BOARD OF WATER SUPPLY

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October 7, 2018

Mr. Omer Shalev
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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 (BWS) Comments on the Navy's Conceptual Site Model (CSM), Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility (RHBFSF) Revision 1 dated June 30, 2019

The BWS has reviewed the above-referenced report and offers the following comments. Please note that BWS has submitted letters in the past that commented on previous versions of the CSM submitted by the Navy under RHBFSF Administrative Order on Consent (AOC) Section 6 (BWS, 2015; BWS, 2016a; BWS, 2016b; BWS, 2016c; BWS, 2016d; BWS, 2017a; BWS, 2017b; BWS, 2017c). We are referencing these past letters as they provide context and historical perspective to our comments contained herein.

General Comments on Navy's Revised CSM Report

The purpose of preparing a RHBFSF CSM is to provide a basis for evaluating groundwater flow, behavior of contaminants in the environment, contaminant transport pathways, and the potential for exposure of human receptors to drinking water potentially impacted by fuel releases from the facility. Our overall assessment is that the Navy's latest version of its CSM still does not provide an adequate basis for developing a groundwater flow model, nor should it be used to support an evaluation of contaminant transport pathways and the potential for receptor exposure. To the contrary, several of the key findings presented in the CSM are either unsupported or contradicted by available evidence. The Navy's most recent CSM report (DON, 2019) was also intended to address deficiencies in the prior version of its CSM (DON, 2018) identified by the

United States Environmental Protection Agency (EPA) and Hawaii Department of Health (DOH) (collectively, "Regulatory Agencies"). However, the Navy's revised CSM report fails to properly address many of the concerns raised about the prior version of the CSM by the Regulatory Agencies (EPA and DOH, 2018) and by the BWS (BWS, 2018a). As a result, many of the concerns previously raised by the Regulatory Agencies and the BWS remain valid.

In short, the Navy's revisions to its CSM are insufficient to render it useful for purposes of providing an accurate description of relevant site features and the surface and subsurface conditions or understanding the extent of identified contaminants of concern and the risk they pose to critical receptors like Halawa Shaft. Consequently, neither the report's findings nor the Navy's conclusions can be used to inform a potential tank upgrade alternative (TUA) unless and until these flaws are corrected. We request that the Regulatory Agencies reject the Navy's revised CSM report and take all steps necessary to protect our drinking water by requiring that the Navy upgrade the RHBFSF tanks with secondary containment or relocate them away from our sole-source groundwater aquifer.

History of CSM Development and Regulatory Concerns

The Navy's revised CSM report (Revision 01), dated June 30, 2019, is a modification of the Navy's prior CSM (Revision 00), dated July 27, 2018. Both CSM documents consist of seven modules that purport to describe the physical setting in Moanalua and Halawa Valleys, RHBFSF construction and operation, past releases and migration of light non-aqueous phase liquid (LNAPL), conceptual models of the vadose zone (subsurface between ground level and the water table) and saturated zone (subsurface below the water table), fate and transport of dissolved and LNAPL contamination, and a model for exposure to fuel contaminants.

The Navy received comments from the BWS, dated October 24, 2018 (BWS, 2018a), and from the Regulatory Agencies, dated October 29, 2018 (EPA and DOH, 2018), and DOH, dated July 1, 2019 (DOH, 2019a) regarding specific inadequacies of the Navy's CSM Revision 00. Among the EPA, DOH, and BWS there was a general consensus that certain interpretations and determinations included in the Navy's CSM Revision 00 (DON, 2018a) were premature and/or inappropriate. For example, the Regulatory Agencies' expressed the following initial concerns with the Navy's CSM Revision 00 in October 2018:

- "Predominant strike and dip of basalt in the geologic model: the direction and magnitude as represented by the Navy thus far do not agree with the lava flow geometry independently evaluated by the Regulatory Agencies and provided to the Navy. This information is important because it will influence Navy's conclusions regarding groundwater flow paths and transport" (EPA and DOH, 2018).

- "Saprolite extent in the interim model vs. depths inferred by seismic profiling: the extent of the modeled saprolite/basalt interface depths do not agree with the seismic profiling. In particular, the seismic profiling indicates that the saprolite layer depth in the upper reaches of the Halawa Valleys constitutes a much less protective barrier to northwest groundwater flow than the (Navy) groundwater flow model (GFM) indicates. This directly impacts the evaluation of risk to the Halawa Shaft" (EPA and DOH, 2018).

- "Preferential pathways: the consideration and methods of incorporation of preferential pathways in both the Navy CSM and the GFM are unclear. Although it is impracticable to precisely characterize these features, the influence that geologic structures, such as voids, fractures, lava tubes, and the permeable interface between lava flows, have on contaminant and groundwater transport should be explained conceptually in the CSM. The influence of these structures should also be incorporated into the GFM using appropriate and traceable mathematical representations. This directly impacts the Navy's ability to evaluate contaminant transport in the vadose zone and in the groundwater" (EPA and DOH, 2018).

In its July 2019 evaluation of the groundwater flow paths in the Moanalua, Red Hill, and Halawa regions, the DOH listed several still-outstanding issues with the Navy's CSM and the Navy's groundwater flow model that need resolution, including:

- The disparity between the measured and modeled groundwater gradient along the axis of Red Hill Ridge and its implications for a reliable CSM and numerical groundwater flow model;

- The absence of supporting field data for the CSM-assumed primary groundwater flow direction toward the southwest and away from Halawa Shaft (one of the key receptors of concern);

- Overestimation of the resistance to northwest groundwater flow posed by the lower-permeability materials (valley fill and saprolite) given seismic study indications that the valley fill/saprolite likely poses little resistance to groundwater flow in the South Halawa valley adjacent to the underground storage tanks (USTs) and in North Halawa valley adjacent to Halawa Shaft; and,

- Lack of consideration of groundwater flow toward the northwest without providing a compelling rationale (DOH, 2019a).

As a result, the Regulatory Agencies requested that the Navy address these concerns and revise its CSM. The Navy's revised CSM report states that a primary goal of the CSM Revision 01 is to address the Regulatory Agencies' comments to the CSM Revision 00. Despite this stated goal, the revised Navy's CSM does not address many of these comments. Accordingly, the BWS requests that the Regulatory Agencies direct the Navy to provide a separate written response to each comment and supplement any inadequate response, and that the Regulatory Agencies provide either an approval or disapproval of such responses in writing. Unless and until the Navy has adequately addressed all outstanding CSM comments, <u>the Regulatory Agencies should not allow the current CSM to inform a potential TUA decision</u>. In the absence of an adequate CSM, and in order to protect Oahu's critical drinking water supply, the Regulatory Agencies should require the Navy to either relocate the RHBFSF tanks away from our sole source groundwater aquifer or, at a minimum, upgrade the tanks with secondary containment. The revised CSM is inadequate in several areas as follows.

Uncertainty and Potential Bias

The revised CSM fails to provide a proper assessment of the significant uncertainty associated with the Navy's characterization of the groundwater flow system and of the nature and extent of groundwater contamination at the RHBFSF. In fact, key analysis associated with the most basic aspects of the uncertainty with groundwater flow systems remain unresolved. For example, nowhere in the CSM does the Navy address the fundamental problem of a lack of an adequate monitoring well network for monitoring water levels and groundwater contamination near the fuel tanks. Although EPA guidelines (EPA, 1988; EPA, 1989) do not specify the number of monitoring wells needed to adequately characterize the groundwater flow system and contaminant plume extent, they clearly indicate the density of monitoring well networks should increase with the hydrogeological complexity of a site. Without a sufficient number of monitoring wells in the right locations, the ability to estimate groundwater flow directions and the properties of contaminant plumes will be subject to considerable uncertainty.

The Navy is essentially relying on data from three monitoring wells (RHMW-01, RHMW-02, and RHMW-03) within 450 feet of the twenty RHBFSF tanks, which is far too sparse a monitoring well network for a facility with such a large fuel storage capacity and complex subsurface geology. The BWS offered suggested monitoring well locations to the Regulatory Agencies and the Navy several years ago to try to mitigate this concern (BWS, 2016b). The BWS proposed, as a starting point only, that at least twelve monitoring wells be added within 50 feet of the tanks to monitor both groundwater and soil vapor (BWS, 2016b). The BWS suggested the additional data from these new wells be used to evaluate the locations for additional wells. The BWS also suggested a process (decision tree) to address how decisions would be made for additional well locations and well installation order based on new data (BWS, 2016a), but to date the Navy has neither implemented these recommendations nor provided a reasonable justification for its current approach.

The sparse monitoring well network used by the Navy to measure water levels and groundwater contamination is a major contributor to this uncertainty. Given the subsurface conditions in the vicinity of the RHBFSF, where LNAPL migration occurs in a highly heterogeneous basalt containing preferential flows, the BWS believes that the Navy's current monitoring well network is inadequate and should be addressed as a major source of uncertainty in the CSM. Because of the considerable uncertainty associated with much of the analysis in the CSM, the BWS recommends that the Navy revise the CSM be compliant with ASTM Guide D5447-92, which states:

> "Provide an analysis of data deficiencies and potential sources of error with the conceptual model. The conceptual model usually contains areas of uncertainty due to a lack of field data. Identify these areas and their significance due to a lack of field data. Identify these areas and their significance to the conceptual model evaluated with respect to the project objectives. In cases where the system may be conceptualized in more than one way, these alternative conceptual models should be described and evaluated" (ASTM, 1999).

Even where recent studies shed light on the uncertainties regarding groundwater flow, the Navy's revised CSM fails to adequately incorporate them. Section 2.14 "Addressing Uncertainty" of the CSM states:

> "Resolving uncertainty regarding groundwater levels and hydraulic gradients in the site vicinity is an important objective of recently completed, ongoing, and planned investigation. These investigations include the well elevation survey and the gyroscope survey for Red Hill groundwater monitoring wells, synoptic water level measurement recently collected by the United States Geological Survey (USGS) and installation of new monitoring wells at Red Hill and in North and South Halawa Valleys" (DON, 2019) (citations omitted).

The BWS is concerned that despite the CSM having been released a year after the completion of the three studies referenced above, the Navy's CSM does not provide any flow directions based on this data. This critical omission should be deemed unacceptable by the Regulatory Agencies given the fact that both the BWS and the Regulatory Agencies have been able to produce maps of hydraulic contours using the USGS synoptic data.

Finally, based on our review of the data, the Navy's revised CSM appears biased to promote site conditions and processes that would favor a conclusion that there is a low risk of groundwater contamination from a fuel spill. For example, with respect to groundwater flow, the CSM treats basalt as an equivalent homogeneous media, assumes that valley fill and/or saprolite acts as an effective barrier to shallow groundwater flow, and concludes that groundwater flow is primarily from mountain (mauka) to the ocean (makai).

An important set of alternative conceptual models that should be identified and discussed by the Navy in its CSM are those that would lead to a more conservative prediction of risks to the sole-source aquifer. Examples of alternative conceptual models for the groundwater flow system that the BWS recommends consideration are the following:

- In the vicinity of RBHFSF, a principal component of groundwater flow is toward the northwest.
- The groundwater flow and transport in the basalt cannot be treated as an equivalent porous media (EPM) and groundwater flow is principally within preferential flow paths define by the interconnection of clinker zones. The measured water levels in the upper 30 feet of the basalt is not reflective of the groundwater flow system at depths greater than 100 feet.

The Navy's apparent bias in interpreting site data is particularly evident in its development of a clinker-zone model, which is discussed in greater detail below. This model, which was presented to the public as representative of site conditions, includes locating a single clinker zone along the axis of RHBFSF that provides a preferential pathway to Red Hill Shaft. This clinker-zone model effectively manufactures hydrogeological conditions that would act like a conduit for draining shallow groundwater from beneath the fuel tanks to Red Hill Shaft. The Navy continues to advocate for this model even though the physical attributes of the clinker zone are physically and geologically implausible and the simulated hydraulic gradients are opposite of the direction indicated by the measured hydraulic gradients. Simply put, the clinker-zone model is unrealistic and inconsistent with existing site data.

Characterization Hydrogeology

The Navy's revised CSM is deficient in its characterization of certain important site features and conditions, most notably hydraulic gradients and the aquifer properties of preferential flow and saprolite. These features and conditions are important because they largely determine groundwater flow direction and groundwater flow velocity.

Hydraulic Gradients

A major issue with the Navy's interim groundwater model has been its inability to reproduce the direction and magnitude of the measured hydraulic gradients. This issue is caused by, at least in part, the model's reliance on certain CSM findings that are unsupported and/or contradicted by available evidence. As stated by DOH and previously discussed by this letter, a major point of disagreement between the Regulatory Agencies and the Navy's current CSM and interim groundwater flow model is the groundwater flow direction in the vicinity of the RHBFSF tanks (DOH, 2019a). The key disparity is that where the modeled groundwater gradients are principally along the axis of Red Hill ridge the measured groundwater gradients are principally across the axis of the Red Hill ridge.

Unfortunately, the CSM Revision 01 does not resolve these issues. To address these concerns, the Navy needs to further revise the CSM to provide a detailed analysis of the measured hydraulic gradients, to determine to what extent the hydraulic gradients can be characterized by horizontal gradients, and to provide maps of flow lines as specified by ASTM Guide D5447-92 (ASTM, 1999), which is titled "Application of a Ground-Water Flow Model to a Site-Specific Problem." This standard specifies that the analysis of the flow system must include "the assessment of vertical and horizonal gradients, delineation of ground-water divides, and mapping of flow lines."

As a result of concerns raised by Regulatory Agencies and the BWS, the Navy has changed several declarative assertions regarding groundwater flow directions included in the previous CSM to statements of "likely" conditions in its current CSM. Two examples of these revisions are:

1. "General transport of COPCs [contaminants of potential concern] in the dissolved plume **is** in the southwest direction toward Red Hill Shaft" (DON, 2018a) (emphasis added) was changed to "General transport of COPCs in the dissolved plume is **expected to be** in the southwest direction toward Red Hill Shaft" (DON, 2019) (emphasis added).

2. "Migration to the southeast and northwest **is** limited by the extent of lower permeability material" (DON, 2018a) (emphasis added) was changed to "Migration to the southeast and northwest **is expected to be** limited by the extent of lower-permeability material" (DON, 2019) (emphasis added).

Based on our review of the data, these changes do not sufficiently address the considerable deficiencies raised by the Regulatory Agencies and the BWS about the Navy's assessment of the actual data. For example, despite having over a year to update the analysis of water level data, the revised CSM does not provide a single map showing groundwater contours of water levels and inferred groundwater direction based on the 2017-2018 synoptic monitoring event.

Throughout the revised CSM, the Navy attempts to justify its decision not to map contours of water levels by claiming that because of the highly permeable basalt, the water table is flat and hydraulic gradients cannot be determined with great confidence. This is not supportable and the BWS, the EPA and DOH all concur that mapping contours here is possible (BWS, 2019; EPA and DOH, 2018).

In both the revised CSM and the prior version, the Navy presents the measured water levels in wells during the 2017-2018 synoptic water level survey but does not include contours of water levels. Figures 1 through 4 below provide the missing contours for four dates using water levels uncorrected for barometric pressure. Despite the relatively flat water levels, the water table contours interpolated from the measured water levels provide a very consistent set of results for the four dates. Most notably, all four figures show a much larger hydraulic gradient to the northwest than the southeast at the RHBFSF. It should also be noted that the results in Figures 1 through 4 are very similar whether or not the water levels are corrected for barometric pressure.

Figure 1 Measured water levels at 01/15/2018 6:00 after Red Hill Shaft has been not pumping for five days

Source: Honolulu Board of Water Supply (BWS). 2019. Letter from BWS to EPA and DOH dated April 12, 2019. Subject: Board of Water Supply (BWS) Comments on the Red Hill Administrative Order on Consent (AOC) Statement of Work (SOW) Sections 6 and 7 Groundwater Modeling Working Group Meeting No. 14 held March 13, 2019

Figure 2 Measured water levels at 01/19/2018 21:00 after Red Hill Shaft has been pumping five days at 7.7 MGD

Source: Honolulu Board of Water Supply (BWS). 2019. Letter from BWS to EPA and DOH dated April 12, 2019. Subject: Board of Water Supply (BWS) Comments on the Red Hill Administrative Order on Consent (AOC) Statement of Work (SOW) Sections 6 and 7 Groundwater Modeling Working Group Meeting No. 14 held March 13, 2019

Figure 3 Measured water levels at 02/05/2018 19:00 after Red Hill Shaft has been pumping as usually and Halawa Shaft has not been pumping

Source: Honolulu Board of Water Supply (BWS). 2019. Letter from BWS to EPA and DOH dated April 12, 2019. Subject: Board of Water Supply (BWS) Comments on the Red Hill Administrative Order on Consent (AOC) Statement of Work (SOW) Sections 6 and 7 Groundwater Modeling Working Group Meeting No. 14 held March 13, 2019

Figure 4 Measured water levels at 02/19/2018 13:00 after Red Hill Shaft has been pumping as usually and Halawa Shaft has maintained averaged pumping rate

Source: Honolulu Board of Water Supply (BWS). 2019. Letter from BWS to EPA and DOH dated April 12, 2019. Subject: Board of Water Supply (BWS) Comments on the Red Hill Administrative Order on Consent (AOC) Statement of Work (SOW) Sections 6 and 7 Groundwater Modeling Working Group Meeting No. 14 held March 13, 2019

Figure 5 was generated by the DOH and includes a greater area and a different set of contour intervals. Figure 5 demonstrates that the Navy's presumption that groundwater flow in the vicinity of the RHBFSF is from mountain (mauka) to ocean (makai) is not supported by the measured water levels. In its discussion of the hydraulic gradients, the DOH acknowledges that other modeling studies have also assumed mauka to makai flow in the Red Hill area. However, after their review of the measured water level the DOH states:

> "The groundwater elevation contours beneath the Red Hill Ridge and beneath the Halawa-Aiea area indicate that at least where the penetration of the saprolite into aquifer is either shallow or non-existent, the relative groundwater elevations indicate groundwater flow to the northwest. More specifically, the groundwater contouring strongly suggests that the flow direction beneath the upper part of the facility is to the northwest. This observation is in direct contrast to the Navy's expectation that the water flows along the shortest mauka to makai path from the high elevation recharge areas to the coast" (DOH, 2019a).

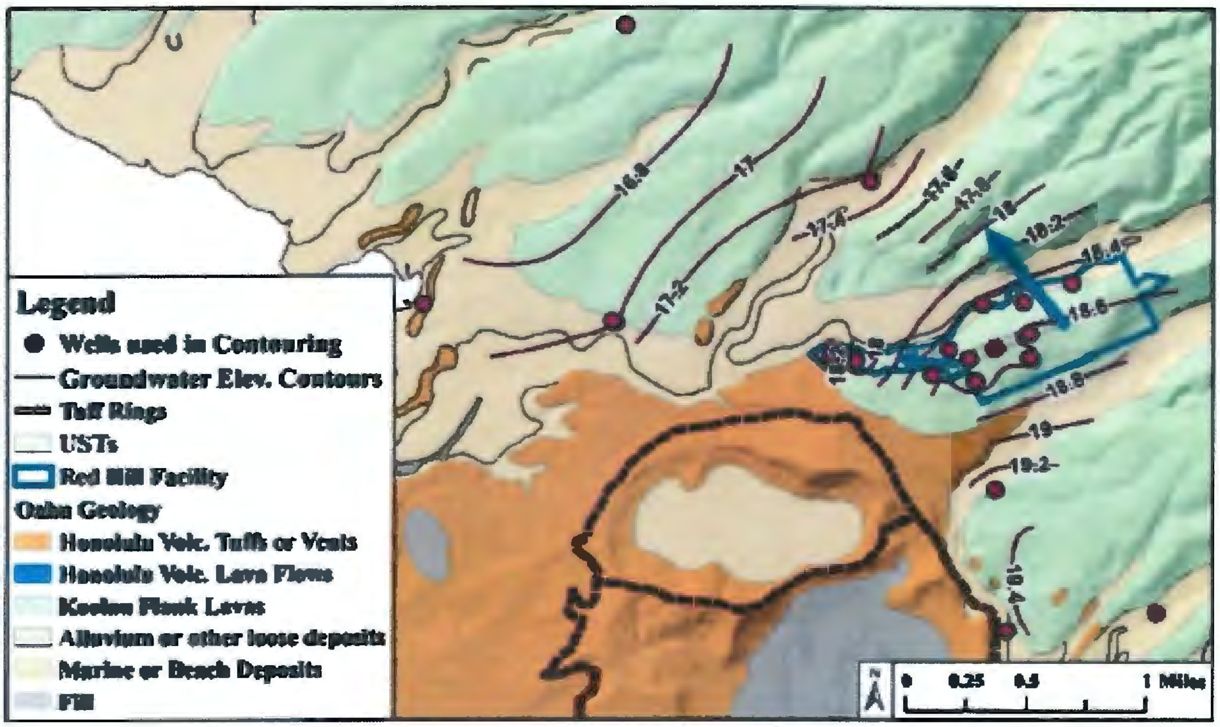


Figure 5 Water level contours interpolated from water levels measured at 2/05/2018 after pumping as usual and Halawa Shaft has not been pumping. Arrow indicated the implied groundwater flow directions based on groundwater elevation contours

Source: Department of Health, Safe Drinking Water Branch (DOH). 2019a. Hawaii Department of Health Evaluation of Groundwater Flow Paths in the Moanalua, Red Hill, and Halawa Regions, Revision 2 by Whitter, R.B., Thomas, D.M., and Becket, G.D. July 11.

It is clear to the BWS and consistent with comments from the Regulatory Agencies that the available evidence simply does not support the Navy's mauka to makai only groundwater flow regime. Despite all the analysis and data that has been presented to the Navy on this issue since its last CSM iteration, the revised CSM still does not appear to consider this information and does not meaningfully discuss any alternative conceptual models for the groundwater flow system. This is a critical flaw that undermines the Navy's entire analysis.

Aquifer Properties – Preferential Flows

The Navy's revised CSM presents considerable data that shows that preferential flow paths and zones of high permeability are not uncommon in the basalt. The Navy also states that interconnection of clinker zones represents the preferential flow paths that could account for a significant portion of groundwater flow. The BWS agrees that clinker zones provide preferential flow pathways for groundwater. However, after the Navy identifies clinker zones as being of paramount important to groundwater flow, the Navy goes on to promote conceptualizing and modeling the basalt as an EPM without describing how the preferential flow pathways could bias data analysis and risk predictions. The concerns that the BWS has with the current CSM are consistent with comments prepared by Matt Tonkin (Tonkin, 2018), EPA, and DOH (EPA and DOH, 2018) regarding the previous CSM, which are:

> "Studies from other basalt regions, however, indicate a high potential for connected flow-paths that can enhance migration distances and rates versus EPM assumptions: and, though few controlled experiments are published for conditions directly analogous to Red Hill, studies in simpler environments show heterogeneous migration even under ideal conditions. At Red Hill, the documented geology, stratigraphic exposures in the nearby quarry, and variable hydraulic gradients indicate the subsurface is more complex than the current CSM and groundwater model represent" (Tonkin, 2018).
>
> "The consideration and methods of incorporation of preferential pathways in both the CSM and the groundwater model are unclear. Although it is impracticable to precisely characterize these features, the influence that geologic structures, such as voids, fractures, lava tubes, and the permeable interface between lava flows, have on contaminant and groundwater transport should be explained conceptually in the CSM. The influence of these structures should also be incorporated into the GFM [groundwater flow model] using appropriate and traceable mathematical representations. This directly impacts the Navy's ability to evaluate contaminant transport in the vadose zone and in the groundwater" (EPA and DOH, 2018).

In July 2019, the Regulatory Agencies expressed significant concerns that the Navy has prematurely dismissed the importance of preferential pathways and presumed that the basalt could be modeled as an EPM:

> "[I]t is typical in scientific literature that the character of the host rock is demonstrated to be reasonably approximated at relevant scales using an EPM. This has not yet been demonstrated at Red Hill. The agencies have noted in past comments that aspects of the fractured and void-influenced system need to be quantified as an initial basis to understand the scale and behavior of LNAPL and associated contaminant transport in this system.
>
> ...
>
> If it can be demonstrated that the character of the void/fracture structure at Red Hill can be reasonably approximated at relevant scales using an EPM assumption, it is then necessary to develop parameters for the distributed porous media model that reasonably represent the movement of fluids through the host rock" (DOH and EPA, 2019) (citation omitted).

During Groundwater Modeling Working Group Meeting No. 14 (March 2019) the Navy stated that it would continue with a clinker-zone model and will also construct a "heterogeneous" model. The results of the Navy's clinker-zone model are cited throughout the revised CSM and were presented in a November 2018 Honolulu City Council meeting to demonstrate the Navy's interim model is adequately predicting groundwater levels. As previously discussed by BWS, the Navy's clinker-zone model and its simulated water levels is physically implausible and inconsistent with field data and therefore should not be considered as a viable model (BWS, 2019).

The clinker model scenario is shown in Figure 6, a sole clinker is located within only model layer 2 and within a narrow lateral zone that is aligned with the location of the fuel tanks and provides a connection to Red Hill Shaft. The dip angle and thicknesses required to create the clinker realization in Figure 6 is physically unrealistic and incompatible with the CSM data included as part of the geological cross-section shown in Figure 7. To generate a flat hydraulic gradient the hydraulic conductivity of the clinker was set to 250 times greater than the basalt. Figure 8 shows the flat hydraulic gradient simulated by the clinker-zone model. The contours show that the hydraulic gradient is toward the middle of the topographic ridge, which is the opposite direction of the measured hydraulic gradient (also see Figures 2 and 3) (BWS, 2018d).

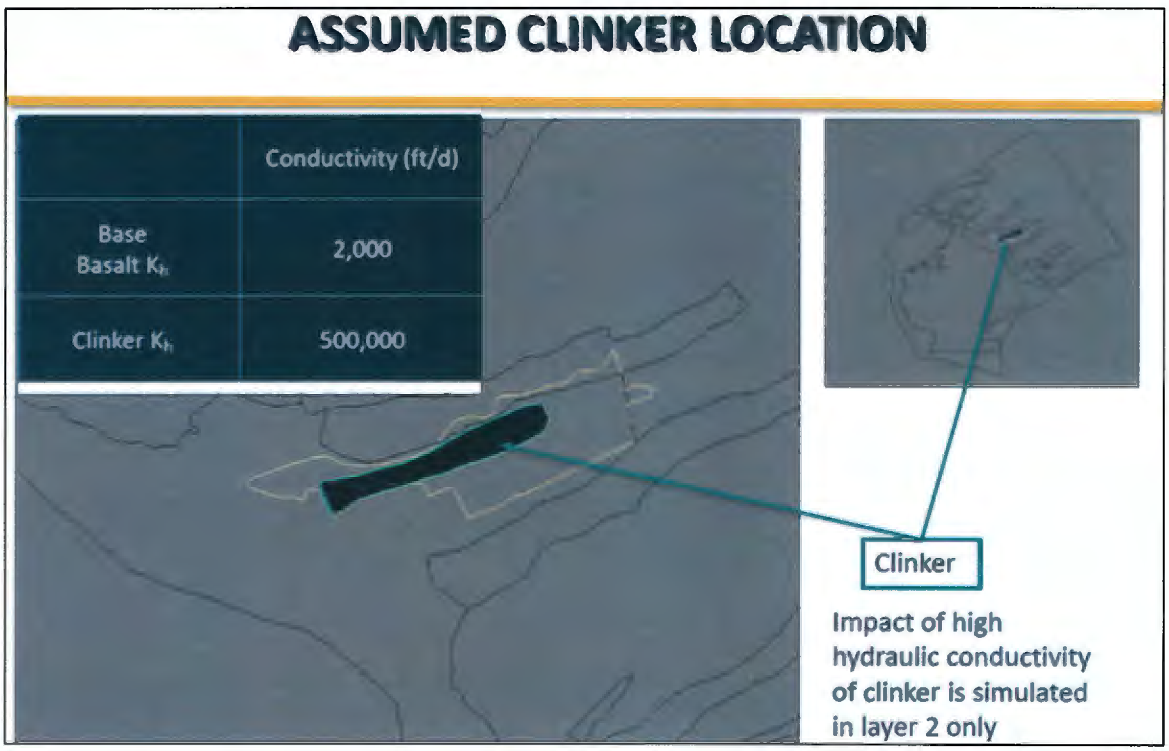


Figure 6. Location and hydraulic properties associated with Clinker Zone depicted in the Navy's Conceptual Clinker Model (modified from slide presented by the Navy on March 16, 2018 during Groundwater Modeling Working Group Meeting No. 9)

Source: Honolulu Board of Water Supply (BWS). 2018d. Letter from BWS to EPA and DOH dated April 24, 2018. Subject: Honolulu Board of Water Supply (BWS) Comments on the Red Hill Administrative Order on Consent (AOC) Statement of Work (SOW) Sections 6 and 7 Groundwater Modeling Working Group Meeting No. 9 Held March 16.

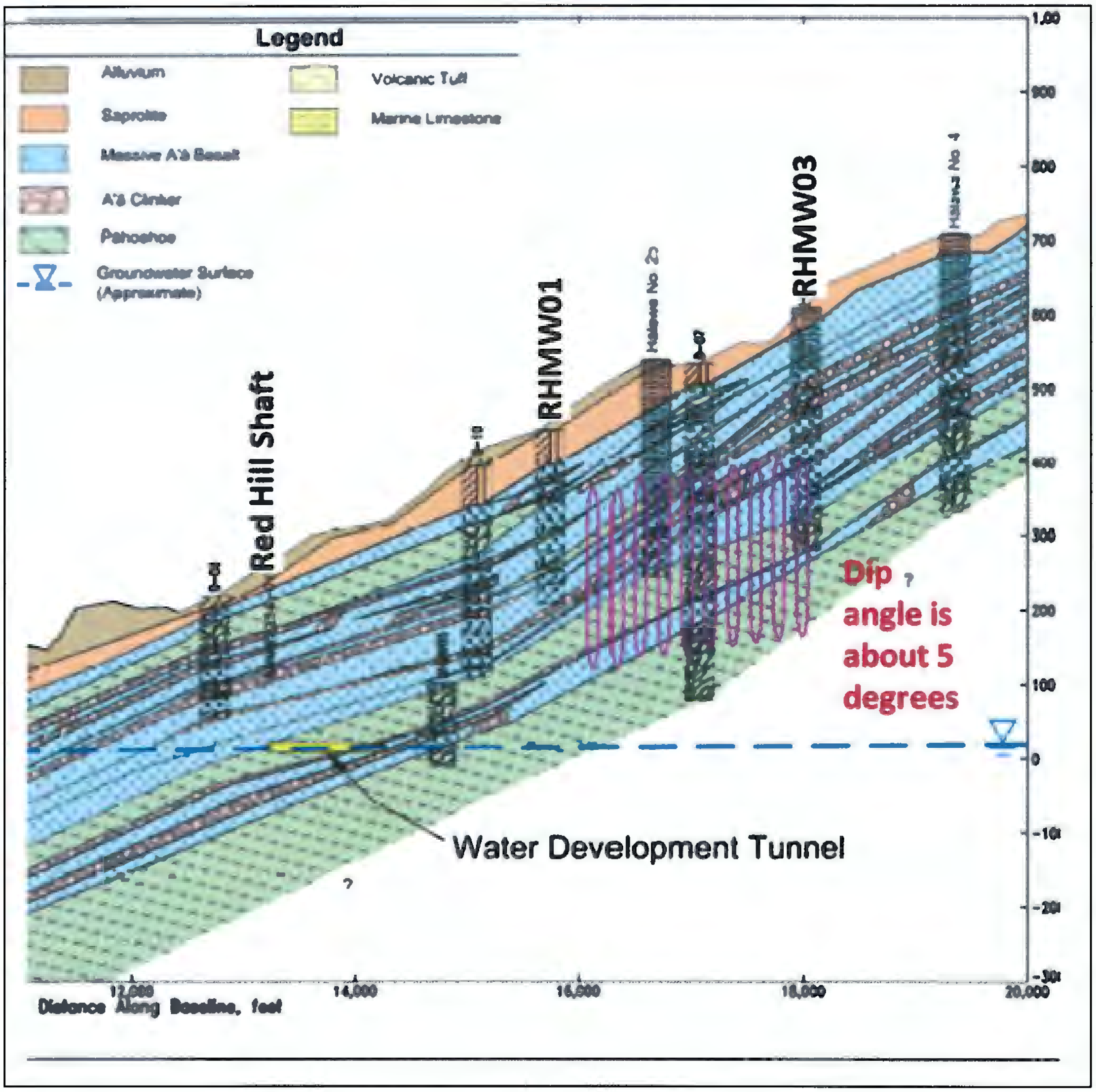


Figure 7. Mapped Basalt Zones showing dipping clinker zones in the vicinity of Red Hill Shaft and monitoring wells RHMW01 and RHMW02 (DON, 2018a Figure 5-2).

Source: Department of the Navy (DON), 2018a. Conceptual Site Model, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Storage Facility. Joint Base Pearl Harbor-Hickam, Oahu, Hawaii. July 27,2018 Revision 00, prepared by AECOM Technical Services, Inc.

Neither the Navy's revised CSM nor its groundwater flow model can be relied upon to support a TUA decision. Moreover, the CSM cannot be considered to be complete unless and until the CSM provides, at a minimum, the geologic framework used to guide and constrain the location, size, and orientation of clinkers as well as the type and amount of aquifer heterogeneity ultimately incorporated into the Navy's groundwater flow model. The Navy's clinker-zone model does not satisfy this concern. To the contrary, the Navy's clinker-zone model and its simulated water levels is physically implausible and inconsistent with field data and, therefore, should not be considered as a viable model (BWS, 2019). While the BWS acknowledges that clinker zones represent preferential flow paths, there is no geological evidence that indicates that a single clinker zone connects the shallow groundwater flow zone beneath the tanks to Red Hill Shaft as presumed by the Navy's clinker-zone model. The revised CSM does not provide any geologic information from either the tank barrel logs or the monitoring well drilling logs to model a clinker zone as shown in Figure 6. Moreover, this model is inconsistent with available data that indicates thin clinker zones dip through multiple layers and are interconnected vertically by fractured basalt.

With regard to providing information to guide the development of alternative groundwater flow and transport models, the revised CSM is limited in that it does not:

1. Provide the necessary geologic constraints needed to construct the groundwater flow models that the Navy has designated as the clinker-zone model and the heterogeneous model; and,

2. Provide the necessary information to describe quantify the potential impacts of preferential flow on groundwater transport.

The BWS recommends that the Regulatory Agencies require the Navy's CSM to include a detailed description of the Navy clinker-zone model because it is used to calculate biodegradation rates from measured concentration values in wells. The BWS also recommends that the Regulatory Agencies consider the CSM to be incomplete until it is modified to include hydrogeological constraints to guide the development of groundwater flow models to represent preferential flows and/or heterogeneity in the saturated basalt in the RHBFSF. The Navy should not be allowed to rely on the groundwater modeling for any decision unless and until it completes this analysis.

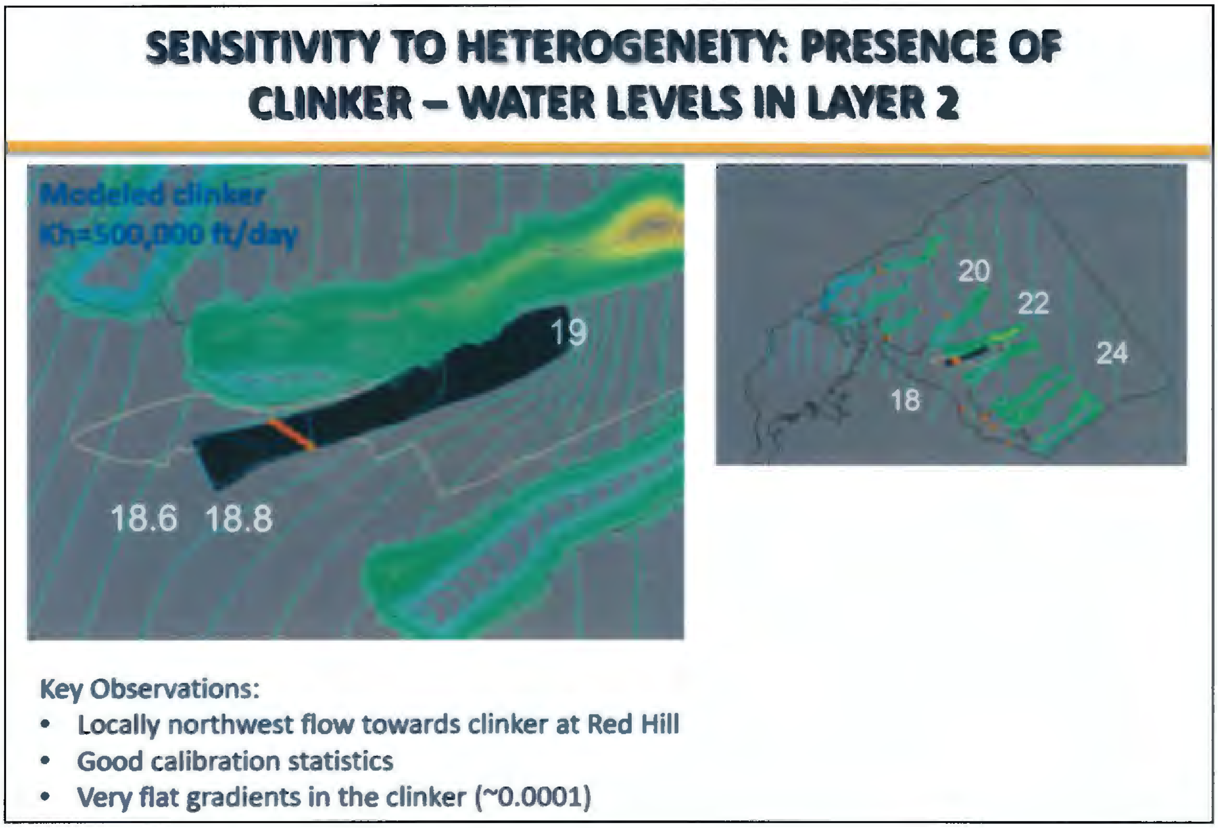


Figure 8 Simulated hydraulic heads produced by the Navy's Conceptual Clinker Model (modified from slide presented by the Navy on March 16, 2018 during a Groundwater Modeling Working Group Meeting No. 9)

Source: Honolulu Board of Water Supply (BWS). 2018d. Letter from BWS to EPA and DOH dated April 24, 2018. Subject: Honolulu Board of Water Supply (BWS) Comments on the Red Hill Administrative Order on Consent (AOC) Statement of Work (SOW) Sections 6 and 7 Groundwater Modeling Working Group Meeting No. 9 Held March 16.

Aquifer Properties – Saprolite

The Navy's revised CSM incorrectly assumes that lower-permeability saprolite acts as an effective barrier to shallow groundwater flow. The depth of the saprolite/basalt interface is important in many areas of the model but is particularly important in the valley locations where the Navy's interim groundwater model has extended the saprolite/basalt interface below the water table. The BWS (BWS, 2018b, BWS, 2018c), EPA and DOH (EPA and DOH, 2018) review of available information in the CSM and the Navy Geophysical Seismic Report (DON, 2018c) indicates that the depth and hydraulic conductivity of the saprolite is highly uncertain and that the Navy's representation of the saprolite is unreasonably limited to deep below the water table and acting as barrier to groundwater flow across South Halawa Valley.

An overarching concern with the Navy's interpretation of the seismic data to create cross-sections are the numerous, unverified assumptions (BWS, 2018c) and that there is only one control point. With an understanding of the limitation of the seismic data, the DOH (DOH, 2019a) used the six transects in Figure 9 to create a three-dimensional geologic model that maps the basalt/saprolite in North Halawa and South Halawa valleys. Based on the interpretations of the geologic model, the DOH concludes:

> "The important conclusion of this saprolite/basalt interface depth evaluation is that the resistance to northwest groundwater flow posed by the valley fill/saprolite sequence is likely over-estimated by the Navy's current conceptual model. **Extrapolations based on the seismic study indicates that the valley fill/saprolite sequence likely poses little resistance to groundwater flow in the South Halawa Valley adjacent to the USTs and in North Halawa valley adjacent to the Halawa Shaft**" (DOH, 2019a) (emphasis added).

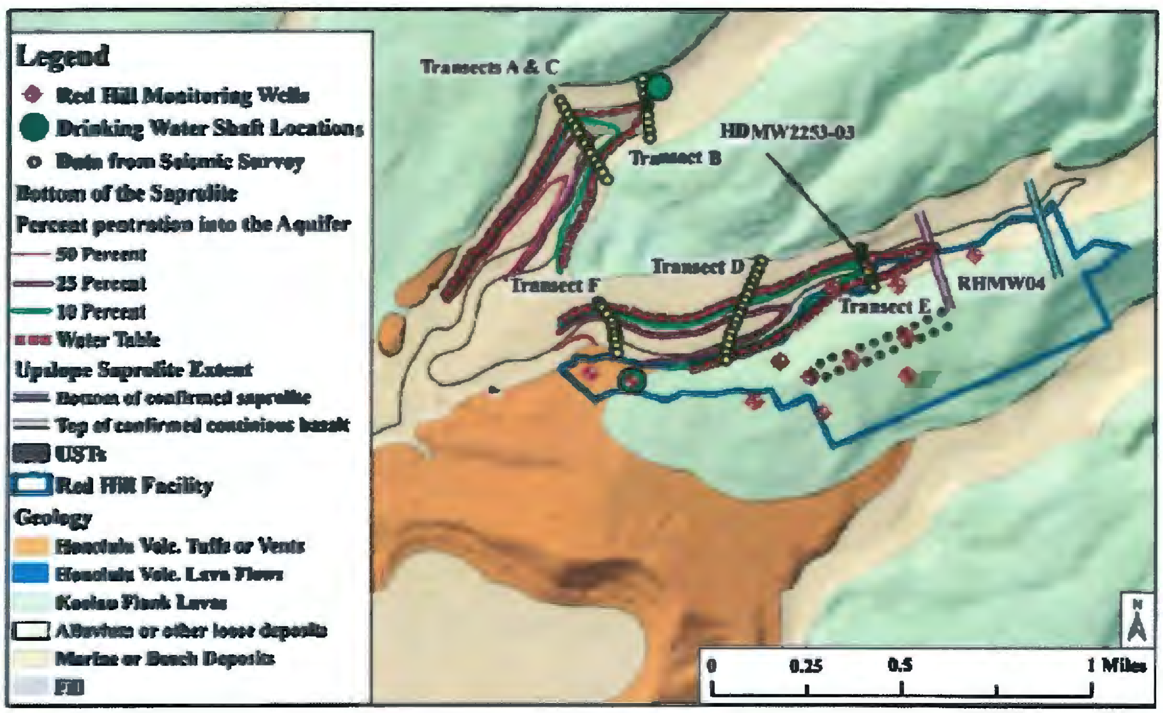


Figure 9 Estimated depth to which saprolite extends to the freshwater aquifer expressed as the percent of the total aquifer

Source: Department of Health, Safe Drinking Water Branch (DOH). 2019b. Hawaii Department of Health Evaluation of Groundwater Flow Paths in the Moanalua, Red Hill, and Halawa Regions, Revision 2 by Whitter, R.B., Thomas, D.M., and Becket, G.D. July 11.

The DOH used the six transects (shown in Figure 9) to calculate the slope of the basalt/saprolite interface. Its analysis of these six transects demonstrates that, except for the region between Transect F and Transect D, the dip angle for the basalt/saprolite interface is much greater than the 3% slope assumed by the Navy. In fact, the DOH analysis indicates that the dip angle for the basalt/saprolite is 9.1% between Transect D and Transect E in South Halawa Valley and is 24% between Transect A and Transect B in North Halawa Valley.

Other important DOH findings include:

- "In North Halawa Valley, the deepest saprolite/Basalt interface depth estimated by seismic survey at Transect B was -20 ft msl. Projecting up North Halawa Valley the saprolite/basalt interface is estimated to rise above the water table slightly before the Halawa Shaft" (DOH, 2019b).

- "the 2015 and the 2017-2018 Synoptic Water Level Studies show that groundwater elevation at RHMW04 is about a foot higher than at the Halawa Shaft; and the groundwater elevation at OWDF-MW1 is 1.5 ft higher than at HBWS observation well T-45. With this difference in head across Halawa Valley and the limited saprolite penetration, groundwater almost certainly flows from Red Hill beneath and around the valley fill/saprolite sequence to the Halawa side of North Halawa Valley" (DOH, 2019b).

- "As noted in Section 6.1.4 of the CSM report (DON, 2018a), the hydraulic head in the basalt zones of RHMW11 generally define a downward gradient. This is consistent and would be expected for groundwater flowing to the northwest by passing under the saprolite/basalt interface. Figure 6-10 of the CSM report (DON, 2018a) shows that the groundwater elevation in RHMW11-Zone 5 is more than a foot higher than that at the Halawa Shaft when the pumps are off. As Figure [9] shows, the saprolite between RHMW11 and the Halawa Shaft extends much less than 25 percent into the aquifer, making well over 80 percent of the aquifer thickness available to transmit water from the Red Hill side of South Halawa Valley to the north side of North Halawa Valley" (DOH, 2019b).

Based on the findings from the EPA and DOH analysis of the seismic data (EPA and DOH, 2018; DOH, 2019b), the BWS recommends that the Regulatory Agencies require the CSM be considered incomplete until it is modified to include a similar evaluation as performed by the DOH and hydrogeologic constraints to guide the development of saprolite/basalt boundary in South Halawa and North Halawa valleys.

Contaminant Transport

A stated above, a significant problem with developing a CSM for the groundwater flow system at RHBFSF is the sparse well monitoring network. The importance of an adequate monitoring network is even more important when developing a CSM for groundwater contaminant transport. A common thread of concern that the BWS has with the Navy's entire discussion of groundwater transport and biodegradation is that the Navy's findings are based more on speculation and conjecture than logical deductions.

In the August 1, 2019 Groundwater Modeling Working Group Meeting No. 15, the DOH emphasized BWS concerns and with the following summary statements:

- There are substantial differences in the interpretation of available field data for the Red Hill Area (DOH, 2019a);
- These interpretations are the foundation for the risk analysis and levels of computed risks to Oahu's drinking water sources (DOH, 2019a); and,
- These differences, to a significant degree, are the results of the limited data set that is inadequate to definitely resolve rates and directions of groundwater flow (DOH, 2019b).

This problem could be addressed by the installation of additional wells and the Navy's sparse monitoring well network is a primary contributor to the difficulty associated with developing unique and technical defensible groundwater flow paths and exposure routes in the RFBFSF. For the 20 fuel storage tanks at Red Hill, there are only three monitoring wells within 450 feet of the tanks. As discussed in greater detail above, the need for more wells here is made critical due to the fact that groundwater flow is primarily controlled by preferential flow paths through clinker zones that have not be delineated by the Navy.

In Section 1.3 of the CSM, the Navy states that a primary goal of CSM Revision 01 is to address the Regulatory Agencies comments on the CSM Revision 00 provided in a letter dated October 29, 2018 (EPA and DOH, 2018). The Revised CSM, however, fails to address comments related to the fate and transport of groundwater contaminants. An examination of the Navy's calculation of biodegradation rates and the Navy's thermal Natural Source Zone Depletion (NSZD) investigation is illustrative.

Biodegradation Rates

The Navy's revised CSM improperly develops its biodegradation rates on modeling that is inconsistent with available data. The Navy assumes that monitoring wells RHMW01 and RHMW02 are aligned with a west-southwesterly groundwater flow path through the tank farm based on the fact that "the Navy current interim groundwater model and clinker-zone model indicates that they [the two monitoring wells] are on the same flow path" (DON, 2019). However, as discussed above, neither the Navy's current interim groundwater model nor the clinker-zone model provide acceptable matches to the measured water level data.

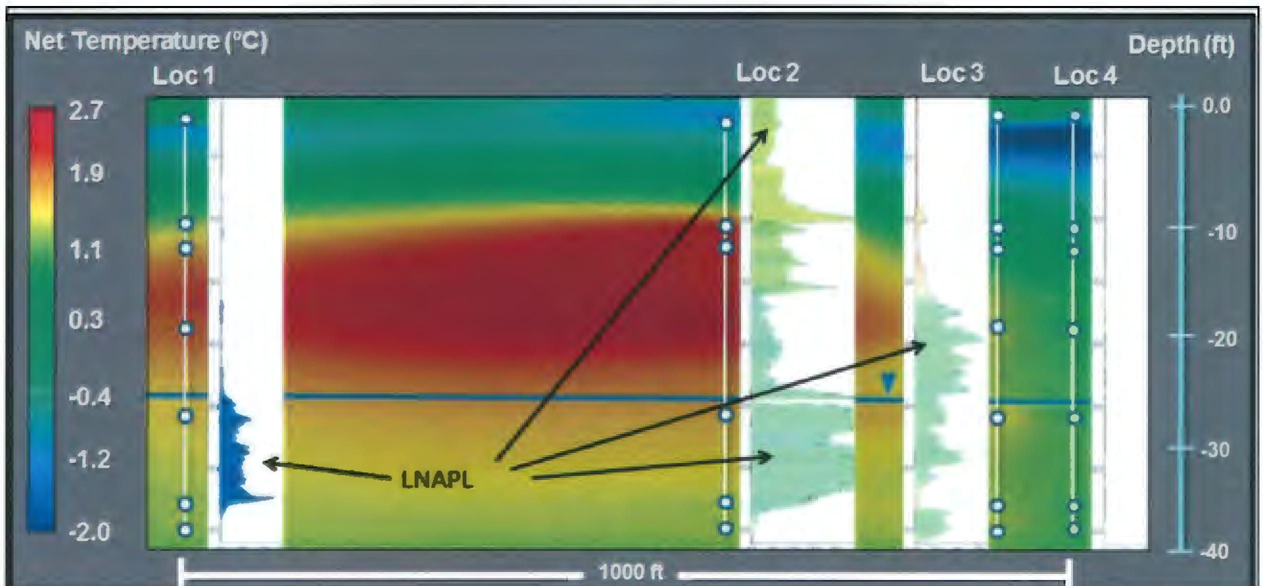
The biodegradation rates cannot be deemed reliable given that they are based on results from models that do not provide reasonable matches to the measured differences in water levels. Therefore, BWS asks that the Regulatory Agencies consider the CSM incomplete and unacceptable for supporting any groundwater transport modeling until the Navy has fully addressed both BWS and Regulatory Agency concerns regarding the calculation of biodegradation rates.

Thermal NSZD Investigation

The Navy's revised CSM has not addressed previous comments regarding the Navy's underlying assumption that an increase in the temperature profile can be used to determine the vertical distribution of LNAPL in the vadose zone. The Navy makes this assertion without offering sufficient evidence to establish the relationship. The BWS (BWS, 2018a), EPA, and

DOH, have questioned the validity of the Navy's critical assumption (EPA and DOH, 2018). The Regulatory Agencies have stated:

> "A net positive temperature profile indicates the effects of exothermic biologic reactions and is affected by a variety of subsurface factors. In general, that relationship can be useful to infer lateral distributions of LNAPL biodegradation but is highly uncertain with respect to the LNAPL vertical distribution. In many cases, as shown in the example thermal profile in our August 15, 2018 presentation (reproduced as Figure 10), the LNAPL vertical mass distribution cannot be inferred from the temperature profile. A review of data in the 2007 Red Hill investigation report (DON, 2007) shows that the rock cores were evaluated at well RHMW02 for evidence of petroleum contamination by checking for odor and by screening with a photo-ionization detector. No evidence of petroleum contamination was found" (EPA and DOH, 2018).



after Stockwell, E., 2015. Colorado State University.

Figure 10 Result from a field study presented by EPA and DOH on August 15, 2018 that shows that there is not a correlation between temperature change in the vadose zone and the presence of LNAPL

Source: U.S. EPA and Hawaii Department of Health (EPA and DOH). 2018. "Approval to revise schedule for deliverables 6.3 - Investigation and Remediation of Releases Report and 7.1.3. - Groundwater Flow Model Report of the Red Hill Administrative Order on Consent ("AOC") Statement of Work ("SOW) and Comments on Interim Environmental Reports. Letter to Captain Marc Delao, Regional Engineer, Navy Region Hawaii from Mr. Omer Shalev, EPA Project Coordinator and Ms. Roxanne Kwan, DOH Interim Project Coordinator. October 29.

A second key assumption made by the Navy regarding the analysis of their thermal profile in the CSM is that the elevated temperature profiles in monitoring wells RHMW02 and RHMW03 were caused by the LNAPL release from Tank 5. With regard to monitoring well RHMW03, the data indicates that the vertical zones of elevated temperature have existed since the vapor sampling ports were installed. The groundwater temperature in monitoring well RHMW03 measured during sampling has also remained unchanged at about 26.5°C since first sampled in 2005 to the present, indicating that the temperature profile recently measured by the Navy likely existed when RHMW03 was first drilled (EPA and DOH, 2018). During the drilling and the installation of the vapor sample points in 2005, the Navy reports that no evidence of petroleum contamination in the rock cores was detected by checking for odor and by screening with a photoionization detector (PID) (DON, 2007).

At monitoring well RHMW02, there are three reasons to question the Navy assertion that the elevated temperature profile is evidence of LNAPL.

- The first reason is that the temperature elevation is so slight that its occurrence (see Figure 7) is dependent on the choice of the background well. The background well used by the Navy is RHMW05, which is away from the influence of the main access tunnel. Among the possible factors affecting the temperature profile at RHMW02 besides biodegradation is the conduction into the vadose zone of the heat brought into the subsurface access tunnels by ventilation, which may lead to an overestimate of heat produced by any on-going biodegradation. The important influence of the main access tunnel on temperature is acknowledged by the Navy but it has not been quantified.

- The second reason is that if there is LNAPL that is undergoing biodegradation that causes a rise in temperature, that LNAPL may be from a fuel leak of unknown volume from Tank 6 reported by the Navy to the DOH in 2002 or other unreported fuel leaks from the RHBFSF.

- The third reason is that in-situ vapor probe responses around Tank 5 in the timeframe following the 2014 release can be interpreted as indicating that the primary vapor migration may have been to the northwest side of that tank and not in the direction of RHMW02 (see Figure 11). Actual LNAPL transport outcomes beneath Tank 5 in 2014 below the vapor probes is unknown; the conservative assumption based on this limited data is that transport was potentially to the northwest and is not represented with any certainty by the spatially limited monitoring well array.

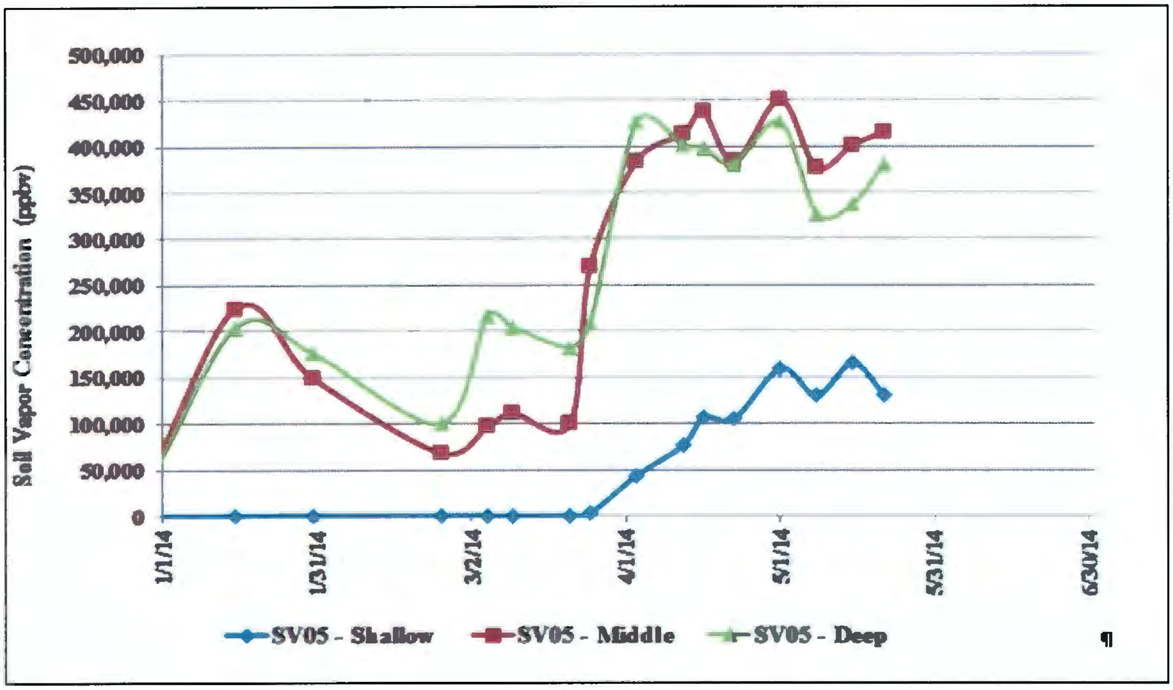


Figure 11 Soil vapor probe readings beneath Tank 5 following the January 2014 release. The deep probe is toward the outside of the tank corridor and the shallow probe closest to the tunnel. These data can be interpreted as initial release migration to the northwest of this Tank; note the shallow probe has low level detections that are not visible on a linear plot

Source: U.S. EPA and Hawaii Department of Health (EPA and DOH). 2018. "Approval to revise schedule for deliverables 6.3 - Investigation and Remediation of Releases Report and 7.1.3. - Groundwater Flow Model Report of the Red Hill Administrative Order on Consent ("AOC") Statement of Work ("SOW) and Comments on Interim Environmental Reports. Letter to Captain Marc Delao, Regional Engineer, Navy Region Hawaii from Mr. Omer Shalev, EPA Project Coordinator and Ms. Roxanne Kwan, DOH Interim Project Coordinator. October 29.

As part of the Groundwater Modeling Working Group Meeting held on August 1, 2019, the USGS expressed additional concerns with the Navy's unsupported assumptions and finding's regarding the thermal investigation presented in the CSM (USGS, 2019). Among the important conclusions in the USGS presentation is that there are no known published articles that have demonstrated that heat (temperature profiles) can be used to locate LNAPL bodies. Another important issue raised by the USGS during its presentation is that the Navy's CSM analysis of the thermal data should be checked in order to confirm that it properly accounts for effects of the tunnel and other infrastructure on the thermal profiles near the fuel tanks. In its presentation, the USGS demonstrated that the temperature drops faster in the areas of the tunnels because the surface temperature is maintained at only 80 feet above the water table.

The BWS continues to have serious concerns regarding the Navy's analysis of the thermal data and recommends that the entire section of the revised CSM report related to the Navy's thermal analysis be omitted as not technically defensible. Because the fate of fuel from the Tank 5 spill is of paramount importance to the conceptual model for LNAPL migration, the BWS recommends that the Regulatory Agencies require the CSM be considered incomplete until the Navy has fully addressed both BWS and Regulatory Agency concerns regarding the validity of its thermal analysis.

Summary of Comments

The Navy's revised CSM does not provide an adequate basis for developing a groundwater flow model and the inherent deficiencies are such that it cannot be used to support an evaluation of contaminant transport pathways and the potential for receptor exposure. Specifically, the revised CSM fails to adequately address the considerable uncertainty associated with the Navy's characterization of the groundwater flow system and of the nature and extent of groundwater contamination at the RHBFSF. Moreover, the Navy analysis is incomplete, incorrect, and/or inconsistent with available evidence as it pertains to characterizing hydraulic gradients and certain important aquifer properties, like preferential flow pathways and saprolite. Many of these and other concerns have been repeatedly brought to the Navy's attention, but to date the Navy has either failed to address or has not adequately addressed them. Given the enormous amount of fuel stored, the location of the RHBFSF relative to our groundwater aquifer, and the potential for impacts to Oahu's critical drinking water resources, the BWS requests that the Regulatory Agencies reject the Navy's revised CSM report and require that the Navy upgrade the RHBFSF tanks with secondary containment or relocate them away from our sole-source groundwater aquifer.

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,

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