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CERTIFIED NO: 7016 0910 0001 0898 4927

Mr. Omer Shalev
U.S. Environmental Protection Agency
Region IX
75 Hawthorne Street
San Francisco, CA 94105

CERTIFIED NO: 7016 0910 0001 0898 4934

Ms. Roxanne Kwan
State of Hawaii Department of Health
Solid and Hazardous Waste Branch
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Pearl City, HI 96782

Dear Mr. Shalev and Ms. Kwan:

Subj: US ENVIRONMENTAL PROTECTION AGENCY (EPA) AND STATE OF HAWAII DEPARTMENT OF HEALTH (DOH) LETTER OF JULY 1, 2019, COMMENTS ON VADOSE ZONE MODELING FOR THE RED HILL ADMINISTRATIVE ORDER OF CONSENT (AOC) STATEMENT OF WORK (SOW)

The Navy is in receipt of your letter dated July 1, 2019 "Comments on Vadose Zone Modeling for the Red Hill AOC SOW". This letter addresses your concerns and describes the evolution of the modeling process. We are providing clarifications and comments to help address any concerns. As noted in your letter, the complexity of the environment makes deterministic Vadose Zone modeling unrealistic as well as impractical. Therefore, we are addressing complexity with the use of a bounding multi-model approach (this multi-model approach is similar to the approach being used for the Groundwater Flow Modeling).

During the initial AOC Scoping Meetings in 2015, the Regulatory Agencies agreed that a numerical light non-aqueous phase liquid (LNAPL) model would likely not be useful due to site heterogeneity and complexity. Therefore, the Navy developed a statistical (Monte Carlo) approach for evaluation of basalt holding capacity and natural source-zone depletion (NSZD) relative to both a small chronic release as well as a larger sudden release. This effort was conducted to estimate the range of release volumes that can potentially be attenuated within the Vadose Zone without causing a significant impact to groundwater. The information is valuable for understanding the potential consequences of different spill sizes, rates, duration between spills, etc., and helps improve our understanding of the risk related to impacts to groundwater

from various spill scenarios, and thus assists with associated site management. The effort was never intended to evaluate potential LNAPL plume migration in the Vadose and Saturated Zones other than estimating holding capacity.

DOH and their contractors stated in meetings held in 2018 that the Navy should be using a numerical LNAPL migration model, even though it was agreed during the initial AOC Scoping Meetings that LNAPL migration modeling would not be conducted. The Regulatory Agencies have since requested that the Navy consider LNAPL modeling, in part for establishing the source term to be used in the groundwater contaminant fate and transport (CF&T) model. In response, the Navy has further evaluated the modeling effort to help bound LNAPL migration under a range of release scenarios and geologic conditions (at the February 13, 2019 face-to-face AOC Technical Working Group Meeting). Due to site complexity (heterogeneity), the model was not intended to be used as a definitive predictor of LNAPL migration – such a model is not possible to develop. Rather, through bounding analyses, the model can provide useful information for management considerations relative to potential bulk LNAPL migration, which in turn can be used to establish source terms for the CF&T model.

The Navy assimilated available data and conducted preliminary simulations of LNAPL migration behavior to evaluate parameter correlations and significance and understand impacts of various assumptions and uncertainties related to LNAPL modeling. The Navy also conducted an exhaustive literature search for key petrophysical properties related to basalts at Red Hill and conducted laboratory testing on a range of basalts from borings at Red Hill. The literature evaluation and testing were used to develop a reasonable range of basalt and LNAPL properties for initial LNAPL modeling inputs. For the estimated parameter ranges, uncalibrated models cannot bracket LNAPL migration with confidence. Therefore, information from the 2014 Tank 5 release would be used to help constrain the LNAPL migration behavior to historical conditions in terms of estimated release rates and volumes and associated LNAPL migration extent. A presentation related to basalt and LNAPL properties for use in the proposed model and a procedure for refining those properties as part of an initial modeling process were presented in the May 17, 2019 Webinar with the Regulatory Agencies.

Due to subsurface geologic complexity (heterogeneity) and considering available data, no model can express geologic detail with certainty. Adding complexity using geologic interpretations cannot improve model predictability. Instead, such introduced complexity only masks an understanding of the LNAPL migration through the Vadose Zone. However, use of a homogeneous model calibrated to the estimated bulk LNAPL migration behavior provides a tool to evaluate various potential spill conditions. Furthermore, through a bounding analysis as proposed by the Navy, the model can provide an understanding of the possible extreme impacts, which is helpful in making risk determination. Sensitivity analyses on a conceptual clinker zone within the Vadose Zone is also proposed, which will provide evaluation of the impact of such fast-flow pathways in a meaningful and deliberate manner. This is the technical rationale for

employing an Equivalent Porous Media (EPM) model along with various sensitivity analyses for LNAPL migration evaluations. The Navy has not committed to conducting the modeling effort, but will further describe the appropriateness of using an EPM approach versus a discrete fracture network (DFN) approach if the modeling is conducted.

The Regulatory Agencies stated that they believed an EPM model could potentially facilitate a general understanding of how releases from the Facility will tend to move in environments like those found at Red Hill. They further stated that the Navy's proposed EPM model should provide insights for the Investigation and Remediation of Releases [IRR] Report and the CSM [Conceptual Site Model], however it will not provide conservative inputs to the saturated zone contaminant fate and transport [CF&T] model. Further clarification by the Regulatory Agencies is needed because the Navy's approach would provide conservative inputs to the saturated zone model. Because agreement has not been reached regarding LNAPL modeling, no LNAPL modeling results have been included in the IRR and CSM reports at this time. Model sensitivity to a conceptual clinker zone will provide insight into the migration behavior through such fast-flow pathways. The conceptual clinker is the largest of the fast-flow pathways, and therefore this analysis would provide an extremely conservative impact evaluation.

The Navy presented the Simplified 3D LNAPL modeling approach to the Regulatory Agencies during the March 2019 face-to-face meetings and solicited Regulatory feedback. The Regulatory Agencies indicated that they would provide feedback on the approach within 2 weeks. After the AOC Parties Technical Working Group meeting (webinar) held on May 17, 2019, the Regulatory Agencies said that they would review the LNAPL modeling parameters proposed by the Navy and respond in approximately 2 weeks. At the time, the Navy stressed the necessity of receiving a response in a timely manner so that comments could be carefully considered for evaluation of whether or not the Navy would proceed with LNAPL modeling. Without regulator input, no work has taken place since the May meetings. Regulatory input was necessary for the Navy to evaluate any potential for doing LNAPL modeling, and without such input, the Navy has not obtained additional funding to support such an effort. The Navy also stressed that in order for the Navy to make progress, agreement was needed on the final GW model report so that results would be able to be incorporated into the CF&T and later AOC deliverables. Comments were not provided until the July 1, 2019 letter.

We hope we have addressed the Regulators' concerns. We hope this clarification is helpful. As previously stated, the Navy believes that the proposed LNAPL modeling approach would provide a useful management tool. We are hopeful that the Regulatory Agencies will agree that the proposed modeling approach can provide useful information. We appreciate consideration of the information we have outlined above.

We have also provided specific comments to the DOH consultant's memorandum (attached to your letter). We appreciate consideration of the information we have outlined above. Please let us know if you would like to discuss further.

Subj: US ENVIRONMENTAL PROTECTION AGENCY (EPA) AND STATE OF HAWAII DEPARTMENT OF HEALTH (DOH) LETTER OF JULY 1, 2019, COMMENTS ON VADOSE ZONE MODELING FOR THE RED HILL ADMINISTRATIVE ORDER OF CONSENT (AOC) STATEMENT OF WORK (SOW)

Should you have any questions, please contact Mr. Aaron Poentis of our Regional Environmental Department at (808) 471-3858 or at aaron.poentis@navy.mil.

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

Enclosure: Response to Comments of Aqui-Ver, Inc. memo of June 18, 2019, Review of LNAPL Modeling Proposed by the US Navy Red Hill Bulk Fuel Storage Facility Technical Team, AOC Sections 6 & 7, received as an attachment to EPA and DOH letter of July 1, 2019, Comments on Vadose Zone Modeling for Red Hill AOC SOW

Response to memo from DOH consultant Aqui-Ver (G.D. Beckett) on review of LNAPL modeling proposed by the U.S. Navy for Red Hill Bulk Fuel Storage Facility Technical Team.

Introduction

This response is to the June 18, 2019 memo by DOH consultant Aqui-Ver (G.D. Beckett) titled "Review of LNAPL Modeling Proposed by the U.S. Navy Red Hill Bulk Fuel Storage Facility Technical Team." The memo was an attachment to the letter to the Navy dated July 1, 2019 from the Environmental Protection Agency (EPA) and the State of Hawaii Department of Health (DOH), titled "Comments on Vadose Zone Modeling for the Red Hill Administrative Order on Consent (AOC) Statement of Work (SOW)." We hope that the following response clarifies the Navy's approach and rationale for light non-aqueous-phase liquid (LNAPL) modeling that considers available data, site complexity, and time constraints.

Background

The memo correctly characterizes the objective of performing LNAPL numerical transport modeling: to estimate how far, how fast, and in what direction fuels (e.g., LNAPL) might travel as a result of various release scenarios. We agree that modeling for decision making should provide results that are reliable, are of high technical quality, and have reasonable conservatism. The LNAPL modeling strategy that the Navy has presented does exactly that through a multi-model approach by providing a conservative understanding of bulk LNAPL migration behavior for informing groundwater protection decisions related to key questions. Key questions are related to potential impacts to Red Hill and Halawa Shafts. The Navy disagrees with the contention that the currently proposed approach would not be useful because of the proposed simplifications. The approach could provide useful information on the bulk behavior of a spill, the vadose zone retention capacity of different spills, and migration distances and duration in the vadose zone and along the water table, along with an understanding of the sensitivity and significance of parameters or geologic complexities. Adding some hypothetical rendering of geologic complexity to the model itself will not provide a better understanding of likely LNAPL migration behavior or better predictions.

The Navy team has proposed a simplified numerical approach to modeling LNAPL flow, and there is general agreement on this approach and its computational benefits. We have conducted literature searches and laboratory evaluations of petrophysical properties of the basalt to help bound their values for the site. We have also conducted preliminary simulations of LNAPL migration behavior with the proposed approach to evaluate parameter correlations, sensitivity, and significance, and to understand the impacts of various assumptions and uncertainties. The simulations demonstrated strong correlations between dip and anisotropy, a direct relationship between travel distance and porosity or residual water saturation, and a relative insensitivity to the other retention parameters. Thus, even using a homogeneous model, there could be no reasonable understanding of LNAPL migration behavior with an uncalibrated model. As previously stated, adding a hypothetical rendering of geologic complexity to the model will not improve the model's ability to reasonably bound the migration of releases. Therefore, to bound the LNAPL migration behavior in a reasonable fashion, the Navy intends to use investigation results of the 2014 Tank 5 release to estimate bulk released volumes and where/how it could have moved in the vadose zone. History-matching of this scenario with the models can provide a bulk understanding of LNAPL migration behavior. This history includes LNAPL monitoring

and dissolved constituent analytical results from monitoring wells, and soil vapor monitoring results from soil vapor monitoring wells. Adding complexity to the parameterization does not add value, as there is no associated complexity in LNAPL migration observations (also considering that reasonable parameter ranges gave no indication of non-aqueous-phase liquid [NAPL] migration behavior).

LNAPL Modeling Approach

With this background, the Navy developed an approach that would bound potential LNAPL migration associated with a range of release scenarios using available site information. The approach was to first parameterize the simplified LNAPL transport model by history-matching to the 2014 Tank 5 release. Proposed details include a 3-degree dipping grid with vertical anisotropy, homogeneous hydraulic conductivity, a flat water table underlying 100 feet of unsaturated basalt, fine vertical and horizontal gridding, and a hydraulic flow barrier representing elevated hydraulic heads in valley fill, saprolite, and weathered basalt. A range of petrophysical properties was developed from evaluation of laboratory results and literature values. While the Navy recognizes that some of the laboratory values may be skewed due to the types of laboratory procedures used, the range of values would be further optimized once the model is calibrated to observed conditions.

The multi-model approach would then be used to evaluate the impact of a range of release scenarios and hydrogeologic conditions including:

- Small chronic release, intermediate release (2014 Tank 5 release), large release, and a catastrophic release (tunnel impact)
- Potential LNAPL migration toward critical receptors: Red Hill Shaft (release at lower tanks) and Halawa Shaft (release at upper tanks)
- Bounding analysis on impact of pre-existing residual LNAPL saturation, porosity, and residual water saturation (sensitivity to available pore space for new LNAPL migration)
- Bounding analysis on other parameter sensitivities (specifically, hydraulic conductivity anisotropy and retention/relative permeability parameters)
- Conceptual clinker zone between the tanks and the water table (sensitivity to fast-flow pathways)
- Reduction of LNAPL saturation in the vadose zone considering natural source-zone depletion (NSZD)

The Navy previously developed lumped holding capacity conceptualizations to evaluate the 2014 Tank 5 release and hypothetical future releases. These conceptualizations were developed using a Monte Carlo approach and were presented in the July 2018 *Groundwater Protection and Evaluation Considerations* report. The Simplified Three-Dimensional (3D) LNAPL migration model would be compared with the lumped holding capacity conceptualization to determine if they are consistent, which would provide greater confidence in the lumped holding capacity model. The model would also provide source terms for the contaminant fate and transport (CF&T) modeling.

Approach to Addressing Regulatory Agency Concerns

The concerns expressed by the Regulatory Agencies can be summarized as an issue of model parameterization, heterogeneity, and scale of that heterogeneity. The other issue of non-Darcian flow is simply academic.

Non-Darcian Flow: During presentations by Aqui-Ver to the Navy in 2018 and 2019, a visual demonstration was provided depicting how LNAPL might behave in the vadose zone under the Red Hill Facility using the LNAPL modeling code Magnas. Magnas, which was co-developed by one of the Navy's subject matter experts (Dr. Sorab Panday), also uses an equivalent porous medium (EPM) approach using a Darcian flow assumption. Separate from the Darcian assumption and EPM approach, the Navy had significant issues with the demonstration as being unrealistic for Red Hill site conditions (e.g., two-dimensional, no representation of local dip, apparent continuous vertical fractures) and does not consider it to be representative of LNAPL behavior at Red Hill. If the agencies feel that Aqui-Ver's model is a useful work product for depicting LNAPL flow in Hawaii or at Red Hill the Navy again requests that the model files along with the assumptions used in the model be provided to the Navy for further evaluation.

Most modeling codes assume that a nonlinear form of Darcy's Law governs flow of fluids. Non-Darcian codes are developed and used primarily in the domain of research and academia. In general, for a wide range of field conditions, an equivalent hydraulic conductivity value can be fit to any non-Darcian flow model. Considering that modeled K-values are mainly calibrated parameters (i.e., not specified based on field and/or laboratory data) and that even the example provided-by Aqui-Ver simulates Darcian flow, the issue of non-Darcian flow is not relevant.

Homogeneous Lumped Model: The proposed Simplified 3D LNAPL model is not a homogeneous lumped model. The model is spatially distributed with a refined grid that can address spatial and temporal migration behavior of LNAPL. The models would be constrained by history-matching to the 2014 Tank 5 LNAPL release. Various bounding conditions for parameter values would be evaluated using homogeneous conditions, to evaluate plausible impacts for various releases. A conceptual clinker sensitivity would also be used to demonstrate the response of higher permeability flow features. Therefore, all simplifications suggested in the approach are appropriate and deliberate and provide an understanding of the impact of various settings including conservative scenarios that quantify the fast-flow domains. The Navy has also conducted a statistical analysis of lava flow over Red Hill, which resulted in a very low probability of lava tubes interconnecting the upper and lower tank farm and Red Hill Shaft. The Navy and Regulators have previously agreed that there is a very low probability of a lava tube connecting the area of the tanks to Halawa Shaft. This information was transmitted to the Regulators in meetings and webinars, and is documented in the *Conceptual Site Model* (CSM) report Revision 01 (June 2019).

A homogeneous assumption is the only reasonable approach that can be justified by available data. As stated earlier, parameter correlations and ranges preclude any coherent LNAPL migration behavior. Therefore, information analyzed on a bulk scale from the 2014 release is the only source of data to calibrate LNAPL spill impacts with the Simplified 3D LNAPL model. No lateral migration through fast pathways was noted or inferred from the 2014 release event, so there is no observed basis for providing such complexity to a numerical model. On the other hand, the subsurface is complex and heterogeneous, with fast pathways of various types such as lava tubes and clinker zones. To specifically understand their impact, the modeling includes a conceptual clinker model (which will be conservative with respect to Red Hill Shaft in comparison to smaller, more disconnected pathways). Decision makers can then consider the probability of such a pathway existing, to determine the probability that such an impact could occur, while the homogeneous model, also calibrated to the 2014 release, provides the most likely average impact.

EPM Justification: The assumption of an EPM system is justified considering available data from the 2014 release and the intended use of the model for bounding the impact of various releases to the water table as a way to inform risk decisions. The impact of fast-track geologic features known to be present within the subsurface would also be considered using the clinker sensitivity model to evaluate reasonable and conservative end-members. The clinker sensitivity is an extreme case of discrete features and would be significantly more conservative than adding smaller discrete networks with associated numerical issues, complexities, and disagreements on their alignment, density, size, etc. Therefore, refraining from adding undue complexity to the model is appropriate for understanding LNAPL migration behavior in this setting and the impact of model parameters or different conceptualizations. Furthermore, since the fracture systems at Red Hill primarily comprise cooling joints with spacings of 3–6 feet constrained to single flow beds, use of a discrete fracture network (DFN) approach is certainly not warranted. Finally, the main issue here is that of heterogeneity offered by discrete fast-flow features—at a small-enough grid-block scale, everything can be simulated as a heterogeneous EPM.

Model Parameterization: Criticism of the use of surrogate parameters is also not relevant. Model parameters are surrogates and are calibrated to match observed conditions for practical applications in remedial investigations and consulting. With few exceptions, only theoretical academic research tries correlating such parameters with frequency of fractures, aperture, connectivity, etc., and then upscaling the properties to a numerical grid-block scale (which would then be modified via calibration anyway).

Capillary properties have been selected for the study from available literature and petrophysical studies of onsite cores. Preliminary evaluations had indicated that these are far less sensitive than other parameters, and therefore focusing on them may distract from the bigger issues. The Navy team fully understands impacts of the various parameters of LNAPL simulations and controlling mechanisms. Sensitivity studies (multi-model approach) are required to know if a particular set of parameters is "conservative" or not, and therefore a blanket statement that those values used are non-conservative is incorrect. The Navy would, however, conduct a sensitivity analysis to the capillary parameters to satisfy this demand. The Navy has requested alternative parameter values (with supporting justification) that DOH feels may be more "reasonably" conservative.

No Background LNAPL Conditions: This concern is being addressed by the Navy. Higher residual water, reduced porosity, and higher residual LNAPL all behave in the same manner to reduce available pore space for intrusion of additional LNAPL into the domain. A preliminary sensitivity analysis to the available pore space suggested that it was inversely correlated to travel distance. The proposed approach includes a sensitivity to this pore space (and thus residual LNAPL associated with previous releases). Therefore, this impact can be estimated by appropriately scaling the results of any of the models. Also, the approach includes a resilience evaluation for LNAPL, which can provide background conditions for a second release at some later time. Sensitivity analyses would address the concern of existing residual LNAPL in the vadose zone.

Consistency Criteria: The final issue in the Aqui-Ver memo is related to consistency criteria. This is essentially the historical information that would be used to calibrate the model. The Navy team has expended considerable effort to estimate bounds on LNAPL movement from the 2014 release. Our recent multifactor/cluster analysis study presented to the AOC Parties on July 26, 2019 (per an earlier agreement with the Regulatory Agencies to proceed with this work effort) further reinforces the Navy's

position. The Navy's position is that based on available data, (1) there is no indication that LNAPL has reached outlying wells, and (2) the 2014 release did not appear to impact groundwater. However, the Navy acknowledges that impacts from the 2014 release or any previous releases may have occurred that are not seen in the current groundwater monitoring network or Red Hill Shaft. The Navy welcomes additional any constructive comments, supported by scientific evidence, from the Regulatory Agencies related to the consistency criteria.

Please let us know if you have any questions or comments.