BOARD OF WATER SUPPLY

CITY AND COUNTY OF HONOLULU
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May 27, 2016

Mr. Bob Pallarino
United States Environmental Protection Agency
Region 9
Underground Storage Tank Program Office
75 Hawthorne Street (LND-4-3)
San Francisco, California 94105

and

Mr. Steven Y.K. Chang, P.E., Chief
State of Hawaii
Department of Health
P.O. Box 3378
Honolulu, Hawaii 96801-3378

Dear Messrs. Pallarino and Chang:

Subject: 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

The BWS and its consultants have reviewed the various reports and outlines prepared by the Navy and Defense Logistics Agency (DLA) in accordance with the AOC SOW for the sections below.

- Section 2: Tank Inspection, Repair, and Maintenance (TIRM)
- Section 3: Tank Upgrade Alternatives (TUA)
- Section 4: Current Fuel Release Monitoring Systems Report
- Section 5: Corrosion and Metal Fatigue Practices Report
- Section 8: Risk/Vulnerability Assessment (RVA)

The BWS has the following comments regarding these sections as outlined below.

BWS Comments on Section 2 Regarding Tank Inspection, Repair and Maintenance (TIRM)

This section is to provide a work plan for the inspection, repair and maintenance of Red Hill tanks to keep tanks permanently leak free in the future. BWS is greatly concerned that the AOC only covers the Red Hill tanks, and does not consider the three three-mile long fuel lines (over nine miles of fuel pipe). BWS has identified the following data gaps and has provided our recommendations on how to address these data gaps.

Detailed information about the current status of tanks and their inspection and repair history has not yet been provided in this section.

Presently, the TIRM section does not provide a current status of which tanks have been inspected and which tanks have not been inspected in accordance with the current American Petroleum Institute (API) standards being used.

Recommendations:

<u>TIRM Recommendation 1</u>: The Navy/DLA should provide an up-to-date table in the introduction of this section describing which tanks are currently in service, which have been inspected and repaired, and when these activities were completed. A table has previously been provided by the Navy in the Naval Audit Service report[1], which showed that some of the tanks, as of 2010, had not been inspected for more than 46 years. This table is shown below.

Exhibit F:

Tank Inspection and Record of Maintenance Intervals

Tank #	Status	Fuel Type	Last Inspection or Record of Maintenance	Approximate years since last Inspection of ANY kind (as of 2009)	Next API 653 Inspection Scheduled (per MTMP Apr 09 or Inspection Report)	Approximate years between last and next scheduled inspection
1	Out-of-service	N/A	2007	2	N/A	N/A
2	Active	JP8	2008	1	2028	20
3	Active	JP8	1982	27	2012	30
4	Active	JP8	1982	27	2011	29
5	Active	JP8	1982	27	2009	27
6	Active	JP8	2007	2	2027	20
7	Active	JP5	1998	11	2014	16
8	Active	JP5	1998	11	2014	16
9	Active	JP5	1996	13	2012	16
10	Active	JP5	1998	11	2015	17
11	Active	JP5	1980	29	2011	31
12	Active	JP5	1995	14	2012	17
13	Active	F76	1995	14	2013	18
14	Active	F76	1995	14	2010	15
15	Active	F76	2005	4	2026	21
16	Active	F76	2006	3	2026	20
17	Active	JP5	1974	35	2009	35
18	Active	JP5	1963	46	2010	47
19	Out-of-service	JP5	1989	20	2009	20
20	Active	JP5	2008	1	2028	20

* Yellow shading indicates tanks with longest intervals since last recorded inspection maintenance event.

[1] Naval Audit Service, 2010, *Audit Report: Department of the Navy Red Hill and Upper Tank Farm Fuel Storage Facilities*, Report Number N2010-0049, August 16, 2010; p. 69.

Another table similar to this has been recently updated by the Environmental Protection Agency (EPA), as shown in their response to a Freedom of Information Act (FOIA) to request EPA-R9-2016-004238[2]. This table shows that some tanks have not been inspected for 53 years. BWS recommends that updated tables similar to these be provided in the introduction and background section to the TIRM statement of work as well as in all TIRM deliverables.

TIRM Recommendation 2: Currently, the TIRM section does not discuss which tanks are actively being inspected and repaired. Ensure that TIRM Section 6 contains information about which tanks are currently being inspected and repaired.

TIRM Recommendation 3: Currently, the TIRM section does not discuss any of the nine miles of fuel piping and pipeline supports. These pipelines have been inspected and repaired, which the current version of this section does not discuss. This section should provide a description of the leaks, inspections, and repairs that have been performed on this piping. It should also discuss what current inspection and repair efforts are underway and/or planned.

TIRM Recommendation 4: There is no information in the TIRM section that provides a discussion of what methodology will be used to select the next tanks for inspection and repair, or when this will occur. In the absence of any other compelling information regarding the conditions of the tanks BWS may not be aware of, BWS believes this selection process should be based on which tanks have had the longest elapsed time from the last inspection. Ensure that TIRM Section 6-6 (Determination of order of tanks) contains detailed information about the schedule for future tank inspection and repair, and how such a risk-mitigation based schedule was developed.

[2] Department of the Navy, undated, Red Hill Tank Inspection and Record of Maintenance Intervals, Record LND-16-004238.

Red Hill Tank Inspection and Record of Maintenance Intervals

Tank	Status	Fuel Type	Last Inspection or Record of Maintenance	Approximate last inspection of any kind (as of 2016)	Next Inspection Scheduled in Report	Approximate years between last & scheduled inspection
1	Out of service	N/A	2007	9	N/A	N/A
2	Active	JP8	2008	8	2028	20
3	Active	JP8	1982	34	2012	30 ?
4	Active	JP8	1982	34	2011	29 ?
5	Active	JP8	2014	2	2009	-5
6	Active	JP8	2007	9	2027	20
7	Active	JP5	1998	18	2014	16 ?
8	Active	JP5	1998	18	2014	16 ?
9	Active	JP5	1996	20	2012	16 ?
10	Active	JP5	1998	18	2015	17 ?
11	Active	JP5	1980	36	2011	31 ?
12	Active	JP5	1995	21	2012	17 ?
13	Active	F76	1995	21	2013	18 ?
14	Active	F76	1995	21	2010	15 ?
15	Active	F76	2005	11	2026	21
16	Active	F76	2006	10	2026	20
17	Active	JP5	2012	4	2009	-3
18	Active	JP5	1963	53	2010	47 ?
19	Out of service	N/A	1989	27	N/A	N/A
20	Active	JP5	2008	8	2028	20

Detailed information about Tank 5 condition and pre-release repair practices.

Detailed information about what happened, why it happened, what lessons have been learned, and what preventative measures have been put in place have not yet been fully enumerated in this section.

Recommendations:

TIRM Recommendation 5: Provide a description of the API inspection results for Tank 5 prior to filling and the detection of leaks. This should provide background on what repairs were performed and why. The section should discuss how many defects found were from corrosion, weld defects, and dents. The location of all defects, including whether they were situated on the inner surface, outer surface, or within the welds should be included. The TIRM section should also describe the rationale the Navy used for selecting which of the defects would be repaired.

TIRM Recommendation 6: Section 2-2.2.4 states: "What was tested: Welds, particularly defects including leaks and corrosion." This seems to imply that leaks were found prior to weld repairs on Tank 5. Is this correct? The report should list all leaks that were found in Tanks 5 prior to repair.

TIRM Recommendation 7: Provide a procedure with details on how weld repairs were historically and are presently performed. For instance, we understand that the Navy first drills a hole in the plate at the location to be repaired, and then checks for vapor or liquid behind the plates. The report should comment on how many holes were drilled, and how many of these holes leaked vapor, water or fuel. The size and thickness of the plates welded over the drilled holes and defect sites should also be described. According to statements made at the May AOC meetings, there were more than 70 leak sites identified on Tank 5, but little information on the nature and location of these leaks was provided. The location and nature of leak sites should be described, as well as how the leak sites were identified.

TIRM Recommendation 8: The TIRM section should describe what has been found in the past when drilling the ¼-inch holes. For instance, in Note 3 it states that: "... This is a safety requirement since hydrocarbons have been found in contact with the back wall surfaces in past tanks." This section should clearly and as completely as records allow describe the location of the holes on each tank that has leaked combustible vapor, fuel, or water when the holes were drilled. If such records do not exist as part of the current record keeping procedure for tank repair, BWS recommends that all future repairs document of what is found when such holes are drilled.

TIRM Recommendation 9: Include a detailed description of why the Tank 5 plate welds leaked. We understand that the holes drilled to check for explosive vapors behind the tank were not filled prior to welding on the patch plates. If this is true, then it should be clearly stated. If the holes in the tank wall were not filled with weld metal, then the leak path was therefore through the weld on the patch plates. Again, this should clearly be stated in the TIRM section. This section should also have a description of the cause(s) of the welded plate leaks. For instance, was the weld leak path a result of weld porosity, weld or heat affected zone cracking, incomplete welding, or a result of some other type of weld defect?

TIRM Recommendation 10: Include what weld inspection methodology (visual, dye penetrant, ultrasonic, vacuum plate, etc.) was used during Tank 5 repairs. This is important to include as the method used was not very effective. This section should also discuss what methodology will be used during future repairs to prevent leaks from occurring after repair welding.

TIRM Recommendation 11: Provide information about the extent to which original construction/corrosion-fatigue or the subsequent repairs led to the Tank 5 leak. BWS recommends that some of the weld patches that leaked on Tank 5 be removed prior to placing the Tank back into service. Such plates, once removed, could be non-destructively (ultrasonic, dye penetration, x-ray radiographed) and destructively (metallography) examined to determine the nature of the leak path (i.e., cracking, weld porosity, lack of fusion, etc.). This will provide valuable information that may influence future repair weld practices.

TIRM Recommendation 12: Provide a detailed description of recommended contractor practices regarding plugging of holes drilled during tank repair, future recommendations for welding, weld inspection, and weld inspection oversight. This should include detailed description of contractor quality control and Navy quality assurance actions that have been revised to address the shortcomings from the Tank 5 repair. The Navy should also explain how, when, and if these changes will be included on the Whole Building Design Guide web site.

Discussion of mechanisms known to have resulted in leaks is lacking.

Currently the TIRM section does not include a description of mechanisms that have caused historical leaks at the Red Hill facility. BWS has the following recommendation.

Recommendation:

TIRM Recommendation 13: Numerous leaks have been noted in Red Hill tanks over the past 75 years. The causes appear to cluster into several categories as listed below:

- Earthquake induced: A leak was noticed and discussed in Bechtel's 1949 report that occurred shortly after an earthquake of approximately magnitude 5 on the Richter scale.[3] Therefore, the potential for earthquake-induced leaks should be discussed in this Section.

- Given the recent release from Tank 5, the enormous amount of welds in each tank (more than 2.1 miles – not counting the length of welds in the top and bottom domes), and the fact that these welds were made in the early 1940s on steel plate of uncertain quality, it is likely that there were and will continue to be numerous leaks resulting from weld defects. Therefore, the potential for weld defect induced leaks should be discussed in this section.

- There also appear to have been several instances of through-wall holes that occurred as a result of corrosion. Instances of through-wall corrosion induced leaks should be discussed.

- Leaks from the tell-tale piping system. These leaks should be discussed in this section. For instance did the leaks that were observed from the tell-tales develop from the inner surface (exposed to water) or outer surface (exposed to the fuel)? In the recent meeting that BWS attended, it was stated that the tell-tales corroded from the outer surface as a result of exposure to water that had collected at the bottom of the Red Hill tanks. This is important information to consider, as it may mean that water is not effectively draining from the bottom of the tanks. It was also indicated that some tanks currently in use may have tell-tale systems in place but not in use. The current status of the tell-tale system should be clearly explained. For instance, does not in-use mean that the tell-tale pipes have been cut off at the tank walls and plates welded over the holes but the piping itself not removed?

Probability of detection (POD) curves.

This section states that the POD curves are not available for the various non-destructive testing (NDT) techniques that were used at Red Hill. Such information is important to consider when performing an inspection. For instance, if you are only 90% certain you

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[3] Bechtel Corporation (Bechtel). 1949. Report on Engineering Survey of U.S. Navy Petroleum Facilities at Pearl Harbor.

can find a defect that is ¼ or ½ of the wall thickness, then this would have a big effect on setting safe inspection intervals. Re-inspection would likely occur more frequently in order to ensure a high probability of leak free operation.

Recommendation:

TIRM Recommendation 14: Clarify the extent to which POD curves are not available or cannot be developed for the TesTex Falcon Mark II 2000 (Section 2-2) **with** additional literature and/or experimental data. Also, Section 2-2 states that POD curves are available for the TesTex TS-2000.

Detailed information about extent of tank inspections should be included in the TIRM Report.

This section states that Tanks 2, 6, 15, 16, and 20 were 100% inspected by TesTex. However, this appears to be in conflict with other documents, for instance the API 653 2007 inspection report.

Recommendations:

TIRM Recommendation 15: Clarify what is meant by "100% inspection" – does 100% inspection include top, sides, and bottom of the tank? For instance, the API 653 inspection report for Tank 6 in 2007 states that the Tank was only 80% inspected. It is difficult to reconcile the statement of 100% inspection with API reports that appear to show partial inspection. BWS recommends that a table be provided that shows for each tank API inspection, what percentage of the top dome, bottom dome, and tank barrel was inspected and when it was inspected. BWS also recommends that this section provide the reader with some information regarding the enormity of the scope of inspection for each tank. For instance, each tank has over 68,000 sq. ft. of area to be inspected, and over 2.1 miles of welds to be inspected on the tank barrel alone.[4]

TIRM Recommendation 16: Provide detail regarding inspection of piping (including hydrostatic testing) leading from tank bottoms to the tunnels. For instance, when has this piping been inspected, by what methods, and what defects were found and repaired? Some of the tanks have had the 32-inch and 18-inch piping connected to the tank hydrostatically tested. This section should indicate which tanks have had piping hydrostatically tested, when it was tested, the details of the testing, and what was found. If there is other piping leading from the bottom of the tank to the tunnels (i.e., tell-tales and fuel sampling tubes), the report should describe how these are inspected, and the results of the inspections.

TIRM Recommendation 17: Provide information and details regarding the inspection frequency and results of test coupon inspection in the pipeline.

Description of what Quality Control procedures were implemented leading up to the Tank 5 leak and which procedures will be implemented in future TIRM operations.

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[4] Weston Solutions Inc., *Final API-653 Inspection Report, PRL 03-12: Internal Inspection of Tank 6, Red Hill, FISC Pearl Harbor, Hawaii (Administrative Index Record #380)*. 2007. p. 75.

The Tank 5 leak occurred due to improper quality control (QC) procedures. This section needs to provide a clear explanation of what procedures were used to repair the welds, and what quality assurance and inspection procedures were used to confirm that the repairs were done appropriately.

Recommendation:

TIRM Recommendation 18: Contractor daily logs of the Tank 5 work and any quality assurance/quality control (QA/QC) reports submitted as part of Tank 5 repair should be included in this section. This section should also describe the extent to which the contractor did not follow the QC requirements. Information regarding the lack of oversight in implementation of contractor QC requirements as well as methods for future QA/QC protocols that include oversight should be added. There should be a clear description of the program to be implemented to ensure independent oversight, including acceptable worker qualifications, Non-destructive Evaluation (NDE) equipment calibration/certification, defect repair, repair work inspection, etc.

BWS Comments on Section 3 Regarding Tank Upgrade Alternatives (TUA)

The draft section currently does not have any write up (other than the outline of the Executive Summary) regarding the scope, purpose, and limitations of this section. From discussions in the recent meeting between BWS and AOC members, it is BWS's understanding that Section 3 is supposed to provide a set of tank upgrade alternatives along with various screening criteria that can be used to evaluate each of the alternatives against each other. This section contains information about the current tank configuration and historic structural integrity issues with the tanks. It then discusses the many available technology and techniques for upgrading and/or restoring the tanks, as well as some advantages and disadvantages of the various options. BWS has identified the following data gaps and has provided our recommendations on how to address these data gaps.

No details for scope and purpose of TUA section.

The current TUA draft does not clearly describe what this section is supposed to accomplish.

Recommendations:

TUA Recommendation 1: The outline does not contain an introduction section, which is needed. The introduction section should include background, purpose and scope subsections that clearly define the goals and limitations of this section.

TUA Recommendation 2: The outline does not discuss the limitation that was expressed by EEI (Enterprise Engineering Incorporated, the Navy's contractor for this section) in a recent meeting that this section does not provide the guidelines by which each of the alternatives will be evaluated. A clear description of this limitation should be provided in the scope and purpose, and it should re-direct the reader to the section of the AOC work plans that will describe the selection process. BWS suggests an appropriate section describing and outlining the selection process between the various tank upgrade alternatives is Section 8 of the report that covers the risk and vulnerability assessment. The reason for this suggestion is the risk and vulnerability assessment has the longest lead time, and each of the tank upgrade alternatives should be compared and weighed against each other on the basis of risk to the environment.

Some obvious tank upgrade alternatives are missing from this section.

The TUA section outline does not include or consider tank relocation as an upgrade alternative.

Recommendation

TUA Recommendation 3: Add tank relocation as a tank upgrade alternative to be considered as part of the cost-benefit and risk/vulnerability analysis. Closure of the Red Hill Fuel Storage Facility and relocation of the tanks to another location such as Hickman Field should be considered as an option for comparison along with other tanks repair and re-design options. This option, although expensive and potentially difficult for the Navy to implement, is one of the best options from BWS's viewpoint, as it has the greatest ability to reduce the risk of future leaks into the water supply. By not considering relocation as a viable option, BWS's preferred option is not even compared and contrasted to rank among the other options.

The process by which the various tank alternatives will be compared against each other is not described.

The process that will be used by the Stakeholders to evaluate and rank the various tank upgrade alternatives is not clearly described. A description of this process is necessary to allow each Stakeholder to have input to the selection process and to provide transparency on how the selection process will be conducted.

Recommendations:

TUA Recommendation 4: The report should clearly state which section should describe how the tank upgrade selection process will be conducted. Possibilities include this section (but as previously discussed EEI did not think it fit in this section), Section 8 covering risk, or a new report section. The report should describe how the tanks alternatives will be evaluated, and how each Stakeholder's weighting of every characteristic for each alternative will be taken in to account.

TUA Recommendation 5: The BWS recommends using a cost-benefit analysis to determine the best ALARP (as low as reasonably practicable) risk solution. This could be part of the risk analysis (Section 8).

Streamline the number of characteristics and attributes by which each tank alternative will be evaluated

The current document lists several attributes with a ranking system applied to each attribute (Table 5-1). There are 47 attributes listed, and in many cases the table column for ranking the importance of the attribute of each system is blank. Having such a large number of attributes with which to evaluate each alternative will make the evaluation process quite difficult, potentially leading to a ranking with no clear winner.

TUA Recommendation 6: Consider combining some of the attributes into one attribute or characteristic. Such modifications to the current evaluation/scoring matrix may help with simplification of the weighting process for each of the characteristics/attributes. As currently structured, BWS is concerned that the weightings for increases in reliability and leak detection associated with secondary containment systems (vs. single wall alternatives) may be too low given all the other attributes listed.

There is limited information currently available about specific proposed alternatives; additional information regarding the details for these alternatives is needed in this section.

The current draft of TUA Section 5.3 is missing large amounts of information for each of the specific proposed alternatives. This information must be provided in order to accurately assess and rank the alternatives.

TUA Recommendation 7: Specify whether a composite system (such as proposed Alternative 2B) has been shown to work on other tanks or similar tank systems.

TUA Recommendation 8: Explain if it is possible to slightly redesign Alternative 2A or 2B, such that it would not be necessary to fill the interstitial space with grout (as grout filling will make leak detection more difficult).

TUA Recommendation 9: If Alternatives 2A or 2B are selected with grout filling of the interstitial spaces, this design should consider the additional alternative that cathodic protection is built into the design.

BWS Comments on Section 4 Regarding Leak Detection

Section 4 of the report outlines the current fuel release detection system, as well as tank leak testing procedures, and evaluates them. It also includes information regarding tank filling procedures and the sensitivity of release detection systems. BWS has identified the following data gaps and has provided our recommendations on how to address these data gaps.

This section does not clearly state what leak detection systems have been used, and are currently used, and when they were placed into operation.

The leak detection section covers static and dynamic leak detection systems; however, there is limited information provided regarding the details of the leak detection systems and no records from the leak detection systems or historical leak information are included in Section 2 of the report.

Recommendation:

LD Recommendation 1: The introduction and background sections should clearly describe each leak detection method that has been used at Red Hill: tell-tales, physical measurements of fuel level detection from upper tunnel, automated fuel handling equipment (AFHE), tank tightness testing with Mass Technology Corporation (MTC) Precision Mass Measurement System, inventory control from pump metering, etc. The section should also physically describe how each leak detection system functions. This description should include: when each detection method was placed into service, which methods are currently in use for each of the tanks, the conditions for alarm for each detection method, the frequency of testing, the minimum leak detection rate, and the time required for each detection method to achieve its minimum leak detection rate.

LD Recommendation 2: Revise Section 5-3 to clearly state that the Red Hill tanks are not equipped with any dynamic release detection systems. Also, the section should provide installation dates of static leak detection systems currently and historically in place at Red Hill.

Leak detection alarm testing, validation, and bypass protocols need to be more clearly explained.

Warning and critical alarms are utilized with the automated fuel handling equipment leak detection. It is important to test alarms to ensure proper functioning in the case of a leak. Given the role of the leak detection alarm in the Tank 5 leak, validation and bypass protocols should be enumerated in this section.

Recommendations:

LD Recommendation 3: This section should clearly discuss how the static warning/critical alarms are tested and/or validated. Given the shortcomings for the Tank 5 leak wherein "the AFHE system generated unanticipated fuel movement alarms and these alarms were cleared through the use of operator intervention and alarm clearing evolutions,"[5] this section should discuss what changes have been made to operator protocols, hardware, and/or software to prevent a repeat of the improper response.

LD Recommendation 4: This section should clearly describe how the standard operating procedures (SOPs) and responses to unanticipated fuel movements (UFMs) have been revised (as described in this section on page 5).

Records and analysis of historical performance of leak detection systems should be added to this section.

Some information regarding the current leak detection systems is provided; however, no records are included. For each historic release, the status of the leak detection system during the leak, as well as the size of the leak should be included.

Recommendation:

LD Recommendation 5: Provide explanations regarding historic releases, and where possible the extent that the leak might have been mitigated by better detection.

- For example, the Tank 6 loss of unspecified amount of JP-5 reported in April 2002.[6]

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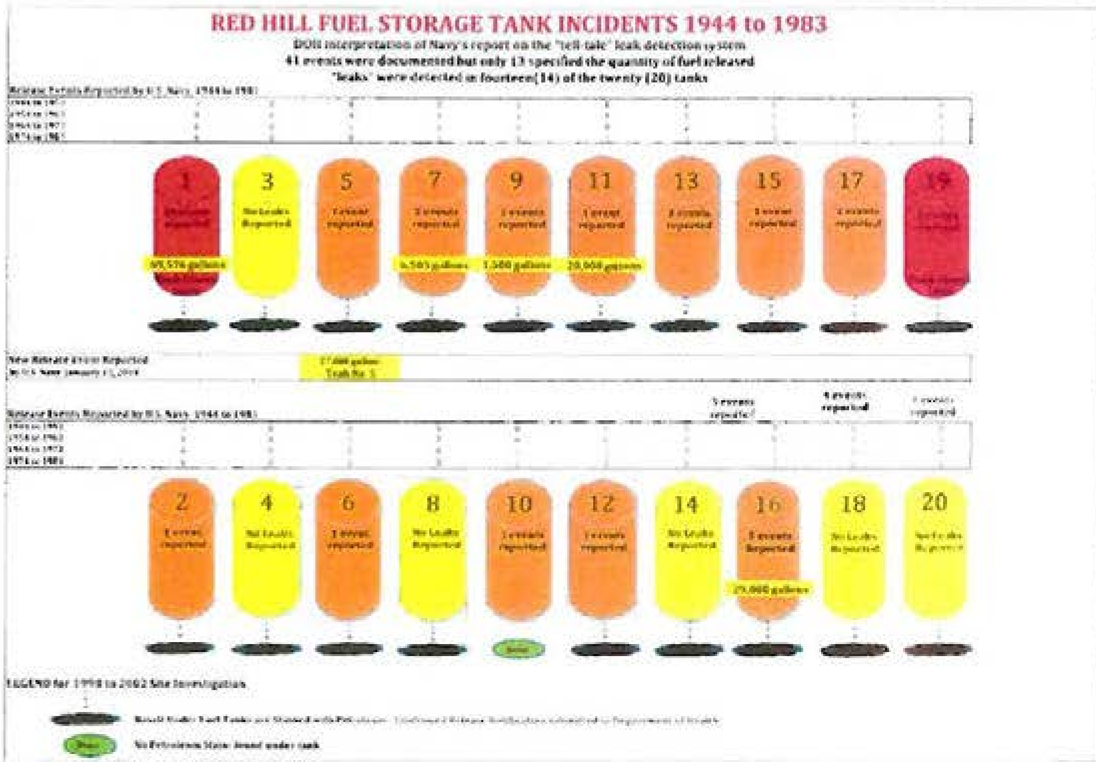
[5] Space and Naval Warfare, 2014, AFHE Pearl Harbor Tank 0105 Findings (Attachment "B"), February 6, 2014.

[6] Sommer, J. T. 2002. Confirmed Release Notification for Release at Tank 6 Red Hill Tank Complex, Fleet and Industrial Supply Center (FISC) Pearl Harbor, 5090 Ser N465/0013, Apr 17, 2002. Time to drain tank stated as period in between 6 am on January 13 and 2:20 am on January 18.

- For example, the Tank 5 loss of 27,000 gallons of JP-8 reported in January 2014.[7]

Provide a table that lists what is known about prior leaks. The Hawaii Department of Health's (DOH) chart shown below provides a basis for what should be included.



Additional information regarding the capabilities of currently-employed leak detection systems should be added.

The capabilities of the currently implemented leak detection systems should be explicitly included in this section to help determine what upgrades are needed, as well as to provide important information for the risk assessment (Section 8).

Recommendations:

<u>LD Recommendation 6:</u> This section should discuss the amount of fuel that that can escape from a leak during the approximately 116 hours required to drain a full tank.[8] For instance, assume a leak is detected at 20% above the minimum detection limit and the leak site is in the bottom of the tank. This leak will continue at this rate (slowing somewhat as the pressure decreases with lowering of the fuel level) during the 116

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[7] Commander Navy Region Hawaii (Navy). 2014. Tank 5 Initial Release Response Report, Red Hill Bulk Fuel Storage Facility, JBPHH, Oahu, Hawaii, Letter 5090 Ser N45/044, Jan 23, 2014.

[8] Commander Navy Region Hawaii (Navy). 2014. Tank 5 Initial Release Response Report, Red Hill Bulk Fuel Storage Facility, JBPHH, Oahu, Hawaii, Letter 5090 Ser N45/044, Jan 23, 2014.

hours it takes to empty. The amount of fuel lost during the emptying time should also be reported.

LD Recommendation 7: Provide the probability of detecting leaks of a defined flow rate as a function of time. For instance after a planned fuel movement (evolution), how long would it take to identify a small leak? Important values to report include not only the minimum leak rate that can be detected, but also the time it takes to determine this minimum leak rate after a fuel evolution. This information should be clearly stated in the report to assist with the risk analysis as well as evaluation of future systems.

LD Recommendation 8: Details regarding the current configuration of the tanks is needed. BWS understands from the meeting that multiple tanks containing the same product (e.g., JP-5) are connected together through a common discharge line. Doing so potentially allows all connected tanks to have the same fuel level. However, the Navy stated that this configuration is never allowed in practice. Use of this configuration during past, present, and future operations should be clearly explained.

LD Recommendation 9: A full explanation is needed regarding the 0.5, 0.75, 1.0 and 1.5 inch UFM alarm thresholds, as well as what actions are taken when alarm levels are reached. Also, the section should describe how much fuel could escape before triggering the 1.5" critical alarm. A simple calculation would indicate that this would correspond to a loss of 7,445 gallons (gal) of fuel lost; if it took a day for the critical alarm to actuate, the 1.5-inch of fuel level movement corresponds to a rate of 7,445 gal per 24 hours (hr), which equals 305 gal/hr or 5 gal per minute (min). If the 1.5-inch critical alarm was activated over 3 hours, the same amount of fuel would be lost, but the minimum detectable leak rate would be 40 gal/min. These issues should be discussed in the section.

LD Recommendation 10: Additional documentation regarding how the 0.5 gal/hr detection limit is arrived at should be included. Discussion of the applicability of the leak detection limits equation from Mass Technology Corporation, and confirmation that the equation can be applied to tanks as large as the Red Hill tanks should also be included.

LD Recommendation 11: The section should address discrepancies between various leak detection limits outlined in this report (including appendices) and the 2010 Naval Audit Service Report, which indicates that fuel volumes in excess of 28,910 gallons may be released into the environment on an annual basis without any tanks failing. Alternate calculation approaches for estimates of the amount of fuel that could be released on an annual basis without detection are shown in the table below. Similar calculations should be provided in this section, along with any methods by which undetected releases could be mitigated.

LD Recommendation 12: The section should describe why guided wave level detection methodologies cannot be used in these tanks or why they do not provide any additional accuracy over the currently implemented techniques.

LD Recommendation 13: Table 3-2 from the National Work Group on Leak Detection Evaluations regarding leak detection systems classified the Mass Technology Corporation Precision System as realistically applicable to the Red Hill tanks with a leak detection limit of 0.5-0.6 gal/hr and nonstandard transducers. This section should describe how the system is implemented, and how the leak detection limit used in the section was arrived upon.

Type of Testing	Frequency	Leak Detection Limit (gal/hr)	Max. Undetectable Fuel Loss (gal/year/tank)	Max. Undetectable Fuel Loss for 15 Tanks (gal/year)
Tank Tightness Testing	Annually/Biennially[9]	0.22[10]	1,930	28,950
Tank Tightness Testing	Annually/Biennially[11]	0.50[12]	4,380	65,700
Tank Tightness Testing	Annually/Biennially[13]	0.70[14]	6,130	91,980
UFM Alarm (0.75 inch)	Continuous	5.12[15]	44,850	n/a
MTG 3000/AFHE System	Continuous	23.5[16]	205,860	n/a

LD Recommendation 14: BWS recommends that leak detection incorporate real time monitoring of vapor levels in the bores below each tank.

BWS Comments on Section 5 Regarding Metal Fatigue and Corrosion

[9] The AOC/SOW includes provisions for annual tank tightness testing; prior to the AOC/SOW agreement, DLA Energy agreed to test the Red Hill tanks biennially.

[10] Based on test method calculated rate; p. 14 of Leak Detection Report.

[11] The AOC/SOW includes provisions for annual tank tightness testing; prior to the AOC/SOW agreement, DLA Energy agreed to test the Red Hill tanks biennially.

[12] Based on pilot testing in February 2008; p. 14 of Leak Detection Report.

[13] The AOC/SOW includes provisions for annual tank tightness testing; prior to the AOC/SOW agreement, DLA Energy agreed to test the Red Hill tanks biennially.

[14] According to the appendix to the Leak Detection Report, the last biennial tests of 15 of the 18 tanks (completed in 2013) were successful with no detectable leaks above the test method's minimum detectable leak rate of 0.7 gallons per hour.

[15] Assuming one month in between evolutions and gallon per inches of movement value derived from Space and Naval Warfare, 2014, AFHE Pearl Harbor Tank 0105 Findings (Attachment "B"), February 6, 2014, where a loss of 8 inches in fuel level reportedly corresponds to a maximum of 39,312 gallons of fuel (i.e., 4,914 gallons per inch, or 3,686 gallons per 0.75 inches).

[16] According to the appendix to the Leak Detection Report, the MTG 3000/AFHE System, as configured, has a minimum detectable leak rate of approximately 23.5 gal/hr. if the tank level changes by 0.75 inches in a one week period. The 23.5 gal/hr. rate is also mentioned in Naval Audit Service, 2010, Audit Report: Department of the Navy Red Hill and Upper Tank Farm Fuel Storage Facilities, Report Number N2010-0049, August 16, 2010. The audit report indicates that a 23.5 gal/hr. leak rate could translate to 4,000 gallons of fuel being released in the time period required for trend analysis to identify an anomaly.

Section 5 of the report reviews current corrosion control practices including cathodic protection and coatings applied at Red Hill, as well as integrity assessments that have been performed. The section also discusses metal fatigue design considerations and fatigue inspections. BWS has identified the following data gaps and has provided our recommendations on how to address these data gaps.

Metallurgical evaluation data for Tank 16 liner sample at TesTex facility or out-of-service Tanks 1 and 19 are not included.

Data regarding the initial distribution (frequency, size) of weld defects from the original construction welds or from repair welds along with any growth of these defects from corrosion or fatigue are not included in the section. These data are important for TUA considerations. Analysis of the samples of the steel liners from Tanks 1, 16, and 19 could provide evidence of current tank status, along with internal and external corrosion rates for the tank liners.

Recommendations:

MF&C Recommendation 1: Perform destructive testing (DT) on the Tank 16 sample that has already been removed and is currently located at TesTex facility. A portion of this sample could provide immediate information regarding the steel metallurgy, welding metallurgy, and information regarding weld defects.

- The Navy stated during the May meeting that they could not get a sample of this plate. Has the Navy even asked TesTex for some of this plate for investigational purposes? Is not this plate Navy property? When will the Navy retrieve the plate or a sample from the plate?

MF&C Recommendation 2: Perform Non-destructive Testing (NDT) followed by DT on out-of-service tanks, such as Tank 1 and Tank 19, to determine probability of detection (POD) for each NDT technique used for tank inspections using qualified NDT inspectors under actual tank inspection conditions. After these tanks have been inspected for defects, a statistically based experimental plan (i.e. design of experiments) should be developed with two goals in mind. The first goal is to develop information regarding the reliability of the inspection techniques including development of POD curves for the various techniques used. The second goal is to help determine the nature of the defects and the actual size distribution, i.e., corrosion, fatigue or cracking, dents, weld porosity, defects in repair welds, etc. The experimental plan should then select a suitable number of areas of the tank that NDT indicate large defects as well as areas of the tank that NDT indicate no, or small defects. It should also include original plate materials and welds as well as plate and welds from previously repaired regions. Each area cut from the tanks should be 2 feet by 2 feet square or larger. These plates should then be subjected to x-ray radiography to clearly identify the location of any defects and then these plates can be marked for destructive examination by cutting and polishing sections in order to characterize the nature and size of the defects. These results will help to more fully characterize the corrosion rate distribution at various locations in the tank along with the weld defect distribution in the original and repair welds. This NDT analysis is needed to quantify the probability of detection of a defect of a certain size, which is needed during the risk assessment.

Evidence-based external and internal corrosion rates for steel tank liners should be included in the section.

To accurately predict corrosion rates of the steel liners, rate estimates should be based upon direct observation of tank corrosion behavior. Tracking the thickness of the liner plates over time allows for accurate assessment of the general corrosion behavior.

Recommendation:

MF&C Recommendation 3: The corrosion rate estimation should be based on actual tank plate corrosion. For instance, the plate removed from Tank 16 in 2006 (now at TesTex), showed severe thinning from the concrete side as well as two through holes. The observed corrosion corresponds to a corrosion rate greater than 1/4-inch in 65 years, i.e. 0.0038 inch/year or 3.8 mils per year (mpy). This rate is much higher than the "external corrosion rate" the Navy calculates on a theoretical basis and doubles to 3.5 mpy as a "conservative engineering assumption." However, the Navy's calculated corrosion rate multiplied by two is not conservative because it is still lower than an observed corrosion rate for a plate removed from the Red Hill tanks. Thus, even without calculating a corrosion rate, corrosion rates high enough to penetrate the tanks wall have been observed. The corrosion rate was high enough to have penetrated a plate at least 10 years ago. The impact of the observed corrosion rates need to be discussed and considered in this section.

- During the meeting the Navy appeared to indicate that the corrosion on the plate from Tank 16 was anomalous and not representative of the tanks as a whole. The Navy believes this high corrosion rate was a result of a piece of wood being in contact with the steel and was therefore not representative of normal corrosion. However, the Navy should discuss the following:
    - The corrosion on the Tank 16 sample was described as a general plate thinning, not just two holes where wood block was in contact.
    - As wood was used extensively in the original construction, it is likely that similar areas are present in other locations in other tanks.

Information about evidence of metal fatigue and corrosion in tank and related piping is not included.

Section 5-3 states that there are no inspection data that suggest metal fatigue issues are present in the tanks. However, there are no records provided that indicates on what basis fatigue is being dismissed. In addition, this section does not provide historic records regarding corrosion in the tanks and related piping.

Recommendations:

MF&C Recommendation 4: This section should discuss what inspection data was used to make the determination that fatigue is not an issue.

MF&C Recommendation 5: A summary of the following should be discussed in this section:

- Tank coating surveys
- Pipeline inspection result programs.[17] This section should discuss the results of in line inspection (ILI) of the piping to the tanks and data regarding number/size of defects. It should also discuss the nature and cause of the following incident: "during the inspection, a critical leak was discovered that likely would have resulted in a catastrophic failure if left undetected."[18]
- Tunnel leaks surveys.[19] This section should also discuss the tunnel leaks observed, and the conclusion of this report that the Navy should "... perform a tunnel integrity survey to determine the cause of the water dripping into the tunnel."[20] It should also state whether or not this analysis that was recommended in 2007 was performed, and what the results were.

MF&C Recommendation 6: Destructive analysis should be performed on any plate or piping removed to fully characterize the number, size, type, and depth of defects and corrosion. All the results obtained should be included in the section, and also used to estimate future corrosion estimates and current defect size distributions.

MF&C Recommendation 7: Pipe schedule/thickness data for all tank-related piping currently in operation should be included. The pipe specifications, along with corrosion data from removed pipe can be used to more accurately estimate the Tanks remaining life.

MF&C Recommendation 8: The Navy has expended much time, effort, and money to perform API inspections of some of the Red Hill tanks. This data should be analyzed and summarized in this section. For instance, the number and size distribution of weld defects and size distributions for fuel side and concrete side corrosion depths could be constructed from this data.

Corrosion-related comments made during AOC Meetings should be incorporated into the report.

During the May meeting, statements regarding corrosion observations regarding the Red Hill tanks were made and should be discussed in this section.

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[17] Office of the Secretary of Defense, 2007, *Department of Defense Report: Effort to Reduce Corrosion on the Military Equipment and Infrastructure of the Department of Defense*, June 2007; p. VI-4

[18] Office of the Secretary of Defense, 2007, *Department of Defense Report: Effort to Reduce Corrosion on the Military Equipment and Infrastructure of the Department of Defense*, June 2007; p. VI-5

[19] Office of the Secretary of Defense, 2007, *Department of Defense Report: Effort to Reduce Corrosion on the Military Equipment and Infrastructure of the Department of Defense*, June 2007; p. VI-5

[20] Office of the Secretary of Defense, 2007, *Department of Defense Report: Effort to Reduce Corrosion on the Military Equipment and Infrastructure of the Department of Defense*, June 2007; p. VI-5

Recommendation:

MF&C Recommendation 9: This section should discuss the following:

- The May 12, 2016 meeting mentioned weld pinholes and "bands of corrosion." These effects should be discussed.
- Evidence and analysis to support the Navy's statement in the May 11, 2016 meeting that "backside corrosion [is] not as big as people think."

BWS Comments on Section 8, Risk/Vulnerability Assessment

Section 8 of the report should provide a risk assessment for the Red Hill tanks, as well as for the alternatives, including the alternative to relocate the tanks from the current Red Hill area. BWS has identified the following data gaps, and has provided recommendations on how to address these data gaps.

"Acceptable risk" levels need to be defined

The "acceptable risk" has not been provided to the contractors performing the risk analysis. There are currently no details regarding what failure modes will be considered and how seismic effects will be taken into account.

For any risk assessment to be valid, the Stakeholders must determine what level or risk is acceptable (and what level of risk is NOT acceptable), and which failure scenarios to consider. The current section is an outline; however, the acceptable risk level and all failure scenarios considered need to be clearly stated. Furthermore, there is currently no mention of seismic effects, which BWS believes should be considered in the risk assessment.

Recommendations:

RVA Recommendation 1: The current draft of the risk assessment section does not include any details on who will define what level of risk can be tolerated. "Acceptable risk" target levels should be jointly defined by all Stakeholders before commencing the risk assessments. The agreed upon level should provide an acceptable target likelihood for tank rupture/leak, as well as acceptable volumes of fuel released by such rupture/leaks, and acceptable concentrations of fuel in the groundwater. Subject matter experts should be consulted to assist in determination of the likelihood and severity of failure scenarios. The risks to existing and future water supply points (especially Halawa shaft, Moanalua wells, and Red Hill shaft) and to the Southern Oahu Sole Source Aquifer must be evaluated and calculated.

RVA Recommendation 2: Clarification is needed in the scope of the section to state whether the risk assessment is only for the tanks in their as-is condition, or it's meant to incorporate planned upgrades and/or other leak mitigation activities. BWS recommends that both should be done because this will allow a comparison of risk between the various alternatives.

RVA Recommendation 3: The current outline does not state whether seismic effects will be considered. BWS believes that it is important that seismic effects be taken into account, and also that the method and inputs to the models need to be agreed upon by the Stakeholders. This section should provide details about the analysis method, as well as inputs for the seismic risk analysis, and eventually the results of the analysis after completion.

RVA Recommendation 4: Given that additional information will be forthcoming as reports and analyses are released, it should be ensured that the risk assessment be modified and revised as additional information becomes available. Additional areas that should be included in the risk assessment include, but not limited to, weld crack size and corrosion depth distribution data from additional NDT and destructive testing.

Details regarding existing fuel level and leak detection, as well as alarms and interlocks are not available for review.

To perform an accurate risk assessment, complete specifications and historic information from the Red Hill tanks need to be provided to the risk assessor. The amount of fuel stored in the tanks, ability to detect leaks, interlocks, and the response to warning and critical alarms need to be available, and are not currently included in the report.

Recommendations:

RVA Recommendation 5: Information regarding the current ability to detect and mitigate leaks needs to be added to the report. This section should provide information regarding what conditions trigger automatic valve closure on the UFM, and the residual leak rate after shutdown. The BWS recommends performing a Safety Integrity Level (SIL) assessment or a Layers of Protection Analysis (LOPA) of the tank system's interlocks/alarms.

- SIL/LOPA will assess the need for automatic emergency shutdown valves on pipelines that minimize leak severity

RVA Recommendation 6: Given the large amount of uncertainty with both the current state of the Red Hill tanks as well as potential failure modes, a sensitivity analysis should be performed to understand the underlying uncertainties in the risk assessment modeling assumptions.

Selection and evaluation of mitigation techniques to maximize decrease of risk for each failure scenario should be included in the RVA.

The current section outline does not detail how the risk assessment will be performed. BWS recommends that the evaluation maximize the decrease in risk for all failure modes that are considered.

Recommendation:

RVA Recommendation 7: To select the optimum mitigation technique, a sensitivity analysis identifying those mitigation actions that would result in the largest decreases in aquifer contamination risk should be performed. The analysis should take into effect as many failure scenarios as possible, and details of the inputs and results should be provided in the report.

Additional information for selection of failure scenarios for evaluation should be provided.

The basis for selection (and exclusion) of failure scenarios should be provided in the section.

Recommendations:

RVA Recommendation 8: This section should include information on how failure scenarios were selected, as well as rationale for exclusion of failure scenarios. There are many unknowns and potential failure scenarios that should be considered, which include, but are not limited to:

- Condition of tank (testing results are not available for review)
- Condition of pipeline(s) (testing results not available for review)
- Include risks (including but not limited to):
    - Risk (including seismic risk) associated with the Red Hill pipe supports/racking. Some supports appear to be welded directly to pipes that could tear off during a seismic event. Furthermore, a Department of Defense report suggests that there are only 26 pipe supports for over 3 miles of piping, which is likely a seismic risk.[21]
        - In a meeting, it was stated that the original design included a seismic analysis. The report should document which standard was used, and how the standard differs from current seismic design standards.
    - Earthquake-induced ruptures from Diesel, JP-5 and JP-8 pipeline into the tunnel
    - Seismic rupture of water pipeline and subsequent impact to fuel pipelines
    - Leak/rupture of small bore pipelines (sampling lines)
    - Tank leak/rupture
    - Tank overfill/spill
    - Fire
    - Maintenance accident
    - Human factors (incorrect operation)
    - Sabotage (internal/external)

RVA Recommendation 9: The scope of the risk assessment should be expanded to include costs associated with contamination of the aquifer. Consideration of how the costs are affected by volume of leaked fuel, location of the leak, etc. should be included.

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[21] Office of the Secretary of Defense, 2007, *Department of Defense Report: Effort to Reduce Corrosion on the Military Equipment and Infrastructure of the Department of Defense*, June 2007; p. VI-4.

Additional data is required for selection scenarios to evaluate as well as to establish the severity and likelihood of scenarios.

For the risk assessment to provide accurate results, complete records of the Red Hill tanks and the impact of leaks on the aquifer should be evaluated.

Recommendations:

RVA Recommendation 10: The scope appears to omit downstream evaluation of the risk of groundwater contamination. This is a critical risk that must be considered.

RVA Recommendation 11: There are gaps in the data for contaminant health effect studies, tank inspection records, tank leak records, pipeline inspection records, pipeline leak history, and seismic analysis data for the Red Hill pipe supports/racking that should be reviewed in order to select the scenarios for evaluation. These gaps should be filled to the extent possible to improve the accuracy of the risk assessment.

RVA Recommendation 12: BWS recommends that detailed piping and instrumentation diagrams/drawings (P&IDs) be developed, showing the layout of tank valves, tank instrumentation, pipeline valves and associated instrumentation and interconnections between various tanks etc. Without such P&IDs it is possible that some critical failure modes may be "overlooked."

Information about how the results for risk assessment for TUAs will be compared and verified is not included currently in the section.

The current scope of the risk assessment is to evaluate the level of risk of the Red Hill Fuel Storage Facility and assist in selection of the best available practicable technology decisions. However, there is little information on how this will be accomplished in the current outline of the section. In order to select the best TUA, an impartial method needs to be selected for comparison of the TUAs.

Recommendations:

RVA Recommendation 13: An independent review of the analysis should be performed after completion to ensure accurate and unbiased results. The current outline does not include independent verification of the results, which should be performed as part of the risk assessment.

RVA Recommendation 14: Information on how the risk assessment will use Fate and Transport modelling should be included in this section. The severity and location of location of a fuel release may affect how the groundwater is influenced and the potential impacts to water extraction facilities, especially Halawa shaft, Moanalua wells, and Red Hill shaft. The report should address how Fate and Transport modelling will be used to assess the risk of groundwater contamination.

RVA Recommendation 15: There should be inclusion of a method for comparison of risk level between the current storage location and alternative locations. The basis for the comparison should be included together with the results to ensure that the total risk is minimized.

Selection of methods for presentation of the results should be decided to and agreed upon.

To select the optimum TUA, the outcomes of the risk assessments must be compared with one another. The current section outline does not include a section on how this will be done. BWS feels that this is very important in order to ensure selection of the optimum TUA that will reduce the overall risk of the storage facility.

Recommendation:

RVA Recommendation 16: The risk assessment should be used to determine which of the alternatives provide the optimum decrease in risk, while balancing cost and time of implementation. The current draft of the report does not detail how the comparison will be performed nor the results presented. BWS recommends using a cost-benefit analysis to determine the best ALARP risk solution.

If you have any questions, please feel free to contact me at 808-748-5061.

Very truly yours,

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