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CERTIFIED NO: 7016 0910 0001 0891 7451
Mr. Omer Shalev
U.S. Environmental Protection Agency, Region 9
75 Hawthorne Street
San Francisco, CA 94105

CERTIFIED NO: 7016 0910 0001 0891 7468
Ms. Roxanne Kwan
State of Hawaii Department of Health
Solid and Hazardous Branch
2827 Waimano Home Road
Pearl City, HI 96782

Dear Mr. Shalev and Ms. Kwan,

SUBJECT: RISK AND VULNERABILITY ASSESSMENT FOR THE RED HILL ADMINISTRATIVE ORDER ON CONSENT ("AOC") STATEMENT OF WORK ("SOW") SECTION 8

In accordance with the Red Hill Administrative Order on Consent ("AOC") Statement of Work ("SOW"), Section 8: Risk/Vulnerability Assessment (Reference 1), the Section 8 SOW for a Quantitative Risk and Vulnerability Assessment ("QRVA") was established jointly with the U.S. Environmental Protection Agency ("EPA") and Hawaii Department of Health ("DOH"), collectively the "Regulatory Agencies", and submitted via cover letter (References 2, 3, and 4). The QRVA Phase 1 Report ("Report") was submitted as an interim status to the Regulating Agencies for discussion at face-to-face meetings (Reference 5).

The following is a summary of the discussions between the Navy and the Regulatory Agencies during the meetings of March 11 through March 15, 2019:

a. The Navy is concerned that this initial baseline assessment may not be absolutely accurate. The reported frequency of events leading to a release do not align with historical record. This suggests further effort is needed to refine the models used in the quantitative assessment to improve accuracy.

b. To meet the AOC's 18-month delivery requirement, the Navy's consultant was required to interpret massive amounts of reference data from multiple sources. When data was not readily available, they made necessary assumptions, which were documented extensively. The Navy has begun reconciling the data used by the consultant and was looking towards additional effort to provide necessary updates to increase the absolute accuracy of the reported frequencies and/or potential release volumes.

c. While the absolute accuracy of some of the reported frequencies and/or consequences are in question, the Report did provide a valuable assessment of risk and vulnerabilities and their relative importance to each other.

d. The Regulatory Agencies and their SMEs concur that additional effort to refine this initial baseline Phase 1 QRVA with additional sensitivity case studies would not significantly benefit the effort on the AOC as it relates to informing a BAPT decision, and therefore may not be cost effective or timely, given estimates for time to completion.

e. One of the Regulatory Agencies' SMEs suggested a more qualitative, "workshop" approach to the risk and vulnerability assessment SOW, utilizing subject matter expertise in fire, flood, and seismic events.

f. The QRVA Phase 1 Report provided by the Navy's consultant was discovered to not be Section 508 compliant and was returned to the consultant for further processing.

In lieu of continuing a nuclear industry standardized quantitative risk and vulnerability analysis, the Navy is requesting that the AOC Section 8.3 SOW be modified to complete Phases 2 (fire and flood initiating events), 3 (seismic events), and 4 (other external events) with a more screening level, qualitative approach. Using the baseline Phase 1 initiating events and event sequences as a starting point, we propose to have subject matter experts provide input on what the vulnerabilities are. This discussion would be followed by a targeted, quantitative analysis of key vulnerabilities and then summarized in a concise report. The Navy's intent is to complete the remaining phases of the Risk and Vulnerability Assessment in a more useful, cost effective and timely manner to more effectively inform decisions on facility upgrades to improve environmental and operational performance. We anticipate that by adopting this change in scope as outlined below, we can fulfill the AOC/SOW Section 8 requirements by early 2020. By comparison, the current period of performance of the Quantitative Phase 2 and 3 Assessment will complete in late 2021, with Phase 4 likely to follow in 2022.

a. The Navy will not expend further resources to improve the accuracy of the baseline Phase 1 assessment. The Navy feels that the QRVA Phase 1 report has provided valuable insight into which vulnerabilities are of concern and their relative importance to risk. There is little benefit in attempting to improve the reported frequencies or consequences. The vulnerabilities have been identified and the Navy will focus on addressing them.

b. The Navy is providing an independent Risk and Vulnerability Assessment Summary (enclosed) outlining some of the Navy's concerns and identified in the ABS Phase 1 Report, an interpretation of the results and insights provided in the consultant's Phase 1 Report, and the consultant's Phase 1 report as the AOC Section 8.3 deliverable.

c. The Navy will initiate new contract actions and/or modify existing task orders to retain subject matter experts in the fields of fire sciences and protection, civil engineering, and structural engineering. Credentials will be validated by the Regulatory Agencies prior to execution.

d. The Navy will request inter-agency consultation with the USGS to provide additional input on seismic activity in the area.

e. The Navy proposes to have a series of scoping discussions via teleconference and webinar to determine a suitable methodology and approach to a risk and vulnerability assessment related to Phase 2, 3, and 4 of the original QRVA SOW. The discussions will include SMEs and essentially draft the revised SOW to a 90% level of completion.

f. The Navy requests that a new scoping meeting be held with the Regulatory Agencies and internal/external SMEs present. The scoping meeting will include a workshop discussion on potential vulnerabilities of the facility to fire, flood, seismic, and other external events. The workshop will conclude with a short list of calculations to be done to quantify the top vulnerabilities. The top vulnerabilities will be identified as realistic, probable, and of concern to the facility. This scoping meeting and workshop will likely last 1-2 days and be scheduled in August 2019 to accommodate contract actions. The Navy will submit a revised SOW for the risk and vulnerability assessment for regulatory agency approval and will include the specific vulnerabilities and calculations as determined by the workshop.

g. The Navy will execute additional contract actions, as required, to address any additional calculations identified in the workshop/scoping meeting. As discussed, known vulnerabilities of interest have been identified and at a minimum the following will be addressed: pipe support performance in a seismic event, nozzle vulnerability in a seismic event, and wave action on the center tower from fuel during a seismic event.

h. The deliverable risk and vulnerability assessment to cover Phases 2, 3, and 4, as defined in the original SOW will include documentation of the screening level workshop and scoping meeting, targeted calculations and quantitative analysis of top vulnerabilities. Events will be linked to the internal initiating events identified in Phase 1 where possible. The assessment will consider causes of initiating events, but not effects on human reliability or event sequences.

i. This follow on vulnerability assessment will likely be ready for review late in 2019, and submitted as a final deliverable in early 2020. This approach would provide actionable insights 2-3 years ahead of the full Quantitative approach.

If you have any questions, please contact Mark S. Manfredi, the Red Hill Program Director/Project Coordinator at (808) 473-4148 or at mark.manfredi@navy.mil.

Sincerely,

M. R. DELAO
Captain, CEC, U.S. Navy
Regional Engineer
By direction of the
Commander

Reference:

1. EPA DKT No. RCRA 7003-R9-2015-01/DOH DKT No. 15 UST-EA-01 Administrative Order on Consent ("AOC") between the Navy, Defense Logistics Agency, State of Hawaii Department of Health, and the U.S. Environmental Protection Agency
2. Letter to Mr. Pallarino and Mr. Chang from CAPT. Hayes dated April 13, 2017, Re: Administrative Order on Consent Statement of Work Section 8.2 Scope of Work, Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor-Hickam, Oahu, Hawaii
3. Letter to CAPT Hayes from Mr. Pallarino and Mr. Chang dated May 16, 2017, Re: Conditional Approval of Red Hill Administrative Order on Consent Statement of Work ("AOC-SOW") Section 8.2 Scope of Work – Risk/Vulnerability Assessment
4. Letter to Mr. Pallarino and Mr. Chang from CAPT Delao dated 15 Aug 2017, Re: Administrative Order on Consent Statement of Work Conditional Approval Letter for Section 8.2 and overall Section 8 outline for Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor-Hickam, Oahu, Hawaii.
5. Letter to Mr. Shalev and Ms. Kwan from CAPT Delao dated March 8, 2019, Re: Quantitative Risk and Vulnerability Assessment ("QRVA") Phase 1 Report for the Red Hill Administrative Order on Consent ("AOC") State of Work ("SOW") Section 8

Enclosures:

1. The Navy's independent Phase 1 Risk and Vulnerability Assessment Summary
2. Section 508 compliant redacted version of the ABS QRVA Phase 1 Report

Red Hill Bulk Fuel Storage Facility
Administrative Order on Consent Section 8.3

Navy's Risk and Vulnerability Assessment Summary

May 29, 2019
NAVFAC Hawaii

Background

In September 2015, the U.S. Navy, the U.S. Environmental Protection Agency (EPA), and the State of Hawaii's Department of Health (DOH) entered into an agreement regarding the Red Hill Bulk Fuel Storage Facility (RHBFSF). The primary purpose is to ensure that the drinking water resources in the vicinity of the RHBFSF are protected and the fuel storage facility is operated and maintained in an environmentally protective manner.

In accordance with the Administrative Order on Consent (AOC), the Navy initiated a Quantitative Risk and Vulnerability Assessment (QRVA) study to provide a comprehensive risk analysis of the RHBFSF. This report will enable the Navy to establish a starting point to identify potential risks and ways to reduce risks as it continues evaluating and implementing the best available practices to ensure our drinking water sources in the vicinity are protected.

A comprehensive QRVA of a facility of this size and complexity generally takes five to seven years to complete. To meet the AOC delivery requirement of 18 months, the QRVA was divided into four phases:

- Phase 1: Internal events without fire or flood
- Phase 2: Internal and External Fire and flood events
- Phase 3: Seismic events
- Phase 4: Additional external events

The Phase 1 report was intended to satisfy the AOC Section 8.3 delivery deadline. The remaining phases would then be used to inform the 5-year review cycle of the best available practicable technologies (BAPT) following the Navy's initial Tank Upgrade Alternatives (TUA) decision that will be submitted to the regulatory agencies later this year.

The Navy's Consultant and Baseline Assessment

The Navy contracted an environmental engineering consultant to perform the risk and vulnerability assessment. The consulting team included Element Environmental LLC, HDR Engineering, Inc., and ABS Consulting. ABS specializes in risk and vulnerability assessments, with experience derived from standards used in the nuclear power industry. Working with the regulatory agencies, the Navy and its consultants agreed to a Scope of Work (SOW) to perform a quantitative risk and vulnerability assessment. The consultants' approach was to produce an independent and objective assessment that met industry standards and could be legally defensible. As such, while the Navy provided requested information and facilitated review and comments from internal and external stakeholder subject matter experts, the Navy was not significantly involved in the development of the model used to computationally simulate event sequences.

The QRVA Phase 1 Report is meant to be a baseline. Sensitivity case studies would be required to modify certain parameters of the baseline model to evaluate the impacts to the baseline results. This is an assessment of risk and is presented as potential frequency and potential release volume. After review of the roughly 1,600-page report and attached reference files, the Navy has determined that the baseline model would require sensitivity case studies to improve the accuracy of the reported risks as well as evaluate risk improvements from approved Tank Inspection Repair and Maintenance (TIRM) procedures and updated operational procedures and training.

The following is a list of the Navy's concerns with the baseline QRVA Phase 1 model and results:

- The report cited the possible frequency of an initiating event resulting in a fuel release between 1,000 and 30,000 gallons is 27.6%. This is an assessment of the probability of an event happening, and not that the event will actually happen. It also does not reflect the historical record, which shows that, since 1983, the Navy has not identified a release other than the 27,000 gallons from Tank 5 that was reported in 2014, which is 1 event in 35 years. This suggests that the methodology or input parameters may need to be reexamined to improve the accuracy of the baseline model.
- The assessment included a design freeze date of July 27, 2017. A sensitivity case study would be required to evaluate the impact of decommissioning the smaller nozzles in accordance with TIRM, which was approved by the Regulatory Agencies, but yet to be executed on current tank repairs. The nozzles were identified as important to risk.
- The liner leak rate through a 0.5-inch diameter equivalent hole is likely overestimated using an open orifice calculation. The consultants do not 'credit' the concrete for containment properties, but several feet of concrete will provide significant flow resistance at any sized hole. This will overstate the release consequence, given a specific reaction time. A sensitivity case study would need to be performed to provide more realistic performance of the concrete/grout structure supporting the steel liner.
- It appears that the historic American Petroleum Institute (API) 653 inspection reports, which identify numbers of through holes developing as well as the recorded size, was used to inform frequency and potential consequence throughout the tank. However, it is unclear if the model differentiates between the frequency and size of holes developing in the upper dome (vapor zone) or those found in the barrel (typically wetted). Corrosion through holes are expected to be more prominent in the vapor zones than on the wetted surfaces. More investigation would be needed by the Navy to understand and validate the methodology used by the Navy's consultant in the computational model.
- While the Navy's consultant acknowledges the higher risk of release during a return to service after TIRM, it is unclear if the historic data has been segregated by this criteria, and used as input parameters to the model. The highest leakage rate events considered by the Navy's consultant appear to be caused by TIRM processes where the tank was not leaking before being taken out of service. It may be more appropriate that these initiating events be segregated from initiating events that develop during normal operations because there are different mitigating actions available. Further investigation and/or sensitivity case studies would need to be performed to provide more realistic event sequences associated with relevant source data.
- Chronic releases appear to be distributed near the threshold for detection. The Navy's consultants also state in the report that "it is important to recognize that these postulated fuel leakage rates involve a number of conservative assumptions, which make the estimates likely to be overstated." With advanced release detection technology being considered by the Navy, it would follow that the estimate will drop to reflect the revised threshold of detection. It would still likely be overstated. A sensitivity case study would be needed to estimate the impact of implementing advanced leak detection.
- Chronic release simulations appear to consider 18 tanks in service during the year. This does not account for the expected 3 tanks that are expected to be out of service for TIRM at any given time. This may cause the chronic release estimate to further be overstated. More investigation is needed by the Navy to understand and validate the methodology used by the Navy's consultant in the computational model. A sensitivity case study would be needed to estimate the impact of implementing advanced leak detection.

- The tank tightness testing results appear to be used to postulate chronic release. The assumptions documented were missing results for Tank 5 and Tank 17 before being taking out of service. These documents do exist and can be provided to the Navy's consultant. It is unclear how this may affect the chronic release estimate. More investigation would be needed by the Navy to understand and validate the methodology used by the Navy's consultant in the computational model.
- Groundwater Flow and Contaminant Fate and Transport modelling is ongoing, with oversight and review by the regulatory agencies and their subject matter experts. The initial volume used in this assessment to determine the frequency of an event leading to a release of fuel that would likely affect the aquifer is preliminary. Based on the concerns outlined above, it's possible that the frequency is overstated because the rate of release used may not be accurate. Further investigation and/or sensitivity case studies would need to be performed to better assess the probability of a single event affecting the aquifer.

While the above concerns may or may not have an impact on the absolute values presented in the Phase 1 Report, individual risks can still be compared on a relative basis. *Figure 1* shows that based on frequency, initiating events related to the steel tank liner account for 98% of sequences resulting in a release (84% Liner Leaks + 14% Overfill). However, based on a significant release volume of 120,000 gallons or more, the initiating events related to the nozzle are 5 times that of the steel liner in *Figure 2*.

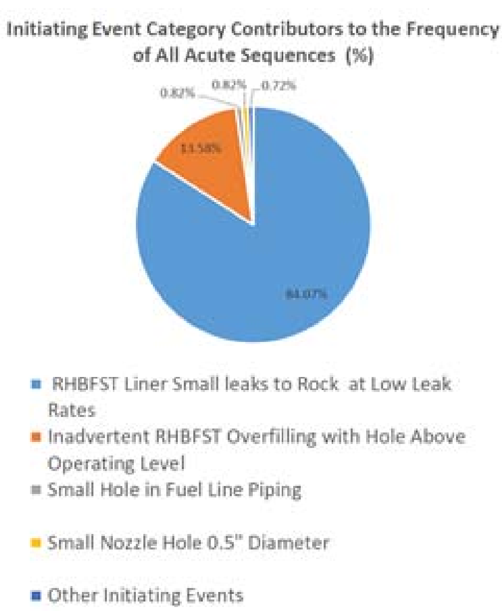


Figure 1

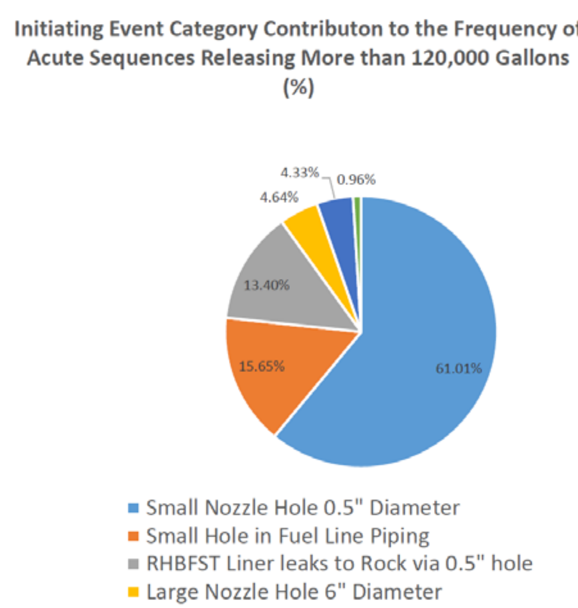


Figure 2

According to the baseline model, nozzle leaks contribute about twice the potential release volume per year than small liner leaks (<1.5gpm). The baseline model projected that a small nozzle hole results in an acute release of between 8 and 33 times the volume of small liner leak. The model projected that a large nozzle hole results in an acute release of between 33 and 166 times the volume of a small liner leak.

The following items, in order of importance, were identified as key contributors to risk:

- Availability of tank ullage to accommodate emergency movement of fuel from a leaking tank to a safe storage location;

- Availability and quality of potential fuel release emergency procedures and associated operator training;
- The capability and reliability of tank fuel inventory (fuel level) instrumentation and control systems;
- In response to potential fuel release scenarios, operator actions are generally more important than equipment failures to overall risk
- Following tank inspections and maintenance, quality control during tank return-to-service processes;
- Strategies for responding to fuel releases inside the lower access tunnel;
- Potential fuel releases from the tank nozzles;
- The capability and reliability of fuel piping isolation in response to fuel release incidents in the lower access tunnel;
- Safety management and control of specific maintenance actions at the facility;
- The design and proximity of the lower access tunnel to the Red Hill water shaft.

The Navy's Actions to Mitigate Risk

While the vulnerabilities identified were already known, the risk assessment provided a ranking of relative importance of each. This is a useful tool in planning risk mitigations to address the vulnerabilities effectively with the available resources. The following is a brief discussion on the Navy's approach to controlling the risks.

Availability of tank ullage to accommodate emergency movement of fuel from a leaking tank to a safe storage location is important to risk.

This is identified as having the most influence on risk. If a leak is detected, the ability of the Navy to transfer the fuel from the suspect tank is critical to minimizing the potential release of fuel from the facility. Addressing this vulnerability is not straight forward. Federal Regulations currently prohibit maintaining an asset that is not operationally used – i.e., an empty tank. Further, an empty tank is much more difficult and costly to maintain because unlike a full tank where the fuel serves as a corrosion inhibitor, an empty tank is far more subject to internal corrosion. Currently, the Navy fuel operations director for Joint Base Pearl Harbor-Hickam is responsible for having situational awareness of inventory and potential spare ullage available at any given time. There are three types of fuel stored at Red Hill, each with their own options for alternate storage locations. Given the large volume of a Red Hill tank, there is a concern that available ullage is not readily available for the entire contents. A study is being planned to review the Fuel Facility Storage Solution (F2S2) possibilities for fuel on Oahu. This study will review options for the Navy on alternative and hybrid solutions for operational, reserve, and emergency fuel storage. Until an engineered control is available, administrative controls will be implemented via situational awareness to limit risk.

Availability and quality of potential fuel release emergency procedures and associated operator training is important to risk.

The Tank 5 event reported in 2014 involved human errors made by the Navy's operators. Since then, an updated, comprehensive Operations Manual was developed for the facility and the operator training program has been revised, and includes procedures to handle fuel releases. The Navy will continue to provide and improve administrative controls to limit risks of human reliability related to fuel release response.

The capability and reliability of tank fuel inventory (fuel level) instrumentation and control systems is important to risk.
An engineered control to this risk has been implemented with the recent upgrade to the Automated Fuel Handling Equipment (AHFE) system.

Another engineered control is planning to install advanced leak detection equipment for Tank Tightness Testing. This equipment is independent of the AHFE, but can possibly be developed to provide supplemental monitoring and active leak detection. Further development and improvements of the AHFE and leak detection systems will allow for early detection and initiation of release confirmation and response procedures.

In response to potential fuel release scenarios, operator actions are generally more important than equipment failures to overall risk.
The new procedures outlined in the Operating Manual document the lines of communication and responsibilities of an operator in the event of a release. The revised training program will reinforce the procedures on a regular basis. The Navy will continue to provide and improve administrative controls to limit risks of human reliability related to fuel release response.

Following tank inspections and maintenance, quality control during tank return-to-service processes is important to risk.
The historic data and, specifically, the event at Tank 5 that was reported in 2014 shows that human reliability during the tank Clean, Inspect, and Repair (CIR), a.k.a. Tank Inspection, Repair, and Maintenance (TIRM) is critical to release prevention.

Several administrative controls to reduce this risk have been planned and implemented, including:

- Independent scanning and proof up quality control (QC) by the contractor
- Third party Government quality assurance (QA) of the inspection and repair contractor
- Tank tightness testing and documentation prior to taking a tank Out of Service (OOS) for inspection, repair, and maintenance.
- Incremental fill procedures to monitor integrity of the tank at discrete fuel levels
- Tank tightness testing and documentation after tank is filled

These administrative controls will facilitate release prevention and detection.

Strategies for responding to fuel releases inside the lower access tunnel are important to risk.
Several engineered controls have been implemented to address the risks in the lower access tunnel.

Hydraulically/remote operated oil tight doors provide bulkhead separation of the tunnel into independent zones. Each zone is equipped with a sump and pump system. The doors are automatic but can be manually activated. Monitoring wells and the water wells are protected by oil tight caps to prevent direct migration to the aquifer.

Other engineered and administrative controls will be reviewed by the Navy to further reduce the risk to the aquifer.

Potential fuel releases from the tank nozzles are important are risk.
The Navy understands the importance of the tank nozzle to risk because of its un-isolatable section of piping. If an initiating event, such as a small or large hole, occurred at this location, it could not be controlled because the tank contents cannot be isolated from the nozzle piping. The piping is protected from external hazards from outside equipment and tools in the lower tunnel galleries. It is also substantially encased within the concrete superstructure of the tank, embedding it within the mountain, providing a significant level of seismic protection.

The Navy has implemented engineering and administrative controls to protect the nozzles from corrosion. The two smaller nozzles will be decommissioned via the revised TIRM process, which was approved by the regulatory agencies. This leaves the largest of the nozzles for each tank, which, due to its size, can be fully inspected, repaired, and coated to prevent corrosion through holes. The focus of these controls is the prevention of risk.

The capability and reliability of fuel piping isolation in response to fuel release incidents in the lower access tunnel are important to risk.
The pipeline currently undergoes visual inspection daily and is subject to internal and external inspection in accordance with API 570. These are identified industry practices sufficient to mitigate the risk of a release due to corrosion, erosion, or other deteriorating causal agents. The current facility has fuel piping isolation valves installed in the lower access tunnel. While fuel isolation in the pipe is of concern, a more primary concern is to better understand the vulnerability of the pipeline to external initiating events such as seismic activity. Seismic vulnerabilities will be addressed in follow on phases of the risk and vulnerability assessment. This follow on assessment will identify the modifications necessary to reduce risk of a release from the pipeline.

Safety management and control of specific maintenance actions at the facility are important to risk.
Safety management, plant oversight, and maintenance actions are a part of standard operations of the facility, outlined in the revised Operations Manual and fortified with the updated training program. This administrative control is designed to prevent and detect risks.

The design and proximity of the lower access tunnel to the Red Hill water shaft is important to risk.
Red Hill was constructed almost 80 years ago. Since the original construction, the access cover to the Red Hill water shaft infiltration gallery has been replaced with a water-tight cover. In the event of a release into the Red Hill water shaft, this prevents contamination of the infiltration gallery. Based on current efforts, there is little more that can be accomplished using additional engineering controls to isolate the Red Hill water shaft from the lower access tunnel. Some consideration is being taken for administrative controls to reduce impacts of a catastrophic release of fuel into the lower tunnel, but these are in the initial development stages.

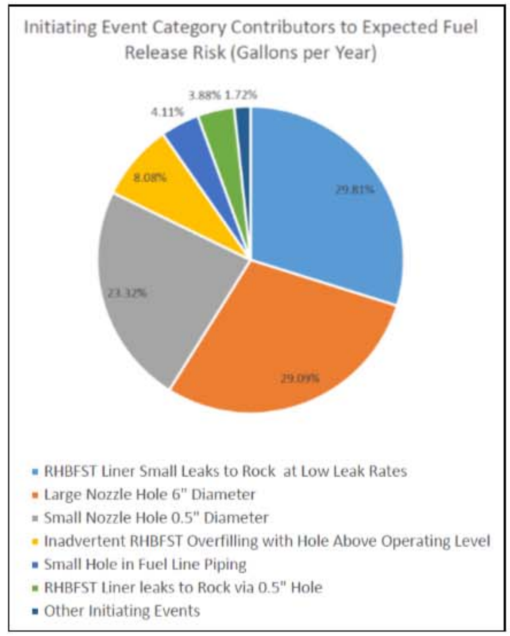
For now, the administrative and engineering controls provided for the nozzles and piping in the lower access tunnel as describe above represent the preventative and corrective risk controls in place. Otherwise, the proximity of the lower tunnel to the Red Hill water shaft is an accepted risk.

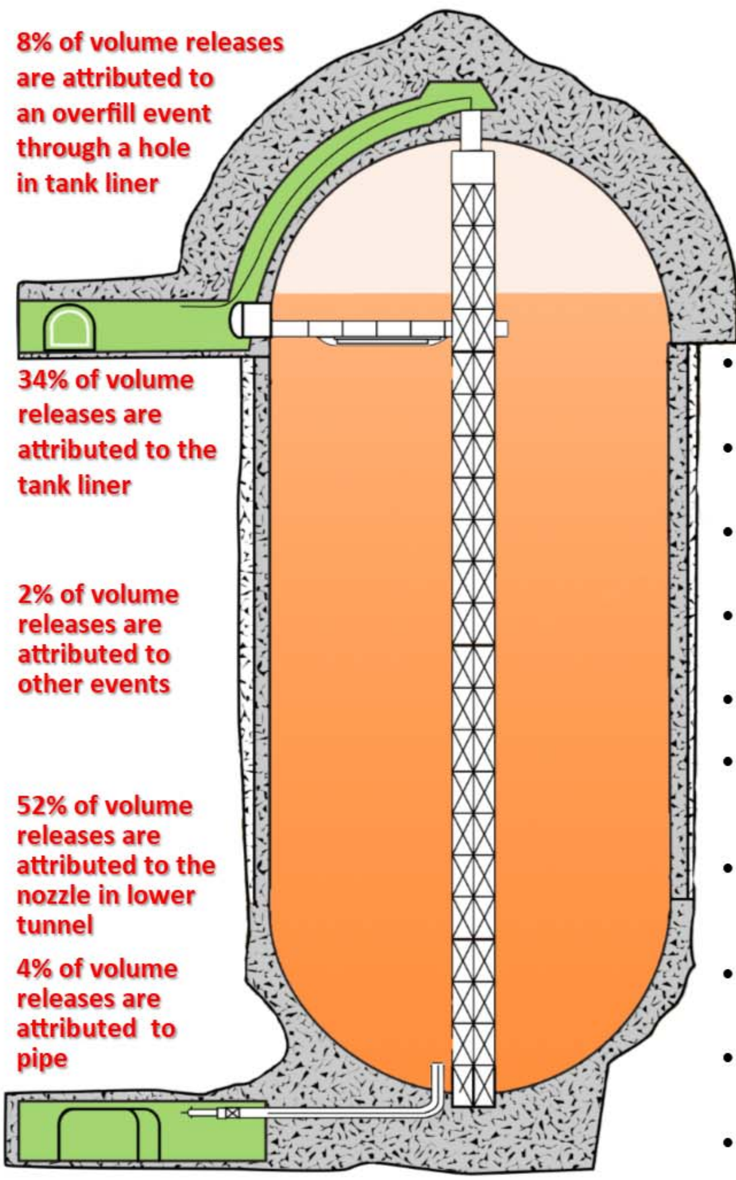
QUANTITATIVE RISK AND VULNERABILITY ASSESSMENT

RED HILL BULK FUEL STORAGE FACILITY, JOINT BASE PEARL HARBOR HICKAM, HAWAII
PHASE 1 INTERIM BASELINE RESULTS AND SUMMARY (MAY 2019)

Important Considerations

- Facility Design Freeze date of July 27, 2017. Any improvements to equipment, facility, or procedures since that date are not accounted for.
- Phase 1 only includes internal events without fire or flooding, and focuses on failure modes and event sequences. It does not include a causal analysis.
- Risk is interpreted as a realistic likelihood, and not a constant rate. Interpreting acute risk results as a continuous or near-continuous release is not appropriate. Release volumes presented in the report cannot be simply added together to estimate release volumes. Risk is presented as a complex function of event sequences, frequencies and probabilities, and potential consequence.





Risk Insights in Order of Predicted Importance

- The availability of tank ullage to accommodate emergency movement of fuel from a leaking tank to a safe storage tank or other safe container is important to risk.
- The availability and quality of potential fuel release emergency response procedures and associated operator training is important to risk.
- The capability and reliability of tank fuel inventory (fuel level) instrumentation and control systems are important to risk.
- In response to potential fuel release scenarios, operator actions are generally more important than equipment failures to overall risk.
- Following tank inspections and maintenance, qualify control during tank return-to-service is important to risk.
- Strategies for responding to fuel releases inside the RHBFSF Lower Access Tunnel (e.g., strategies for removing and controlling fuel released into the Lower Access Tunnel) are important to risk.
- Potential fuel releases from the tank nozzles (the main fuel flow piping leading into and out of the main storage tanks up to the upstream flange connections for the tank skin valves) are important to risk.
- The capability and reliability of fuel piping isolation in response to fuel release incidents in the RHBFSF Lower Access Tunnel are important to risk.
- Safety management and control of specific maintenance actions at the facility (e.g., tank nozzle and skin valve maintenance) is important to risk.
- The design and proximity of the RHBFSF Lower Access Tunnel and the Red Hill Water Pump Area is important to risk.