory Committee, Department of Health, Honolulu, Hawaii and Ms. Thu Perry, Public Participation Coordinator at Department of Health, Solid & Hazardous Waste Branch., Subject: Honolulu Board of Water Supply (BWS) Comments on draft "Report to the Thirtieth Legislature, State of Hawaii, 2019, Pursuant to Section 342L-62 Hawaii Revised Statutes. The Third Annual Fuel Tank Advisory Committee Meeting to Study the Issues Related to Leaks of Field-Constructed Underground Storage Tanks at Red Hill Bulk Fuel Storage Facility and Four Other DOD Facilities", Prepared By: State of Hawaii, Department of Health (DOH), Underground Storage Tank Section, dated December 2018, December 24, 2018.

Lau, E. Y. W. 2019a. IMR Test Labs Destructive Analysis of ten (10) Steel Coupons Removed from Red Hill Fuel Storage Tank #14, Report No. 201801967, dated December 17, 2018 pursuant to Section 5.3 of the Red Hill Bulk Fuel Storage Facility (RHBFSF) Administrative Order on Consent (AOC) Statement of Work (SOW), Letter to EPA and DOH, March 6.

Lau, E. 2019b. Navy testimony regarding Senate Concurrent Resolution 35, March 20, 2019, by Captain M.K. Delao and the Navy's Destructive Testing Report, Letter to DOH and EPA, March 29.

Department of the Navy (Navy). 2016a. "General Direct Assessment Statement of Work Talking Points, Section 5.3.1 – Scoping Meetings for Destructive Testing. September 9.

Department of the Navy (Navy). 2016b. "Red Hill Facility Tank Inspection, Repair, and Maintenance Report, Administrative Order on Consent (AOC) Statement of Work (SOW), Section 2.2, Site Specific Report SSR-NAVFAC EXWC-CI-1655, October 11.

Department of the Navy (Navy). 2016c. "General Destructive Testing Statement of Work." December 23.

Department of the Navy (Navy). 2017a. Red Hill Administrative Order on Consent, Attacment A Scope of Work Deliverable. Section 5.3.2 Scope of Work for Destructive Testing. Red Hill Bulk Fuel Storage Facility. May 30.

Department of the Navy (Navy). 2017b. "Red Hill Tanks 14, 17, and 18 Non-Destructive Examination Plan (Redacted)", October 2017

Department of the Navy (Navy). 2018a. Captain R.D. Hayes, U.S. Navy, Letter to Mr. Omer Shalev, EPA and Ms. Kwan, Hawaii State Department of Health, Subject: AOC SOW Section 5 Corrosion and Metal Fatigue Practices, Destructive Testing Plan, Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor-Hickam, Oahu, Hawaii, June 1.

Department of the Navy (Navy). 2018b. "2018 Update, Fuel Tank Advisory Committee (FTAC)", November 1.

Department of the Navy (Navy). 2018c. "Testimony on behalf of Navy Region Hawaii by CAPT Marc Delao" regarding Resolution 18-266, Related to Underground Storage Tanks, presented to Honolulu City Council Committee on Public Works, Infrastructure, and Sunstainability, November 28.

Department of the Navy (Navy). 2019a. Site Specific Report. SSR-NAVFAC EXWC-CI-1941. "Red Hill Bulk Fuel Storage Facility Destructive Testing Results Report, AOC/SOW 5.3.3." July 7.