Groundwater Flow Model Progress Report 01, Red Hill Bulk Fuel Storage Facility

JOINT BASE PEARL HARBOR-HICKAM, O‘AHU, HAWAI‘I

Administrative Order on Consent in the Matter of Red Hill Bulk Fuel Storage Facility, EPA Docket Number RCRA 7003-R9-2015-01 and DOH Docket Number 15-UST-EA-01, Attachment A, Statement of Work Section 6.2, Section 7.1.2, Section 7.2.2, and Section 7.3.2

April 5, 2017
Revision 00

Comprehensive Long-Term Environmental Action Navy
Contract Number N62742-12-D-1829, CTO 0053

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April 5, 2017
Revision 00

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CONTENTS

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ACRONYMS AND ABBREVIATIONS

AOC	Administrative Order on Consent
BWS	Board of Water Supply, City and County of Honolulu
CF&T	contaminant fate and transport
CSM	conceptual site model
CWRM	Commission on Water Resource Management, State of Hawai‘i Department of Land and Natural Resources
ft	feet
GHB	general-head boundary
mgd	million gallons per day
msl	mean sea level
SHB	specified-head boundary
SME	subject matter expert
SOW	scope of work
SWAP	Source Water Assessment Program
USGS	United States Geological Survey
WP	work plan

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1. Introduction

This *Groundwater Flow Model Progress Report 01* is the first of a series of modeling progress reports that describes the technical status of the groundwater flow modeling effort being conducted for the Investigation and Remediation of Petroleum Product Releases and Groundwater Protection and Evaluation project at the Red Hill Bulk Fuel Storage Facility ("Facility"), Joint Base Pearl Harbor-Hickam, O'ahu, Hawai'i. The progress report is a component of the overall project reporting as specified in the *Work Plan / Scope of Work* (WP/SOW) (DON 2017). The WP/SOW presents the process, tasks, and deliverables that address the goals and requirements of Statement of Work Sections 6 and 7 of the *Administrative Order on Consent* (AOC) *In the Matter of Red Hill Bulk Fuel Storage Facility* (EPA Docket No: RCRA 7003-R9-2015-01; DOH Docket No: 15-UST-EA-01) (EPA Region 9 and DOH 2015). Submittal of groundwater flow model progress reports at a minimum of every 4 months is stipulated in AOC Statement of Work Section 7.1.2.

1.1 REPORTING PERIOD

Reporting period 01 covered in this report represents progress for the first 4-month period following conditional approval of the project WP/SOW by the Regulatory Agencies, which was received by the Navy on December 5, 2016 (EPA Region 9 and DOH 2016).

2. Work Completed This Period

2.1 CURRENT STATUS

The groundwater modeling work completed during this reporting period included assessing the usefulness and limitations of the existing data for the planned groundwater modeling, which are described in the *Existing-Data Summary and Evaluation Report for Groundwater Flow and Contaminant Fate and Transport Modeling* dated March 5, 2017. In addition, a detailed review of the archived 2007 model files was performed to evaluate the groundwater model reported in the *Red Hill Bulk Fuel Storage Facility Final Technical Report* (DON 2007). A summary of files received is shown in Table 1. The archived model files were found to provide a reasonable starting point for the model update, but some uncertainties and limitations have been identified as discussed below and as detailed in the *Data Gap Analysis Report for Groundwater Flow and Contaminant Fate and Transport* [CF&T] *Modeling* that is currently being prepared. These issues will be addressed when updating the 2007 model to incorporate new data being collected in the Red Hill area, refine the model setup, and calibrate the model for current conditions.

2.1.1 Technical Progress

The main objectives of evaluating the archived model files were to evaluate whether the archived model files are sufficiently complete to allow numerical model simulations, and to compare the parameter values and simulation results to those described in the Red Hill *Final Technical Report* (DON 2007).

Work performed to date has involved opening the model files received and tabulating the files by filename, date, and content. Table 1 summarizes the model files received; the files show 24 different model runs, which include both groundwater flow (MODFLOW 2000) and reactive transport (RT3D) input files. The model files were then compared to the previously reported parameter values, model layers, grid-cell sizes, pumping well locations, and pumping rates. During this process, selected archived model files were converted from MODFLOW 2000 to MODFLOW 2005 for additional simulations.

Table 1: Summary of Model Files Received

File Sources and Folder Names	Model File Name	Model Features	(Total) Pumping Rate, mgd	Model Layer Elevation Range (m)	Model Dated/ Developed	Model Evaluation	Notes
Rotzoll	RH_19ssBC	Steady state flow model	42.646	-350 to 556	01/07/07	Checked pumping rates	Converted from v6, and fixed in v10.1; deleted other non-necessary model files
	RH_23_17d_Bob	Transient flow model	—	—	07/10/07	Reported initial steady state of 131 days, and followed by 53 stress periods & 276 time steps for 17 days transient calibration (DON 2007)	Not convertible & not operable files due to incomplete model files
	RH_25_Rhoff_max	Steady state flow model, with no pumping from Red Hill Shaft	57.886	-350 to 556	01/27/14	Converted from MODFLOW 2000 to MODFLOW 2005	Converted modeling platform to GMS v10.2
	RH_25_ssBC	Steady state flow model, with no pumping from Red Hill Shaft	—	—	01/27/14	01/04/00	Converted flow to v10.2
TEC Red Hill CFT Files (Redhill Model_New-BC)	TPH-Compliance_New-BC	Flow and transport model, with pumping of Hālawa Shaft, Red Hill Shaft, and others	116.702	-350 to 556	08/06/07	Converted from MODFLOW 2000 to MODFLOW 2005, converted boundary conditions from specified head to general head (GHB), simulated flow, processed contours	Converted to GMS v10.1, and extensively evaluated; both flow and transport are in running conditions with the latest flow field for transport, compared to original flow model only
070915_1118 RT3D Simul Inst Rx	Instn-Rx	Flow and transport	—	—	04/30/07	—	Reviewed (briefly)
070915_1136 RT3D Simul Bz Compl III	Benzene-III	Flow and transport	—	—	04/12/07	—	Reviewed (briefly)
070915_1204 RT3D TPH Compl Run3	TPH-Compliance_New-BC-III	Flow and transport	—	—	08/09/07	—	Reviewed (briefly)
070915_1242 RT3D Drought TPH Compl2	TPH-Compliance_New-BC-II	Flow and transport	—	—	08/06/07	—	Reviewed (briefly)
070918_0636 RT3D Simul Bz Compl I	Drought	Flow and transport	—	—	04/30/07	—	Reviewed (briefly)
070918_1151 RT3D Simul Bz Compl I NewBC	Benzene_Compliance_New-BC	Flow and transport	—	—	08/09/07	—	Converted to GMS v10.1, and extensively evaluated; both flow and transport are in running conditions with the latest flow field for transport, compared to original flow model only

File Sources and Folder Names	Model File Name	Model Features	(Total) Pumping Rate, mgd	Model Layer Elevation Range (m)	Model Dated/ Developed	Model Evaluation	Notes
071004_1144 Default Rx	Benezene_Compliance_ New-BC-II	Flow and transport	—	—	08/11/07	—	Reviewed (briefly)
071004_1203 Benzene VI	Benzene-VI	Flow and transport	—	—	04/16/07	—	Reviewed (briefly)
071004_1225 Drought	Drought	Flow and transport	—	—	04/16/07	—	Reviewed (briefly)
071004_1246 LNAPL at IG	LNAPL-at-IG	Flow and transport	—	—	05/22/07	—	Reviewed (briefly)
071004_1305 Navy Rerun I	Navy_Re_Run-I	Flow and transport	—	—	09/13/07	—	Reviewed (briefly)
071010_0655 Navy Rerun II	Navy_Re_Run-II	Flow and transport	—	—	09/14/07	—	Reviewed (briefly)
071010_0715 Porosity10	Porosity-10	Flow and transport	—	—	05/01/07	—	Reviewed (briefly)
071016_0655 Sensitiv I	Sensitivity-1	Flow and transport	—	—	04/27/07	—	Converted to GMS v10.1, and extensively evaluated; both flow and transport are in running conditions with the latest flow field for transport, compared to original flow model only
071016_0710 Sensitiv II	Sensitivity-II	Flow and transport	—	—	05/18/07	—	Reviewed (briefly)
071016_0727 Sensitiv V	Sensitivity-V	Flow and transport	—	—	04/27/07	—	Reviewed (briefly)
071030_1335 TPH Compl MOD2 UH Modeling	Multiple SWAP models	Flow and transport	—	—	06/28/05	—	Reviewed (briefly)
071031_0618 Sensitiv III	Sensitivity-III	Flow and transport	—	—	04/28/07	—	Reviewed (briefly)
071031_0637 Sensitiv IV	Sensitivity-IV	Flow and transport	—	—	05/05/07	—	Reviewed (briefly)

SWAP Source Water Assessment Program

Notes:

1. TPH_Compliance_New-BC is applicable to update of both flow and transport.
2. Benzene_Compliance_New-BC is applicable to update of both flow and transport.
3. Sensitivity-1 is applicable to update of both flow and transport.
4. All transport models used RT3D code.
5. MODFLOW and MODPATH were used for saturated groundwater flow, and particle tracking.

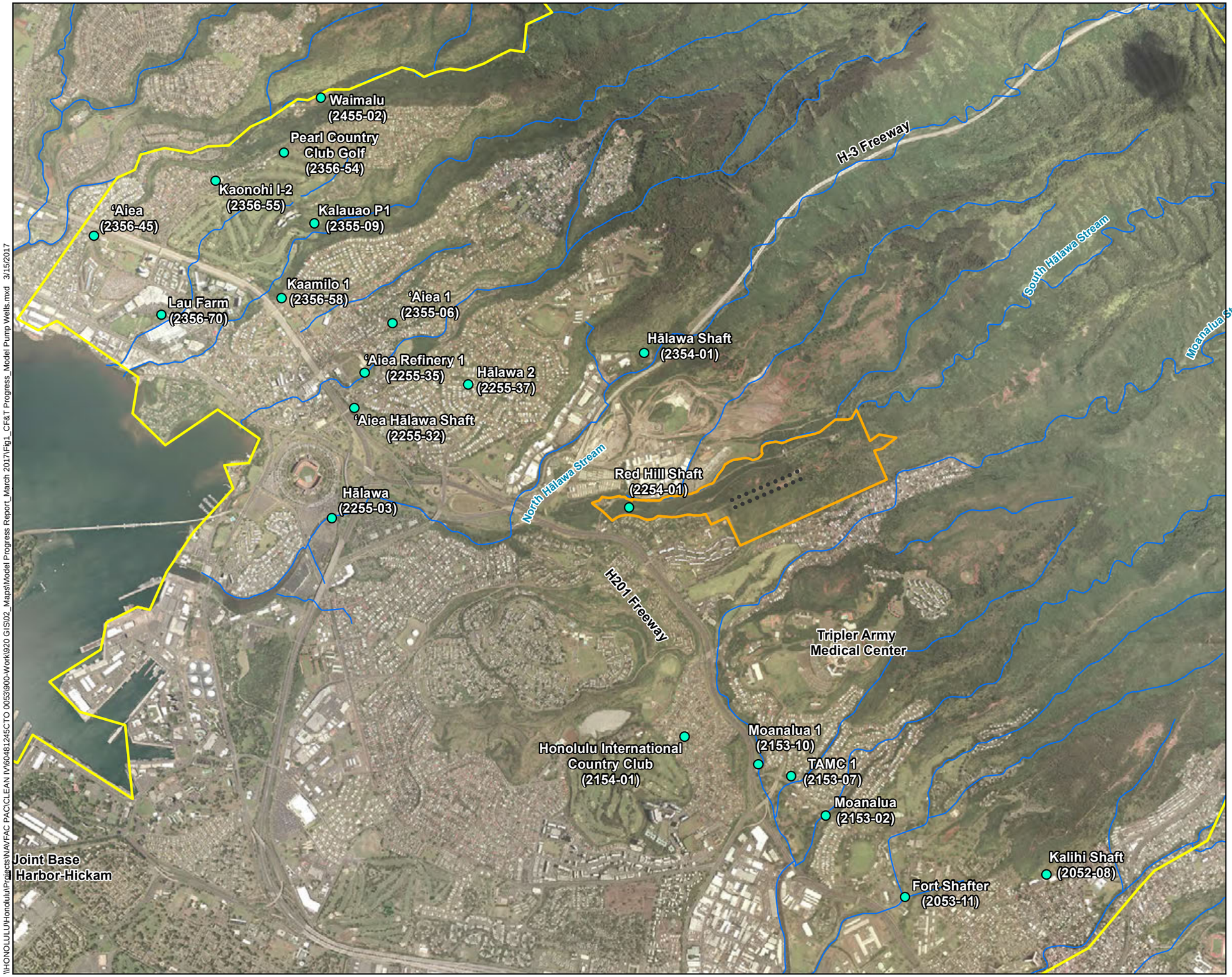
The model files show the groundwater model layers and parameter values are consistent with the local groundwater model setup and results described in the 2007 model report (DON 2007). Well locations and pumping rates assigned in the model were identified for three different scenarios, which total 45 million gallons per day (mgd), 58 mgd, and 81 mgd for all the pumping wells combined. Figure 1 shows the pumping well locations within the model, and Table 2 shows the pumping rates of wells for these three scenarios compared to the previously reported rates (DON 2007).

An additional set of MODFLOW files represents the groundwater flow modeling described in the brief 2014 modeling addendum (Rotzoll 2014). In 2014, this additional groundwater flow modeling was performed to determine the effects of petroleum contamination occurring at the Facility on the nearby Board of Water Supply (BWS) wells (Rotzoll 2014). The model parameters were the same as the August 2007 model, except that the model was analyzed with the Navy Red Hill Shaft (03-2254-01) not in operation. The 2014 modeling delineated 10-year capture zones for drinking water wells near the Facility under two pumping scenarios: 1) withdrawal at all surrounding wells except Red Hill Shaft (03-2254-01) at a 10-year average pumping rate and 2) withdrawal at all surrounding wells except Red Hill Shaft.

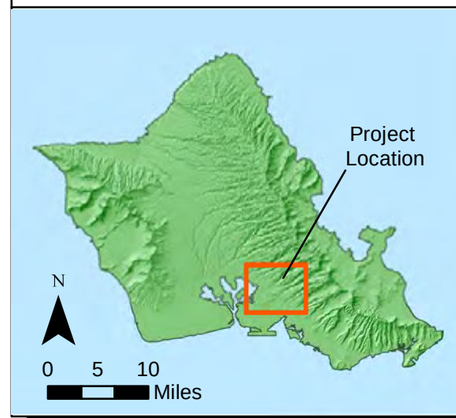
Table 2: Well Geometry and Pumping Rates for the Local Model

Aquifer	Well No.	Elevation (ft msl)	Top Screen (ft msl)	Bottom Screen (ft msl)	Pump Rate (mgd)
Waimalu	2255-32	95	14	-4	0.48
	2255-35	119	-32	-77	0.03
	2255-37	256	-29	-49	0.99
	2354-01_1	165	0	-18	4.58 [a]
	2354-01_2	367	2	-16	2.29
	2354-01_3	492	3	-15	1.83
	2354-01_4	535	5	-13	1.37
	2354-01_5	541	7	-11	0.92
	2354-01_6	489	8	-10	0.46
	2355-03	304	16	-38	0.79
	2355-06	258	-32	-102	1.24
	2355-09	160	-61	-253	8.72
	2356-45-53	25	-180	-315	1.19
	2356-54	374	-21	-178	0.78
	2356-55	252	-37	-290	1.33
	2356-58	147	-43	-193	1.00
	2356-70	18	-152	-202	0.04
	2455-02	128	-12	-78	0.28
Red Hill	2254-01_1	200	24	-10	1.76
	2254-01_2	200	24	-10	0.88
	2254-01_3	194	24	-10	0.70
	2254-01_4	240	24	-10	0.53
	2254-01_5	299	24	-10	0.35
	2254-01_6	322	24	-10	0.18
Moanalua	2052-08	160	30	6	7.43
	2053-11	21	-154	-309	0.64
	2153-02	20	-59	-269	0.04
	2153-07	30	-22	-272	0.37
	2153-10	36	-114	-264	3.27
	2154-01	14	-89	-280	0.29

Source: (DON 2007), Appendix L, Table 7
ft feet
msl mean sea level
[a] For the maximum pumping rate scenario (81 mgd total), the Hālawa Shaft pumping rate equals 27.46 mgd.



Location Map



Legend

- Pumping Well
- Modeling Area
- Red Hill Bulk Fuel Storage Facility Boundary
- Stream
- Red Hill Fuel Storage Tank

Notes

1. Map projection: NAD 1983 UTM Zone 4N
2. Base Map: DigitalGlobe, Inc. (DG) and NRCS. Publication_Date: 2015

N

0 1,250 2,500 5,000 Feet

Figure 1
Pumping Well Locations
Groundwater Flow Model Progress Report 01
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

\\HONOLULU\Honolulu\Projects\NAVFAC PACIFIC\CLEAN IV\60481245\CTO 0053\900-Work\920 GIS\02_Maps\Model Progress Report_March 2017\Fig1_CF&T Progress_Model Pump Wells.mxd 3/15/2017

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Another important goal of this work was to evaluate the perimeter boundaries of the 2007 local model to ascertain whether the boundary conditions assigned may affect or constrain future model results, and if so, whether the perimeter boundary locations need to be revised for future model simulations. Each perimeter boundary (shown on Figure 2) extends vertically from the top of the upper model layer to the bottom of the lowest model layer.

As described in the previous Red Hill groundwater modeling report (DON 2007), specified-head boundary (SHB) conditions were assigned along each side of the local model area. Head values assigned to these SHBs were imported from the regional Source Water Assessment Program (SWAP) model (DON 2007).

The 2007 local model boundaries are located along natural hydrogeologic boundaries, each of which is 2 miles or more from the Facility. The northeastern boundary lies along the east side of the dike-free basalt area mapped by the United States Geological Survey (USGS) (Izuka et al. 2016). The northwestern model boundary is located along the center of Waimalu Valley (Figure 2), about 2.5 miles away from the Facility and about 1.8 miles north of BWS's Hālawa Shaft at the closest point. The USGS regional model (Oki 2005) assigned a valley-fill barrier along the bottom of Waimalu Valley on the basis of well logs.

The southeast boundary is located along the middle of Kalihi Valley, which is about 2.5 miles south of the Facility at the closest point. The USGS regional model (Oki 2005) also used Kalihi Valley as the southern boundary, and specified it to be a no-flow boundary to reflect the presence of a deep valley fill barrier, which likely exceeds 1,000 feet thickness (Oki 2005). The western boundary of the 2007 model is located along the shore of Pearl Harbor (Figure 2), which is about 2.8 miles west of the Facility and about 1.4 miles west of Hālawa Shaft at the closest point.

Work during this period evaluated whether the locations of the SHBs in the 2007 model unduly constrain future modeling results. This evaluation included conducting new simulations with the 2007 flow model after setting different boundary conditions, known as general-head boundary (GHB) conditions, at the same locations as the SHBs. In MODFLOW, a GHB package is used to simulate a head-dependent flux boundary. On the other hand, the basic SHB package is used to set constant values of hydraulic head along the boundary. Unlike a SHB, a MODFLOW GHB allows the hydraulic head to change along the boundary in response to pumping within the model domain. Thus, the degree to which the SHB locations may affect the model results (e.g., constrain pumping drawdowns) were evaluated by comparing model simulations using the same pumping wells and pumping rates after changing the SHBs to GHBs.

These new model simulations show no substantial differences in simulated heads using GHBs compared to SHBs, even for the highest pumping rate scenario (81 mgd). To illustrate this finding, plots have been prepared showing hydraulic heads simulated by the 2007 model along two lines crossing the area of interest in the vicinity of the Facility, Red Hill Shaft, and Hālawa Shaft, as indicated on Figure 2. Figure 3 is oriented northeast to southwest, and Figure 4 is oriented northwest to southeast across the model area. The Y-axis of these plots shows the model-simulated heads (groundwater table elevations) using SHB conditions, and the X-axis shows the heads simulated by the model after assigning the GHBs. There is no substantial difference in simulated water level contours for the model with GHB conditions compared to using SHB conditions, indicating that the SHBs do not constrain the model's capability to simulate groundwater levels caused by pumping wells in the area of interest, even with high pumping rates. Thus, it is concluded that there is no need to change the locations of the perimeter boundaries for future model simulations.

2.1.2 Technical Issues

The work so far has revealed several uncertainties and limitations in the archived model files, including:

- It is not possible to directly match individual model files or sets of files to the simulation scenarios described in the 2007 modeling report (DON 2007) with the information currently obtained because the archived files are not organized or named the same as scenarios previously reported. Additional information will need to be obtained to match the files to the simulation scenarios.
- A calibrated base case model simulation was not identified in the model files that were provided, and thus it is not possible to independently evaluate the previous steady-state calibration. However, it is intended to run the 2007 model to simulate non-pumping conditions at Red Hill Shaft to compare the results to the recently measured groundwater levels (November 2016).
- Some sets of model files do not contain all of the input files needed to run simulations using MODFLOW 2000, and converting those files to MODFLOW 2005 may be problematic. This is not likely to invalidate any of the 2007 modeling results but may complicate future use of the archived model files.
- Both the 2007 and 2014 model simulations involved other pumping wells that were not reported (DON 2007), and no information for these wells, such as well I.D., rationale of the pumping rates, and screen depth interval has been obtained. This is not likely to invalidate any of the 2007 modeling results but will require additional effort to obtain the missing well information.
- Both the 2007 and 2014 models show errors regarding starting heads and bottom elevations, e.g., starting heads below bottom elevations, and/or specified heads below bottom elevations in some model cells. This is a minor technical issue, which may need more evaluation before using the 2007 model for additional simulations. During the model update, refining or reconstructing the model layers is expected to fix this issue.

2.1.3 RHMW08 and RHMW09 Boring Logs and Well Construction Diagrams

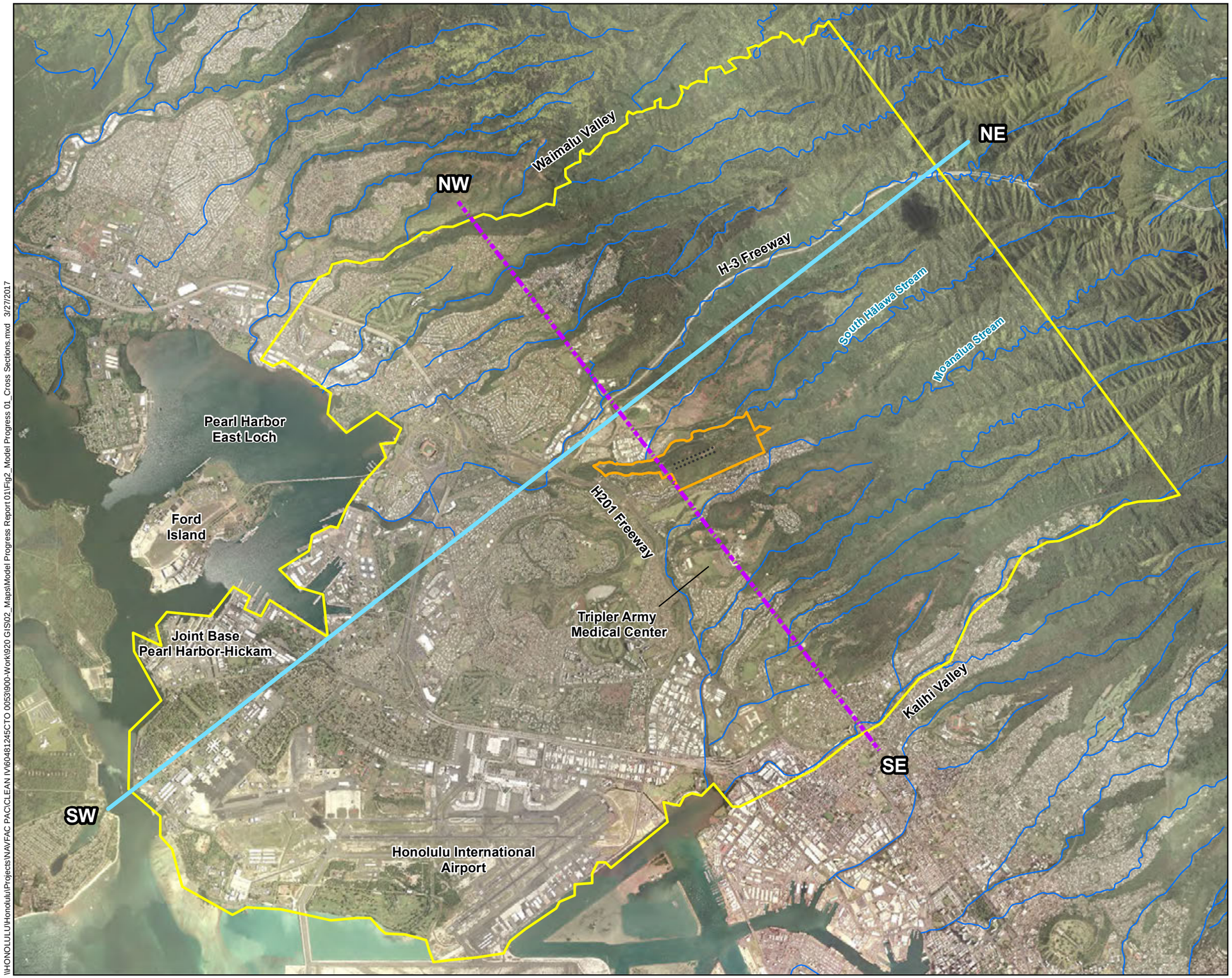
Lithological boring logs and well construction diagrams for new monitoring wells RHMW08 and RHMW09, constructed between July and October 2016, are presented in Appendix A.

2.2 SUBMITTAL OF MODELING DELIVERABLES

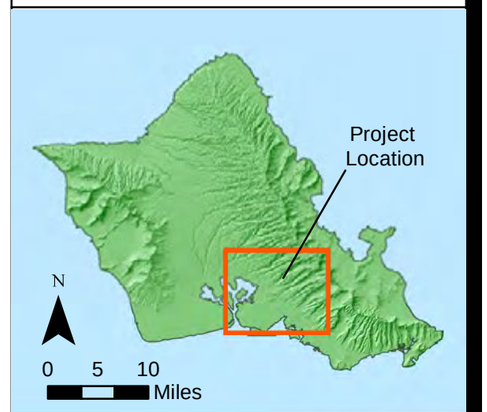
2.2.1 Current Period

Other relevant deliverables submitted during this reporting period include:

- *Final Fourth Quarter 2016 - Quarterly Groundwater Monitoring Report, Red Hill Bulk Fuel Storage Facility* (February 2017)
- *Existing Data Summary and Evaluation Report for Groundwater Flow and Contaminant Fate and Transport Modeling, Red Hill Bulk Fuel Storage Facility* (March 5, 2017)



Location Map



Legend

- Modeling Area
- Red Hill Bulk Fuel Storage Facility Boundary
- Stream
- Red Hill Fuel Storage Tank
- NE to SW Line
- NW to SE Line

Notes

1. Map projection: NAD 1983 UTM Zone 4N
2. Base Map: DigitalGlobe, Inc. (DG) and NRCS. Publication_Date: 2015
3. GHB- general head boundary
   NE- northeast
   NW- northwest
   SE- southeast
   SHB- specified-head boundary
   SW- southwest

N

0 3,000 6,000 9,000 Feet

Figure 2
Model Boundary and Locations for Comparison of Simulated Heads of GHB and SHB Groundwater Flow Model Progress Report 01 Red Hill Bulk Fuel Storage Facility JBPHH, O'ahu, Hawai'i

\\HONOLULU\Honolulu\Projects\NAVFAC PACIC\LEAN IV\60481245CTO 00539\00-Work\920 GIS\02_Maps\Model Progress Report 01\Fig2_Model Progress 01_Cross Sections.mxd 3/27/2017

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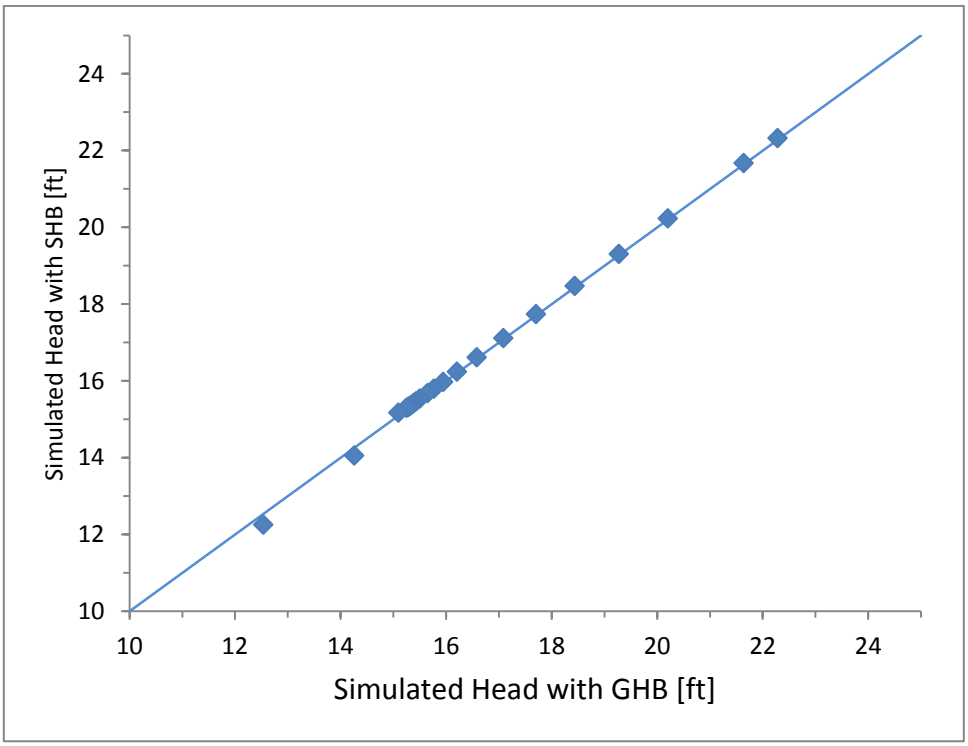

Figure 3: Comparison of Simulated Heads of GHB and SHB (NE/SW Orientation)

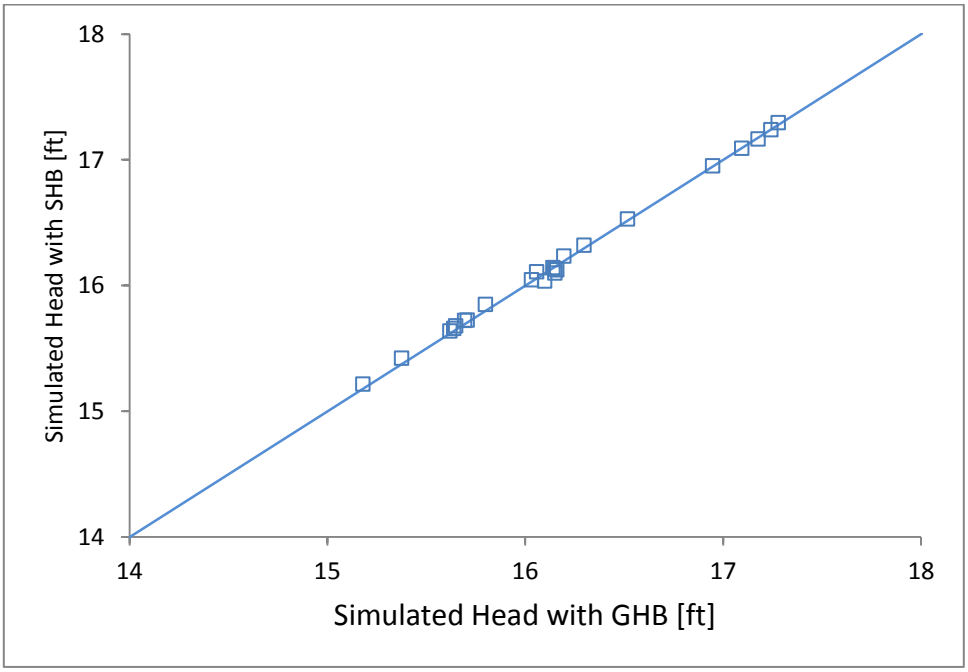

Figure 4: Comparison of Simulated Heads of GHB and SHB (NW/SE Orientation)

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2.2.2 Next Period

Additional deliverables due for submittal during the next 4-month reporting period include:

- *Data Gap Analysis Report for Groundwater Flow and Contaminant Fate and Transport Modeling, Red Hill Bulk Fuel Storage Facility*
- *Conceptual Site Model Development and Evaluation Plan, Red Hill Bulk Fuel Storage Facility*
- *Attenuation Evaluation Plan, Red Hill Bulk Fuel Storage Facility*
- *Groundwater Model Evaluation Plan, Red Hill Bulk Fuel Storage Facility*
- *Final First Quarter 2017 - Quarterly Groundwater Monitoring Report, Red Hill Bulk Fuel Storage Facility*
- *Final Second Quarter 2017 - Quarterly Groundwater Monitoring Report, Red Hill Bulk Fuel Storage Facility*

3. Schedule Status

The modeling is proceeding on schedule; no delays are anticipated at the present time.

4. Outstanding Issues

Outstanding issues center around filling the data gaps identified in the forthcoming *Data Gap Analysis Report*.

5. Anticipated Work Next Reporting Period

- Present initial findings of 2007 model evaluation to Regulators and subject matter experts (SMEs).
- Continue to evaluate the 2007 flow and transport model.
- Evaluate new hydrogeologic information to develop the conceptual site model (CSM) and update the 2007 flow model, including:
  - Well locations, construction details, borehole geologic logs and pumping data (from BWS and the Hawai'i Department of Land and Natural Resources' Commission on Water Resource Management [CWRM])
  - May 2015 pumping test data from BWS and USGS
  - Evaluate screen depth intervals in monitoring wells for model calibration
  - GIS shape files from USGS for maps of groundwater recharge rates, caprock thickness and top of basalt
  - Map showing altitude of base of fresh water aquifer (from CWRM and/or USGS)
  - Participate in meeting with USGS to discuss and obtain in-progress USGS modeling files for hydraulic properties along 2007 model boundaries
  - Work closely with project team to develop detailed geological characterization of the Red Hill area, including basalt and clinker beds and effective porosity distributions
- Participate in detailed planning of regional aquifer test with synoptic monitoring, and assist with coordination of stakeholder activities.

- Prepare the *CSM Development and Update Plan* and *Groundwater Model Evaluation Plan*.
- Present updated CSM in the next *Groundwater Flow Model Progress Report*, anticipated for submittal in August 2017.

6. References

Department of the Navy (DON). 2007. *Red Hill Bulk Fuel Storage Facility Final Technical Report, Pearl Harbor, Hawaii*. Prepared by TEC Inc., Honolulu, HI. Pearl Harbor, HI: Naval Facilities Engineering Command, Pacific. August.

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Environmental Protection Agency, United States, Region 9; and Department of Health, State of Hawaii (EPA Region 9 and DOH). 2015. *Administrative Order on Consent In the Matter of Red Hill Bulk Fuel Storage Facility, EPA Docket No: RCRA 7003-R9-2015-01; DOH Docket No: 15-UST-EA-01*. September.

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Rotzoll, K. 2014. "Addendum to Rotzoll and El-Kadi (2007) Numerical Ground-Water Flow Simulation for Red Hill Fuel Storage Facilities, NAVFAC Pacific, Oahu, Hawaii." To: J. Shimabuku, NAVFAC HI; E. Lau, HBWS; cc: R. Whittier, HDOH; A. El-Kadi, University of Hawaii. January 29. Water Resources Research Center, University of Hawaii.

Appendix A:
Boring Logs and Well Construction Diagrams, RHMW08 and RHMW09

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Project: CTO53 - Red Hill Bulk Fuel Storage Facilty
Project Location: CTO53
Project Number: 60481245

Key to Log

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery, %	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SOIL SAMPLES: Type	Number	Blows /12 in.	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

COLUMN DESCRIPTIONS

1 **Elevation:** Elevation (in feet) referenced to mean sea level (MSL).

2 **Depth:** Distance (in feet) below the collar of the borehole.

3 **Run No.:** Number of the individual coring interval.

4 **Box No.:** Number of the core box which contains core from the corresponding run.

5 **Recovery:** Amount (in percent) of core recovered from the coring interval; calculated as length of core recovered divided by length of run.

6 **Fractures per Foot:** (Fracture Frequency) The number of naturally occurring fractures in each foot of core; does not include mechanical breaks (induced by drilling) or healed fractures. "NA" indicates not applicable due to lack of core recovery.

7 **R Q D:** (Rock Quality Designation) Amount (in percent) of intact core (pieces of sound core greater than 4 inches in length) in each coring interval; calculated as the sum of lengths of intact core divided by length of core run. RQD of highly weathered/altered rock does not meet soundness requirements, but provides some indication of rock quality with respect to the degree of fracturing.

8 **Fracture Drawing:** Sketch of the naturally occurring fractures and mechanical breaks, showing the angle of the fractures relative to the cross-sectional axis of the core. "NR" indicates no recovery.

9 **Fracture Number:** Location of each naturally occurring fracture (numbered) and mechanical break (labeled "M"). Naturally occurring fractures are described in Column 11 (keyed by number) using descriptive terms defined on Sheet 2 (Items a through g).

10 **Lithology:** A graphic log of material encountered using symbols to represent differing soil and types; graphic symbols are explained below.

11 **Description:** Lithologic description in this order: rock type, color (Munsel), texture, grain size, weathering, strength, and other features; descriptive terms are defined on Sheet 2. Also, abbreviated description of fractures numbered in Column 9 using terms defined on Sheet 2.

12 **Well Schematic:** Schematic of piezometer, inclinometer or well installation; graphic symbols are explained below.

13 **Sample Type:** Type of soil sample collected at depth interval shown; sampler symbols are explained below.

14 **Sample Number:** Sample identification number.

15 **Blows /12 in.:** Number of blows required to advance sampler 12 inches beyond first 6 inch interval or distance noted, using a 140-lb hammer with a 30-inch drop (unless otherwise noted).

16 **Drill Time [Rate]:** Time (in 24-hour clock) marking start and finish of each run; drill rate (in feet per hour) is reported in brackets.

17 **Field Notes and Test Results:** Comments and observations regarding drilling or sampling made by driller or field personnel. Field and lab tests are indicated using abbreviations explained below.

TYPICAL MATERIAL GRAPHIC SYMBOLS


Silty SAND (SC)


Clayey SAND (SC)


Fat CLAY (CH)


BASALT Breccia


BASALT a'a Clinker


Basalt

TYPICAL SAMPLER GRAPHIC SYMBOLS


Grab sample


Standard Penetration (SPT) split spoon sampler


Modified California sampler with brass liners

TYPICAL WELL GRAPHIC SYMBOLS


Blank casing in cement grout


Blank casing in filter sand


Blank casing in cement-bentonite grout


Slotted casing in filter sand


Blank casing in bentonite pellets


Filter sand, native fill or slough

OTHER GRAPHIC SYMBOLS


First water encountered at time of drilling and sampling (ATD)


Water level measured at specified time after completion of drilling and sampling

Minor change in material properties within a stratum

Inferred or transitional contact

FIELD AND LABORATORY TEST ABBREVIATIONS

LL Liquid Limit (from Atterberg Limits)
PI Plasticity Index (from Atterberg Limits), NP=Non Plastic
PP PP Pocket penetrometer field consitency reading, tst
SA Sieve Analysis, %fines (<#200 sieve) and gravel (>#4 sieve)
WA Wash on #200 sieve, % fines (<#200 sieve)
UC Unconfined compressive strength (qu), psf

Soil classifications are based on the Unified Soil Classification System. Descriptions and stratum lines are interpretive; field descriptions may have been modified to reflect lab test results. Descriptions on these logs apply only at the specific boring locations and at the time the borings were advanced; they are not warranted to be representative of subsurface conditions at other locations or times.

Project: CTO53 - Red Hill Bulk Fuel Storage Facilty Project Location: CTO53 Project Number: 60481245	**Key to Log** Sheet 2 of 2

KEY TO DESCRIPTIVE TERMS USED ON CORE LOGS

DISCONTINUITY DESCRIPTORS

a Dip of discontinuity, measured relative to a plane normal to the core axis.

b **Discontinuity Type:**

- F - Fault
- J - Joint
- Sh - Shear
- Fo - Foliation
- V - Vein
- B - Bedding

c **Aperture (inches):**

- W - Wide (0.5-2.0)
- MW - Moderately Wide (0.1-0.5)
- N - Narrow (0.05-0.1)
- VN - Very Narrow (<0.05)
- T - Tight (0)

d **Type of Infilling:**

- Bi - Biotite
- Cl - Clay
- Ca - Calcite
- Ch - Chlorite
- Ep - Epidote
- Fe - Iron Oxide
- H - Healed
- K^+ - Potassium
- My - Mylonite
- No - None
- Py - Pyrite
- Qz - Quartz
- Sd - Sand
- Si - Silt
- SiCl - Silty Clay
- Uk - Unknown

e **Amount of Infilling:**

- Su - Surface Stain
- Sp - Spotty
- Pa - Partially Filled
- Fi - Filled
- No - None

f **Surface Shape of Joint:**

- Pl - Planar
- Wa - Wavy
- St - Stepped
- Ir - Irregular

g **Roughness of Surface:**

- Slk - Slickensided [surface has smooth, glassy finish with visual evidence of striations]
- S - Smooth [surface appears smooth and feels so to the touch]
- SR - Slightly Rough [asperities on the discontinuity surfaces are distinguishable and can be felt]
- R - Rough [some ridges and side-angle steps are evident; asperities are clearly visible, and discontinuity surface feels very abrasive]
- VR - Very Rough [near-vertical steps and ridges occur on the discontinuity surface]

ROCK WEATHERING / ALTERATION

Description	Recognition
Residual Soil	Original minerals of rock have been entirely decomposed to secondary minerals, and original rock fabric is not apparent; material can be easily broken by hand
Completely Weathered/Altered	Original minerals of rock have been almost entirely decomposed to secondary minerals, although original fabric may be intact; material can be granulated by hand
Highly Weathered/Altered	More than half of the rock is decomposed; rock is weakened so that a minimum 2-inch-diameter sample can be broken readily by hand across rock fabric
Moderately Weathered/Altered	Rock is discolored and noticeably weakened, but less than half is decomposed; a minimum 2-inch-diameter sample cannot be broken readily by hand across rock fabric
Slightly Weathered/Altered	Rock is slightly discolored, but not noticeably lower in strength than fresh rock
Fresh/Unweathered	Rock shows no discoloration, loss of strength, or other effect of weathering/alteration

ROCK STRENGTH

Description	Recognition	Approximate UCS Range
Extremely Weak Rock	Can be indented by thumbnail	35 to 150 psi
Very Weak Rock	Can be peeled by pocket knife	150 to 750 psi
Weak Rock	Can be peeled with difficulty by pocket knife	750 to 3,500 psi
Medium Strong Rock	Can be indented 5 mm with sharp end of pick	3,500 to 7,500 psi
Strong Rock	Requires one hammer blow to fracture	7,500 to 15,000 psi
Very Strong Rock	Requires many hammer blows to fracture	15,000 to 37,500 psi
Extremely Strong Rock	Can only be chipped with hammer blows	>37,5000 psi

Project: CT053 – Red Hill Bulk Fuel Storage Facilty Project Location: CT053 Project Number: 60481245	Log of Boring RHMW08 Sheet 1 of 20

Date(s) Drilled	08/17/2016	Logged By	D.Rector, J Kronen	Checked By (Date)	J. Kronen
Drilling Method	HQ core / air rotary	Drill Bit Size/Type	HQ diamond bit / 8" tricone bit	Total Depth of Borehole	315.0 feet
Drill Rig Type	Mobile B-59 / T3	Drilling Contractor	Valley Well Drilling	Approximate Surface Elevation	307.8
Groundwater Level		Location		Inclination from Horizontal/Bearing	90°
Borehole Completion	4-inch diameter monitoring well. See RHMW08 Well Cross Section for details			Hammer Data	140 lbs/30-inch drop

Elevation, feet	Depth, feet	ROCK CORE: Run No.	ROCK CORE: Box No.	ROCK CORE: Recovery,%	ROCK CORE: Fractures per Foot	ROCK CORE: R Q D, %	ROCK CORE: Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	SAMPLES: Number	SAMPLES: Blows per foot	SAMPLES: PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	0								FILL Soft, moist, dark reddish-brown (5YR 3/3), Sandy CLAY (CL), with abundant debris (concrete, metal pipe pieces, rebar etc.)							
	1															
306	2															
	3															
304	4															
	5															
302	6								ALLUVIUM Moist, dark reddish brown (5YR, 3/3), Sandy CLAY (CL) with some large gravel							
	7															
300	8															
	9															
298	10		1													
	11															
296	12	1		46		0								0	48	
	13															

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW08

Sheet 2 of 20

Elevation, feet	Depth, feet	Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES Type	SAMPLES Number	SAMPLES Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
294	13															
	14								BASALT Volcanic Breccia Red (2.5YR, 4/8) mottled with dark reddish gray (2.5YR, 4/1), moderately weathered, weak rock							
	15															
292	16				0		M									
	17				0		M		1. 45, J, N, Mn, Su, Pl, SR 2. 30–50, J, N, Mn, SP, Ir, SR							
290	18	2		96	1	60	1							0	72	
	19				1		2		highly weathered zone							
288	20				1		M									
	21				0		M									
	22				1		1 M M									
286	23	3		96	10+	56			highly fractured zone					0	60	
	24				10+		M									
284	25				10+				highly weathered and fractured zone becomes moderately strong, with 2% vesicles							
	26		2		2		1 1									
282	27				1		2 M		1. 60, J, N, Mn, Sp, Pl, SR 2. 65, J, N, Mn, SP, Pl, SR 3. 70, J, N, Cl, Sp, Wa, R							
	28	4		100	1	66	M		becomes weak					0	48	
280	29				10+		3		highly fractured zone							

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW08

Sheet 3 of 20

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	29				0		M									
278	30								BASALT Volcanic Breccia Red (2.5YR, 4/8), highly to completely weathered, extremely weathered. Breaks down to a soft moist Sandy CLAY(CL)							
	30				NA											
	31	5		73	NA	0								0	170	
276	32															
					NA		NR									
	33								BASALT Massive a'a Dark gray (N3), slightly weathered, strong							
					0		M									
274							M									
	34	6		50		40			BASALT a'a Clinker Red (2.5YR, 4/8) mottled with gray (2.5YR, 4/1), highly weathered weak rock					0	30	
					NA		NR									
	35		3													
272					NA											
	36															
					NA											
	37															
		7		100	NA	12								0	72	
270	38															
					NA											
	39															
					1				1. 65, J, N, Mn, Su, Pl, SR							
268									BASALT Massive a'a Dark gray (N3), slightly weathered, strong to very strong, with 2% vesicles (vesicles mostly 0.5mm with few 5.0mm in diameter).							
	40				1											
									1. 75, J, Mw, Fe+Mn, Sp, Pl, SR 2. 20, J, N, Fe, Sp, Pl, SR 3. 18, J, N, Fe+Mn, Sp, Pl, SR 4. 22, J, N, Fe+Mn, Sp, Pl, SR 5. 60, J, N, Fe, Sp, Pl, SR							
	41						M									
					2		1									
266	42															
		8		100	2	78	1							0	84	
	43															
					1		2									
264																
	44						3 4									
					NA				← becomes moderately weathered with 3% vesicles, that are stretched and varying in size							
							5		BASALT a'a Clinker							
	45															

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW08

Sheet 4 of 20

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type Number Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	45				NA				Red (2.5YR, 4/8) to dark red (2.5YR, 3/6), highly weathered weak rock.					
262	46						NR							
			4		NA									
	47													
		9		50	NA	0						0	168	
260	48													
					NA									
	49													
					NA									
258	50													
					NA									
	51													
					NA									
256	52													
		10		96	NA	0						0	108	
	53						M		BASALT Massive a'a					
					1		M		Dark gray (N3), moderately weathered, strong, with 15% vesicles (vesicles 1.0 mm to 5.0mm in diameter, few are partially filled with clay or calcite, partially stretched).					
254	54						1							
					1				1. 85, J, N, Cl+Fe, Sp, Pl, R					
	55						M							
					1		1							
252	56								← with a few large (>7.0 mm) vesicles					
					1		M							
							2							
	57								1. 30, J, N, Cl, Pa, Wa, R					
		11	5	100	1	96	3		2. 20, J, N, Mn, Sp, Pl, SR			0	84	
250	58								3. 10, J, N, Fe, Su, Pl, SR					
					0		M							
	59						M							
					0		M							
248							M							
	60						M		BASALT Volcanic Breccia					
					NA				Dark gray (N3) clasts with reddish yellow (5YR, 7/8) matrix, highly weathered, weak to moderately strong.					
	61													

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW08

Sheet 5 of 20

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	61				NA											
246	62	12		80	NA	NA								0	60	
	63				NA											
244	64				NA		NR									
	65								becomes moderately weathered, strong							
242	66		6		0		M									
	67				0		M									
		13		100	0	95	M							0	60	
240	68				0											
	69				0		M									
238					0											
	70				NA				red (2.5YR, 5/8), highly weathered, weak							
	71				0											
236	72				0											
		14		100	0	52	M		BASALT Massive a'a Dark gray (N3), moderately weathered, moderately strong, with 2% vesicles, 1.0 mm in diameter.					0	84	
	73				0				1. 50, J, N, Mn, SP, Pl, SR							
234	74						J									
					10+				weak zone with many mechanical fractures							
	75								becomes moderately weathered, strong to very strong							
			7		0		M									
232	76						M									
					0											
	77						M									

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW08

Sheet 6 of 20

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	77															
		15		100	0	100	M							0	72	
230	78						M									
					0		M									
	79						M									
					0		M									
228	80						M									
					1				with 5% vesicles that are 0.5 mm to 5.0 mm and slightly stretched							
	81						1									
					0											
226	82						M									
		16		100	1	99	2		1. 10, J, N, Cl, Sp, Wa, SR 2. 40, J, N, Cl+Fe, Sp, Wa, SR					0	72	
	83															
					0											
224	84						M									
			8		0											Drilled to 100 feet bgs on 8-19-2016. Apparent perched water zone noticed at around 92 feet bgs, based on groundwater level measurements and water observed recharging in the borehole. This coincides with a basalt a'a clinker interval encountered between 90.8 feet and 93.5 feet bgs. Drilled ahead to 140 feet bgs on 8-26-2016. Encountered massive a'a basalt flow at 110 feet to 114.5 feet bgs. Depth to water dropped to 123 feet bgs. A basalt a'a clinker interval encountered between 100 feet and 110 feet bgs may also contain perched water. Borehole was backfilled with bentonite until conductor casing could be installed to seal off perched zones.
	85															
					1		1									
222	86								1. 65, J, N, Cl, Sp, Wa, SR 2. 75, J, N, Cl+Fe, Sp, Wa, SR 3. 30, J, N, Cl, Su, Wa, SR 4. 35, J, N, Cl, Sp, Wa, SR 5. 80, J, N, Cl+Fe, Sp, Wa, SR							
					1		M									
	87						M									
		17		100	1	98	2							0	72	
220	88						M									
					1		3									
	89						M									
					1		M									
218	90						4									
					NA		SA		vesicles partially filled with carbonate							
	91								BASALT a'a Clinker Dark gray (N3) with red oxidation (2.5YR, 4/8), highly weathered, weak, with red clay on the surface of may clasts.							
					NA											
216	92	18		100		20								0	102	
					NA											
	93															

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW08

Sheet 7 of 20

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	93															
			9		10+				BASALT Massive a'a Dark gray (N3), moderately weathered, moderately strong, with 10% vesicles. Some vesicles are large, irregularly shaped and partially filled with red clay.							
214	94	19		100	10+	52	M M							0	60	
	95				0		M		← decrease in weathering							
212	96						M M									
					1		M		← dark gray (N3), moderately weathered, moderately strong to strong							
	97						1									
		20		100	1	90	M							0	72	
210	98						SJU 3		← increase to 20% vesicles							
					2				1. 60, J, N, Cl+Fe, Sp, Wa, SR 2. 50, J, N, Cl+Fe, Sp, Wa, SR 3. 45, J, N, No, N, Wa, SR 4. 10, J, N, Sl+Fe, Sp, Wa, SR							
	99						4									
					1		M									
208							M									
	100				1				BASALT a'a Clinker Dark gray (N3) with red oxidation (2.5YR, 4/8), highly weathered, weak, with red clay on the surface of may clasts.							
					NA											
	101	21		80		8			} solid piece of massive a'a					0	72	
206	102				NA											
					NA											
	103	22	10	100		NA								0	360	
					NA											
204	104	23		100		NA			} welded a'a clinker					0	300	
					NA											
	105				NA											
202	106															
		24		80	NA	NA								0	132	
	107															
					NA											
200	108								← with some welded a'a clinker							
					NA											
	109															

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW08

Sheet 8 of 20

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	109	25		80	NA	NA								0	60	
198	110				1				BASALT Massive a'a Dark gray (N3), moderately to slightly weathered, strong, with 7% vesicles that are slightly stretched.							
	111				2		1 M D 3		1. 10, J, N, Cl, Sp, Wa, SR 2. 30, J, N, Cl+Fe, Sp, Wa, SR 3. 30, J, N, Cl, Sp, Ir, R 4. 20, J, N, Fe+Cl, Sp, Wa, SR							
196	112						M									
		26	11	100	1	75	4 M		highly weathered zone with clay on surface of broken clasts					0	60	
	113				0		M		increase to 15% vesicles							
194	114															
					NA		M		BASALT a'a Clinker Dark gray (N3) with red oxidation (2.5YR, 4/8), highly weathered, weak, with red clay on the surface of may clasts.							
	115															
192	116				NA											
					NA											
	117															
		27		72	NA	NA								0	180	
190	118						M		BASALT Massive a'a Dark gray (N3), moderately to slightly weathered, strong, with 10% vesicles that are slightly stretched.							
					0		M									
	119								1. 20, J, Mw, Fe+Cl, Sp, Wa, SR 2. 30, J, N, Fe+Cl, Sp, Wa, SR 3. 25, J, N, Fe+Cl, Sp, Wa,SR 4. 35, J, N, No, N, Wa, SR							
					4		J G D 4									
188	120															
					2		M									
	121								1. Many mechanical fractures partially coated with Fe 2. 50, J, Mw, Fe+Mn, Su, Pl, SR 3. 50, J, N, Fe+Mn, Sp, Pl, SR 4. 20, J, N, No, N, Wa, SR							
					2		M									
186		28		94		57	M							0	222	
	122				0		M		with a few large vesicles							
	123															
			12		1				decrease to 1% vesicles							
184							J									
	124								increase to 5% vesicles							
		29		100	0	100	M		1. 70, J, N, Fe, Su, Pl, SR					0	60	
	125															

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW08

Sheet 9 of 20

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type Number Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	125				NA				BASALT a'a Clinker Dark gray (N3) with red oxidation (2.5YR, 4/8), highly weathered, weak to very weak, matrix supported.					
182	126				NA									
	127				NA									
		30		52	NA	NA						0	144	
180	128				NA									
	129				1		NR							
178	130				NA									
	131				NA									
176					NA									
	132	31		96		NA			with manganese staining on some the surface of some of the clasts			0	130	
	133				NA									
174	134						M							
		32	13	90	1	60	M		BASALT Massive a'a Dark gray (N3), moderately to highly weathered, strong rock.			0	360	
	135						M		becomes highly fractured					
172					10+									
	136								1. 40–70, J, Mw, Fe+Cl, Sp, Ir, SR					
					10+									
	137													
		33		72	0	8	M		massive a'a pieces, dark gray (N3), moderately weathered, strong, 15% vesicles			0	72	
170							M							
	138								BASALT a'a Clinker Dark gray (N3) with red oxidized clay (2.5YR, 4/8), highly weathered, weak to very weak					
					NA									
168	139													
					NA		NR							
	140													
					NA									
	141													

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW08

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
166	141						NR									
		34		50	NA	0								0	26	
	142															
					NA											
	143															
164					0				BASALT Massive a'a Dark gray (N3), slightly weathered, very strong, with 7% vesicles							
	144	35		92		92								0	60	
					0											
	145		14				1									
162					0		M									
	146						2									
					0		M									
	147								1. 60, J, T, Mn, Su, Pl, S 2. 45, J, N ,Cl, Fl, Wa, SR 3. 85, J, N, Cl, Fl, Wa, SR							
		36		94	0	74								0	30	
160	148						M									
					1											
	149						3									
					2		4									
158							5									
	150						1									
					1		M		1. 90, J, Vn, Fe+Mn, Su, Pl, S 2. 0, J, N, Cl, Pa, Wa, SR 3. 20, J, T, Fe+Mn, Su, Wa, SR 4. 10, J, Vn, Cl, Fi, Wa, SR 5. 80, J, Vn, Cl, Fi, Pl, SR 6. 45. J, T, Fe, Su, Wa, SR							
	151															
					5		2									
156							M									
	152						3									
							4									
		37		100	2	50								0	38	
	153						5		← 1% vesicles							
					0		M									
154																
	154								BASALT Pahoehoe Dark reddish brown (10R 3/4), moderately weathered, strong, 10–15% small vesicles							
			15		2		M									
	155															
					2		M									
152							M									
	156						1		1. 60, J, T, Fe, Su, Pl, SR 2. 10, J, T, Fe, Su, Pl, S 3. 45, J, T, Mn, Su, Pl, SR 4. 45, J, N, Cl, Fl, Pl, SR 5. 45, J, N, Cl, Fl, Pl, SR 6. 45, J, N, Fe, Su, Pl, SR 7. 60, J, Vn, Fe, Su, Pl, SR							
					2		2									
	157															

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW08

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	157															
		38		100	2	80			Dark gray (N3), slightly weathered, with 25–30% vesicles					0	100	
150	158				0											
	159				3				vesicles increase in size to >1/8" in diameter							
148	160				0				1. 30, J, Vn, Mn, Su, Wa, R 2. 45, J, N, Cl, Fi, Wa, SR 3. 10, J, N, Cl, Pa, Wa, R 4. 10, J, N, Cl, Pa, Ir, R 5. 70, J, T, Fe+Mn, Su, Pl, SR							
	161				1											
146	162															
		39	16	100	2	78			Dark reddish brown (10R 3/4), moderately weathered					0	60	
	163				1											
144	164				1											
	165				2				1. 45, J, Vn, Cl, Pa, Ir, R 2. 20, N, Cl, Fi, Wa, R 3. 30, T, Mn, Su, Pl, SR							
142	166				0											
	167															
		40		100	1	78								0	100	
140	168						3		flow boundary							
					0											
	169						M									
					2		M									
138	170								Dark gray (N3), slightly weathered to fresh, very strong, with 30% vesicles							
					0											
	171		17				M									
					0											
136	172						M		20% vesicles, up to 1/4" diameter							
		41		100	0	86								0	100	
	173															

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW08

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	173															
					0				1. 30, J, Vn, Fe+Mn, Su, Pl, SR 2. 85, J, Vn, Cl, Pa, Wa, SR 3. 10, J, Vn, Cl, Pa, Wa, SR							
-134	174				3											
	175															
					1				1. 0, J, N, Cl, Fi, Wa, SR 2. 0, J, Vn, Cl, Pa, Wa, SR 3. 70, J, Mw, Cl, Fi, Wa, SR							
-132	176				2											
	177															
		42		100	0	36								0	75	
-130	178				0											
	179		18													
					1				4. 45, J, T, Fe+Mn, Su, Wa, SR							
-128	180															
					2				1. 20, J, T, Fe, Su, Ir, SR 2. 70, J, T, Fe, Su, Wa, SR 3. 70, J, N, Cl, Pa, Wa, SR							
	181															
					1				flow boundary							
-126	182															
		43		100	0	78								0	100	
	183															
					0											
-124	184															
					2		3		4. 10, J, T, Fe+Mn, Su, Wa, SR 5. 70, J, Vn, Fe+Mn, Su, Wa, SR							
	185															
					0		M		BASALT a'a Clinker Dark gray (N3) with red Clay (2.5YR, 4/8), highly weathered, weak to very weak							
-122	186						M		very little recovery							
					1											
	187								BASALT Massive a'a Dark gray (N3), slightly weathered, very strong, with 15% vesicles							
		44		72	1	0	M							0	43	
-120	188						M		highly fractured							
					2				1. 90, J, Mw, Cl, Fi, Wa, R 2. 30, J, N, Cl, Pa, Pl, SR							
	189															

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW08

Sheet 13 of 20

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	189		19		1				3. 30, J, N, Cl, Pa, Pl, SR							
118	190															
					2		1 M 2		1. 10, J, T, Fe, Su, Wa, SR 2. 10, J, Vn, Cl, Pa, Wa, SR 3. 20, J, Vn, Cl, Pa, Wa, SR							
	191				NA		3									
116	192	45		100	NA	10			BASALT a'a Clinker Grayish red (10R, 4/2), highly to completely weathered, very weak, with clay infilling					0	60	
	193				NA											
114	194				NA											
	195								thin zone of massive a'a core							
112					NA											
	196				NA									0		
	197								BASALT Massive a'a Dark gray (N3), slightly weathered, strong, with fractures with clay infilling							
110		46		100	1	0									60	
	198				3		1									
	199						2 3		1. 90, J, N-Mw, Cl, Fi, Wa, SR 2. 0, J, T, Fe+Mn, Su, Pl, S 3. 85, J, Vn, Cl, Pa, Pl, S 4. Complex fractures, J, N, Cl, Pa, Wa, SR							
108					2											
	200						4		BASALT a'a Clinker Grayish red (10R, 4/2), highly to completely weathered, very weak, with clay infilling							
					NA											
	201								BASALT Massive a'a Dark gray (N3), slightly weathered, strong, with fractures with clay infilling, with 1-5% vesicles							
			20		2											
106	202						1 2		1. 10, J, N, Cl, Fi, Wa, R 2. 45, J, Mw, Cl, Fi, Wa, SR 3. 45, J, N, Cl, Pa, Pl, SR 4. 45, J, T, Fe+Mn, Wa, SR 5. 0, J, Vn-N, Cl, Pa, St, R							
		47		100	2	75								0	50	
	203						3									
					2		4									
104	204						5									
					0											
	205															

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW08

Sheet 14 of 20

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	205								<1% vesicles							
					1		M		1. 45, J, T–Vn, Fe+Mn, Pa, Pl, SR							
102	206								2, Complex fractures, J, T–Vn, Fe+Mn, Su, Pl, S							
		48		100	2	63	1									
	207						2									
					0		M							0	45	
100	208								10% vesicles							
					1		1		1. 10, J, Mw, Cl, Fi, Ir, SR							
	209	49		100		95								0	40	
					0		M									
98	210								5% vesicles							
					2		M		1. 70, J, N, Cl, Pa, Wa, SR							
	211						2		2. 20, J, Vn, Cl+Fe, Su, Ir, SR							
					1		M		3. 0, J, Vn, Cl+Fe, Su, Ir, SR							
96	212						3		4. 0, J, N, Cl, Pa, Wa, SR							
		50		100	1	40								0	45	
	213						M									
					3											
94							M									
	214						5		5. 90, J, Vn–N, Cl, Pa, Pl, S							
					2		M		6. 0, J, Mw, Cl, Fi, Wa, R							
	215						M									
					1		1		1. 80, J, T, Fe+Mn, Su, Pl–Wa, S							
92	216								2. 60, J, Bn, Fe, Su, Pl, S							
					2		2		3. 0, J, T, Fe+Mn, Su, Wa, SR							
	217						3									
		51		100	0	74								0	50	
90	218						M									
					0											
	219						M									
					0				becomes Welded a'a Clinker							
88																
	220								BASALT a'a Clinker Dark reddish brown (10R, 4/6), highly to completely weathered, very weak to weak							
					NA											
	221															

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW08

Sheet 15 of 20

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	221				NA											
86	222	52		94	0	20			BASALT Pahoehoe Thin flows with variable color (10R, 4/6 to 10R, 4/2), moderately weathered, moderatel strong to strong, with 30% vesicles 1/2" in diameter					0	50	
	223				1		1 M		vesicles become 1/8" in diameter							
84	224				0				1. 50, J, Vn, Fe+Mn, Su, Pl, SR							
	225				2		1		1. 40, J, T, Fe+Mn, Su, Pl, SR							
82	226				1		2		2. 40, J, T, Fe+Mn, Su, Wa, SR vesicles vary in size							
	227	53		100	0	68	M		Dark gray (N3), slightly weathered, strong to moderately strong					0	100	
80	228				0				3. Complex of 10, 70, 70, 0 degree, J, T, Fe+Mn, Su, Wa, SR							
	229				2		3									
78	230				0				40% very small vesicles (1/16" diameter)							
	231				2		1									
76	232				0		2 M		1. 10, J, Vn-N, Cl, Pa, St, SR 2. 70, J, Vn, Cl, Pa, Wa, SR 3. 0, J, Mw, Cl, Fi, Wa, R 4. 90, J, Vn, Cl, Pa, Wa, SR 5. 0, J, T, Fe, Su, Pl, SR					0	150	
	233	54		100	2	72	3									
74	234				1		4 5									
	235				0				30% vesicles (1/4" to 1/8" diameter)							
72	236				0											
	237						M		30%-40% vesicles (1/16" diameter)							

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW08

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	237															
		55		100	2	96	1							0	100	
-70	238						2		— 20–30% vesicles (1/4" to 1/8" diameter)							
					0				1. 30, J, Vn, Cl, Pa, Pl, SR 2. 60, J, Vn, Cl, Pa, Pl, SR							
	239						M									
					0											
-68	240															
					0		M									
	241															
					1		1		— moderately reddish brown (10R, 4/6), moderately weathered, moderately strong to strong					0		
-66	242						M									
		56		100	2	58	2		1. 45, J, T, Fe, Su, Pl, S						100	
							3		2. 0, J, Mw, Cl, Pa, Ir, R							
	243						M		3. 90, J, N, Cl, Fi, Wa, SR							
					1		4		4. 45, J, Bn, Cl, Pa, Wa, SR 5. 80, J, N, Cl, Fi, Wa, SR							
-64	244															
					1		5									
							M									
	245								— dark gray (N3), slightly weathered, strong to very strong							
					1											
-62	246						1		1. 70, J, T, Fe+Cl, Su, Pl, SR							
					2				2. 20, J, N, Cl, Pa, Wa, SR 3. 40, J, N, Cl, Pa, Wa, SR					0		
	247						2		4. 30, J, T, Fe+Cl, Su, Pl SR 5. 0, J, N, Cl, Fi, Wa, SR							
		57		100	3	80									100	
-60	248						3									
					0											
	249						M									
					2		4									
-58	250						5									
					2		1									
	251															
					2		2		1. 45, J, Vn, Cl, Pa, Pl, SR 2. 45, J, Vn, Cl, Pa, Pl, SR							
							3		3. 45, J, Vn, Cl, Fi, Pl, SR					0		
-56	252						M		4. 30, J, N, Cl, Fi, Pl, SR 5. 15, J, N, Cl, Fi, Pl, SR							
							M									
		58		100	1	84	4								100	
	253															

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW08

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	253				0		M									
54	254				1		M M 5		moderately reddish brown (10R, 4/6), moderately weathered, moderately strong							
	255				2		1 2		dark gray (N3), slightly weathered, moderately strong to strong							
52	256				1		3		1. 15, J, Vn, Cl, Fi, Pl, SR 2. 45, J, N, Cl, Fi, Ir, R 3. 10, J, Vn, Cl, Pa, Wa, SR 4. 45, J, Vn, Cl, Pa, Pl, SR 5. 45, J, Nw, Cl, Fi, Wa, SR					0		
	257						4									
50	258	59		80	1	52	M								60	
	259				1		5									
48	260				0				no recovery 40% vesicles (<1/16" diameter)							
	261				1		1 2		1. 20, J, Mw, Cl, Fi, Ir, R 2. 20, J, T, Fe+Mn, Su, Pl, S 3. 30, J, Mw, Cl, Fi, Wa, SR 4. 90, J, N, Cl, Fi, Wa, SR flow boundary 30% vesicles (1/16" to 1/8" diameter)					0		
46	262				3		3 4 M									
	263	60		100	1	74	5 M		15% vesicles (1/4" to 1/2" diameter)						60	
44	264				2		M 6		5. 45, J, Vn, Cl, Pa, Pl, SR 6. 0, J, N-MW, Cl, Fi, Wa, SR 7. J, Vn, Fe+Cl, Su, Pl, SR							
	265				1		7									
42	266				1		M									
	267				0				1. 5, J, Vn, Cl, Pa, Wa, R					0		
40	268	61		100	0	86	1								150	
	269				1											

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW08

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	269				0		M M									
38	270								highly weathered, weak, with vesicles filled with clay dark gray (N3), slightly weathered, very strong							
					0											
	271															
					0											
36	272															
		62		100	1	88	M		1. 90, J, N, Cl, Pa, Wa, R 2, 60, J, Vn, Cl, Pa, Pl, SR					0	100	
	273						1									
					0											
34	274															
					1		2									
	275								grayish red (10R, 8/2), moderately weathered, moderately strong, with 20% small vesicles							
					1		1									
32	276						M									
					1		M									
							2		dark yellowish brown (10YR, 2/2), moderately to slighlty weathered, strong, with 30% vesicles (1/8" to 1/4" diameter)							
	277						M									
		63		100	0	84			1. 20, J, Vn, Cl Pa, Ir, R 2. 30, J, Vn, Cl, Pa, Pl, SR 3. 75, J, Vn, Cl, Fi, Pl SR 4. 70, J, Vn, Cl, Pa, Pl, SR					0	150	
30	278						M									
					1		3									
	279						M		dark gray (N3), slightly weathered, very strong, with 20% vesicles (1/4" to 1/2" diameter)							
					1											
28	280						4									
					0											
	281						M		1. 0, J, Vn, Cl, Fi, Wa, Pl, SR 2. 60, J, T, Fe+Mn, Su, Pl, SR 3. 70, J, T, Fe, H, Pl, SR							
					1		1									
26	282						M									
		64		100	0	92								0	75	
	283															
					0											
24	284								moderately weathered, strong, with 40% vesicles (<1/16" diameter)							
					2		/									
	285						/									

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW08

Sheet 19 of 20

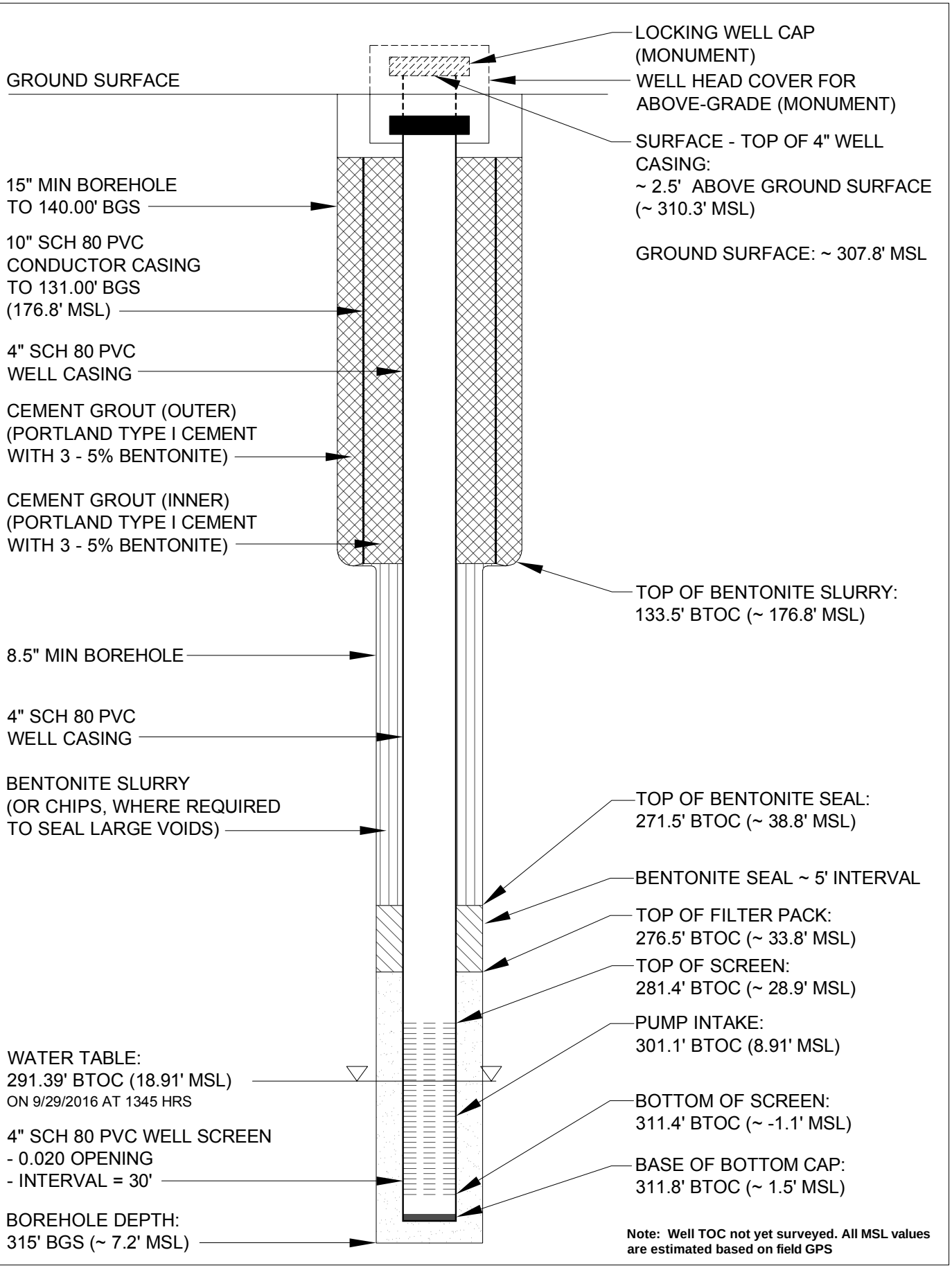
Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	285															
					2		1 3 2		1. 0, J, N, Cl, Fi, Wa, SR 2. 0, J, N, Cl, Fi, Wa, SR							
22	286															
					1		3		← moderately dark gray (N4), slightly weathered, very strong to moderately strong with 40% vesicles (<1/16" diameter)							
	287						M									
		65		100	1	66	M 4							0	100	
20	288								← slightly weathered, very strong, with 35% vesicles (1/8" to 1/4" diameter)							
					0											
	289								3. 30, J, Mw. Cl, Fi, Pl, SR 4. 70, J, T, Fe+Mn, Su, Pl, S 5. 60, J, T, Fe+Mn, Su, Wa, SR							
					1		5									
18	290															
					1				1. 75, J, Bn, Cl, Pa, Pl, SR 2. 60, J, T, Fe+Cl, Su, Pl, SR 3. 20, J, Bn, Fe+Cl, Pa, Pl, SR							
	291															
					1		1 M									
16	292															
		66		96	0	66								0	100	
	293						M 2		← moderately weathered, strong, with 35% vesicles (<18" diameter)							
					2		3									
14	294						M									
					0											
	295															
					0		M		1. 80, J, Vn, Cl, Pa, Pl, SR 2. 0, J, Vn, Fe+Cl, Pa, Wa, S							
12	296								← 40% to 50% vesicles (<1/16" diameter)							
					2		M 1 2									
	297						M									
		67		90	1	60	M		3. 50, J, T, Fe, Su, Pl, SR					0	100	
10	298						3 M									
					NA				BASALT a'a Clinker light brown (5YR, 6/4) to moderate reddish orange (10R, 6/6), highly weathered, weak							
	299															
					NA											
8	300								← no recovery							
					NA											
	301															

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW08

Sheet 20 of 20

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	301															
		68		87	NA	0			thin flow of massive a'a, grayish red (10R, 4/2), moderately weathered, strong					0	36	
6	302				NA											
	303															Boring drilled with tricone reaming bit from 303' to 315'. No core recovered or logged.
4	304															
	305															
2	306															
	307															
0	308															
	309															
-2	310															
	311															
-4	312															
	313															
-6	314															
	315															
-8	316															
	317															



S:\Projects\NAVFAC PAC\CLEAN IV\60481245CTO 0053\300-Work\910 CAD\20-SHEETS\MW WP\Appendix A_Fig1_RHMW08_Well.dwg 04/05/17 9:54 AM namocl

Appendix A Figure 1
Cross Section of RHMW08 Monitoring Well
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

Project: CT053 – Red Hill Bulk Fuel Storage Facilty Project Location: CT053 Project Number: 60481245	Log of Boring RHMW09 Sheet 1 of 26

Date(s) Drilled	07/19/2016	Logged By	D.Rector	Checked By (Date)	J. Kronen
Drilling Method	HQ core / air rotary	Drill Bit Size/Type	HQ diamond bit / 8" tricone bit	Total Depth of Borehole	405.0 feet
Drill Rig Type	Mobile B-59 / T3	Drilling Contractor	Valley Well Drilling	Approximate Surface Elevation	391.52
Groundwater Level	El. 17.7' (7/29/2016)	Location	N73533.685 E1675173.406	Inclination from Horizontal/Bearing	90°
Borehole Completion	4-inch diameter monitoring well. See RHMW09 Well Cross Section for details			Hammer Data	140 lbs/30-inch drop

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time (Rate, ft/hr)	FIELD NOTES AND TEST RESULTS
	0								ALLUVIUM Soft, moist, reddish-brown (5YR 5/3), CLAY to Silty CLAY (CL)							Hand cleared to 5 ft bgs
	1															
390	2								VOLCANIC SAPROLITE Highly to completely weathered volcanic rock. Weathers to – Soft, moist, mottled reddish brown (5YR 5/3) to grey-brown (5YR 3/2), CLAY (CL)							
	3															
388	4															
	5															
386	6															
	7															
384	8															
	9															
382	10		1									1	50/3"	0		HSA drilling becomes hard; refusal at 13.5 ft bgs
	11															
380	12								BASALT Massive a'a Gray (5YR 3/5), moderately weathered, strong, 1% vesicles							
	13															

Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Sheet 2 of 26

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
378	13															
	14	1		100	1	100								0	[9]	
	15															
376	16				1				1. 45, J, Vn, Fe+Mn, Su, Wa, SR 2. 45, J, Vn, Mn, Su, Pl, SR 3. 0, J, Vn, Mn, Su, Wa,SR 4. 45, J, Vn, Mn, Su, Wa, SR 5. 40, J, Vn, Mn, Su, Wa, SR 6. 70, J, T, Fe+Mn, Su, Wa, SR 7. 45, J, T, Fe+Mn, Su, Wa, SR 8. 10, J, Vn, Fe+Mn, Su, Wa, SR						
	17				2											
374	18	2		100	3	58								0	[23]	
	19				2											
372	20				1											
	21				2				1. 0, J, T, Fe, Su, Wa, R 2. 25, J, T, Fe, Su, Wa, R 3. 60, J, T, Fe, Su, Wa, R 4. gray clay seam							
370	22				2											
	23	3		100	3	73			red (5YR 6/8) clay oxide filling fractures					0	[20]	
368	24				0											
	25		2		0				0–5% vesicles							
366	26				1				1. 80, J, Vn, Cl, Fi, Pl, SR 2. 80, J, MW, Cl, Fi, Pl, SR 3. 70, J, Vn, Fe, Su, Wa, SR							
	27				1				becomes non-vesicular							
364	28	4		100	0	62								0	[30]	
	29				1											

Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

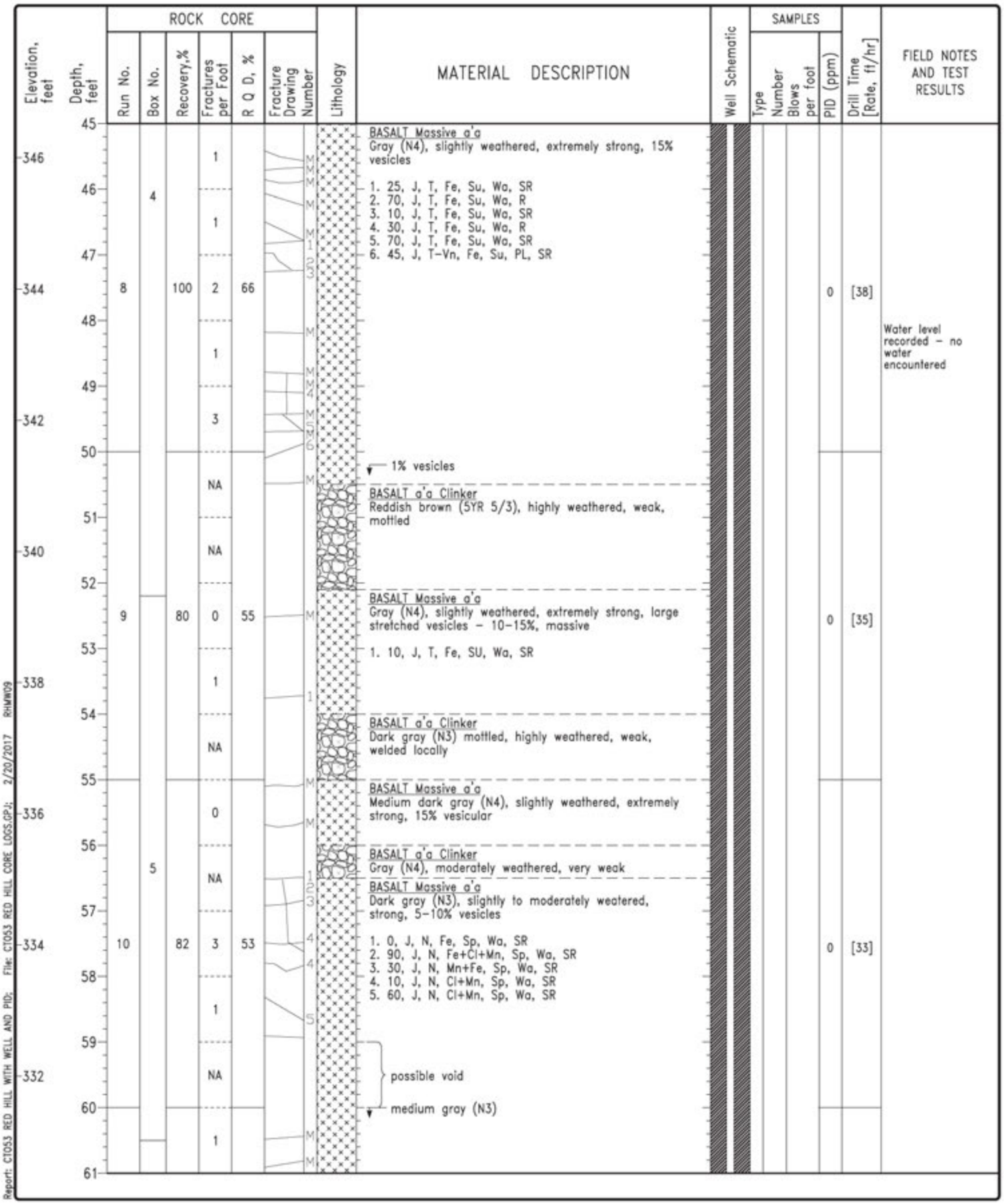
Sheet 3 of 26

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
362	29				1		M									
	30								1. 20, J, T, Fe, Su, Pl, SR 2. 15, J, T, Fe, Su, Pl, SR 3. 70, J, T, Fe, Su, Pl, SR							
					4				4. 0, J, T, Ch, Su, IR, SR 5. 80, J, T, Fe, Su, Wa, SR							
360	31				NA				BASALT a'a Clinker Reddish brown (5YR 5/3), moderately to highly weathered, moderately strong to weak, welded locally							
	32	5		70	NA	13								0	[21]	
	33								a'a core, slightly weathered, strong							
358	34				1		M		BASALT Massive a'a Orangish-red (10R 4/4), slightly weathered, strong, aphanitic, 10–15% vesicles							
			3		NA				No recovery							
356	35				NA				BASALT Massive a'a Reddish gray-brown (5YR 5/2), slightly weathered, very strong, massive, fractured, 10–15% vesicles							
	36						M									
					0		M		gray (5YR 5/1), less weathered							
	37						1		1. 0, J, T, Fe, Su, Pl, SR 2. 45, J, T, Fe, Su, Pl, SR							
354		6		100	4	53	2		3. 45, J, Vn, Cl, Fi, Pl, SR 4. 0, J, T, Fe, Su, Wa, SR 5. 30, J, T, Fe, Su, Wa, SR					0	[20]	
	38						3		6. 0, J, T, Fe, Su, Wa, SR							
					3				7. 0, J, T, Fe, Su, Wa, SR 8. 45, J, T, Fe, Su, Wa, SR							
	39						5									
352					3		7									
	40						8									
							M		BASALT a'a Clinker Dark gray (N3) with mottled reddish brown (5YR 5/3) Fe-oxide, highly to completely weathered, very weak to weak, welded locally							
	41				NA											
350																
	42				NA											
		7		64		7			a'a core, gray (N3), slightly weathered, strong to very strong					0	[30]	
	43				NA				a'a core, gray (N3), slightly weathered, strong to very strong							
348																
	44				NA				1. 0, J, T, Fe, Su, Wa, SR							
									no recovery							
	45															

Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09



Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Sheet 5 of 26

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
330	61															
	62				3				1. 15, J, N, M, Sp, Wa, SR 2. 60, J, Mn+Uk, Sp, Wa, SR 3. 10, J, Mn+Cl, Sp, Wa, SR 4. 45, J, N, Fe, Sp, Wa, SR 5. 45, J, N, Fe+Mn, Sp, Wa, SR						
		11		100	3	75								0	[50]	
328	63				2											
	64															
					0											
326	65		6		1				BASALT Pahoehoe Brown (5YR 4/4), moderately weathered, weak to moderately strong, 100% infilling of vesicles with clay, 40% small vesicles						
	66															
	67				2											
324		12		100	1	14								0	[50]	
	68				2				highly fractured, very weak 1. 40, J, T, Fe, Su, SR 2. 45, J, T, Fe, Su, SR 3. 30, J, T, Fe, Su, SR 4. 0, J, T, Fe, Su, SR 5. 0, J, T, Fe, Su, SR 6. 70, J, Vn, Cl, Pa, SR						
	69															
322					0											
	70				NA				completely weathered, extremely weak, pervasive alteration of pahoehoe							
	71															
320					NA											
	72															
		13		40	NA	0								0	[100]	
	73															
318					NA				no recovery							
	74															
					NA											
	75								BASALT Volcanic Breccia Dark reddish brown (10R 3/4), variegated colors of clasts, moderately to highly weathered, weak						
316					NA											
	76		7													
					NA											
	77															

Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Sheet 6 of 26

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
314	77															
		14		100	NA	0								0	[23]	
	78				NA											
	79				NA											
312					NA											
	80				NA											Water in core rods dropped from 15.5 to 22.5 ft bgs over 6 minutes; no perched water
	81				NA											
310					NA											
	82								dusky red (10R 2/2)							
		15		100	NA	20								0	[43]	
	83															
308					NA											
	84								BASALT Massive a'a Medium gray (N5), slightly weathered, extremely strong, 1–5% vesicles							
					1		M		1. 90, J, T–Vn, Cl, Pa, Wa, SR							
	85						1		nonvesicular							
306					2		2									
	86						3		1. 45, J, Vn, Fe+Cl, Pa, Wa, SR 2. 30, J, Vn, Fe+Cl, Pa, St, R 3. 10, J, T, Fe, Su, Wa, R							
					2				4. 55, J, T, Fe, Su, Wa, SR							
	87		8						5. 15, J, T, Fe, Su, Wa, SR 6. 85, J, Vn, Fe+Cl, Pa, Pl, Sm							
304		16		100	1	100	4							0	[50]	
	88						5									
					1											
	89															
302					1		M									
	90						M		1. 10, J, T, Fe, Su, Wa, SR							
					1		M		2. 10, J, T, Fe, Su, Wa, SR 3. 15, J, T, Fe, Su, Wa, R							
	91						M		4. 15, J, T, Fe, Su, Wa, R							
							1		5. 90, J, N, Cl+Fe, Pl–Wa, SR–R							
300					3		3									
		17		100		25	M							0	[50]	
	92						4									
					2		M									
	93						5									

Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	93															
298					NA				BASALT Welded a'a Clinker Dark reddish brown (10R 3/4), variegated color of clasts, moderately to highly weathered, weak							
	94	18		100		0										
					NA									0	[50]	
	95															
296					NA											
	96		9						BASALT Massive a'a Reddish brown (10R 4/6), completely weathered, weak, vesicles infilled with clay							
					0											
	97								grayish red (10R 4/2), moderately weathered, 10–15% vesicles							
294		19		100	1	0	1		1. 70, J, Vn, Cl, Fi, Wa, SR 2. 20, J, T, Fe, Su, Wa, R 3, 90, J, N, Cl, Fi, Pl, SR					0	[43]	
	98						M									
					1		2		highly weathered, with 1% vesicles							
	99															
292					1		3									
	100						1		medium gray (N4), slighly weathered, 20% large vesicles							
					2		2		1% vesicles							
	101						3		1. 80, J, N, Fe+Cl, Pa, Wa, SR							
290					1		M		2. 45, J, N, Fe+Cl, Pa, Wa, SR 3. 30, J, N, Cl, Su, Wa, SR							
	102						M		4. 40, J, T, H, No, Pl, SR 5. 45, J, Mw, Fe+CL, Fi, Wa, SR							
		20		100	2	0	4		6. 20, J, Mw, Fe, Sp, Wa, SR					0	[60]	
	103						5									
							6		breccleated							
288					0		M									
	104						M									
									pale brown (5YR 5/6, slightly weathered, strong, less than 1% vesicles							
					0											
	105		10						BASALT Volcanic Breccia Pale reddish-brown (10R 5/4), highly weathered, weak to moderately strong; note clayey matrix in weaker zones, stronger zones appear welded							Water in core rods dropped from 63.18 to 78 ft bgs in 5 minutes; no perched water
286					NA											
	106															
					NA											
	107															
284		21		100	NA	0								0	[60]	
	108															
					NA											
	109															

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
282	109				NA											
	110								moderately strong							Water in core rods dropped from 60.4 to 78.05 ft bgs in 10 minutes; no perched water
					NA											
	111															
280					2				BASALT Massive a'a Medium gray (N5), slightly weathered, very strong, massive, less than 1% small vesicles							
	112						1 3D									
		22		100	1	32	3		1. 70, J, MW-W, Fe+Cl, Pa, Wa, R 2. 15, J, N, Fe+Cl, Pa, Wa, R 3. 15, J, N, Fe+Cl, Pa, Wa, R					0	[75]	
	113						M		4. 60, J, T, Fe, Su, Wa, SR 5. 90, J, T, Fe, Su, Wa, SR 6. 30, J, T, Fe, Su, St, R 7. 15, J, T, Fe, Su, St, SR							
			11													
278					1		6 5A									
	114						7									
					4		7									
							M									
	115								1–5% vesicles							
276					0				1. 70, J, T, Fe, Su, W, SR 2. 50, J, T, Fe, Su, Wa, SR 3. 20, J, T, Fe, Su, Wa, SR							
	116						M									
					1		1									
	117						2									
274		23		100	2	78								0	[33]	
	118						M		5–10% vesicles							
					0											
	119						3									
272					1		M									
							M									
	120						M									
							M		1. 45, J, T, Fe, Su, Pl, S 2. 20, J, T, Fe, Su, Pl, S 3. 30, J, T, Fe, Su, Pl, S							
					1		M									
	121						1									
270					2		3D									
	122								BASALT a'a Clinker Dark reddish brown (10R 3/4), highly weathered, very weak							
		24		34	NA	14								0	[43]	
	123															
268					NA				no recovery							
	124		12													
					NA											
	125															

Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Sheet 9 of 26

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
-266	125				NA											
	126				NA											
	127															
-264		25		75	NA	0								0	[40]	
	128				NA				no recovery							
	129								BASALT Massive a'a Dark reddish gray (2.5YR 3/1), moderately weathered, moderately strong, 5% vesicles, massive							Water in core rods dropped from 62 to 76.7 ft bgs in 5 minutes; no perched water
-262					1		M		1. 90, J, N, Fe+Cl, Pa, Wa, R							
	130						1		dark gray (2.5Y 4/1)							
					0											
-260	131				0											
	132								weak red (10R 4/2), welded a'a clinker							
		27		96	0	65								0	[60]	
	133															
-258					0											
	134								dark gray (2.5Y 4/1), slightly weathered, very strong, less than 1% vesicles							
					0											
	135		13						1. 40, J, T, Fe+Mn, Su, Wa, SR 2. 60, J, Vn, Cl, Pa, Wa, SR 3. 45, J, Vn, Cl, Pa, Wa–Pl, SR 4. 45, J, Vn, Cl, Pa, Wa, Sm 5. 60, J, T, Mn, Su, Wa, SR 6. 60, J, T, Mn, Su, Wa, SR 7. 80, J, T, Mn+Cl, Su, St, SR 8. 90, J, T, Mn, Su, St, R							
-256					1		1									
	136				4		2									
	137						3 4 5 6 7									
-254		28		100	3	50	M							0	[33]	
	138				1		M									
	139						M									Water level recorded – no water encountered
-252					0		M									
	140				1		M		dark bluish gray (Gley 4/1), 1–5% vesicles							
					1											
	141															

Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	141															
250					1		1, 2		1. 55, J, N, No, N, Pl, SR 2. 55, J, N, No, N, Pl, SR 3. 70, J, N–MW, Cl+Fe, Pa, Pl, SR 4. 25, J, N, Cl, Pa, Wa, SR							
	142															
		29	14	100	1	84	M, 3							0	[43]	
	143															
248					1											
	144						4									
					1											
	145						1		1. 65, J, N, Mn, Sp, Wa, SR 2. 45, J, M, No, N, Wa, SR 3. 5, J, MW, Fe+Cl, Sp, Wa, SR 4. 25, J, N, Fe+Cl, Sp, Wa, SR 5. 20, J, N, Fe+Cl, Su, Pl, SR 6. 15, J, N, Fe+Cl, Pa, Wa, SR 7. 5, J, N, Fe+Cl, Pa, Wa, SR 8. 5, J, N, Ca, Sp, Pl, SR						
246					1		M									
	146						2									
					1											
	147						M									
							M									
244		30		100	1	74	3							0	[50]	
	148						4									
					4		5, 6									
	149						7									
242					2		8									
	150								BASALT a'a Clinker Dark reddish brown (10YR 3/4), highly weathered, very weak							
					NA											
	151															
240					NA											
	152															
		31		36	NA	0			no recovery					0	[75]	
	153		15													
238					NA											
	154															
					NA											
	155															
236					NA											Water in core rods dropped from 84 to 89.9 ft bgs in 7 minutes; no perched water
	156															
					0				BASALT Massive a'a Bluish gray (Gley 4/2), moderately weathered, strong, 5% small to medium vesicles; highly fractrured/broken							
	157															

Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Sheet 11 of 26

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	157								from 157.4–158 ft bgs, becoming very strong							
234		32		70	0	44			1. 55, J, N, Mn, Sp, Wa, SR 2. 45, J, N, Ca, Sp, Wa, SR 3. 45, J, N,					0	[60]	
	158						1									
					1											
	159															
232					2											
	160						3									
					10+				highly fractured							
	161															
230					10+											
	162						1		5–10% vesicles							
							2									
		33		90	3	54	M		1. 50, J, N, Na, N, Wa, SR 2. 40, J, MW, Fe+Cl, Pa, Wa, SR 3. 70–90, J, W, Cl+Ca+Fe, Fi, Wa, SR					0	[43]	
	163								4. 20, J, MW, Cl+Mn, Sp, Wa, SR 5. 20, J, MW, Cl+Mn, Sp, Wa, SR							
228					2		3									
							4									
	164						5									
			16		2		M									
	165						1		1. 80, J, N, Fe, Sp, Wa, SR 2. 75–90, MW, Cl+Fe, Pa, Wa, R 3. 65, MW, Cl+Fe, Sp, Wa, R 4. 65, MW, Cl+Fe, Sp, Wa, R							
226					3		2									
	166						3									
					2		M		highly fractured							
							4									
	167						M									
224		34		100	1	34	M							0	[38]	
	168						M									
					0		M									
	169						M									
222					0		M									
	170						M									
					3		1									
	171						2		1. 15, J, N, Fe, Sp, Pl, SR 2. 30, J, Mw, Fe+Cl, Sp, Wa, SR 3. mechanical 4. 65, J, N, Cl+Fe, Sp, Wa, SR							
220					1		M		5. 55, J, N, Fe+Mn, Sp, Wa, R 6. 30. J, N, Fe, Sp, Wa, R							
	172						4		7. 65, J, N, Mn, Sp, Wa, R 8. 60, J, N, No, N, Wa, R							
							M		9. 45, J, N, No, N, Wa, R							
		35		100	1	40	M							0	[30]	
	173															

Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Sheet 12 of 26

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
218	173		17		3											
	174				1											
	175								1. 15, J, N, Fe, Sp, Wa, R 2. 10, J, N, Fe, Sp, Wa, R 3. 85, J, Fe, Su, Wa, R 4. 70, J, Fe, Su, Wa, SR 5. 50, J, Mn, Sp, Pl, SR 6. 45, J, Fe, Sp, Wa, SR						
216					3											
	176															
					3											
	177															
214		36		100	NA	44			BAKED PALEOSOL Dark reddish brown (10R 3/4), highly weathered, weak					0	[20]	
	178															
					NA											
	179								BASALT Volcanic Breccia Reddish gray (10R 5/1), moderately weathered, strong, clasts are rounded ranging in size from sand to gravel; becomes predominantly sand size clasts, weak to very weak at 180.4 ft bgs							
212					1											
	180															Water in core rods dropped from 164.8 to 165.6 ft bgs in 10 minutes; circulation water is mixed with foam and bentonite, slowing dissipation into formation; no perched water
					NA				Highly weathered, very weak, many mechanical breaks							
	181															
210					NA											
	182															
		37		64	NA	64								0	[50]	
	183		18													
208					NA											
	184															
					NA											
	185															
206					NA											
	186															
					NA											
	187															
204		38		66	NA	46			BASALT Massive a'a Medium gray (N4), slightly weathered, very strong, 5–10% vesicles					0	[30]	
	188								1. 45, J, MW, Mn, Su, Wa, R							
					0											
	189															

Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
202	189				1		1									
	190				0											Water in core rods dropped from 147.6 to 153.3 ft bgs over 23 minutes; circulation water is mixed with foam and bentonite, slowing dissipation into formation; no perched water
					0		M									
200	191															
					0		M									
	192						M									
		39		90	10+	44	M							0	[50]	
	193		19						becomes moderately weathered weak rock, moderately oxidized with some vesicles filled with Fe+Mn							
198					10+											
	194															
					NA											
	195															
196					NA											
	196								becomes slightly to moderately weathered, strong							
					1		M		1. 80, J, Mw, Fe, Sp, Wa, R 2. 70–90, J, N, Fe, Su, Wa, SR							
	197						1		3. 70, J, N, Fe, Sp, Wa, SR 4. 55, J, N, Wn, Sp, Wa, SR							
194		40		80	2	30	2							0	[43]	
	198						3									
					2		4									
	199						M		▼ Highly weathered							
							M									
192					NA											
	200						M		BASALT Massive a'a Medium gray (N4), highly weathered, very weak							
					NA											Water in core rods dropped from 162.7 to 167 ft bgs over 36 minutes; circulation water is mixed with foam and bentonite, slowing dissipation into formation; no perched water; stop drilling due to sheared rod at 130 ft bgs, repaired on 7/23/16
	201															
190					NA				no recovery							
	202															
		41		44	NA	20	M		▼ slightly weathered, very strong, 1–5% vesicles					0	[43]	
	203						M									
188					0		M									
	204		20				M									
					10+		M		highly broken/fractured							
	205															

Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	205								BASALT Massive a'a Medium to dark gray (N4), slightly weathered, weak to moderately strong							
-186					0											
	206								weak to moderately strong, highly to intensely fractured							
					10+				1. 75, J, N, Mn, Sp, Wa, SR 2. 65, J, N, Na, N, Wa, SR							
	207						1 2									
-184		42		84	2	32			very strong rock					0	[38]	
	208								weak to moderately strong, highly to intensely fractured, with little recovery							
					10+											
	209															
-182					10+											
	210															
					NA											
	211								BASALT Massive a'a Medium dark gray (N4), slightly weathered, strong, 5–10% noticeably stretched and with subverticle angle vesicles							
-180					0		M									
	212						M		highly weathered, weak zone							
		43		80	0	54			1. 70–90, J, N, Mn, Su, Wa, SR					0	[60]	
	213						M									
-178					0											
	214						M									
					1		M 1									
	215		21				M									
-176					1		1									
	216	44		100		56			1. 85–90, J, N, Mn, Sp, Wa, SR							
					0		M									
	217						M									
-174					1		M							0	[15]	
							M		1. 5, J, N, Mn+Cl, Sp, Wa, SR 2. 70, J, N, Mn, Su, Wa, SR							
	218						1									
					2		M									
		45		76		48										
	219						2 M									
-172					NA				BASALT a'a Clinker Dusky red (10R 3/3), clasts are moderately weathered, strong							
	220															
					NA											
	221															

Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Sheet 15 of 26

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
170	221				NA											
	222	46		20	NA	0			No recovery					0	[19]	
	223															
168					NA											
	224															
					NA											
	225															Water level recorded – no water encountered
166					NA				No recovery							
	226															
					NA		M		BASALT Massive a'a							
	227		22				M		Medium dark gray (N4), slightly to moderately weathered, strong to moderately strong, 10–15% vesicles (many mechanical breaks)							
164		47		70	1	66	1		1. 15, J, N, Uk+Mn, Sp, Wa, SR					0	[33]	
	228						M									
					0		M									
	229						M									
162					0		M									
	230						M		half of the vesicles become large and elongated							Water level recorded – no water encountered
					0		M		1. 20, J, N, Cl, Su, Wa, SR							
	231						M		2. J, N, Cl, Su, SR							
							M		3. 10, N, Cl+Mn, Sp, Sa, SR							
160					0		M		4. 15, N, Cl+Mn, Sp, Wa, SR							
	232						M		5. 70–90, Mn, Sp, Wa, SR							
		48		100	1	78	M							0	[33]	
	233						1									
158					2		D									
	234						3									
					4		4									
	235						5									
							1		1. 80, J, N, Cl, Pa, Wa, SR							
156					3		D		2. 30, J, N, Cl, Pa, Wa, SR							
	236						2		3. 75–80, Jn, N, Mn+Cl, Sp, St, SR							
							3		4. 25, J, N, Cl+Mn, Pa, Wa, SR							
							M		5. 70, J, N, Mn, Sp, Wa, SR							
					1		M		6. 65, J, N, No, N, Wa, R							
	237						M		7. 25, J, N, Cl, Sp, Wa, R							

Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

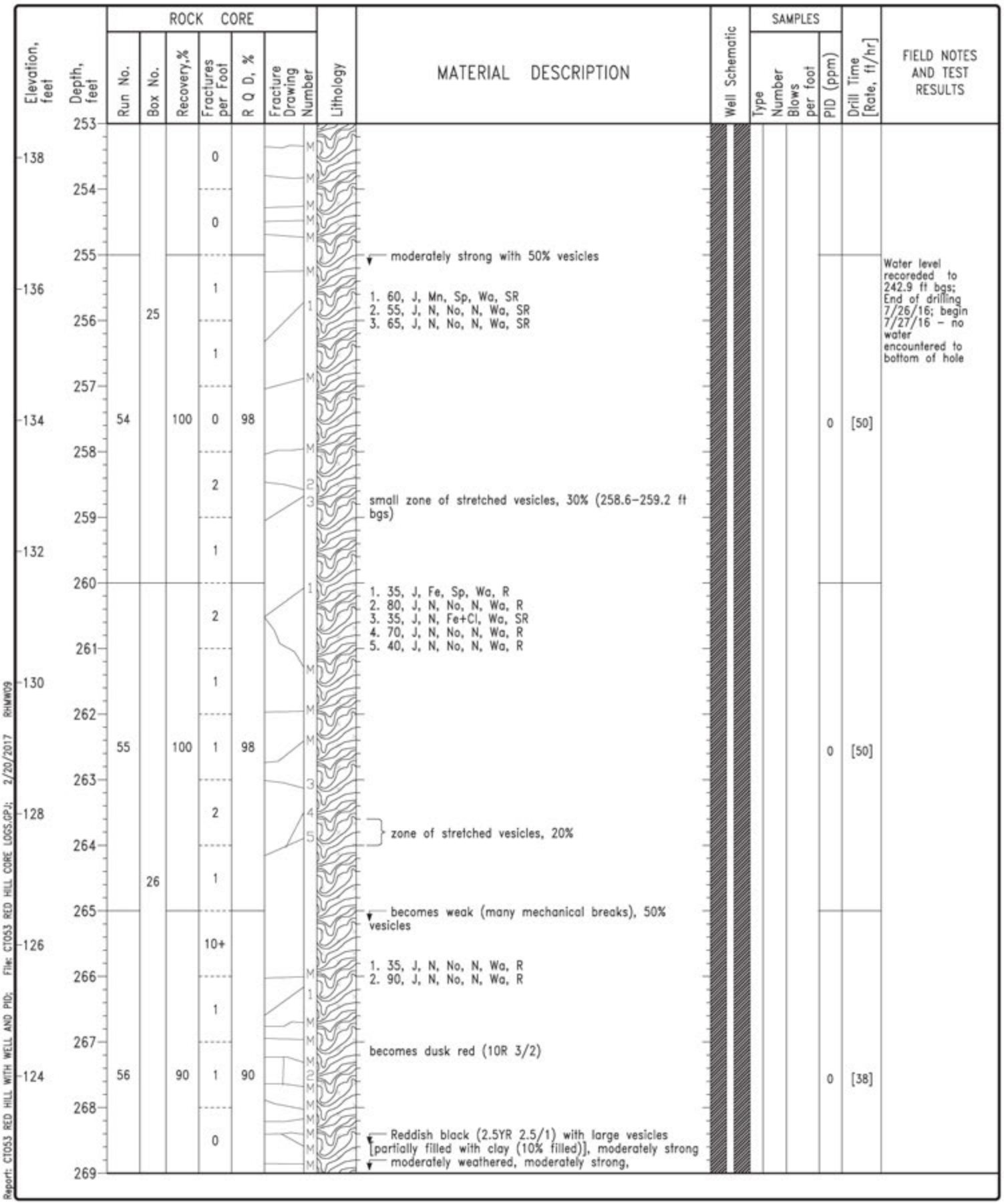
Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	237															
154		49		100	2	60								0	[25]	
	238															
					1				BASALT Pahoehoe Dark reddish brown (2.5 YR 2.5/4), moderately weathered, moderately strong to strong, 50% vesicles (unstretched); 3-inch zone of completely weathered at 238.8 ft bgs							
	239		23													
152					2											
	240															
					1				vesicles become partially filled with clay							
	241								grades to very dark gray (5YR, 3/1), slightly weathered							
150					1											
	242	50		93		78			1. 70-30, J, N, Mn, Sp, IR, R 2. 65, J, N, Cl, Sp, Wa, R					0	[17]	
					0											
	243															
148					0											
	244								50-60% vesicles, moderately strong to weak, increase in mechanical fractures							
		51		100	0	100								0	[60]	
	245								1. 80-90, J, N, No, N, Wa, R 2. 25, J, N, Fe, Su, IR, SR 3. 10, J, N, Fe+Mn, Su, Wa, SR 4. 20, J, N, Mn, Sp, Wa, SR 5. 15-20, J, N, Mn+Fe, Sp, Wa, SR							
146					1											
	246															
					0											
	247															
144		52	24	100	1	80								0	[43]	
	248								slightly oxidized							
					2											
	249															
142					1											
	250								moderately strong							
					0											
	251								zone of large vesicles							
140					2											
	252								1. 30, J, N, Fe, Sp, Wa, R 2. 45, J, N, No, N, Wa, R 3. 45, J, N, No, N, Wa, R							
		53		100	2	86								0	[50]	
	253								weak with lots of mechanical fractures							

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09



Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
-122	269				0				50–60% vesicles (stretched dipping)							
	270				1				1. 70, J, N, No, N, Wa, SR 2. 25, J, N, Mn, Sp, Wa, SR 3. 10, J, N, Mn+Other, Pa, Wa, SR 4. 50, J, N, Mn+Sd, Sp, Wa, R 5. 70, J, N, Mn, Sp, Wa, SR							
-120	271				2				40% small vesicles starting at 271 ft bgs							
	272	57		100	1	90			Dusky red (10R 3/2), moderately strong to weak					0	[38]	
-118	273		27		2											
	274				0				moderately strong, 50% vesicles (larger)							
-116	275				0				grades to reddish black (2.5YR 2.5/1)							
	276				2				1. 70, J, N, No, N, Wa, R 2. 85–90, J, N, Mn, Sp, Wa, SR 3. 25, J, N, Mn, Su, Wa, SR to S 4. 65, J, N, Fe+Mn, Sp, Wa, SR 5. 10, J, N, Fe+Cl, Sp, Wa, SR 6. 10, J, N, Fe+Cl, Sp, Wa, SR 7. 65, J, N, Mn, Sp, Wa,							
-114	277	58		92	2	62								0	[43]	
	278				2											
-112	279				1				FAT CLAY Soft, moist, pale brown (10YR 6/3), Fat CLAY (CL). Surrounded by 1–inch completely/highly weathered clay rich gravel, very weak on top and bottom		RH062					
	280				2				BASALT Massive a'a very dark gray (5Y 3/1), slightly to moderately weathered, strong, 5% stretched vesicles							
-110	281				4				1. 60, J, N, Cl, Sp, St, SR 2. 80–90, J, N, Mn, Sp, Wa, SR 3. 70–80, J, N, Mn, Sp, Wa, SR 4. 30, J, N, Mn, Su, Wa, SR 5. 35, J, N,							
	282	59	28	100	2	40								0	[30]	
-108	283				NA				BASALT a'a Clinker Weak red (10R 4/3), moderately to highly weathered, weak, highly fractured							
	284				NA											
	285															

Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
-106	285				NA											Water recorded – 284.4 ft bgs and dropping
	286				0		M M M		BASALT Massive a'a Very dark gray (10YR 3/1), highly weathered, weak, 5–10% vesicles 1. 70–90, J, N, Cl, Sp, Wa, R 2. 50–60, J, N, Mn, Sp, Wa, SR 3. 30, J, N, Mn, Sp, Wa, SR							
-104	287	60		80	1	48	1 2 2							0	[33]	
	288				3		2 2 2									
-102	289				2		M M 3		moderately strong to weak (many mechanical fractures)							
	290				1		M M M M									
-100	291				0		M									
	292	61	29	76	0	70	M M		vesicles (5%) become large and irregular shaped with mechanical breaks along vesicles					0	[33]	
-98	293				0		M M									
	294				NA		M		BASALT a'a Clinker Dark reddish brown (2.5YR 3/3), moderately to highly weathered, weak, highly fractured							
	295				NA				no recovery							Water in core rods dropped from 294 to 295 ft bgs in 10 minutes; no pereched water
-96	296	62		50		0								0	[20]	
	297				NA				no recovery							
-94	298				NA		1		BASALT Massive a'a Very dark gray (10YR 3/1), slightly weathered, moderately strong, 10% vesicles							
	299	63		83	1	70	M		1. 70, J, N, Fe+Mn, Sp, Wa, R					0	[36]	
-92	300				0											
	301				NA				BASALT Pahoehoe Dark red (10R 3/6), moderately weathered, weak, 60–70% vesicles; no recovery from 300–300.4 ft bgs; grades to dark gray (N3), moderately weathered,							

Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	301								moderately strong at 300.8 ft bgs							
-90					1				1. 30, J, N, Mn+Cl, Sp, Wa, SR 2. 10, J, N, Fe, Sp, Pl, SR							
	302															
		64	30	90	0	80			zone with large vesicles					0	[50]	
	303															
-88					2											
	304															
					1				slightly oxidized, 50–60% vesicles							
	305								1. 30–40, J, N, Fe, Sp, Wa, R 2. 70, J, N, Fe+Cl, Sp, Wa, R							
-86					0											
	306															
					1											
	307								dark reddish brown (2.5YR 3/3), weak (many mechanical fractures/breaks)							
-84		65		100	1	95								0	[75]	
	308															
					1											
	309															
-82					0											
	310								very dark gray (7.5YR 3/1), moderately weathered, moderately strong, with 50–60% vesicles							
					1				1. 30, J, N–MW, Fe+Mn, Su, Wa, S+Slk 2. 20, J, N, Fe, Sp, Wa, R 3. 65, J, N, Cl+Sa, Sp, Wa, R							
	311															
-80			31		NA				moderately to highly weathered, oxidized, weak zone							
	312															
		66		100	1	76								0	[100]	
	313															
-78					NA				moderately to highly weathered, oxidized, weak zone							
	314															
					1				50% vesicles, vesicles become medium to large							
	315								1. 20, J, N, Fe, Su, Wa–Pl, SR 2. 65, J, N, Fe, Mn, Sp, Wa, SR							
-76					0											
	316															
					0											
	317															

Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	317															
-74		67		100	1	95	1		moderately strong to weak (many mechanical fractures)					0	[75]	
	318						M									
					0		M									
	319						M									
-72					1		2									
	320		32				M									
					0		M									
	321						M									
-70					0		M									
	322						M		1. 80–90, J, N, Mn, Sp, Wa, R							
		68		100	0	80	M		2. 5, J, N, M+Fe, Sp, Wa, SR					0	[100]	
	323						M		3. 50–90, J, N, Mn+Sa, Wa, R							
-68					2		1									
	324						2									
					1		3									
	325						M									
							1									
-66					1		M		grades to dark reddish brown (2.5YR 3/4), 50–60% vesicles							
	326						M		1. 20–40, J, N, Fe+Cl, Sp, IR, R							
					2		2		2. 60, J, N, Fe, Sp, Wa, SR							
	327						3		3. 20, J, N, Mn, Sp, Wa, SR							
-64		69		100	0	90	4		4. 50–70, J, N, Fe, Su, Wa, SR to S					0	[100]	
	328						M		moderately to highly weathered zone with some vesicles filled with clay or CaCO3							
							M									
	329		33		0		M		moderately weathered, moderately strong							
-62							M									
	330				0		M		dark reddish gray (10R 3/1), with 40% vesicles (large)							
					1		1		discrete change from large to small/medium vesicles, 50–60% (possible pahoehoe flow contact)							
	331						M		1. 5, B, N, No, N, Wa, R							
-60					0		M									
	332						M		60% vesicles (small)							
		70		100	0	100	M							0	[75]	
	333						M									

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Sheet 22 of 26

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
-58	333				0				grades to very dark gray (10YR 3/1) with 40–50% large to medium vesicles							
	334															
					0				few vesicles contain apparent olivine crystals							
	335								vesicles become small to medium							Water level recorded – no water encountered
-56					0											
	336								1. 15, J, N, Fe, Su, Wa, SR 2. 10, J, Fe, Su, Pl, SR							
					1											
	337						1		slightly oxidized zone							
-54		71	34	100	0	99			60–70% vesicles (small)					0	[100]	
	338															
					1		2		slightly oxidized zone							
	339															
-52					0											
	340								1. 15, J, N, Fe+Mn, Sp, Wa, SR 2. 15, J, N, Fe, Su, Wa, R							
					0											
	341															
-50					1											
	342						1									
		72		100	0	99								0	[150]	
	343															
-48					1											
	344						2									
					0											
	345															
-46			35		0											
	346															
					0											
	347								few apparent olivine crystals							
-44		73		100	0	100								0	[150]	
	348															
					0											
	349															

Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Sheet 23 of 26

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	349						M									
-42					0		M									
	350						M		40–50% vesicles							
					0		M									
	351						M									
-40					0											
	352						M									
		74		100	0	100	M							0	[100]	
	353															
-38			36		0											
	354						M									
					0		M									
	355						M									
									becomes brownish black to very dark gray (10YR 3/1), moderately to slightly weathered, moderately strong, 50% small vesicles							End of drilling 7/27/16; 1,700 gallons of water used with 2 cups of foam; begin drilling 7/28/16
-36					1											
	356						1		1. 55, J, N, Fe, Sp, Wa, R							
					0		M									
	357															
-34		75		100	1	94	M							0	[100]	
	358						2									
					1		M		highly weathered oxidized zone							
							3		40–50% vesicles (medium to large)							
	359						M									
-32					0											
	360						1		zone with only 5% vesicles							
					1											
	361						2									
-30					1		M		1. 65, J, N, Fe+Mn, Sp, Wa, SR 2. 25, J, N, Fe, Sp, Wa, R 3. 30, J, N, Fe, Sp, Wa, R							
			37													
	362						M									
		76		100	0	98								0	[75]	
	363						M									
-28					0											
	364						3		oxidized, moderately weathered							
					2											
							3		oxidized, moderately weathered							
	365															

Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	365								1. 80, J, N, Mn+Cl, Sp, Wa, R							Water in core rods dropped from 352.1 to 357.9 over 20 minutes; no perched water
-26					0		M									
	366						M									
					0		M									
	367						M									
-24		77		100	1	90	1							0	[75]	
	368						M									
					0		M									
	369						M		highly weathered, oxidized							
-22			38		0		M									
	370								grades to very dark gray (5YR 3/1), moderately weathered, moderately strong, 40% vesicles (medium)							
					0		M									
							M		1. 45, J, MW, Fe+H, Fi, Wa, SR 2. 0, J, MW, Fe, Su, Wa, SR							
	371															
-20					2											
	372						1									
		78		100	0	94	1							0	[100]	
	373						M									
-18					0											
	374															
					1		M		highly weathered, oxidized							
	375						2									
							M		1. 20, J, MW, Fe+Mn, Fi, Wa, SR							
-16					0		M									
	376															
					0		M									
	377		39													
-14		79		100	0	99								0	[100]	
	378						M									
					0		M									
	379															
-12					1		M									
							1		slighly oxidized, weak to moderately strong (many mechanical breaks)							
	380						1		1. 15, J, N, Fe, Su, Wa, R 2. 65, J, N, Fe, Su, Wa, R							
					1		M									
	381															

Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Sheet 25 of 26

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	381															
10					0											
	382															
		80		100	1	99			vesicles partially filled with Fe oxide					0	[100]	
	383															
8					0											
	384															
					0											
	385		40						1. 20, J, N, Cl, Sp, Wa, SR, 30% of vesicles filled with clay							Water level recorded – Steady at 373.5 ft bgs after multiple readings
6					0				2. 20, J, N, Fe, Su, Wa, SR-R, small bands of Fe weathering above							
	386								3. 30, J, N, Cl, Sp, Wa, SR, 20% of vesicles filled with clay							
					0											
	387															
4		81		100	1	99			30% vesicles					0	[75]	
	388															
					1				moderately to highly weathered, oxidized, increase to 50% vesicles, oxidized 2mm-thick bands of reddish brown (10R 4/6)							
	389															
2					1				moderately strong							
	390															
					1				1. 10, J, N, Cl+Fe+Mn, Sp, Wa, SR, vesicles partially filled							
	391								2. 10, J, N, Cl+Mn, Sp, Wa, SR-R, 10% of vesicles with spotty Cl+Mn infilling							
0					0				highly fractured, weak (possible void)							
									vesicles(large) decrease to 20-30%							
	392								highly fractured							
		82		80	0	44								0	[100]	
	393															
-2					2											
	394		41													
					NA				no recovery							
									vesicles decrease to 15%, become large, minimally stretched							
	395								vesicles significantly decrease to less than 5%							
-4					0											
	396															
					0											
	397															

Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

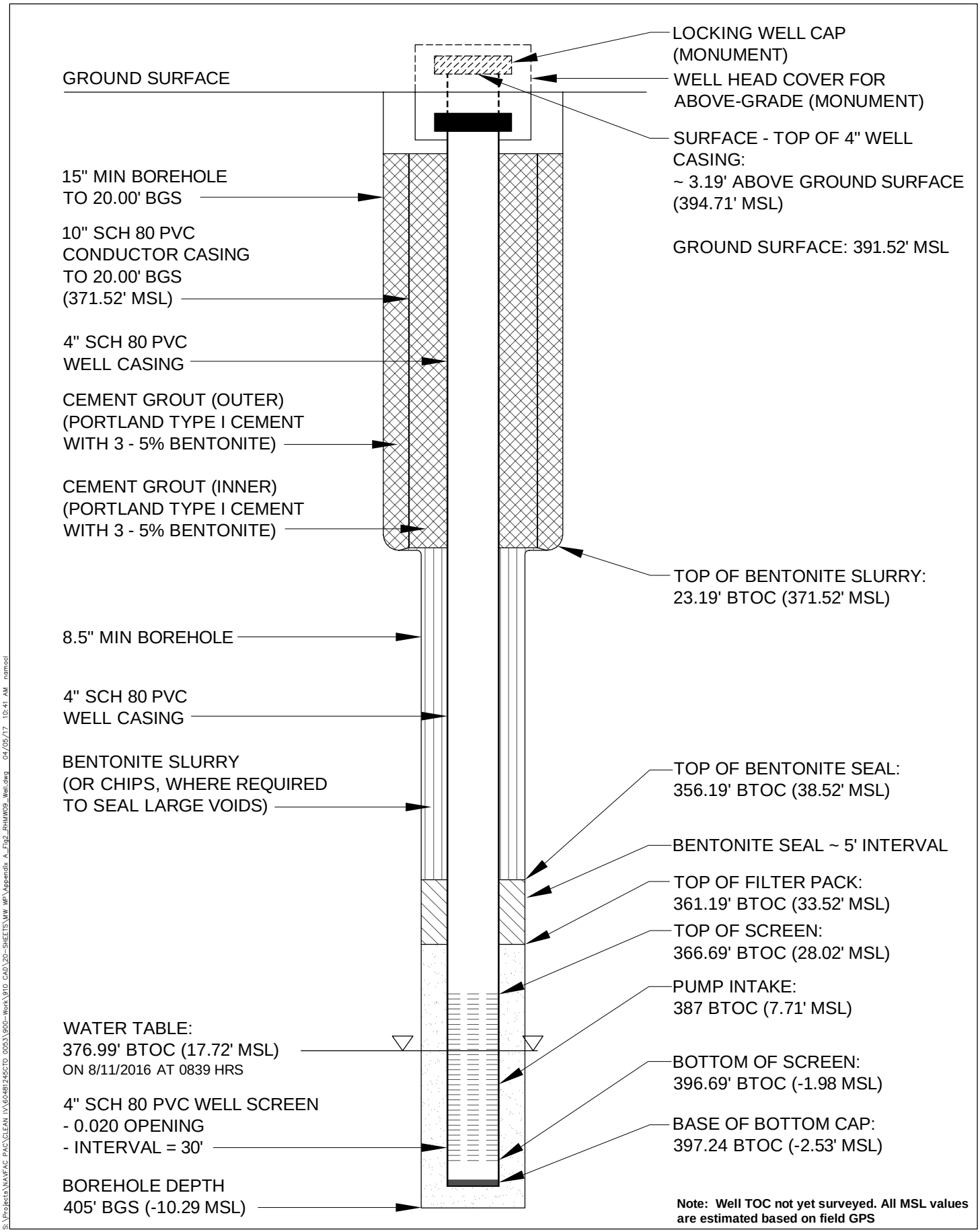
Project: CT053 – Red Hill Bulk Fuel Storage Facilty
Project Location: CT053
Project Number: 60481245

Log of Boring RHMW09

Sheet 26 of 26

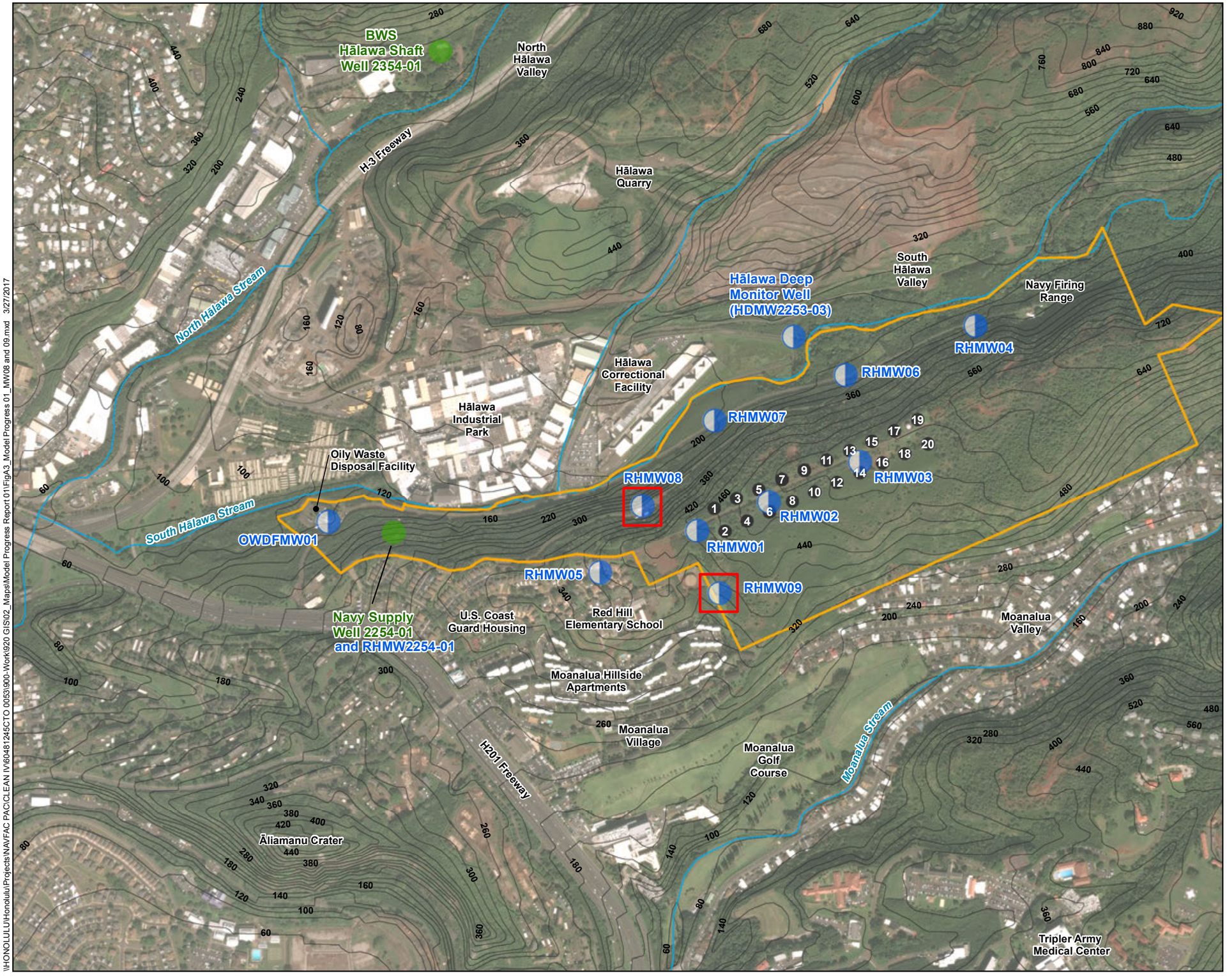
Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery,%	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	Well Schematic	SAMPLES: Type	Number	Blows per foot	PID (ppm)	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	397								20–30% vesicles (medium)							
-6		83		80	0	80	M M							0	[75]	
	398				0				becomes highly weathered, oxidized							
	399								no recovery							
-8					NA				dark red (10R 4/8), highly weathered, highly fractured, weak with 15% of vesicles filled with coralline fine–medium sand							
	400															
					10+											
	401								1. 50, J, N, Sd, Sp, Wa, SR							
-10					10+		1									
	402		42													
		84		94	0	60	M M M M							0	[75]	
	403															
-12					0		M M									
	404						M M M									
					0		M									
	405								Bottom of Boring; TD = 405 ft bgs							Complete drilling 7/28/16; 1,150 gallons of water used downhole, 650 gallons of water–foam mix including 2 cups of foam injected from top of casing
-14	406															
	407								Used a total of 14,000 gallons of circulation water; 1,300 gallons of water–foam mix with 3.3 gallons of foam, added from top of casing; 235 gallons of MaxGel–water slurry with 5, 50–lb bags of MaxGel bentonite powder.							
-16	408															
	409															
-18	410															
	411															
-20	412															
	413															

Report: CT053 RED HILL WITH WELL AND PID; File: CT053 RED HILL CORE LOGS.GPJ; 2/20/2017 RHMW09

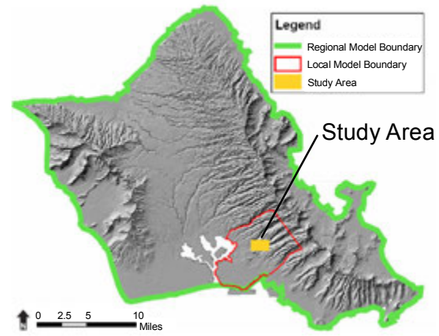


S:\Projects\NAVFAC_PAC\CLEAN_IV\60481245\TO_0053\900--Work\910_CAD\2D--SHEETS\MW_WP\Appendix A_Fig2_RHMW09_Well.dwg 04/05/17 10:41 AM namocl

Appendix A Figure 2
Cross Section of RHMW09 Monitoring Well
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i



Groundwater Modeling Domain



Legend

- Existing Monitoring Well Location
- Existing Water Supply Sampling Point
- Red Hill Fuel Storage Tank
- Stream
- Topographic Contour (feet above mean sea level)
- Red Hill Bulk Fuel Storage Facility Boundary

Notes

1. Map projection: NAD 1983 UTM Zone 4N
2. Base Map: DigitalGlobe, Inc. (DG) and NRCS. Publication_Date: 2015

N

0 500 1,000 1,500 2,000 Feet

Appendix A Figure 3
RHMW08 and RHMW09 Locations
Groundwater Flow Model Progress Report 01
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

\\HONOLULU\Honolulu\Projects\NAVFAC PAC\CLEAN IV\60481245\CTO 0053\900-Work\920 GIS\02_Maps\Model Progress Report 01\FigA3_Model Progress 01_MW08 and 09.mxd 3/27/2017

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