BOARD OF WATER SUPPLY

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April 24, 2018

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and

Ms. Roxanne Kwan
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Dear Mr. Shalev and Ms. Kwan:

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, 2018

The BWS offers the following comments on the above referenced meeting. Our comments focus on the development of the interim groundwater model to date and include previous concerns that we believe have not been adequately addressed. To aid in the understanding of our comments, a copy of the Navy slide presentation from the March 16, 2018 meeting is included as Attachment A. In summary, the BWS continues to be concerned about the interim groundwater flow model's unsuitability to predict groundwater flow in the area of concern or provide defensible contributions to the tank upgrade alternative (TUA) selection and process.

General Comments:

During the last few Navy Groundwater Modeling Working Group meetings, the Navy's presentations have over-emphasized showing model results at the expense of explaining the assumptions and data used to develop the conceptual site model (CSM) and the numerical interim groundwater flow model. In our opinion, the Navy's

presentation and discussion have fallen very far short of addressing our repeated concerns about the modeling approach and assumptions. We believe that this meeting was not an appropriate use of meeting time with subject matter experts (SMEs) for three reasons. First, the interim model's prediction of steady state 2017 groundwater heads along the Red Hill Bulk Fuel Storage Facility (RHBFSF) continues to yield a poor match to groundwater levels observed during 2017. Second, the Navy did not allocate appropriate time to present and discuss Site data, revisions to the CSM, and justifications for the modeling assumptions, especially those that the BWS has communicated to the AOC Parties. Third, presenting more than one hundred slides during this meeting (and during two previous meetings) is not conducive to collaborative discussion when instead the modeling results could have been summarized using substantially fewer slides with carefully crafted summary tabulations and charts.

Disparities Between Observed and Predicted Red Hill Groundwater Levels

During the February 12, 2018 groundwater modeling working group meeting, Mr. Robert Whittier of the Hawaii Department of Health (DOH) and the BWS asked the Navy's contractors how they could explain why the interim model's predicted flow direction at Red Hill contradicted the observed Red Hill groundwater levels. More recently, in his letter to Ms. Fenix Grange of the DOH dated February 20, 2018 (Whittier, 2018), Mr. Whittier showed how the interim model's predicted groundwater levels create a hydraulic gradient from monitoring well RHMW04 to monitoring well OWDFMW01 where none exists.

Navy's slides 43 and 106 from the March 16, 2018 meeting confirmed Mr. Whittier's statements about the large and unexplained disparity between observed and predicted steady state groundwater levels between monitoring well RHMW04 and OWDFMW01 for 2017. The table on slide 43 shows observed 2017 steady state levels at monitoring wells RHMW04 and OWDFMW01 differed by about 0.14 feet (ft.) or 1.7 inches whereas the predicted 2017 steady state levels differ by about 1.91 ft. or 23 inches. The Navy's results show that the predicted difference between these two monitoring wells is more than 13 times larger than the observed difference. Contours of predicted base case groundwater level contours shown on slide 106 also depict this unrealistically large difference along the Red Hill Facility. We asked the Navy contractor to explain the disparity during the meeting but did not receive an answer.

Comparison of the Navy's predicted 2017 steady state groundwater levels with levels observed at different 2017 dates shows the same alarming disparity for all of the time periods examined. We estimated groundwater levels using depth to groundwater data presented in Appendix A Table A.4-1 of DON (2018a) and corrected elevations for tops of well casings presented in Table 2 of DON (2018b) to create the plots below. Whether for October, July, April, March, February, or January 2017 (Figures 1 to 6 below), the observed levels at monitoring wells RHMW04 and OWDFMW01 consistently show

negligible or very small differences even though there may have been one to four days between measurements. The BWS also examined the data for November 18, 2016 when all wells were measured on the same day and found similar results.

The BWS has little to no confidence in the interim groundwater flow model. The Navy's predicted 2017 steady state groundwater levels do not match any observed levels made during six different months in 2017 at the monitoring wells on the Red Hill Facility. Nor do the model's predictions match the Navy's 2017 steady state observed levels for these same wells. Furthermore, the Navy's measurements of groundwater levels at Red Hill Shaft are 0.8 to 0.9 feet (ft.) higher than the observed level at monitoring well RHMW02, where the greatest contamination has been measured, for five of the six different 2017 time-periods. This contradicts the Navy's modeling results that pumping at Red Hill Shaft will maintain a large capture zone across the entire facility. The BWS asks how can the Regulatory Agencies or the SMEs depend on the Navy's interim model to defensibly inform the TUA selection process when the information available throughout 2017 contradicts both the model's predicted 2017 groundwater levels and its predicted large capture zone across the Red Hill Facility from pumping at Red Hill Shaft?

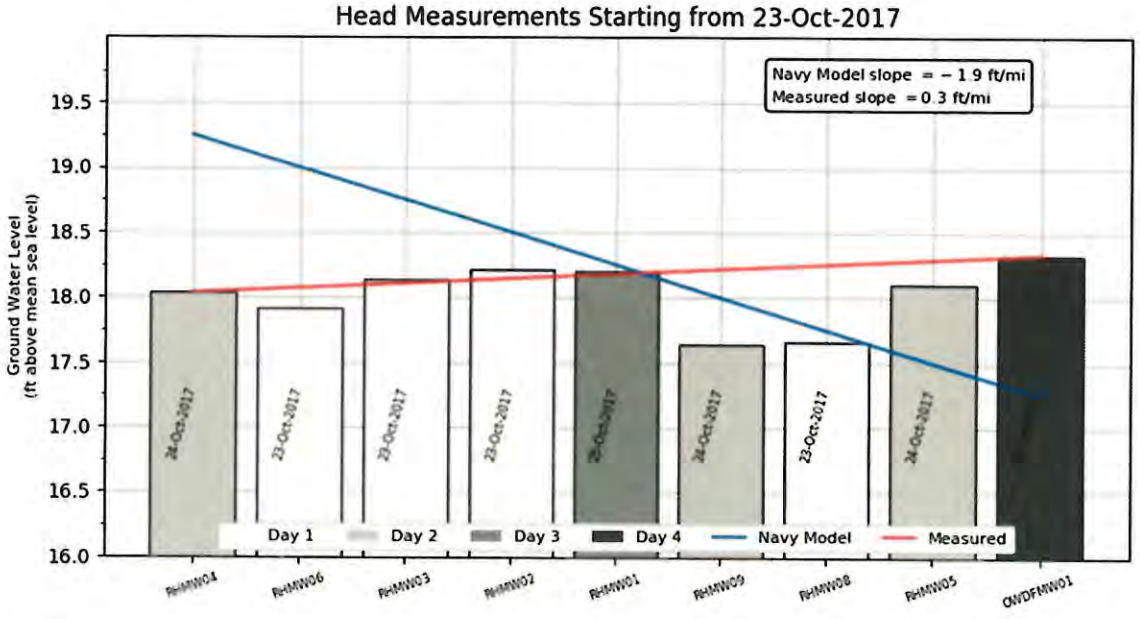

Figure 1. Observed October 2017 and Predicted Steady State Groundwater Levels

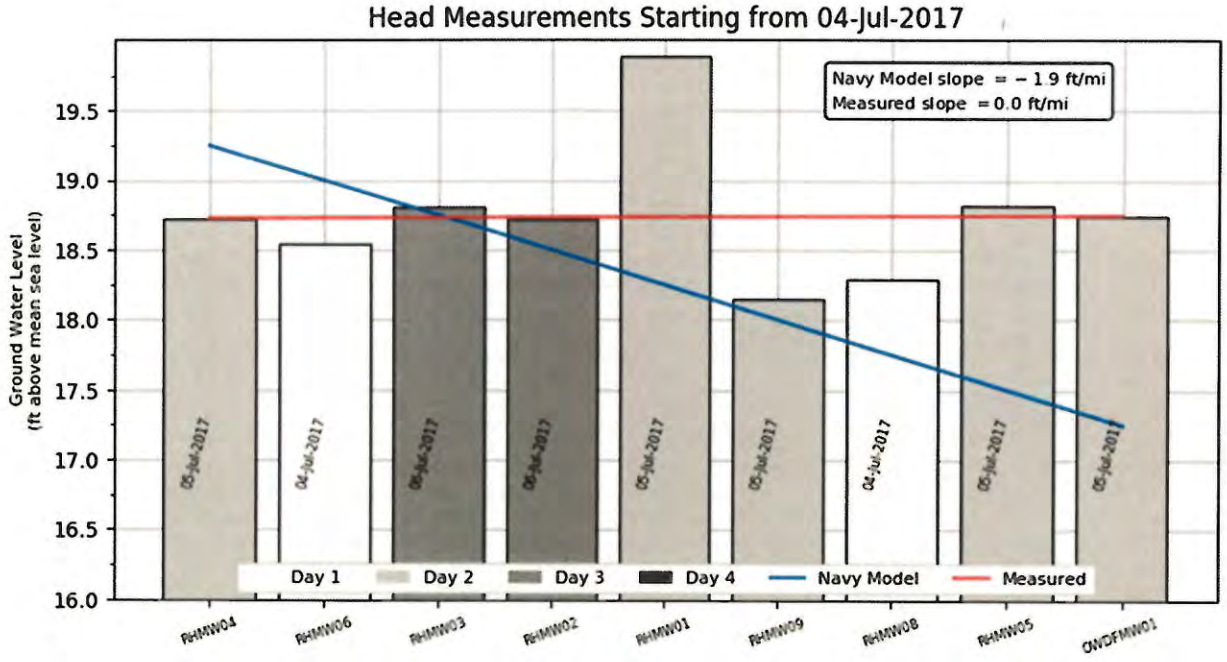

Figure 2. Observed July 2017 and Predicted Steady State Groundwater Levels

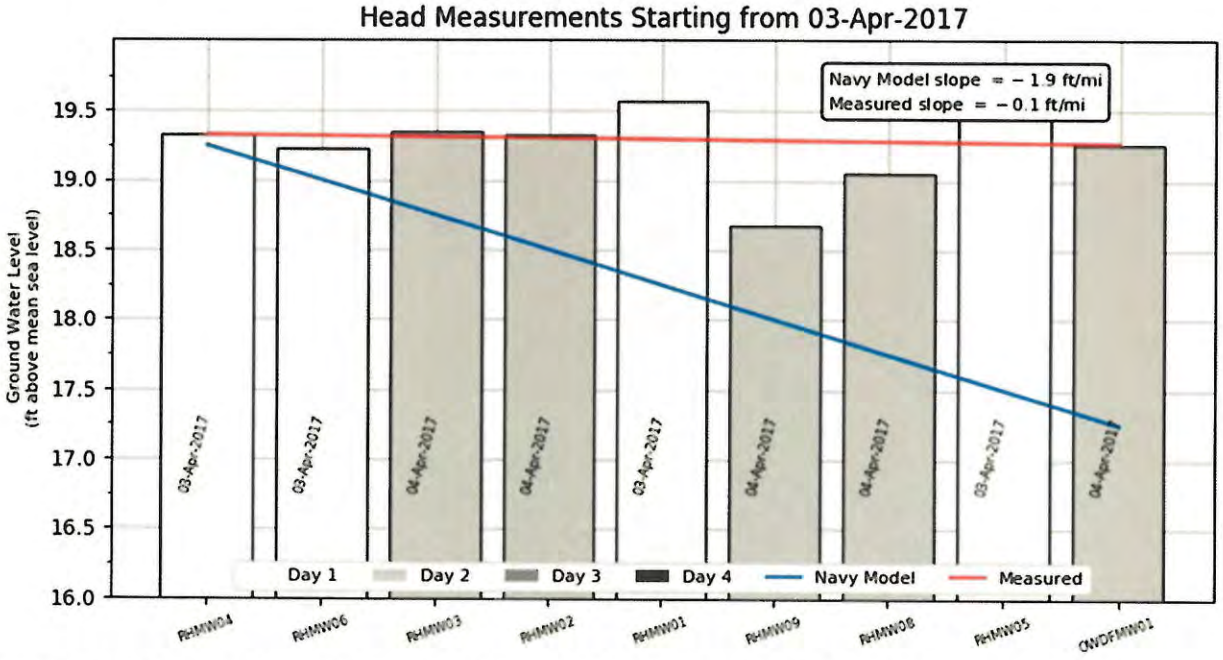

Figure 3. Observed April 2017 and Predicted Steady State Groundwater Levels

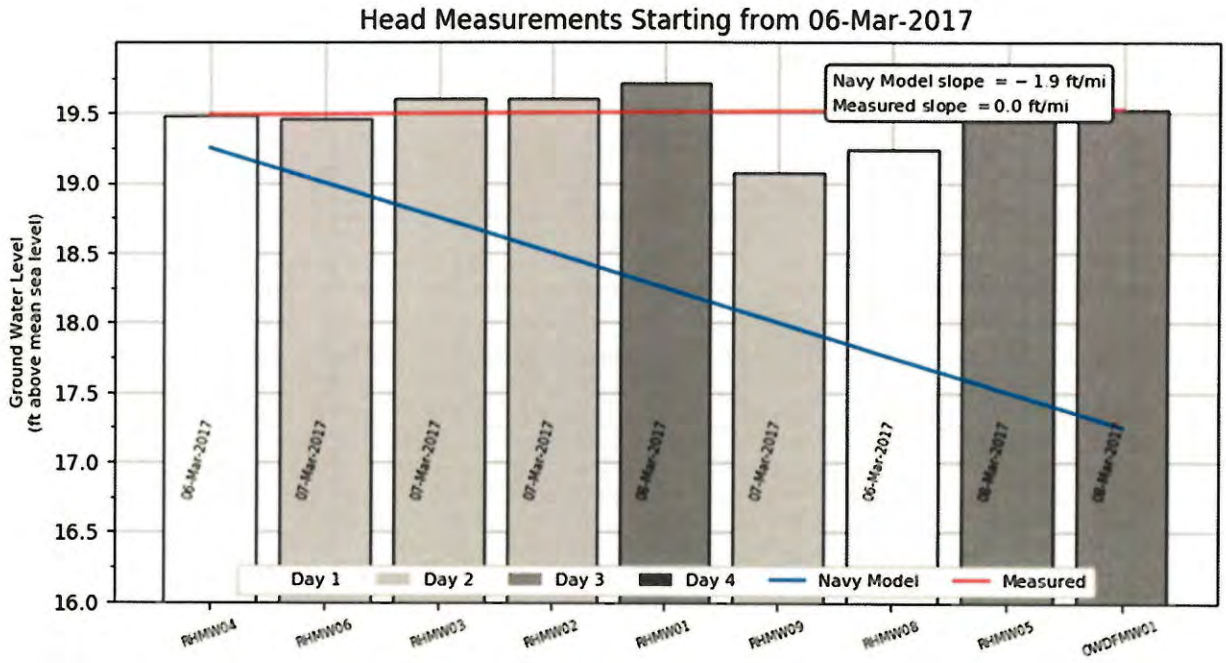

Figure 4. Observed March 2017 and Predicted Steady State Groundwater Levels

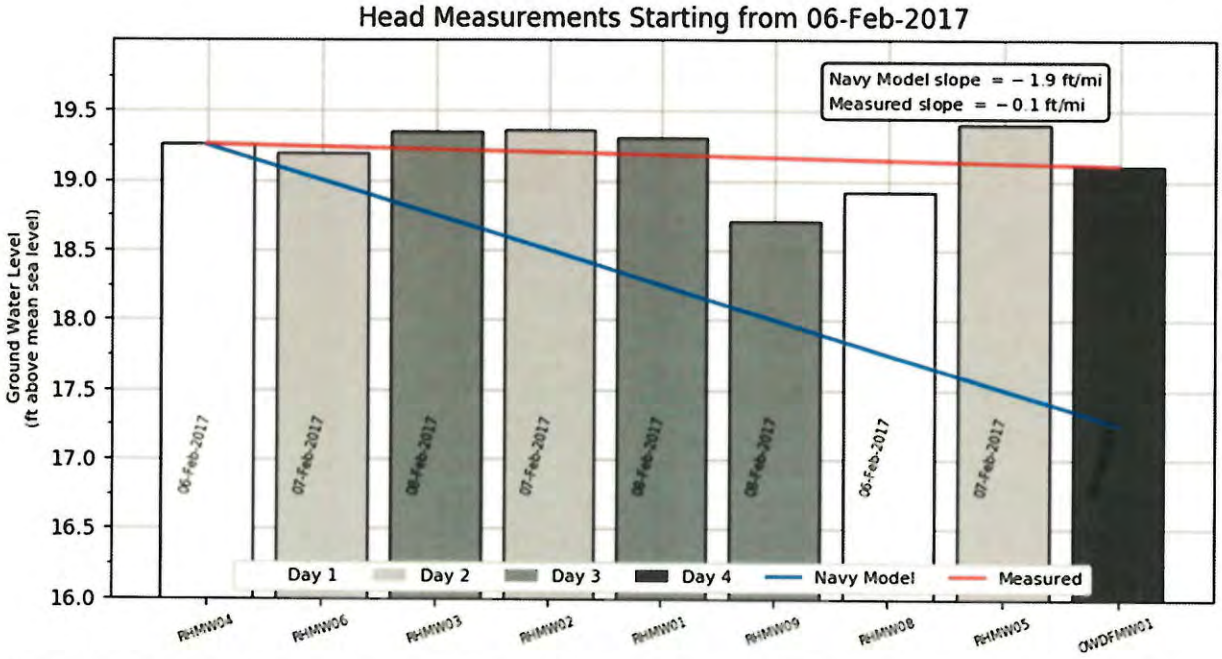

Figure 5. Observed February 2017 and Predicted Steady State Groundwater Levels

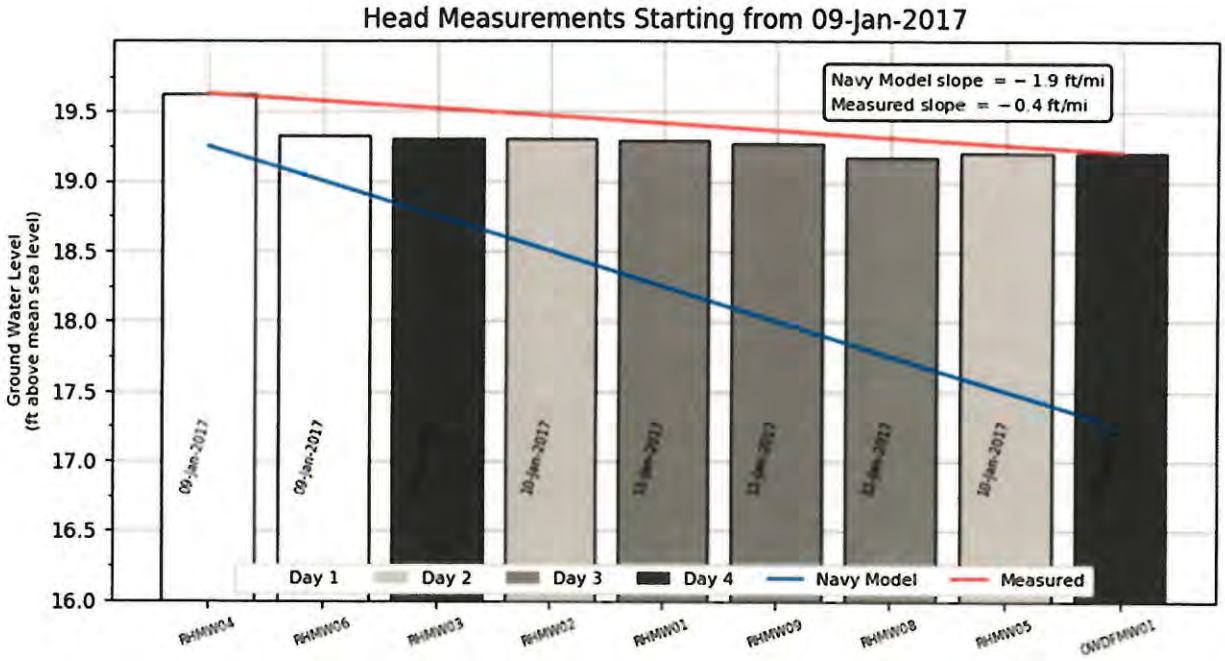

Figure 6. Observed January 2017 and Predicted Steady State Groundwater Levels

Site Data, Conceptual Site Model, and Numerical Model Issues

The BWS has worked hard to understand the reasoning and assumptions behind the Navy's modeling choices but our concerns only continue to grow. Below are the most important issues associated with the model development that the BWS believes have not been adequately addressed.

1. Presumption of Steady-state Conditions for the Base Case Model

   Despite BWS requests during the last several meetings, the Navy has neither provided the rationale nor site data that justifies their use of average values for pumping and water levels to represent steady-state conditions for the groundwater flow field. The Navy has worked under the assumption that the averages of the measured water levels in 2006, 2015, and 2017 are representative of the steady-state water levels that would be achieved by the long-term pumping at the average pumping rates that the Navy calculated for 2006, 2015, and 2017, respectively. Among the BWS concerns is whether any of the water levels used to calculate average water levels at wells for 2006, 2015, and 2017 were actually measured while Red Hill Shaft was pumping. Until the Navy can demonstrate that steady state is a reasonable and workable assumption for their base case model, the BWS does not consider the Navy's model as technically defensible.

2. Model Layers and Where They Intersect Screened Intervals for Monitoring and Pumping Wells

   The Navy has yet to properly explain and justify how the model layers were developed. The BWS considers this as a potentially important issue and is concerned that there are potential biases in the model. One such possible bias was identified in the meeting when, in Slide 14, the Navy showed the assignment of pumping wells to model layers. Halawa Shaft was shown placed in model layer 3 because of an assumed screen bottom of -18 ft. mean sea level (msl). BWS questioned this placement because an as-built drawing for Halawa Shaft indicates that the elevation of -18 ft. msl is associated with a sump and not the intake shaft. Based on an as-built drawing, the intake shaft for Halawa Shaft spans the elevation of -2 to 2 ft. msl. During the meeting, BWS expressed similar concerns over the elevation of -10 ft. msl that the Navy used to place the Red Hill Shaft into the model's layering.

   Listed below are specific issues regarding the model layering that BWS considers as potentially important but have yet to be adequately discussed with SMEs.

   a. Placement of the Top Model Layer at the Water Table

      The Navy has stated that the top model layer is based on the location of the water table. However, the Navy has not shown any evidence to substantiate this claim. The BWS does not understand how the Navy could have known the water table's location throughout the model domain prior to the model development. We realize that previous model results and available measured water levels would help estimate the water table across the model domain, but we nonetheless believe it is important that the Navy demonstrate their top model layer adequately and consistently represents the water table. Among the figures that the Navy should present to demonstrate their claim are maps that show the difference between the simulated steady-state water table and the top of the model.

   b. Assignment of Measured Water Levels to Specific Model Layers

      Water level and water quality parameter measurements are some of the most important data for validating a model's ability to simulate groundwater flow and transport accurately. How a model represents the intersection of a well screen with a model layer is important to understanding and interpreting the relevance and meaning of the difference between the simulated and observed water level (or water quality parameter) at that well. For instance, the comparison of simulated

and observed water quality parameters could be significantly different between a well screen that intersects only one model layer and a well screen that intersects several model layers. As a result, the BWS believes it appropriate that the Navy do the following: (i) tabulate and show the top and bottom of each well screen, along with the top and bottoms of the model layers intercepted by each well screen; (ii) discuss how the Navy will compare simulated and observed water levels, pumping rates, and chemical concentrations (iii) explain why the current model layering is adequate and requires no further adjustments.

c. Comparison of Model Layers to the Observable Geological Features

The thickness and dip angle of the model layer influences simulated flow and transport. Our concern with the model layer thickness and dip angle is whether they are generally aligned with the properties and features of the basalt that influence actual groundwater flow. To investigate this concern, model layers should be evaluated in the light of a site geological conceptual model, geologic profiles of different lava flows logged at boreholes, mapped dip angles, observed faults, and fault patterns.

3. Conceptual Site Model (CSM)

a. A CSM should provide the data and conceptualization of the groundwater flow system that is used to develop the numerical models. The Navy has yet to provide a CSM that supports the development of their interim groundwater model.

b. Listed below are specific issues that BWS considers as potentially important to the model's predictive accuracy that the Navy has yet to address adequately.

i. Basalt Heterogeneity on Flow and Transport

The Navy's representation of the basalt as a single homogeneous unit introduces a significant bias into the modeling results. Considerable site data and information regarding Hawaiian basalts support the premise that the basalt's heterogeneity and preferential flow paths are the key drivers in controlling groundwater flow in the area surrounding Red Hill. Clinker intervals and lava tubes were identified in the barrel logs for the Red Hill storage tanks (Pacific Naval Air Bases Contractors, 1942), the Red Hill Shaft (Macdonald, 1941; Stearns, 1943), and the Halawa Shaft (BWS, 1943). Wentworth (1945) described many different examples of

inhomogeneities that are likely very important preferential flow paths in Halawa Valley. If the Navy is certain that Hawaiian basalt is a single homogeneous unit, then it should provide the regulatory agencies and stakeholders with the data that supports their assumption of basalt homogeneity. The Navy should also show how this evidence of site homogeneity fits the site data collected to date and how it does not introduce any significant bias to hydraulic capture of potential leakage from Red Hill Facility into their predictive simulation compared to a groundwater model that incorporates the heterogeneities observed in the basalt.

ii. Small Hydraulic Head Gradients at Red Hill

As discussed in previous memos by BWS, the DOH (Whittier, 2018), and above, the Navy's draft model reproduces neither the direction nor magnitude of the hydraulic head values near the Red Hill Facility. A primary reason provided by the Navy for their model's inability to represent the measured hydraulic gradient is that the model does not include the heterogeneity of the actual aquifer system. However, the Navy has yet to provide computer model simulations or a CSM to provide possible causes for the difference between measured and simulated gradients and the potential importance of that difference. The Navy should evaluate the potential significance of the mismatch. Among the possible issues that could be contributing to the mismatch is that preferential flow paths are a major component to regional groundwater flow in basalt near Red Hill.

c. Interpretation and Analysis of Monitoring Well RHMW11 Data

The data from monitoring well RHMW11 could have considerable implications to the development of the CSM. Data from monitoring well RHMW11 should be fully incorporated into a revised CSM prior to the Navy finalizing the interim groundwater model.

4. Base Case Model

The Navy's base case model used for all sensitivity analyses should be modified to better represent site conditions. During the meeting, SMEs raised concerns regarding possible adjustments to the Navy's base case model. The regulatory agencies should ask the Navy to closely examine these concerns to determine if changes in the groundwater flow model are appropriate. The first concern is that the Halawa Shaft intake shaft is

simulated in the base case model to be located at -18 ft. msl. The as-built drawing for Halawa Shaft indicates that the intake is between -2 ft. msl and 2 ft. msl. This change in elevation will likely affect which model layer represents the pumping from Halawa Shaft. The second concern is that, near the interface of the edge of caprock (model layer 1) and the basalt (model layer 2), the Navy model should mimic the United States Geological Survey (USGS) model (Oki, 2005) that includes a transition zone with a relatively low hydraulic conductivity. This low permeability zone is important to defining the zone of capture around Red Hill Shaft. The third concern is a change in the hydraulic boundary condition near the ocean so that the Navy's model will better simulate the effects of density-dependent flow.

5. Uncertainty Analysis

   The Navy has yet to carry out the type of uncertainty analysis that the BWS has advocated since groundwater modeling working group meeting No. 3 in August 2017. There was no information presented in the March 16, 2018 groundwater modeling working group meeting No. 9 that would give us reason to change our position.

6. Action Items Compiled by Navy

   At the end of each groundwater meeting, the Navy consultants compile a list of action items based on the meeting discussions. Although the Navy has stated that these lists will be provided to BWS, the BWS has no record of receiving any of the lists. The BWS would appreciate copies of the lists for all groundwater meetings.

Specific Comments to Navy slide presentation

Slides 11 and 12: BWS remains doubtful that using average values for pumping rates and water levels over a year creates a dataset reflective of steady-state conditions. Moreover, slide 12 acknowledges that the averaging process introduces significant uncertainty in the relationship between average pumping and water levels because of the lack of synchronicity between the measured pumping rates and water levels. BWS is concerned that the Navy is disregarding the significant uncertainty and error associated with the approximations and assumptions used to generate a highly simplified model of a very complex and dynamic groundwater flow system. Given that the purpose of the modeling project is to assess risk, the Navy's approach should not discount the site complexity and modeling uncertainty associated with the model hydraulic properties (such as the heterogeneity in the basalt), model inputs (pumping), and

model outputs (water level). A proper uncertainty analysis should be performed to help determine the predictive uncertainty associated with the Navy's model.

Slide 14: The information in slide 14 is incomplete. Model pumping and layering data is one of the critical aspects of the model development, and the Navy is glossing over this. The SMEs cannot properly assess the reasonableness of the model construction and calibration unless additional information is presented beyond the information in slide 14. At a minimum, slide 14 should include the tops and bottoms of the well screens associated with the pumping wells, the tops and bottoms of the model layers used to represent the wells, and the references to the data used to generate the pumping rates and well specification. During the meeting, the USGS questioned whether the pumping for Lau Farm was accurate, and the BWS provided diagrams that show the bottom elevations for Halawa Shaft and Red Hill Shaft were off by 10 to 20 feet. The data used to represent wells in the Navy model is critically important to the SME understanding of how well the model represents the actual physical system. If the comments provided by BWS and USGS result in the Navy changing pumping rates or location of pumping wells, then the Navy procedure for constructing the model should be considered suspect until the Navy proves otherwise.

Slide 16: Despite the potential significance of geological heterogeneity, the Navy has yet to present a geological conceptual model to the SMEs. The BWS has requested that prior to the Navy's submission of a final interim groundwater model, the Navy develop and present a geological conceptual model and its implications to groundwater flow and transport. Based on the meeting discussions, the BWS understands that the Navy will provide the SMEs with a geological conceptual model before the report on the interim flow model is submitted to the Regulatory Agencies.

Slide 23: The current PEST calibration runs do not include the hydraulic properties of the saprolite as a calibration parameter. The Navy should incorporate additional data into their model calibration process that will include impact of the nature and extent of the saprolite on matching water levels used for flow calibration.

Slides 43 to 48: Much of the discussions associated with hydraulic gradients are focused on the regional hydraulic gradients. The analyses presented in these slides completely missed the critical disparity between groundwater level observations and the unrealistically large gradient simulated between RHMW04 and the Red Hill Shaft. Greater emphasis should be placed on the model's ability to reproduce or explain the local hydraulic gradients measured at the Red Hill Fuel Storage Area.

Slide 110: The particle tracks indicate that the Navy model is lacking a region of low permeability between the caprock and the basalt that Dr. Oki believes is a part of the real physical system. Inclusion of this low permeability area could significantly affect the zone of capture for Halawa Shaft. The BWS suggests that the Navy work with the USGS to properly incorporate this low-permeability zone into their model.

We continue to ask that the Navy distribute meeting handouts and other information documents two weeks prior to the start of each meeting to ensure subject matter experts, the BWS, and other stakeholders are afforded the opportunity to thoroughly review the materials ahead of time. We also request that the Navy and its contractors provide copies of all materials disclosed at the meeting that they committed to share with subject matter experts.

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

Very truly yours,

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Enclosure: Attachment A, Navy Slide Presentation Dated March 16, 2018

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