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In reply, please refer to:
File:

April 22, 2024

Rear Admiral Stephen Barnett
Commander, Navy Region Hawaiʻi
850 Ticonderoga Street, Suite 110
Joint Base Pear Harbor Hickam, Hawaiʻi 96860
[via email only: stephen.d.barnett.mil@us.navy.mil]

Dear Rear Admiral Barnett,

SUBJECT: Disapproval of Navy's Consolidated Groundwater Sampling Program in Support of Request to Reduce Red Hill Shaft Flow

The Hawaiʻi Department of Health (DOH) is in receipt of the U.S. Department of the Navy's (Navy's) March 2024 *Consolidation and Optimization of the Groundwater Sampling Programs, Red Hill Bulk Fuel Storage Facility*, hereinafter referred to as the "March 2024 Consolidated Groundwater Sampling Plan," submitted to support the Navy's request to reduce the average daily pumping rate of the Red Hill Shaft (RHS) granular activated carbon (GAC) unit from 4.5 to 1.8 million gallons per day. This is the third version of the Consolidated Groundwater Sampling Plan submitted by the Navy, and comments in the DOH's January 20, 2024 disapproval letter have not been adequately addressed.

Therefore, in the interest of time and conserving natural resources, the DOH disapproves the March 2024 Consolidated Groundwater Sampling Plan and is providing the enclosed revised plan for the Navy's immediate implementation.

No later than April 29, 2024, the Navy is to reduce the daily average pumping rate from 4.5 to 1.8 million gallons per day and implement the enclosed plan, which includes additional requirements on the timely reporting of data, expanding analytes for groundwater monitoring, and other requirements to address the DOH's concerns with the Navy's proposed plan.

Please note, the DOH may provide additional technical comments or revisions to the March 2024 Consolidated Groundwater Sampling Plan that fall outside the scope of reducing the RHS GAC system pumping rate under a separate cover. In addition, based on the data gathered following the reduction of the average daily pumping rate, the DOH may require additional revisions to the enclosed plan.

Should you have any questions regarding this letter or its enclosures, please contact Ms. Kelly Ann Lee, Red Hill Project Coordinator, at (808) 586-4226 or at kellyann.lee@doh.hawaii.gov.

Sincerely,

Kathleen Ho

KATHLEEN S. HO
Deputy Director for Environmental Health

Enclosure 1: Revised Consolidated Groundwater Sampling Plan
Enclosure 2: Revised Consolidated Groundwater Sampling Plan, Red Line Version

c: w/enclosures via email only:
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Consolidation and Optimization of the Groundwater Sampling Programs, Red Hill Bulk Fuel Storage Facility

Joint Base Pearl Harbor-Hickam, Oʻahu, Hawaiʻi

Naval Facilities Engineering Systems Command, Hawaii, JBPHH HI
April 2024

1. Document Management

This document supersedes the Navy's submission of the Consolidation and Optimization of the Groundwater Sampling Programs, Red Hill Bulk Fuel Storage Facility, May 2023, in its entirety. In addition, this document may be further revised in the future to address additional requirements from the Regulatory Agencies.

2. Executive Summary

The Navy has consolidated the previous weekly Notice of Interest (NOI), quarterly Groundwater Long-Term Monitoring (GW LTM), and twice-a-month delineation and sentinel wells into one comprehensive, optimized groundwater sampling program. The new program is based on Hawaiʻi Department of Health (DOH) guidance, the Red Hill Administrative Order on Consent (AOC), the Regulatory Agencies' (RAs') NOI requirements that expired November 13, 2022, the March 8, 2023 meeting with the U.S. Environmental Protection Agency (EPA) and DOH regarding future sampling requirements, the April 13, 2023 Red Hill Remediation Roundtable meeting, and reviews of NOI data collected and analyzed at least weekly from May 2021 through June 2023.

In May 2023, the Navy submitted the initial Consolidation and Optimization of the Groundwater Sampling Programs memorandum to the RAs, and received comments on July 31, 2023. The Navy provided responses to these comments in February 2024 and has addressed the comments in this document.

In September 2023, the Navy submitted a Final Report of Findings, Red Hill Shaft Flow Optimization Study (Flow Optimization Study) (DON 2023) to the DOH, which presented data to evaluate the feasibility of reducing the flow from U.S. Navy Well 2254-01 (also known as "Red Hill Shaft" and "RHS") to meet the objective of long-term sustainability of the drinking water resource. Currently, RHS is pumping at a rate of approximately 4.3 million gallons per day (mgd) to induce drawdown in the aquifer in the vicinity of RHS water development tunnel. This pumped water is treated through a granular activated carbon (GAC) treatment system, then discharged under a National Pollution Discharge Elimination System (NPDES) permit to South Hālawa Stream.

On November 15, 2023, after reviewing the Final Report of Findings, the DOH submitted a letter to the Navy indicating that the study did not provide sufficient evidence that a reduction in pumping of RHS would not result in harm to human health or the environment. However, DOH recognized the importance of conserving the island's natural resources and outlined a path forward, upon DOH approval, to reduce pumping through an increase in monitoring and evaluation once tank defueling activities—defined as removal of fuel from the tank mains and flowable tank bottoms—was completed.

The consolidated sampling approach includes the following changes:

- Integrating and coordinating all the Red Hill groundwater sampling programs into a single program to facilitate better regulatory oversight, and sampling event execution throughout and in the vicinity of the Red Hill Bulk Fuel Storage Facility.
- Revising the previous-NOI analyte list, with a focus on fuel-related analytes.
- Optimizing the previous-NOI sampling frequency from weekly to monthly to facilitate quicker laboratory turn-around times.

- Optimizing previous-NOI monitoring locations to provide comprehensive assessment of the general area.
- Standardizing the previous-NOI sample collection method to use low-flow purging and sampling methodology, as recommended in the DOH *Technical Guidance Manual for the Implementation of the Hawaii State Contingency Plan* (TGM) (DOH 2023).
- Combining the quarterly GW LTM sampling events with the corresponding monthly events to eliminate duplicate analyses, results, and effort.
- During reduced flow conditions at the Red Hill Shaft, increasing the sampling frequency to twice per month to closely monitor any changes in the groundwater quality in the basal aquifer drinking water resource that may indicate migration of contaminants under a reduced RHS average pumping rate.
- Documenting additional data evaluation procedures that will be conducted during reduced Red Hill Shaft flow conditions to identify changes in water quality that indicate uncontrolled fuel contaminant migration as light nonaqueous-phase liquid (LNAPL) or as dissolved-phase analytes.
- Outlining steps to take should any uncontrolled migration of contaminants be identified.

3. Groundwater Sampling Program Improvements

3.1 Sampling Program Integration

To optimize the sampling programs to support accurate and timely analytical chemistry results and achieve more efficient data evaluation, the various programs have been integrated into a single, comprehensive groundwater sampling program. The Consolidated Groundwater Sampling Program requirements include the analytical suite, analytical methods, laboratory turnaround times, sampling locations, sample collection methods, and sampling frequency.

In accordance with the *Sampling and Analysis Plan, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Revision 01* (DON 2017), the U.S. Navy Environmental Restoration Program, Naval Facilities Engineering Systems Command Pacific, *Project Procedures Manual* (DON 2015), and the DOH TGM (DOH 2023), the Consolidated Groundwater Sampling Program includes NOI and GW LTM sampling of inside- and outside-tunnel sampling locations using low-flow sampling techniques. Groundwater sampling also includes measuring depth to groundwater and depth to well bottom from the top of casing and assessing the presence or absence of an immiscible phase. A photoionization detector (PID) is used to evaluate whether volatile organic compound levels in wells are above ambient conditions prior to deploying an oil/water interface probe.

Headspace monitoring for volatile organic compounds is performed at all locations, and fuel product thickness gauging is conducted at wells with screens that bracket the water table. Bailers are used to assess and photo document the presence or absence of floating product on the groundwater surface in wells installed in unconfined conditions, and sample this product for forensic analysis as described in Section 3.2. In addition, a sample aliquot shall be collected from the bailer and analyzed for volatile organic compounds (VOCs) by EPA Method 8260.

Observations, measurements, and field parameters collected during purging prior to groundwater sampling include water level measurements, observations (i.e., water clarity and condition, evidence of free product), dissolved oxygen measurements, and groundwater sampling parameters (turbidity, specific conductance, oxidation reduction potential [ORP], pH, and temperature). Details on reporting and data evaluation procedures for field parameters are provided in Section 3.4.

Finally, the Navy has contracted primary and secondary laboratories that are certified by the Department of Defense (DoD) Environmental Laboratory Accreditation Program (ELAP) for all analyses in the program and capable of providing the requested data packages within the required turnaround time.

3.2 ANALYTE LIST

Previous NOI, GW LTM, delineation well, and sentinel well sampling has generated a substantial dataset characterizing the nature and extent of the fuel releases. The previous NOI sampling included analyses of chemicals of potential concern (COPCs) and additional analytes including chemicals that are not associated with fuels. Therefore, this document presents the notification of changes to the expired NOI sampling program and integration of the various groundwater monitoring programs into one overall program based on the substantial body of laboratory results, DOH guidance, and the composition of the fuels, similar to the process employed under the AOC. Table 1 provides a summary of the analytical list for the consolidated groundwater monitoring program, which includes monthly analytes, analytical methods, and screening criteria. Table 1 includes COPCs related to middle distillates, fuel additives, polynuclear (polycyclic) aromatic hydrocarbons (PAHs), lead scavengers, natural attenuation parameters (NAPs), and general water chemistry parameters. In addition, this list includes field parameters conductivity and total dissolved solids (TDS), which will be verified quarterly by a certified laboratory. Other field parameters are not stable outside of their natural conditions; therefore, they will not be verified in this manner.

The following ten primary COPCs were established in February 2016 (EPA Region 9 and DOH 2016) for the AOC investigations and the GW LTM program and will remain the same for the Consolidated Groundwater Sampling Program:

- Total petroleum hydrocarbons (TPH)-gasoline range organics (TPH-g), TPH-diesel range organics (TPH-d), and TPH-oil range organics (TPH-o)
- Naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene
- Benzene, toluene, ethylbenzene, and total xylenes (BTEX)

During a March 8, 2023 collaboration meeting between the Navy, EPA, and DOH, the Navy presented a list of reduced analytes for NOI sampling. The Navy showed that including non-fuel-related analytes to the target analyte list increased processing time for commercial laboratories, data validators, and shipping without adding valuable information to identify and characterize potential fuel release impacts. This contributed to delays in validation, reporting, and timely analyses of results and impeded rapid assessment of impacts to groundwater and the ability to quickly respond to changes in groundwater conditions. Although it was valuable during emergency response activities in late 2021 and early 2022, sampling and analysis of these non-fuel analytes ran counter to DOH TGM guidance of "Do not simply list chemicals associated with specific laboratory methods that will be used to test samples collected at the site"[1]; as such, certain analytes were previously discontinued from the Consolidated Groundwater Sampling Program.

Laboratory results from the comprehensive set of groundwater monitoring events show inconsistent, low concentrations of non-fuel analytes and confirm that the analytes used as the AOC and GW LTM COPCs are appropriate. However, out of an abundance of caution, additional PAHs analyzed for previous-NOI sampling will also continue as part of the Consolidated Groundwater Sampling Program because some PAHs are potentially associated with jet fuels at low concentrations. The Navy also previously agreed to add non-volatile dissolved organic carbon, and it has been added to the NAP list for the Consolidated Groundwater Sampling Program.

[1] https://health.hawaii.gov/heer/tgm/section-06/

Table 1: Consolidated Groundwater Sampling Program

Parameter	Analytical Method	Analyte(s)	DW Promulgated Criterion (EPA MCL) (µg/L)	Tap Water Screening Criterion (EPA RSL) (µg/L)	GW Screening Criterion (DOH EAL) (µg/L)	GW-LTM Parameters (Added Quarterly)	Consolidated Parameters [a]
TPH	EPA 8015M	TPH-g	—	—	300	—	X
	EPA 8015M	TPH-d	—		400	X [b]	X
		TPH-o	—	—	500	X [b]	X
TPH Calculation	EPA 8015M	Reported as a non-overlapping sum of TPH-g/d/o with BTEX and methylnaphthalenes subtracted	—	—	—	—	X
TEH [e]	EPA 8015M	Total Extractable Hydrocarbons	—	—	—	X	—
TPH with SGC [c]	EPA 3630/8015	TPH-d	—	—	—	X [b]	X
		TPH-o	—	—	—	X [b]	X
VOCs	EPA 8260 GC/MS	Benzene	5	0.46ca	5	—	X
		Ethyl Benzene	700	1.5ca	30	—	X
		Toluene	1,000	1,100	40	—	X
		Total Xylenes	10,000	190	20	—	X
		1,2,4- Trimethylbenzene	—	56	—	—	X
		1,3,5- Trimethylbenzene	—	60	—	—	X
AOC / GW LTM PAHs	EPA 8270 GC/MS SIM	1-Methylnaphthalene	—	1.1ca	10	—	X
		2-Methylnaphthalene	—	36	10	—	X
		Naphthalene	—	0.12ca	17	—	X
PAHs	EPA 8270 GC/MS SIM	Acenaphthene	—	530	20	—	X
		Acenaphthylene	—	—	240	—	X
		Anthracene	—	1,800	0.18	—	X
		Benzo(a)anthracene	—	0.03ca	0.029	—	X
		Benzo(a)pyrene	0.2	1.8	0.2	—	X
		Benzo(b)fluoranthene	—	0.25ca	0.22	—	X
		Benzo(g,h,i)perylene	—	—	0.13	—	X
		Benzo(k)fluoranthene	—	2.5ca	0.4	—	X
		Chrysene	—	25ca	1	—	X
		Dibenzo(a,h)anthracene	—	0.025ca	0.022	—	X
		Fluoranthene	—	800	13	—	X
		Fluorene	—	290	240	—	X
		Indeno(1,2,3-cd)pyrene	—	0.25ca	0.095	—	X
		Phenanthrene	—	—	210	—	X
		Pyrene	—	120	68	—	X

Parameter	Analytical Method	Analyte(s)	DW Promulgated Criterion (EPA MCL) (µg/L)	Tap Water Screening Criterion (EPA RSL) (µg/L)	GW Screening Criterion (DOH EAL) (µg/L)	GW-LTM Parameters (Added Quarterly)	Consolidated Parameters [a]
Fuel Additives	EPA 8270	Phenol	—	5,800	300	—	X
	EPA 8270	2-(2-Methoxyethoxy) Ethanol	—	800	800	X	—
Lead Scavengers	EPA 8011	1,2-Dibromoethane	0.05	0.0075ca	0.04	—	X
	EPA 8260 GC/MS	1,2-Dichloroethane	5	0.17ca	5	—	X
NAPs	SM 3500-Fe	Ferrous Iron	—	—	—	—	X
	RSK 175M	Methane	—	—	—	—	X
	EPA 300.0	Nitrate, Sulfate, Chloride	—	—	—	—	X
	EPA 353.2	Nitrate-Nitrite as Nitrogen	—	—	—	—	X
	SM 2320	Carbonate, Bicarbonate, and Total Alkalinity	—	—	—	—	X
	EPA 9060A	TOC	—	—	—	—	X
	EPA 9060A	NVDOC	—	—	—	—	X
General Chemistry	EPA 300.0 [d]	Bromide, Chloride, Fluoride, Nitrate, Sulfate	—	—	—	X	—
	EPA 6010C [d]	Calcium, Magnesium, Manganese, Potassium, Sodium	—	—	—	X	—
	SMWW4500-Si-D / SIO2-C [d]	Dissolved Silica, Total Silica	—	—	—	X	—
	Method 120.1 and 2510B	Conductivity	—	—	—	X	—
	Method SM2540C-2015	Total Dissolved Solids	—	—	—	X	—

Notes:
As additional COPCs are identified (e.g., cleaning agents, additives), analytes will be added to the Red Hill Consolidated Sampling Program.
µg/L micrograms per liter
BTEX benzene, toluene, ethylbenzene, and total xylenes
ca Carcinogenic risk based screening level
DOH EAL Hawaii Department of Health Environmental Action Level: Fall 2017 (https://health.hawaii.gov/heer/guidance/ehe-and-eals/)
DW drinking water
GW groundwater
EPA MCL US Environmental Protection Agency National Primary Drinking Water Regulations, Maximum Contaminant Level (https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations)
EPA RSL Regional Screening Levels (RSLs): November 2023 (https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables)
mgd million gallons per day
NAP natural attenuation parameter
NVDOC non-volatile dissolved organic carbon
PAH polynuclear (polycyclic) aromatic hydrocarbon
SGC silica gel cleanup
TPH-d total petroleum hydrocarbons - diesel range organics
TPH-g total petroleum hydrocarbons - gasoline range organics
TPH-o total petroleum hydrocarbons - residual range organics
VOC volatile organic compound
— not applicable
X Compound is included in the respective groundwater sampling program.
[a] Collected monthly during 4.3-mgd pumping and twice per month during reduced pumping at the Red Hill Shaft.
[b] Uses 3510 extraction method for Consolidated. Additional 3520 for Quarterly.
[c] Silica Gel Cleanup will be conducted on samples where TPH-d and TPH-o are detected.
[d] Monitored on the first GW LTM event of a new well. Chloride, sulfate and nitrate will also continue to be monitored and evaluated quarterly with the NAPs.
[e] TEH is reported for the total range integrated for the sample based on the TPH-d method.

This consolidation plan combines the GW LTM event that occurs every third month with the previous NOI sampling event that occurs at the same time. This combined consolidated quarterly event will consist of all the previous-NOI sampling parameters and also include the additional GW LTM parameters listed below and shown in Table 1:

- TPH-d and TPH-o using the 3520 extraction method
- Fuel additives 2-(2-methoxyethoxy) ethanol
- NAPs, including ferrous iron, nitrate, sulfate, chloride, nitrate-nitrite as nitrogen, carbonate, bicarbonate, and total alkalinity
- The general chemistry parameters total dissolved solids and conductivity
- The general chemistry parameters calcium bromide, fluoride, magnesium, manganese, potassium, and sodium, which will be sampled once during the first quarterly event associated with a new well

In addition to dissolved groundwater COPCs, the Navy will conduct sampling and analysis of any fuel product recovered during the bailer sampling conducted prior to groundwater sampling. Product or sheen samples will be collected from the bailer in three 40 milliliter (ml) volatile organic analysis (VOA) vials and sent under chain of custody to a non-DoD-certified forensics laboratory for Saturated Hydrocarbon (SHC) and Petroleum Hydrocarbon Identification (PHI) analysis, including qualitative narrative, consisting of:

- Modified Method 8015M approach for extractable hydrocarbons.
- Method is applicable to soil, aqueous, or free product samples.
- Uses the same 80-minute chromatographic runtime encompassing n-alkane hydrocarbons and selected isoprenoids in the C9 through C40 range.
- Data for 32 individual n-alkanes and five isoprenoids are reported, as well as the total concentrations of saturated and total petroleum hydrocarbons.
- Will include a qualitative narrative.

Based on the results of this analysis, a more detailed evaluation may be conducted. Examples of this could include a comparison of current analytical results to historical results, evaluation of tentatively identified compounds, and/or biogenic metabolites, with respect to the Facility's operational history.

3.3 OPTIMIZE SAMPLING FREQUENCY

3.3.1 Monthly Sampling

As discussed during the March 8, 2023 collaboration meeting, weekly NOI sampling conducted after the 2021 release events effectively captured the increase and subsequent decrease of COPC concentrations in the monitoring wells following the releases, which provided an understanding of the impacts of those releases. In addition, the data showed that concentrations have significantly decreased and stabilized, in most cases returning to non-detectable or within historical ranges. As a result, weekly sampling frequency no longer provides added information that was not already captured by monthly (or quarterly) sampling. Reducing the sampling frequency to monthly (at full-time operation of the RHS GAC treatment system) allows for groundwater characterization and trend analyses without sacrificing accuracy, and reduces processing time for the commercial laboratories, the data validators, and sampling and shipping. The monthly sampling frequency is in accordance with the DOH TGM, which states: "Long-term monitoring of groundwater should be carried out at a frequency adequate to assess trends in potential environmental concerns and guide and monitor the effectiveness of remedial actions" (DOH TGM Section 6.6.8.5).[2]

[2] https://health.hawaii.gov/heer/tgm/section-06/

3.3.2 Reduced Red Hill Shaft Pumping Rate Sampling Frequency

In accordance with DOH's November 15, 2023 letter, the Navy will implement reduced pumping and GAC-filtered discharge of water from RHS into South Hālawa Stream under strict evaluation measures to ensure fuel-related contaminants in the basal aquifer—a potable water resource—do not present an unacceptable risk to human health or the environment. The actions listed in Section 3.4 will be taken to ensure that potential migration of contaminants under a reduced RHS average pumping rate are identified in a timely manner.

In addition, the NPDES permit requires that RHS discharge water be sampled when the pumps are turned on after a shutoff period of 24 hours or greater. Details of this requirement are provided in *Red Hill Shaft Recovery Plan NPDES Compliance Sampling Protocol*, March 27, 2023 (IDWST 2023).

Sampling and analysis frequency will increase from monthly to twice per month during reduced pumping. The twice per month sampling events will be conducted with no less than 10 calendar days between the preceding or succeeding sampling events. In consultation with the Regulatory Agencies, the Navy may submit approval requests to adjust the sampling frequency based on the results of data evaluation.

Turnaround times for analytical results and data validation, field checks including headspace testing, and free product gauging will be expedited to allow timely decision-making for response actions based on these results. All groundwater samples will be scheduled so that they can be shipped to the laboratory on the day they are collected, with the objective of minimizing the transit time to 1 calendar day. In some cases, transit time may necessarily be longer in duration based on sampling times, transportation options, weather delays, etc. Samples will be analyzed on an expedited preliminary result turnaround of 5 business days (upon receipt at the laboratory) and will be validated on an expedited seven business day turnaround (upon issuance of the analytical report). If issues are identified that require additional consultation with the project laboratory, final validation turnaround time will be extended to allow necessary revisions and or laboratory clarifications to the laboratory reports and data. This schedule will provide for a review of the 5-business-day preliminary analytical data prior to the next scheduled sampling event. The goals of these expedited turnaround times are to allow the Navy to meet the following:

- Submit tabulated results in spreadsheet format and laboratory reports, validated or not, within 7 calendar days of receipt of initial analytical results from the laboratory.
- Submit time-series plots within 10 calendar days of receipt of initial analytical results from the laboratory.
- Submit validated tabulated results in spreadsheet format and laboratory reports within 30 calendar days after receipt of analytical results from the laboratory.
- Provide the Regulating Agencies with an update identifying the following items on a weekly basis:
  - Any indication of potential fugitive migration
  - The results of the most recent trend analysis
  - Any detections that may be statistically significant above background concentrations
  - Any significant field observations
  - If potential fugitive migration has been identified, a list of what measures are currently being taken.

The standard field checks described in Section 3.1 will also detect potential contamination. Headspace monitoring will be performed at all locations, and fuel product thickness gauging will be conducted at wells with screens that bracket the water table. Bailers will be used to assess and photo-document the presence or absence of floating product on the groundwater surface in wells installed in unconfined conditions.

In addition, the Navy will collect and evaluate groundwater headspace, which consists of collecting liquid samples from the water table using a bailer, a portion of the liquids will be transferred to a clean 1-liter jar, which will be capped and shaken, then the headspace will be measured with a handheld PID. This concentration is representative of LNAPL/dissolved total volatile organic compound (VOC) concentrations and will be used in lieu of headspace readings immediately above the water table.

Table 2 summarizes the frequency for each sampling location monitored twice per month, monthly, and quarterly under the Consolidated Groundwater Sampling Program. As additional monitoring wells are installed, they will be incorporated at similar frequencies as the existing wells.

Table 2: Summary of Consolidated Plan Sampling Frequency by Program

Sampling Program	HDMW2253-03	RHMW2254-01	RHP01	RHP02	RHP03	RHP04A	RHP04B	RHP04C	RHP05	RHP06	RHP07	RHP08	RHMW01R	RHMW02	RHMW03	RHMW04	RHMW05	RHMW06	RHMW08	RHMW09	RHMW10
2015 AOC GW LTM	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
Consolidated Sampling	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Consolidated Sampling (Reduced GAC Operation)	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M

Sampling Program	RHMW11	RHMW12A	RHMW13	RHMW14	RHMW15	RHMW16	RHMW17	RHMW18	RHMW19	RHMW20	NMW24	NMW25	NMW26	NMW30	NMW32	NMW33	NMW34	OWDFMW03A	OWDFMW08A	RHS-Pump
2015 AOC GW LTM	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
Consolidated Sampling	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Consolidated Sampling (Reduced GAC Operation)	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M

Notes:
Q Quarterly
M Monthly
2M Twice Monthly

Table 3 provides the well screen depth interval and pump intake depth below top of casing (ft btoc) for each well to be sampled.

Table 3: Monitoring Well Screen Intervals and Dedicated Low Flow Bladder Pump Intake Depths

Monitoring Well	Top of Screen Depth (ft btoc) [a]	Bottom of Well Screen Depth (ft btoc) [a]	Pump Intake Depth (ft btoc) [a]
RHMW01R	74	94	89
RHMW02	84	99	92
RHMW03	102	117	110
RHMW04	290	305	298

Monitoring Well	Top of Screen Depth (ft btoc) [a]	Bottom of Well Screen Depth (ft btoc) [a]	Pump Intake Depth (ft btoc) [a]
RHMW05	83	90	89
RHMW06	230	260	245
RHMW08	281	311	303
RHMW09	367	397	382
RHMW10	467	497	481
RHMW11 Zone 5	N/A	N/A	285 [b]
RHMW12A	413	433	423
RHMW13 Zone 4 [c]	N/A	N/A	285 [b]
RHMW13 Zone 5a [c]	N/A	N/A	243 [b]
RHMW14 Zone 3	N/A	N/A	325 [b]
RHMW15 Zone 5a	N/A	N/A	297 [b]
RHMW16	488	508	498
RHMW17	223	253	238
RHMW18	592	622	614
RHMW19	415	445	437
RHMW20	223	253	238
RHMW2254-01	N/A	N/A	94
HDMW2253-03	N/A	N/A	252
RHP01	125	155	145
RHP02	110	140	127
RHP03	104	134	124
RHP04A	130	160	146
RHP04B	301	321	311
RHP04C	486	506	496
RHP05	204	234	218
RHP06	239	269	259
RHP07	74	94	88
RHP08	276	306	294
NMW24	80	110	100
NMW25	81	211	201
NMW26	741	771	760
NMW30	282	312	302
NMW32	161	191	181
NMW33	117	137	129
NMW34	56	86	76
OWDFMW03A	141	161	153
OWDFMW08A	140	160	152
RHS-Pump [d]	N/A	N/A	~100

Notes:
ft btoc feet below top of casing
N/A not applicable
[a] Approximate depth rounded to the nearest foot.
[b] Multilevel well sample port depth (ft btoc).
[c] Multilevel well RHMW13 Zone 4 is sampled when there is insufficient sample volume available from Zone 5a.
[d] This is a sampling port in the Red Hill Shaft pump station representing influent to the GAC treatment system.

3.4 DATA EVALUATION AND ACTIONS TAKEN IF POTENTIAL MIGRATION OF CONTAMINANTS IS IDENTIFIED DURING REDUCED PUMPING

Sample collection and expedited shipping, analysis, and review will be scheduled and performed to facilitate early evaluation of field data and preliminary analytical data, such that any desired revisions to the next sampling event can be planned and implemented with haste. Trend analyses will be conducted at a minimum on wells located within the Facility property boundary. If trends indicate the potential for contaminants to migrate beyond the Facility boundary, offsite wells shall be included.

3.4.1 Rationale for Evaluation of Field Parameters and Natural Attenuation Parameters for Plume Stability

The observation of fuel product as an immiscible layer of LNAPL in any well is the most direct real-time correlation to plume stability when evaluating parameters measured with field instruments during sampling and purging (field parameters). However, fuel product is lighter than water and would not be expected in wells screened below the basal aquifer potentiometric surface; therefore, basal aquifer wells with top of screen below the static water level are not expected to have LNAPL as an evaluation parameter.

Another field parameter that is directly related to the presence of fuel-related VOCs in groundwater is groundwater headspace as described in Section 3.3.2. Highly volatile fuels such as aviation gasoline have not been stored at the Facility since before 1970. Since 1970, fuels stored in the Facility have been middle distillates, which have much lower concentrations of VOCs in product. To date, the Navy has collected headspace samples from the top of casing at each well sampled. A calibrated PID sample is collected from the vapor gathered at the top of the well casing immediately after the well cap is first removed from the well prior to purging and sampling. These results have not been strongly correlated to hydrocarbons in groundwater at the tank farm. For example, from 21 groundwater sampling events collected between June 15, 2023 and January 19, 2024, PID headspace readings at the tank farm wells with consistent TPH in groundwater were negligible, as show in Table 4.

Table 4: Field Parameter Summary Statistics for Selected Wells

Well ID	RHMW01R	RHMW02	RHMW03	RHMW10	RHMW16	RHP03
Elevated TPH in Groundwater	Yes	Yes	Yes	No	No	No
Top of Casing Headspace (ppmv)						
Minimum	0.0	0.0	0.4	0.0	0.0	0.0
Maximum	0.9	0.30	1.50	0.20	0.20	0.30
Average	0.09	0.06	0.58	0.02	0.02	0.02
Standard Deviation	0.21	0.10	0.26	0.05	0.05	0.07
Dissolved Oxygen (mg/L)						
Minimum	0	0	0.4	8.1	8.28	3.05
Maximum	0.62	0.25	1.50	8.77	9.21	5.30
Average	0.47	0.11	0.58	8.41	8.65	4.60
Standard Deviation	0.12	0.10	0.26	0.17	0.23	0.54
ORP (mV)						
Minimum	-275	-304	0.4	104	104	80
Maximum	0	-79	1.50	310	310	277
Average	-81.87	-163	0.58	235	235	202
Standard Deviation	69.10	85	0.26	64	64	60

Note: Units in parts per million by volume from field photoionization detectors from top of casing headspace measurements.

The Navy will begin evaluating bailer headspace VOC measurement as described Section 3.3.2 and, based on the results when compared to TPH concentrations in groundwater, may use these as supporting real-time indicators of plume stability.

Biodegradation of fuel hydrocarbons brings about measurable changes in the chemistry of groundwater in the affected area. By measuring these changes, natural attenuation and biodegradation of hydrocarbons can be assessed and the stability of the dissolved hydrocarbon groundwater plume can be estimated. The following field parameters measured during groundwater purging before sampling are indicative of biodegradation (AFCEE 1995):

- Dissolved oxygen is the most thermodynamically favored electron acceptor used in the biodegradation of fuel hydrocarbons. Dissolved oxygen concentrations are used to estimate the mass of contaminant that can be biodegraded by aerobic processes. Decreasing trends of dissolved oxygen may indicate hydrocarbons are undergoing biodegradation hydraulically upgradient from the sample point.
- ORP reactions in groundwater contaminated with petroleum hydrocarbons are usually biologically mediated, and therefore, the redox potential of a groundwater system depends upon and influences rates of biodegradation. Redox potential may be used to provide real-time data on the location of the contaminant plume, especially in areas undergoing anaerobic biodegradation indicated by low or negative ORP values.
- Temperature of the groundwater increases due to exothermic natural attenuation processes. Groundwater temperature increases above background may indicate active natural attenuation processes (biodegradation) and potential plume migration.

In addition to the field parameters above, the following list of electron acceptors and metabolic byproducts may also be indicative of hydrocarbon degradation and trend analysis can provide information on the plume stability, biodegradation potential, and biodegradation activity:

- Ferrous iron and methane are metabolic byproducts of biodegradation of hydrocarbons. During anaerobic degradation, the concentrations of these parameters will be seen to increase to levels above background. Increases in ferrous iron and methane in groundwater may be indicative of anaerobic degradation in upgradient locations.
- Nitrate and dissolved oxygen are electron acceptors that are generally used during biodegradation of dissolve hydrocarbons at rates that are instantaneous relative to the average advective transport velocity of groundwater.
- Sulfate and iron (III) in areas with dissolved fuel-hydrocarbon contamination are used at rates that are slow relative to rates of dissolved oxygen and nitrate utilization. This results in the consumption of these compounds at a rate that could be slower than the rate at which they are replenished by advective flow processes and plumes of contamination can extend away from the source.
- Alkalinity increases in the groundwater due to the production of carbon dioxide by microbial respiration that is converted to carbonate. Aerobic and anerobic (primarily nitrate and sulfate reduction) natural attenuation (biodegradation) result in alkalinity increases that are nearly instantaneous.

Understanding how these parameters change laterally can provide an estimate of the plume location, and the general groundwater flow direction. For example, electron acceptors (dissolved oxygen, nitrates, sulfates), which are used during hydrocarbon biodegradation, are expected to be at higher concentrations upgradient of the dissolved hydrocarbon plume than concentrations downgradient. Metabolic byproducts, such as methane, and ferrous iron are generated during hydrocarbon biodegradation and are expected to be at lower concentrations upgradient of the plume than concentrations downgradient.

Understanding how these parameters change over time can provide an estimate of plume stability. If metabolic byproduct concentrations are increasing and electron acceptor concentrations are decreasing over time at a well, it may indicate that the plume is expanding in that direction, or increasing in hydrocarbon concentration upgradient, and indicating an increase in metabolic activity. Conversely, if metabolic byproducts are decreasing over time and electron receptors are increasing, it may indicate that the plume is contracting upgradient from the sampled well.

There are no regulatory standards used to evaluate these electron acceptor and metabolic byproduct trends. These trends are not absolute evidence of contaminant migration or degradation without primary observations of changes in contaminant concentrations, as there may be other geochemical processes in the aquifer that are causing the observed trends.

3.4.2 Field Parameters

To identify any changing trends, field parameter data from all wells will be tabulated upon collection (twice per month) and compared against the historical data set for the individual well and also the comprehensive data set for all wells.

These data will be provided to the RAs through the Red Hill Joint Base Pearl Harbor-Hickam Environmental Data Management System (EDMS)[3].

Selected Field Parameters in a Single Well Comparison:

1. Selected field parameters to evaluate uncontrolled contaminant migration are:
   a. Selected purge parameters: dissolved oxygen, ORP
   b. Bailer headspace VOCs
   c. Presence of LNAPL and thickness
2. All field parameters and actual LNAPL thickness will be plotted on an individual time- series charts for each well for visual trend analysis.
3. These field parameter trend charts will be qualitatively assessed and compared to TPH groundwater concentrations to develop correlations to support plume stability assessment.
4. Deliverables:
   a. Field parameter trend charts will be submitted to RAs via EDMS in Portable Document Format (*.pdf) by well and sampling date.
   b. The format of the file name will be: Consolidated GW by Well, Field Trend Analysis – <DDMMMYY>.
   c. The files will be stored in EDMS at Library->Field Activity Reports->Wells.

3.4.3 Natural Attenuation Parameters

Similarly, all unvalidated NAPs (including ferrous iron, methane, nitrate, sulfate, nitrate-nitrite as nitrogen, and total organic carbon) will be tabulated and plotted in time-series charts and compared to field parameters, general chemistry, and contaminant concentrations to determine any changes or migration patterns associated with biogeochemical processes. These data will be provided to the RAs through EDMS as unvalidated NAP trend results. Once the data have been completely validated, the trend analyses will be updated, if necessary, with any revised data points, and resubmitted to the regulators through EDMS as validated NAP trend results.

- Deliverables will be in *.pdf format.
- The format of the file name will be:
  – Consolidated GW by Well, Unvalidated NAP Trend Analysis – <DDMMMYY> for unvalidated data

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[3] https://synectics.net/

  - Consolidated GW by Well, Validated NAP Trend Analysis – <DDMMMYY> for validated data
- Files will be stored in EDMS at Library->Field Activity Reports->Wells

3.4.4 Chemicals of Potential Concern

Twice per month, first unvalidated followed by validated groundwater concentrations of specified COPCs (TPH-g, TPH-d, TPH-o, naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene) will be tabulated and plotted in time-series charts and reviewed for any potential anomalies or trends that may be indicative of uncontrolled fuel contaminant migration. When trend analysis from data indicates the potential for uncontrolled contaminant migration, subject matter experts will review the associated TPH chromatographs to verify that the results are from fuel-related analytes. SGC analyses will also be used to evaluate TPH degradation patterns. These data will be provided to the RAs through EDMS at first as unvalidated trend results. Once the data have been completely validated, the trend analyses will be updated, if necessary, with any revised data points and resubmitted to the RAs through EDMS as validated trend results.

- Deliverables will be in *.pdf format.
- The format of the file name will be:
  - Consolidated GW by Well, Unvalidated COPC Trend Analysis – <DDMMMYY> for unvalidated data
  - Consolidated GW by Well, Validated COPC Trend Analysis – <DDMMMYY> for validated data
- Files will be stored in EDMS at Library->Field Activity Reports->Wells.

3.4.5 Evaluating Multiple Lines of Evidence for Response Actions

Multiple lines of evidence will be used to evaluate potential uncontrolled fuel contaminant migration. Potential/primary indications of uncontrolled migration of fuel contaminants may include:

1. Observations of LNAPL in a monitoring well.
2. Multiple consecutive significant observations (two observations or more) of COPCs in a monitoring well. A significant result is defined as one standard deviation above average background (calculated from historical levels using data collected from September 2023 until the initiation of the reduction of the average pump rate of the RHS GAC system). For wells in which these compounds have not been observed, a single observation will be considered significant.
3. A single observation of any COPC in a monitoring well at a concentration that is two standard deviations above average background concentration (calculated from historical levels using data collected from September 2023 until the initiation of the reduction of the average pump rate of the RHS GAC system).
4. Observations of TPH-d or TPH-o at concentrations exceeding the DOH EAL in a monitoring well that historically (using data collected from September 2023 until the initiation of the reduction of the average pump rate of the RHS GAC system) has not seen such an exceedance.
5. Any sufficiently overt data trend in onsite wells (groundwater headspace test, field parameters, etc.) that may suggest mass and uncontrolled migration of contamination, noting the occurrence of LNAPL and fluctuations in dissolved-phase contamination within the source zone and wells /proximate to RHS may reasonably be expected in response to changed flow conditions and should not automatically be evaluated as uncontrolled migration.

Upon observing one or more lines of evidence from verified field observations or unvalidated laboratory data of uncontrolled fuel-related contaminant migration that present an unacceptable risk to human health or the environment, the Navy will notify the RAs within 24 hours. The notification shall include appropriate actions the Navy proposes to implement in accordance with local, State, and Federal regulations for approval by the RAs. Proposed response actions may include:

- Evaluating other indicators (e.g., dissolved oxygen, temperature, other COPCs, etc.) for subtle changes that when evaluated wholistically may indicate potential fugitive migration.
- Illustrate the data on a map to evaluate potential changes spatially in a wholistic manner.
- Increase sampling frequency (at the subject well and/or surrounding wells) to further evaluate the identified potential trends/increases.
- Evaluate migration trends.
- Increase RHS pumping and GAC-filtered discharge rate to increase groundwater containment within the vicinity of RHS.
- Evaluate other remedial response actions (such as pump and treat or pump and containerize systems).
- Conduct a remedial alternatives analysis in accordance with Section 18.5.12 of the DOH TGM (DOH 2023).

3.5 OPTIMIZE MONITORING LOCATIONS

Sampling locations in each program were evaluated and locations were retained or excluded to optimize future sampling. Locations were removed based on their representativeness of groundwater conditions, duplication of (e.g., close proximity to) other sampling locations, anomalous water levels (elevated) and response to pumping conditions or other factors that differ from surrounding wells, or inclusion in another groundwater sampling program. Figure 1 shows the groundwater monitoring well sampling locations. Table 2 and Figure 1 respectively list and illustrate the locations of wells included and planned for in this Consolidated Groundwater Sampling Program. Additional wells will also be included in this sampling program as they are planned and installed. In addition to groundwater monitoring wells, a groundwater sample will be collected from a sampling port located within the RHS pump station, which will represent groundwater that has been pumped through the RHS pumps, prior to entering the NPDES GAC treatment system. This location is designated as RHS-Pump and addresses consistency and repeatability concerns associated with previously sampled pre-chlorination sampling locations that are no longer in the water flow since RHS was removed from the public water supply system.

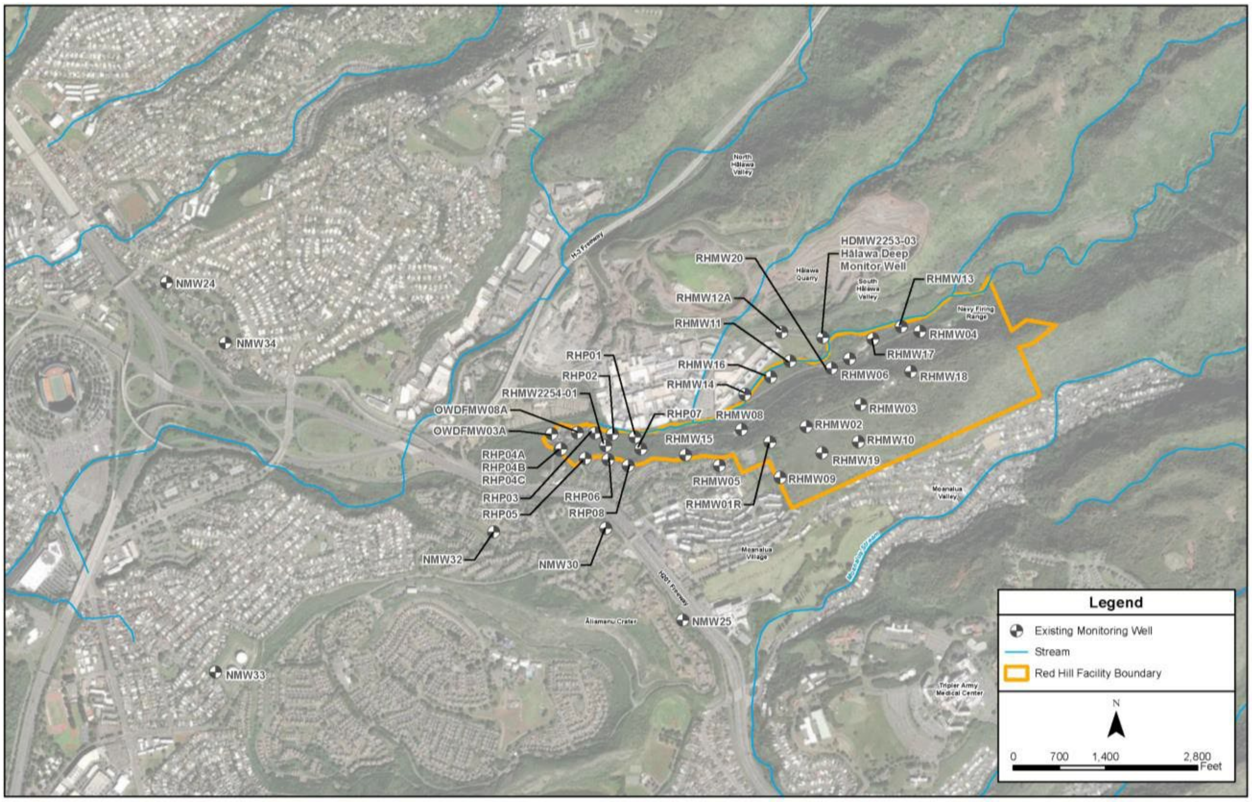

Figure 1: Groundwater Monitoring Well Sampling Locations

3.6 STANDARDIZE SAMPLE COLLECTION METHOD

NOI sampling was previously conducted using both unpurged bailer and low-flow (pump) purging. No fuel product has been observed at monitoring locations to date with the exception of RHS shortly after the November 2021 release event. The use of different sampling methods have resulted in notable differences in analyte concentrations between the NOI and GW LTM programs. The low-flow sampling method is widely accepted to produce results that are more representative of surrounding aquifer conditions, as indicated in the DOH TGM and as discussed in the following.[4] The inconsistency in sampling methods can impede long-term trend analysis of aquifer conditions.

The DOH TGM cautions against sampling with bailers, because "Bailers [are] prone to agitate the water column and result in loss of VOCs or inclusion of suspended sediment in sample if not used properly." In addition, the TGM states that "Caution should also be taken in the use of a bailer to collect samples that are to be tested for highly sorptive, semi-volatile and non-volatile organic compounds and metals due to the possible suspension of sediment in the bottom of the well and bias of data intended to be compared to action levels for dissolved-phase contaminants" (DOH TGM Section 6.6.7.4).[5] For these and other reasons, according to the TGM:

[4] EPA also cautions against collecting unpurged bailer samples because "Stagnant water is subject to physiochemical changes and may contain foreign material, which can be introduced from the surface or during well construction, resulting in non-representative sample data. To safeguard against collecting a sample biased by stagnant water, specific well-purging guidelines and techniques should be followed." One of the appropriate sampling methods discussed in This EPA guidance is sampling via a low-flow sampling pump. *Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers.* https://health.hawaii.gov/heer/files/2021/07/USEPA2002b.pdf.

[5] https://health.hawaii.gov/heer/tgm/section-06/, last accessed March 15, 2023.

> "The HEER Office recommends that low-flow purging and sampling approaches be utilized whenever feasible in order to improve the representativeness of the sample data." (DOH TGM Section 6.6.5.3)[6]

Therefore, the Navy will collect samples in accordance with DOH's and EPA's recommended low-flow methodology in the Consolidated Groundwater Sampling Program to ensure sample integrity, representativeness of aquifer conditions, and compatibility with environmental action levels. Groundwater sampling will include measuring depth to groundwater and depth to well bottom from the top of casing and assessing the presence or absence of an immiscible phase. A PID will be used to record whether VOC levels in wells are above ambient conditions prior to deploying an oil/water interface probe.

Purging of the water column prior to sample collection will be conducted in accordance with Procedure I-C-3, *Monitoring Well Sampling* (DON 2015) and DOH TGM (DOH 2023) requirements, whichever are more stringent. Evaluate water samples on a regular basis (approximately every 5 minutes) during well evacuation and analyze them in the field preferably using a multi-parameter meter and flow-through cell for temperature, pH (indicates the hydrogen ion concentration – acidity or basicity), specific conductivity, dissolved oxygen (DO), oxidation reduction potential (ORP), turbidity, salinity, and TDS. Take at least five readings during the purging process. These parameters are measured to demonstrate that the natural character of the formation water has been pumped into the well. Purging will be considered complete once groundwater parameters have "stabilized" (minimum of five readings with three consecutive sets of readings within ±0.2 degree Celsius for temperature, ±0.1 standard units for pH, ±3 percent for specific conductance, ±10 percent for DO, and ±10 millivolts for redox potential). All purge water will be handled as investigation-derived waste (IDW). For wells in which very low turbidity is appropriate, such as wells screened in volcanic bedrock, turbidity should stabilize within 10 percent and be below 10 NTU.

Once purging has been completed, samples will be collected directly from the bladder pump setup at the same consistent flow rate of less than 300 milliliters per minute (mL/min). All samples will be immediately labelled according to Procedure III-E, *Record Keeping, Sample Labeling, and Chain-of-Custody* (DON 2015) and wrapped with bubble wrap or other appropriate padding to prevent breakage. Samples will then be maintained as close to 4 degrees Celsius as possible from the time of collection through transport to the analytical laboratory. All samples will be handled, stored, and shipped in accordance with Procedure III-F, *Sample Handling, Storage, and Shipping.*

Bailers will be used to collect groundwater for field observations prior to purging and sampling, in wells installed in unconfined basal aquifer conditions and are screened across the water table. These bailer samples will be collected without removing dedicated pumps. Field analysis of bailer samples will include:

- Photo-documentation, which consists of taking pictures of a clear bailer held against a white background to document evidence of signs of product or sheen.
- Groundwater headspace evaluation, as described in Section 3.3.2.

If the presence of LNAPL is observed in a monitoring well bailer, the normal groundwater analyses will not be completed. Instead portions of the water containing the sheen or product will be analyzed for fuel fingerprinting by method including saturated hydrocarbon (SHC) analysis and Petroleum Hydrocarbon Identification (PHI).

4. Methods to Evaluate Condition of Groundwater Monitoring Wells

The Navy is currently evaluating the condition of each of the groundwater monitoring wells within the Red Hill groundwater monitoring well network to ensure each is capable of producing groundwater samples that represent the conditions and quality of aquifer in which each is screened. The Navy uses dedicated pumps

[6] https://health.hawaii.gov/heer/tgm/section-06/, last accessed March 15, 2023.

at each location, and the Consolidated Groundwater Sampling Program is implemented in accordance with Section 6.6 *Groundwater Sample Collection* of the DOH TGM (DOH 2023).

4.1 TGM Well Development and Sample Purging Criteria

In accordance with the DOH TGM, the following criteria are ideally achieved during well development and low-flow purging before sampling (DOH 2023):

- The well water pH stabilizes to within plus or minus (±) 0.1 pH units for three successive readings.
- Well water temperature stabilizes to within ±1 degree Celsius.
- Well water conductivity stabilizes to within ±3 percent.
- Well water oxidation-reduction potential stabilizes to within ±10 millivolts.
- Well water dissolved oxygen concentration stabilizes to within ±0.3 mg/L.
- The well water is clear to the unaided eye, in areas where the local groundwater is known to be clear, and the turbidity readings are below 10 nephelometric NTUs.
- Turbidity stabilizes to within ±10 percent at concentrations larger than 10 NTU. In areas of known turbid groundwater, the final well water may be turbid to the eye.

Well development also includes:

- Removal of at least three well bore volumes, including filter pack (assuming 30 percent porosity).
- The sediment thickness in the well is less than 1 percent of the well screen length or less than 0.1 foot for wells with screens less than 10 feet long.

Low-flow sampling also requires:

- The purge rate should be kept low enough to ensure that the level of the water in the well does not drop more than 4 inches or 10 centimeters (Puls and Barcelona 1996). Typically, a flow rate on the order of 0.1–0.5 liter per minute is used; however, this is dependent on site-specific hydrogeology.

4.2 Well Condition Evaluation and Response Actions

The Navy will review well development and purge logs at each well in the monitoring well network based on these parameters and will identify wells that have significantly different stabilization parameters during sample purging, or significant drawdown is observed during pre-sample purging at low-flow purge rates.

The Navy will work collaboratively with the RAs to confirm that the wells can be removed from the sampling program briefly while additional assessment is conducted, with the understanding that redevelopment may require some period of time before the well returns to stable conditions observed prior to redevelopment. Those wells will be scheduled for pump removal, video camera evaluation of well casing and well screens, and assessment of sedimentation thickness. If the results of the assessment indicate significant degradation that would be improved by additional well development, the Navy will work collaboratively with the RAs to schedule a time for redevelopment that would not interfere with data gathering during the Consolidated Groundwater Sampling Program.

If, necessary, well redevelopment would follow standard operating procedures in accordance with Procedure I-C-2, *Monitoring Well Development* (DON 2015). Well development will consist of a combination of surging and bailing techniques, and pumping groundwater with a submersible pump until fine sediment particles have been removed and the water clarifies. This ensures that formation water enters the well and that the water affected by drilling is removed. The parameters of DO, ORP, pH, temperature, specific conductance, and turbidity will be monitored during the development cycle. Because DO and ORP are affected by the agitation of surging and pumping, the values obtained for these parameters during development may vary and are not representative of the aquifer water. If the development water is not relatively clear and sediment free after ten well volumes, development will be considered complete. The well development activities will be documented in the field book and on computer-generated well development forms.

in the environment. When conditions allow, the Navy will consult with the RAs to potentially transition the consolidated sampling program to normal quarterly sampling, consistent with the GW LTM program.

5. References

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Attachment 1: Justification for Monitoring Location Changes

Location	Description of Change	Reason For Change
Adit 3 Sump	Removal of monitoring location from the Consolidated Program	Not a basal groundwater location. Location was appropriate initially during the emergency response phase of the NOI for source investigation, but not appropriate for assessing risk since the NOI has transitioned to groundwater monitoring. The sump water is sourced by drainage from the tunnel and vadose zone and water samples from the sump are not representative of groundwater. Contribution to detects at Adit 3 Sump are not necessarily attributed to fuel and instead are from external sources unrelated to the fuel stored at the Facility. Sump sampling may occur intermittently during site characterization and remediation activities, as necessary.
RHMW01	Removal of monitoring well from the Consolidated Program; replaced with RHMW01R	Duplicate well with better alternative available. RHMW01 is submerged while 01R is screened across water table. RHMW01R was installed to replace RHMW01 and provide a well that can also be used to measure for the presence/absence of light nonaqueous-phase liquid.
RHMW07	Removal of monitoring well from Consolidated Program; replaced with RHMW16	Not representative; better alternative at RHMW16. Well is screened in a zone lacking strong hydraulic connection with surrounding basal aquifer, as evidenced by elevated water levels and muted response to pumping and barometric pressure changes. RHMW16, located very close to RHMW07, will be included in the sampling program and is installed in a deeper zone with a strong connection to the basal aquifer.
RHMW10	Add monitoring well to Consolidated Program	RHMW10 fills in a potential gap to the southeast from the center of the tank farm; GW LTM program already samples this well.
RHMW16A	Removal of monitoring well from the Consolidated Program	Duplicate well: RHMW16 is screened in a deeper zone with a strong hydraulic connection to the basal aquifer, while 16A is above the water table.
Hālawa Deep HDMW 2253-03	Add monitoring well to the Consolidated Program	Sampling in the vicinity of Halawa Quarry can assess whether any potential COPC migration to the northwest toward Hālawa Shaft is occurring; GW LTM program already samples this well.
OWDFMW03A and OWDFMW08A	Add monitoring wells to the Consolidated Program	These Oily Waste Disposal Facility (OWDF) wells are screened relatively close to the basal water table and are located to provide information about the quality of groundwater migrating off the northwestern boundary of the Facility.
RHP Wells	Add RHP Wells to the Consolidated Program	Red Hill Plume Delineation (“RHP”) Wells have been installed both on and off the Red Hill Facility property to expand the groundwater monitoring network and evaluate the horizontal extent of fuel impacts that were observed following the November 2021 release.
Sentinel Wells	Add Sentinel Wells to the Consolidated Program	Similar to RHP Wells, Sentinel Wells have been installed on and off the Red Hill Facility property to characterize potential contaminant migration following the November 2021 release and to understand the surrounding geology.

Consolidation and Optimization of the Groundwater Sampling Programs, Red Hill Bulk Fuel Storage Facility

Joint Base Pearl Harbor-Hickam, O‘ahu, Hawai‘i

Naval Facilities Engineering Systems Command, Hawaii, JBPHH HI

AprilMarch 2024

1. Document Management

This document supersedes the Navy’s submission of the Consolidation and Optimization of the Groundwater Sampling Programs, Red Hill Bulk Fuel Storage Facility, May 2023, in its entirety. In addition, this document may be further revised in the future to address additional requirements from the Regulatory Agencies.

2. Executive Summary

The Navy has consolidated the previous weekly Notice of Interest (NOI), quarterly Groundwater Long-Term Monitoring (GW LTM), and twice-a-month delineation and sentinel wells into one comprehensive, optimized groundwater sampling program. The new program is based on Hawai‘i Department of Health (DOH) guidance, the Red Hill Administrative Order on Consent (AOC), the Regulatory Agencies’ (RAs’) NOI requirements that expired November 13, 2022, the March 8, 2023 meeting with the U.S. Environmental Protection Agency (EPA) and DOH regarding future sampling requirements, the April 13, 2023 Red Hill Remediation Roundtable meeting, and reviews of NOI data collected and analyzed at least weekly from May 2021 through June 2023.

In May 2023, the Navy submitted the initial Consolidation and Optimization of the Groundwater Sampling Programs memorandum to the RAs, and received comments on July 31, 2023. The Navy provided responses to these comments in February 2024 and has addressed the comments in this document.

In September 2023, the Navy submitted a Final Report of Findings, Red Hill Shaft Flow Optimization Study (Flow Optimization Study) (DON 2023) to the DOH, which presented data to evaluate the feasibility of reducing the flow from U.S. Navy Well 2254-01 (also known as “Red Hill Shaft” and “RHS”) to meet the objective of long-term sustainability of the drinking water resource. Currently, RHS is pumping at a rate of approximately 4.3 million gallons per day (mgd) to induce drawdown in the aquifer in the vicinity of RHS water development tunnel. This pumped water is treated through a granular activated carbon (GAC) treatment system, then discharged under a National Pollution Discharge Elimination System (NPDES) permit to South Hālawa Stream.

On November 15, 2023, after reviewing the Final Report of Findings, the DOH submitted a letter to the Navy indicating that the study did not provide sufficient evidence that a reduction in pumping of RHS would not result in harm to human health or the environment. However, DOH recognized the importance of conserving the island’s natural resources and outlined a path forward, upon DOH approval, to reduce pumping through an increase in monitoring and evaluation once tank defueling activities—defined as removal of fuel from the tank mains and flowable tank bottoms—was completed.

The consolidated sampling approach includes the following changes:

- Integrating and coordinating all the Red Hill groundwater sampling programs into a single program to facilitate better regulatory oversight, and sampling event execution throughout and in the vicinity of the Red Hill Bulk Fuel Storage Facility.
- Revising the previous-NOI analyte list, with a focus on fuel-related analytes.
- Optimizing the previous-NOI sampling frequency from weekly to monthly to facilitate quicker laboratory turn-around times.
- Optimizing previous-NOI monitoring locations to provide comprehensive assessment of the general area.

- Standardizing the previous-NOI sample collection method to use low-flow purging and sampling methodology, as recommended in the DOH *Technical Guidance Manual for the Implementation of the Hawaii State Contingency Plan* (TGM) (DOH 2023).
- Combining the quarterly GW LTM sampling events with the corresponding monthly events to eliminate duplicate analyses, results, and effort.
- During reduced flow conditions at the Red Hill Shaft, increasing the sampling frequency to twice per month to closely monitor any changes in the groundwater quality in the basal aquifer drinking water resource that may indicate migration of contaminants under a reduced RHS average pumping rate.
- Documenting additional data evaluation procedures that will be conducted during reduced Red Hill Shaft flow conditions to identify changes in water quality that indicate uncontrolled fuel contaminant migration as light nonaqueous-phase liquid (LNAPL) or as dissolved-phase analytes.
- Documenting Outlining steps to take should any uncontrolled migration of contaminants be identified that presents a risk to human health or the environment.

3. Groundwater Sampling Program Improvements

3.1 Sampling Program Integration

To optimize the sampling programs to support accurate and timely analytical chemistry results and achieve more efficient data evaluation, the various programs have been integrated into a single, comprehensive groundwater sampling program. The Consolidated Groundwater Sampling Program requirements include the analytical suite, analytical methods, laboratory turnaround times, sampling locations, sample collection methods, and sampling frequency.

In accordance with the *Sampling and Analysis Plan, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Revision 01* (DON 2017), the U.S. Navy Environmental Restoration Program, Naval Facilities Engineering Systems Command Pacific, *Project Procedures Manual* (DON 2015), and the DOH TGM (DOH 2023), the Consolidated Groundwater Sampling Program includes NOI and GW LTM sampling of inside- and outside-tunnel sampling locations using low-flow sampling techniques. Groundwater sampling also includes measuring depth to groundwater and depth to well bottom from the top of casing and assessing the presence or absence of an immiscible phase. A photoionization detector (PID) is used to evaluate whether volatile organic compound levels in wells are above ambient conditions prior to deploying an oil/water interface probe.

Headspace monitoring for volatile organic compounds is performed at all locations, and fuel product thickness gauging is conducted at wells with screens that bracket the water table. Bailers are used to assess and photo document the presence or absence of floating product on the groundwater surface in wells installed in unconfined conditions, and sample this product for forensic analysis as described in Section 3.2. In addition, a sample aliquot shall be collected from the bailer and analyzed for volatile organic compounds (VOCs) by EPA Method 8260.

Commented: While it is stated that a groundwater sample will be collected using low-flow methods from a pump that is located approximately mid-screen, the portion of the water column that is most likely to see impacts from LNAPL is closest to the water table, thus, collecting an additional groundwater sample for VOC analysis from the water table using the bailer before the well is purged will likely aid in identifying potential fugitive migration in a timely manner.

Observations, measurements, and field parameters collected during purging prior to groundwater sampling include water level measurements, observations (i.e., water clarity and condition, evidence of free product), dissolved oxygen measurements, and groundwater sampling parameters (turbidity, specific conductance, oxidation reduction potential [ORP], pH, and temperature). Details on reporting and data evaluation procedures for field parameters are provided in Section 3.4.

Finally, the Navy has contracted primary and secondary laboratories that are certified by the Department of Defense (DoD) Environmental Laboratory Accreditation Program (ELAP) for all analyses in the program and capable of providing the requested data packages within the required turnaround time.

3.2 Analyte List

Previous NOI, GW LTM, delineation well, and sentinel well sampling has generated a substantial dataset characterizing the nature and extent of the fuel releases. The previous NOI sampling included analyses of~~f~~

chemicals of potential concern (COPCs) and additional analytes including chemicals that are not associated with fuels. Therefore, this document presents the notification of changes to the expired NOI sampling program and integration of the various groundwater monitoring programs into one overall program based on the substantial body of laboratory results, DOH guidance, and the composition of the fuels, similar to the process employed under the AOC. Table 1 provides a summary of the analytical list for the consolidated groundwater monitoring program, which includes monthly analytes, analytical methods, and screening criteria. Table 1 includes COPCs related to middle distillates, fuel additives, polynuclear (polycyclic) aromatic hydrocarbons (PAHs), lead scavengers, natural attenuation parameters (NAPs), and general water chemistry parameters. In addition, this list includes field parameters conductivity and total dissolved solids (TDS), which will be verified quarterly by a certified laboratory. Other field parameters are not stable outside of their natural conditions; therefore, they will not be verified in this manner.

The following ten primary COPCs were established in February 2016 (EPA Region 9 and DOH 2016) for the AOC investigations and the GW LTM program and will remain the same for the Consolidated Groundwater Sampling Program:

- Total petroleum hydrocarbons (TPH)-gasoline range organics (TPH-g), TPH-diesel range organics (TPH-d), and TPH-oil range organics (TPH-o)
- Naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene
- Benzene, toluene, ethylbenzene, and total xylenes (BTEX)

During a March 8, 2023 collaboration meeting between the Navy, EPA, and DOH, the Navy presented a list of reduced analytes for NOI sampling. The Navy showed that including non-fuel-related analytes to the target analyte list increased processing time for commercial laboratories, data validators, and shipping without adding valuable information to identify and characterize potential fuel release impacts. This contributed to delays in validation, reporting, and timely analyses of results and impeded rapid assessment of impacts to groundwater and the ability to quickly respond to changes in groundwater conditions. Although it was valuable during emergency response activities in late 2021 and early 2022, sampling and analysis of these non-fuel analytes ran counter to DOH TGM guidance of "Do not simply list chemicals associated with specific laboratory methods that will be used to test samples collected at the site"[1]; as such, certain analytes were previously discontinued from the Consolidated Groundwater Sampling Program.

Laboratory results from the comprehensive set of groundwater monitoring events show inconsistent, low concentrations of non-fuel analytes and confirm that the analytes used as the AOC and GW LTM COPCs are appropriate. However, out of an abundance of caution, additional PAHs analyzed for previous-NOI sampling will also continue as part of the Consolidated Groundwater Sampling Program because some PAHs are potentially associated with jet fuels at low concentrations. The Navy also previously agreed to add non-volatile dissolved organic carbon, and it has been added to the NAP list for the Consolidated Groundwater Sampling Program.

[1] https://health.hawaii.gov/heer/tgm/section-06/.

Table 1: Consolidated Groundwater Sampling Program

Parameter	Analytical Method	Analyte(s)	DW Promulgated Criterion (EPA MCL) (µg/L)	Tap Water Screening Criterion (EPA RSL) (µg/L)	GW Screening Criterion (DOH EAL) (µg/L)	GW-LTM Parameters (Added Quarterly)	Consolidated Parameters [a]
TPH	EPA 8015M	TPH-g	—	—	300	—	X
	EPA 8015M	TPH-d	—		400	X [b]	X
		TPH-o	—	—	500	X [b]	X
TPH Calculation	EPA 8015M	Reported as a non-overlapping sum of TPH-g/d/o with BTEX and methylnaphthalenes subtracted	—	—	—	—	X
TEH [e]	EPA 8015M	Total Extractable Hydrocarbons	—	—	—	X	—
TPH with SGC [c]	EPA 3630/8015	TPH-d	—	—	—	X [b]	X
		TPH-o	—	—	—	X [b]	X
VOCs	EPA 8260 GC/MS	Benzene	5	0.46ca	5	—	X
		Ethyl Benzene	700	1.5ca	30	—	X
		Toluene	1,000	1,100	40	—	X
		Total Xylenes	10,000	190	20	—	X
		1,2,4- Trimethylbenzene	—	56	—	—	X
		1,3,5- Trimethylbenzene	—	60	—	—	X
AOC / GW LTM PAHs	EPA 8270 GC/MS SIM	1-Methylnaphthalene	—	1.1ca	10	—	X
		2-Methylnaphthalene	—	36	10	—	X
		Naphthalene	—	0.12ca	17	—	X
PAHs	EPA 8270 GC/MS SIM	Acenaphthene	—	530	20	—	X
		Acenaphthylene	—	—	240	—	X
		Anthracene	—	1,800	0.18	—	X
		Benzo(a)anthracene	—	0.03ca	0.029	—	X
		Benzo(a)pyrene	0.2	1.8	0.2	—	X
		Benzo(b)fluoranthene	—	0.25ca	0.22	—	X
		Benzo(g,h,i)perylene	—	—	0.13	—	X
		Benzo(k)fluoranthene	—	2.5ca	0.4	—	X
		Chrysene	—	25ca	1	—	X
		Dibenzo(a,h)anthracene	—	0.025ca	0.022	—	X
		Fluoranthene	—	800	13	—	X
		Fluorene	—	290	240	—	X
		Indeno(1,2,3-cd)pyrene	—	0.25ca	0.095	—	X
		Phenanthrene	—	—	210	—	X
		Pyrene	—	120	68	—	X

Parameter	Analytical Method	Analyte(s)	DW Promulgated Criterion (EPA MCL) (µg/L)	Tap Water Screening Criterion (EPA RSL) (µg/L)	GW Screening Criterion (DOH EAL) (µg/L)	GW-LTM Parameters (Added Quarterly)	Consolidated Parameters [a]
Fuel Additives	EPA 8270	Phenol	—	5,800	300	—	X
	EPA 8270	2-(2-Methoxyethoxy) Ethanol	—	800	800	X	—
Lead Scavengers	EPA 8011	1,2-Dibromoethane	0.05	0.0075ca	0.04	—	X
	EPA 8260 GC/MS	1,2-Dichloroethane	5	0.17ca	5	—	X
NAPs	SM 3500-Fe	Ferrous Iron	—	—	—	—X	X—
	RSK 175M	Methane	—	—	—	—	X
	EPA 300.0	Nitrate, Sulfate, Chloride	—	—	—	—X	X—
	EPA 353.2	Nitrate-Nitrite as Nitrogen	—	—	—	—X	X—
	SM 2320	Carbonate, Bicarbonate, and Total Alkalinity	—	—	—	—X	X—
	EPA 9060A	TOC	—	—	—	—	X
	EPA 9060A	NVDOC	—	—	—	—	X
General Chemistry	EPA 300.0 [d]	Bromide, Chloride, Fluoride, Nitrate, Sulfate	—	—	—	X	—
	EPA 6010C [d]	Calcium, Magnesium, Manganese, Potassium, Sodium	—	—	—	X	—
	SMWW4500-Si-D / SIO2-C [d]	Dissolved Silica, Total Silica	—	—	—	X	—
	Method 120.1 and 2510B	Conductivity	—	—	—	X	—
	Method SM2540C-2015	Total Dissolved Solids	—	—	—	X	—

Notes:
As additional COPCs are identified (e.g., cleaning agents, additives), analytes will be added to the Red Hill Consolidated Sampling Program.
µg/L micrograms per liter
BTEX benzene, toluene, ethylbenzene, and total xylenes
ca Carcinogenic risk based screening level
DOH EAL Hawaii Department of Health Environmental Action Level: Fall 2017 (https://health.hawaii.gov/heer/guidance/ehe-and-eals/)
DW drinking water
GW groundwater
EPA MCL US Environmental Protection Agency National Primary Drinking Water Regulations, Maximum Contaminant Level (https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations)
EPA RSL Regional Screening Levels (RSLs): November 2023 (https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables)
mgd million gallons per day
NAP natural attenuation parameter
NVDOC non-volatile dissolved organic carbon
PAH polynuclear (polycyclic) aromatic hydrocarbon
SGC silica gel cleanup
TPH-d total petroleum hydrocarbons - diesel range organics
TPH-g total petroleum hydrocarbons - gasoline range organics
TPH-o total petroleum hydrocarbons - residual range organics
VOC volatile organic compound
— not applicable
X Compound is included in the respective groundwater sampling program.
[a] Collected monthly during 4.3-mgd pumping and twice per month during reduced pumping at the Red Hill Shaft.
[b] Uses 3510 extraction method for Consolidated. Additional 3520 for Quarterly.
[c] Silica Gel Cleanup will be conducted on samples where TPH-d and TPH-o are detected.
[d] Monitored on the first GW LTM event of a new well. Chloride, sulfate and nitrate will also continue to be monitored and evaluated quarterly with the NAPs.
[e] TEH is reported for the total range integrated for the sample based on the TPH-d method.

This consolidation plan combines the GW LTM event that occurs every third month with the previous NOI sampling event that occurs at the same time. This combined consolidated quarterly event will consist of all the previous-NOI sampling parameters and also include the additional GW LTM parameters listed below and shown in Table 1:

- TPH-d and TPH-o using the 3520 extraction method
- Fuel additives 2-(2-methoxyethoxy) ethanol
- NAPs, including ferrous iron, nitrate, sulfate, chloride, nitrate-nitrite as nitrogen, carbonate, bicarbonate, and total alkalinity
- The general chemistry parameters total dissolved solids and conductivity
- The general chemistry parameters calcium bromide, fluoride, magnesium, manganese, potassium, and sodium, which will be sampled once during the first quarterly event associated with a new well

In addition to dissolved groundwater COPCs, the Navy will conduct sampling and analysis of any fuel product recovered during the bailer sampling conducted prior to groundwater sampling. Product or sheen samples will be collected from the bailer in three 40 milliliter (ml) volatile organic analysis (VOA) vials and sent under chain of custody to a non-DoD-certified forensics laboratory for Saturated Hydrocarbon (SHC) and Petroleum Hydrocarbon Identification (PHI) analysis, including qualitative narrative, consisting of:

- Modified Method 8015M approach for extractable hydrocarbons.
- Method is applicable to soil, aqueous, or free product samples.
- Uses the same 80-minute chromatographic runtime encompassing n-alkane hydrocarbons and selected isoprenoids in the C9 through C40 range.
- Data for 32 individual n-alkanes and five isoprenoids are reported, as well as the total concentrations of saturated and total petroleum hydrocarbons.
- Will include a qualitative narrative.

Based on the results of this analysis, a more detailed evaluation may be conducted. Examples of this could include a comparison of current analytical results to historical results, evaluation of tentatively identified compounds, and/or biogenic metabolites, with respect to the Facility's operational history.

3.3 OPTIMIZE SAMPLING FREQUENCY

3.3.1 Monthly Sampling

As discussed during the March 8, 2023 collaboration meeting, weekly NOI sampling conducted after the 2021 release events effectively captured the increase and subsequent decrease of COPC concentrations in the monitoring wells following the releases, which provided an understanding of the impacts of those releases. In addition, the data showed that concentrations have significantly decreased and stabilized, in most cases returning to non-detectable or within historical ranges. As a result, weekly sampling frequency no longer provides added information that was not already captured by monthly (or quarterly) sampling. Reducing the sampling frequency to monthly (at full-time operation of the RHS GAC treatment system) allows for groundwater characterization and trend analyses without sacrificing accuracy, and reduces processing time for the commercial laboratories, the data validators, and sampling and shipping. The monthly sampling frequency is in accordance with the DOH TGM, which states: "Long-term monitoring of groundwater should be carried out at a frequency adequate to assess trends in potential environmental concerns and guide and monitor the effectiveness of remedial actions" (DOH TGM Section 6.6.8.5).[2]

3.3.2 Reduced Red Hill Shaft Pumping Rate Sampling Frequency

In accordance with DOH's November 15, 2023 letter, the Navy will implement reduced pumping and GAC-filtered discharge of water from RHS into South Hālawa Stream under strict evaluation measures to ensure fuel-related contaminants in the basal aquifer—a potable water resource—do not present an unacceptable risk to human health or the environment. The actions listed in Section 3.4 will be taken to ensure that potential migration of contaminants under a reduced RHS average pumping rate are identified in a timely manner.

In addition, the NPDES permit requires that RHS discharge water be sampled when the pumps are turned on after a shutoff period of 24 hours or greater. Details of this requirement are provided in *Red Hill Shaft Recovery Plan NPDES Compliance Sampling Protocol*, March 27, 2023 (IDWST 2023).

Sampling and analysis frequency will increase from monthly to twice per month during reduced pumping. The twice per month sampling events will be conducted with no less than 10 calendar days between the preceding or succeeding sampling events. In consultation with the Regulatory Agencies, the Navy may submit approval requests to adjust the sampling frequency based on the results of data evaluation.

Turnaround times for analytical results and data validation, field checks including headspace testing, and free product gauging will be expedited to allow timely decision-making for response actions based on these results. All groundwater samples will be scheduled so that they can be shipped to the laboratory on the day they are collected, with the objective of minimizing the transit time to 1 calendar day. In some cases, transit time may necessarily be longer in duration based on sampling times, transportation options, weather delays, etc. Samples will be analyzed on an expedited preliminary result turnaround of 5 business days (upon receipt at the laboratory) and will be validated on an expedited seven business day turnaround (upon issuance of the analytical report)~~, when practical~~. If issues are identified that require additional consultation with the project laboratory, final validation turnaround time will be extended to allow necessary revisions and or laboratory clarifications to the laboratory reports and data. This schedule will provide for a review of the 5-business-day preliminary analytical data prior to the next scheduled sampling event. The goals of these expedited turnaround times are to allow the Navy to meet ~~regulatory requests to~~the following:

- Submit tabulated results in spreadsheet format and laboratory reports, validated or not, within ~~45 calendar days after sample shipment to the laboratory or~~ 7 calendar~~7~~ days ~~after~~ of receipt of initial analytical results from the laboratory~~, whichever occurs first~~.
- Submit time-series plots within 10 calendar days of receipt of initial analytical results from the laboratory.
- Submit validated tabulated results in spreadsheet format and laboratory reports within 30 calendar days after receipt of analytical results from the laboratory.
- Provide the Regulating Agencies with an update identifying the following items on a weekly basis:
  - Any indication of potential fugitive migration
  - The results of the most recent trend analysis
  - Any detections that may be statistically significant above background concentrations
  - Any significant field observations
  - If potential fugitive migration has been identified, a list of what measures are currently being taken.

Commented: We understand that preliminary data has not been validated and may be subject to change following data validation, but as this data is being used for decision making, it must be provided to the RAs for review in a timely manner.

[2] https://health.hawaii.gov/heer/tgm/section-06/.

The standard field checks described in Section 3.1 will also detect potential contamination. Headspace monitoring will be performed at all locations, and fuel product thickness gauging will be conducted at wells with screens that bracket the water table. Bailers will be used to assess and photo-document the presence or absence of floating product on the groundwater surface in wells installed in unconfined conditions.

In addition, the Navy will collect and evaluate groundwater headspace, which consists of collecting liquid samples from the water table using a bailer, a portion of the liquids will be transferred to a clean 1-liter jar, which will be capped and shaken, then the headspace will be measured with a handheld PID. This concentration is representative of LNAPL/dissolved total volatile organic compound (VOC) concentrations and will be used in lieu of headspace readings immediately above the water table.

~~[2] https://health.hawaii.gov/heer/tgm/section-06/.~~

Table 2 summarizes the frequency for each sampling location monitored twice per month, monthly, and quarterly under the Consolidated Groundwater Sampling Program. As additional monitoring wells are installed, they will be incorporated at similar frequencies as the existing wells.

Table 2: Summary of Consolidated Plan Sampling Frequency by Program

Sampling Program	HDMW2253-03	RHMW2254-01	RHP01	RHP02	RHP03	RHP04A	RHP04B	RHP04C	RHP05	RHP06	RHP07	RHP08	RHMW01R	RHMW02	RHMW03	RHMW04	RHMW05	RHMW06	RHMW08	RHMW09	RHMW10
2015 AOC GW LTM	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
Consolidated Sampling	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Consolidated Sampling (Reduced GAC Operation)	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M

Sampling Program	RHMW11	RHMW12A	RHMW13	RHMW14	RHMW15	RHMW16	RHMW17	RHMW18	RHMW19	RHMW20	NMW24	NMW25	NMW26	NMW30	NMW32	NMW33	NMW34	OWDFMW03A	OWDFMW08A	RHS-Pump
2015 AOC GW LTM	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
Consolidated Sampling	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Consolidated Sampling (Reduced GAC Operation)	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M

Notes:
Q Quarterly
M Monthly
2M Twice Monthly

Table 3 provides the well screen depth interval and pump intake depth below top of casing (ft btoc) for each well to be sampled.

Table 3: Monitoring Well Screen Intervals and Dedicated Low Flow Bladder Pump Intake Depths

Monitoring Well	Top of Screen Depth (ft btoc) [a]	Bottom of Well Screen Depth (ft btoc) [a]	Pump Intake Depth (ft btoc) [a]
RHMW01R	74	94	89
RHMW02	84	99	92
RHMW03	102	117	110
RHMW04	290	305	298
RHMW05	83	90	89
RHMW06	230	260	245
RHMW08	281	311	303
RHMW09	367	397	382
RHMW10	467	497	481
RHMW11 Zone 5	N/A	N/A	285 [b]

Monitoring Well	Top of Screen Depth (ft btoc) [a]	Bottom of Well Screen Depth (ft btoc) [a]	Pump Intake Depth (ft btoc) [a]
RHMW12A	413	433	423
RHMW13 Zone 4 [c]	N/A	N/A	285 [b]
RHMW13 Zone 5a [c]	N/A	N/A	243 [b]
RHMW14 Zone 3	N/A	N/A	325 [b]
RHMW15 Zone 5a	N/A	N/A	297 [b]
RHMW16	488	508	498
RHMW17	223	253	238
RHMW18	592	622	614
RHMW19	415	445	437
RHMW20	223	253	238
RHMW2254-01	N/A	N/A	94
HDMW2253-03	N/A	N/A	252
RHP01	125	155	145
RHP02	110	140	127
RHP03	104	134	124
RHP04A	130	160	146
RHP04B	301	321	311
RHP04C	486	506	496
RHP05	204	234	218
RHP06	239	269	259
RHP07	74	94	88
RHP08	276	306	294
NMW24	80	110	100
NMW25	81	211	201
NMW26	741	771	760
NMW30	282	312	302
NMW32	161	191	181
NMW33	117	137	129
NMW34	56	86	76
OWDFMW03A	141	161	153
OWDFMW08A	140	160	152
RHS-Pump [d]	N/A	N/A	~100

Notes:
ft btoc feet below top of casing
N/A not applicable
[a] Approximate depth rounded to the nearest foot.
[b] Multilevel well sample port depth (ft btoc).
[c] Multilevel well RHMW13 Zone 4 is sampled when there is insufficient sample volume available from Zone 5a.
[d] This is a sampling port in the Red Hill Shaft pump station representing influent to the GAC treatment system.

3.4 DATA EVALUATION AND ACTIONS TAKEN IF POTENTIAL MIGRATION OF CONTAMINANTS IS IDENTIFIED DURING REDUCED PUMPING

Sample collection and expedited shipping, analysis, and review will be scheduled and performed to facilitate early evaluation of field data and preliminary analytical data, such that any desired revisions to the next sampling event can be planned and implemented with haste. Trend analyses will be conducted at a minimum on wells located within the Facility property boundary. If trends indicate the potential for contaminants to migrate beyond the Facility boundary, offsite wells may shall be included.

3.4.1 Rationale for Evaluation of Field Parameters and Natural Attenuation Parameters for Plume Stability

The observation of fuel product as an immiscible layer of LNAPL in any well is the most direct real-time correlation to plume stability when evaluating parameters measured with field instruments during sampling and purging (field parameters). However, fuel product is lighter than water and would not be expected in wells screened below the basal aquifer potentiometric surface; therefore, basal aquifer wells with top of screen below the static water level are not expected to have LNAPL as an evaluation parameter.

Another field parameter that is directly related to the presence of fuel-related VOCs in groundwater is groundwater headspace as described in Section 3.3.2. Highly volatile fuels such as aviation gasoline have not been stored at the Facility since before 1970. Since 1970, fuels stored in the Facility have been middle distillates, which have much lower concentrations of VOCs in product. To date, the Navy has collected headspace samples from the top of casing at each well sampled. A calibrated PID sample is collected from the vapor gathered at the top of the well casing immediately after the well cap is first removed from the well prior to purging and sampling. These results have not been strongly correlated to hydrocarbons in groundwater at the tank farm. For example, from 21 groundwater sampling events collected between June 15, 2023 and January 19, 2024, PID headspace readings at the tank farm wells with consistent TPH in groundwater were negligible, as show in Table 4.

Table 4: Field Parameter Summary Statistics for Selected Wells

Well ID	RHMW01R	RHMW02	RHMW03	RHMW10	RHMW16	RHP03
Elevated TPH in Groundwater	Yes	Yes	Yes	No	No	No
Top of Casing Headspace (ppmv)						
Minimum	0.0	0.0	0.4	0.0	0.0	0.0
Maximum	0.9	0.30	1.50	0.20	0.20	0.30
Average	0.09	0.06	0.58	0.02	0.02	0.02
Standard Deviation	0.21	0.10	0.26	0.05	0.05	0.07
Dissolved Oxygen (mg/L)						
Minimum	0	0	0.4	8.1	8.28	3.05
Maximum	0.62	0.25	1.50	8.77	9.21	5.30
Average	0.47	0.11	0.58	8.41	8.65	4.60
Standard Deviation	0.12	0.10	0.26	0.17	0.23	0.54
ORP (mV)						
Minimum	-275	-304	0.4	104	104	80
Maximum	0	-79	1.50	310	310	277
Average	-81.87	-163	0.58	235	235	202
Standard Deviation	69.10	85	0.26	64	64	60

Note: Units in parts per million by volume from field photoionization detectors from top of casing headspace measurements.

The Navy will begin evaluating bailer headspace VOC measurement as described Section 3.3.2 and, based on the results when compared to TPH concentrations in groundwater, may use these as supporting real-time indicators of plume stability.

Biodegradation of fuel hydrocarbons brings about measurable changes in the chemistry of groundwater in the affected area. By measuring these changes, natural attenuation and biodegradation of hydrocarbons can be assessed and the stability of the dissolved hydrocarbon groundwater plume can be estimated. The following field parameters measured during groundwater purging before sampling are indicative of biodegradation (AFCEE 1995):

- Dissolved oxygen is the most thermodynamically favored electron acceptor used in the biodegradation of fuel hydrocarbons. Dissolved oxygen concentrations are used to estimate the mass of contaminant that can be biodegraded by aerobic processes. Decreasing trends of dissolved oxygen may indicate hydrocarbons are undergoing biodegradation hydraulically upgradient from the sample point.
- ORP reactions in groundwater contaminated with petroleum hydrocarbons are usually biologically mediated, and therefore, the redox potential of a groundwater system depends upon and influences rates of biodegradation. Redox potential may be used to provide real-time data on the location of the contaminant plume, especially in areas undergoing anaerobic biodegradation indicated by low or negative ORP values.
- Temperature of the groundwater increases due to exothermic natural attenuation processes. Groundwater temperature increases above background may indicate active natural attenuation processes (biodegradation) and potential plume migration.

In addition to the field parameters above, the following list of electron acceptors and metabolic byproducts may also be indicative of hydrocarbon degradation and trend analysis can provide information on the plume stability, biodegradation potential, and biodegradation activity:

- Ferrous iron and methane are metabolic byproducts of biodegradation of hydrocarbons. During anaerobic degradation, the concentrations of these parameters will be seen to increase to levels above background. Increases in ferrous iron and methane in groundwater may be indicative of anaerobic degradation in upgradient locations.
- Nitrate and dissolved oxygen are electron acceptors that are generally used during biodegradation of dissolve hydrocarbons at rates that are instantaneous relative to the average advective transport velocity of groundwater.
- Sulfate and iron (III) in areas with dissolved fuel-hydrocarbon contamination are used at rates that are slow relative to rates of dissolved oxygen and nitrate utilization. This results in the consumption of these compounds at a rate that could be slower than the rate at which they are replenished by advective flow processes and plumes of contamination can extend away from the source.
- Alkalinity increases in the groundwater due to the production of carbon dioxide by microbial respiration that is converted to carbonate. Aerobic and anerobic (primarily nitrate and sulfate reduction) natural attenuation (biodegradation) result in alkalinity increases that are nearly instantaneous.

Understanding how these parameters change laterally can provide an estimate of the plume location, and the general groundwater flow direction. For example, electron acceptors (dissolved oxygen, nitrates, sulfates), which are used during hydrocarbon biodegradation, are expected to be at higher concentrations upgradient of the dissolved hydrocarbon plume than concentrations downgradient. Metabolic byproducts, such as methane, and ferrous iron are generated during hydrocarbon biodegradation and are expected to be at lower concentrations upgradient of the plume than concentrations downgradient.

Understanding how these parameters change over time can provide an estimate of plume stability. If metabolic byproduct concentrations are increasing and electron acceptor concentrations are decreasing over time at a well, it may indicate that the plume is expanding in that direction, or increasing in hydrocarbon concentration upgradient, and indicating an increase in metabolic activity. Conversely, if metabolic byproducts are decreasing over time and electron receptors are increasing, it may indicate that the plume is contracting upgradient from the sampled well.

There are no regulatory standards used to evaluate these electron acceptor and metabolic byproduct trends. These trends are not absolute evidence of contaminant migration or degradation without primary observations of changes in contaminant concentrations, as there may be other geochemical processes in the aquifer that are causing the observed trends.

3.4.2 Field Parameters

To identify any changing trends, field parameter data from ~~selected~~ all wells will be tabulated upon collection (twice per month) and compared against the historical data set for the individual well and also the comprehensive data set for all wells.

These data will be provided to the RAs through the Red Hill Joint Base Pearl Harbor-Hickam Environmental Data Management System (EDMS)[3].

Selected Field Parameters in a Single Well Comparison:

1. Selected field parameters to evaluate uncontrolled contaminant migration are:
   a. Selected purge parameters: dissolved oxygen, ORP
   b. Bailer headspace VOCs
   c. Presence of LNAPL and thickness
2. ~~Each parameter (except for LNAPL thickness) will be normalized to the average value (calculated from historical levels using data collected since January 2022).~~
3. ~~3.~~2. ~~The~~A all ~~normalized~~ field parameters and actual LNAPL thickness will be plotted on an individual~~single~~ time- series charts for each well for visual trend analysis.
4. ~~4.~~3. These field parameter trend charts will be qualitatively assessed and compared to TPH groundwater concentrations to develop correlations to support plume stability assessment.
5. ~~5.~~4. Deliverables:
   a. Field parameter trend charts will be submitted to RAs via EDMS in Portable Document Format (*.pdf) by well and sampling date.
   b. The format of the file name will be: Consolidated GW by Well, Field Trend Analysis – <DDMMMYY>.
   c. The files will be stored in EDMS at Library->Field Activity Reports->Wells.

3.4.3 Natural Attenuation Parameters

Similarly, ~~selected~~ all unvalidated NAPs (including ferrous iron, methane, nitrate, sulfate, nitrate-nitrite as nitrogen, and total organic carbon) will be tabulated and plotted in time-series charts and compared to field parameters, general chemistry, and contaminant concentrations to determine any changes or migration patterns associated with biogeochemical processes. These data will be provided to the RAs through EDMS as unvalidated NAP trend results. Once the data have been completely validated, the trend analyses will be updated, if necessary, with any revised data points, and resubmitted to the regulators through EDMS as validated NAP trend results.

- Deliverables will be in *.pdf format.
- The format of the file name will be:
  - Consolidated GW by Well, Unvalidated NAP Trend Analysis – <DDMMMYY> for unvalidated data
  - Consolidated GW by Well, Validated NAP Trend Analysis – <DDMMMYY> for validated data
- Files will be stored in EDMS at Library->Field Activity Reports->Wells

3.4.4 Chemicals of Potential Concern

Twice per month, first unvalidated followed by validated groundwater concentrations of specified COPCs (TPH-g, TPH-d, TPH-o, naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene) will be tabulated and plotted in time-~~-~~series charts and reviewed for any potential anomalies or trends that may be indicative of uncontrolled fuel contaminant migration. When trend analysis from data indicates the potential for uncontrolled contaminant

[3] https://synectics.net/

migration, subject matter experts will review the associated TPH chromatographs to verify that the results are from fuel-related analytes. SGC analyses will also be used to evaluate TPH degradation patterns. These data will be provided to the RAs through EDMS at first as unvalidated trend results. Once the data have been completely validated, the trend analyses will be updated, if necessary, with any revised data points and resubmitted to the RAs through EDMS as validated trend results.

- Deliverables will be in *.pdf format.
- The format of the file name will be:
  - Consolidated GW by Well, Unvalidated COPC Trend Analysis – <DDMMMYY> for unvalidated data
  - Consolidated GW by Well, Validated COPC Trend Analysis – <DDMMMYY> for validated data
- Files will be stored in EDMS at Library->Field Activity Reports->Wells.

3.4.5 Evaluating Multiple Lines of Evidence for Response Actions

Multiple lines of evidence will be used to evaluate potential uncontrolled fuel contaminant migration. Potential/primary indications of uncontrolled migration of fuel contaminants may include:

1. Observations of LNAPL in a monitoring well.
2. Multiple ~~subsequent~~consecutive significant observations ~~(>~~ (two observations or more) of COPCs ~~naphthalene, 1-methylnaphthalene, or 2-methylnaphthalene~~ in a monitoring well. A significant result is defined as ~~a~~ one standard deviation above average background (calculated from historical levels using data collected from~~since~~ ~~January 2022~~September 2023 until the initiation of the reduction of the average pump rate of the RHS GAC system) ~~increase above the immediately preceding result~~. For wells in which these compounds have not been observed, a single observation will be considered significant.
3. ~~Multiple subsequent observations (> two observations) of TPH-d or TPH-o in a monitoring well, increasing by one standard deviation (calculated from historical levels using data collected since January 2022) above the immediately preceding results.~~A single observation of any COPC in a monitoring well at a concentration that is two standard deviations above average background concentration (calculated from historical levels using data collected from September 2023 until the initiation of the reduction of the average pump rate of the RHS GAC system).
4. Observations of TPH-d or TPH-o at concentrations exceeding the DOH EAL in a monitoring well that historically (using data collected from~~since~~ ~~January 2022~~September 2023 until the initiation of the reduction of the average pump rate of the RHS GAC system) has not seen such an exceedance.
5. Any sufficiently overt data trend in onsite wells (groundwater headspace test, field parameters, etc.) that may suggest mass and uncontrolled migration of contamination, noting the occurrence of LNAPL and fluctuations in dissolved-phase contamination within the source zone and wells proximate to RHS may reasonably be expected in response to changed flow conditions and should not automatically be evaluated as uncontrolled migration.

Upon observing one or more lines of evidence from verified field observations or unvalidated laboratory data of uncontrolled fuel-related contaminant migration that present an unacceptable risk to human health or the environment, the Navy will ~~consult with~~notify the RAs within 24 hours. The notification shall include ~~to determine~~ appropriate actions the Navy proposes to implement in accordance with local, State, and Federal regulations for approval by the Regulating Agencies. Proposed r~~R~~esponse actions may include:

- ~~Increase RHS pumping and GAC-filtered discharge rate to increase groundwater containment within the vicinity of RHS~~Evaluating other indicators (e.g. dissolved oxygen, temperature, other COPCs, etc.) for subtle changes that when evaluated wholistically may indicate potential fugitive migration.

- Illustrate the data on a map to evaluate potential changes spatially in a wholistic manner.
- Increase sampling frequency (at the subject well and/or surrounding wells) to further evaluate the identified potential trends/increases.
- Evaluate migration trends.
- Increase RHS pumping and GAC-filtered discharge rate to increase groundwater containment within the vicinity of RHS.
- Evaluate other remedial response actions (such as pump and treat or pump and containerize systems).
- Conduct a remedial alternatives analysis in accordance with Section 18.5.12 of the DOH TGM (DOH 2023).

3.5 OPTIMIZE MONITORING LOCATIONS

Sampling locations in each program were evaluated and locations were retained or excluded to optimize future sampling. Locations were removed based on their representativeness of groundwater conditions, duplication of (e.g., close proximity to) other sampling locations, anomalous water levels (elevated) and response to pumping conditions or other factors that differ from surrounding wells, or inclusion in another groundwater sampling program. Figure 1 shows the groundwater monitoring well sampling locations. Table 2 and Figure 1 respectively list and illustrate the locations of wells included and planned for in this Consolidated Groundwater Sampling Program. Additional wells will also be included in this sampling program as they are planned and installed. In addition to groundwater monitoring wells, a groundwater sample will be collected from a sampling port located within the RHS pump station, which will represent groundwater that has been pumped through the RHS pumps, prior to entering the NPDES GAC treatment system. This location is designated as RHS-Pump and addresses consistency and repeatability concerns associated with previously sampled pre-chlorination sampling locations that are no longer in the water flow since RHS was removed from the public water supply system.

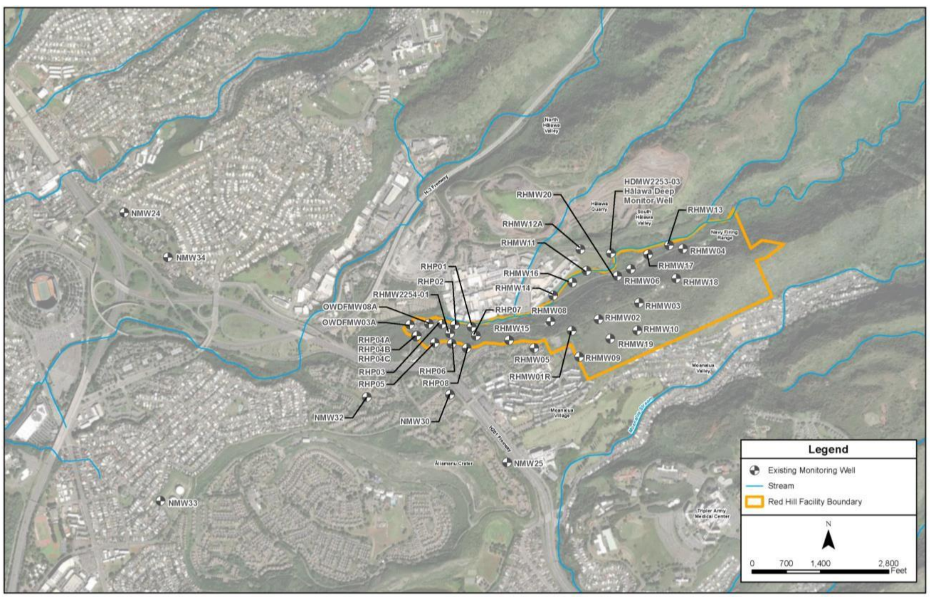

Figure 1: Groundwater Monitoring Well Sampling Locations

3.6 STANDARDIZE SAMPLE COLLECTION METHOD

NOI sampling was previously conducted using both unpurged bailer and low-flow (pump) purging. No fuel product has been observed at monitoring locations to date with the exception of RHS shortly after the November 2021 release event. The use of different sampling methods have resulted in notable differences in analyte concentrations between the NOI and GW LTM programs. The low-flow sampling method is widely accepted to produce results that are more representative of surrounding aquifer conditions, as indicated in the DOH TGM and as discussed in the following.[4] The inconsistency in sampling methods can impede long-term trend analysis of aquifer conditions.

The DOH TGM cautions against sampling with bailers, because "Bailers [are] prone to agitate the water column and result in loss of VOCs or inclusion of suspended sediment in sample if not used properly." In addition, the TGM states that "Caution should also be taken in the use of a bailer to collect samples that are to be tested for highly sorptive, semi-volatile and non-volatile organic compounds and metals due to the possible suspension of sediment in the bottom of the well and bias of data intended to be compared to action levels for dissolved-phase contaminants" (DOH TGM Section 6.6.7.4).[5] For these and other reasons, according to the TGM:

> "The HEER Office recommends that low-flow purging and sampling approaches be utilized whenever feasible in order to improve the representativeness of the sample data." (DOH TGM Section 6.6.5.3)[6]

Therefore, the Navy will collect samples in accordance with DOH's and EPA's recommended low-flow methodology in the Consolidated Groundwater Sampling Program to ensure sample integrity, representativeness of aquifer conditions, and compatibility with environmental action levels. Groundwater sampling will include measuring depth to groundwater and depth to well bottom from the top of casing and assessing the presence or absence of an immiscible phase. A PID will be used to record whether VOC levels in wells are above ambient conditions prior to deploying an oil/water interface probe.

Purging of the water column prior to sample collection will be conducted in accordance with Procedure I-C-3, *Monitoring Well Sampling* (DON 2015) and DOH TGM (DOH 2023) requirements, whichever are more stringent. Evaluate water samples on a regular basis (approximately every 5 minutes) during well evacuation and analyze them in the field preferably using a multi-parameter meter and flow-through cell for temperature, pH (indicates the hydrogen ion concentration – acidity or basicity), specific conductivity, dissolved oxygen (DO), oxidation reduction potential (ORP), turbidity, salinity, and TDS. Take at least five readings during the purging process. These parameters are measured to demonstrate that the natural character of the formation water has been pumped into the well. Purging will be considered complete once groundwater parameters have "stabilized" (minimum of five readings with three consecutive sets of readings within ±0.2 degree Celsius for temperature, ±0.1 standard units for pH, ±3 percent for specific conductance, ±10 percent for DO, and ±10 millivolts for redox potential). All purge water will be handled as investigation-derived waste (IDW). For wells in which very low turbidity is appropriate, such as wells screened in volcanic bedrock, turbidity should stabilize within 10 percent and be below 10 NTU.

Once purging has been completed, samples will be collected directly from the bladder pump setup at the same consistent flow rate of less than 300 milliliters per minute (mL/min). All samples will be immediately labelled according to Procedure III-E, *Record Keeping, Sample Labeling, and Chain-of-Custody* (DON 2015) and wrapped with bubble wrap or other appropriate padding to prevent breakage. Samples will then be maintained as close to 4 degrees Celsius as possible from the time of collection through transport to the analytical laboratory. All samples will be handled, stored, and shipped in accordance with Procedure III-F, *Sample Handling, Storage, and Shipping.*

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[4] EPA also cautions against collecting unpurged bailer samples because "Stagnant water is subject to physiochemical changes and may contain foreign material, which can be introduced from the surface or during well construction, resulting in non-representative sample data. To safeguard against collecting a sample biased by stagnant water, specific well-purging guidelines and techniques should be followed." One of the appropriate sampling methods discussed in This EPA guidance is sampling via a low-flow sampling pump. *Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers.* https://health.hawaii.gov/heer/files/2021/07/USEPA2002b.pdf

[5] https://health.hawaii.gov/heer/tgm/section-06/, last accessed March 15, 2023.

[6] https://health.hawaii.gov/heer/tgm/section-06/, last accessed March 15, 2023.

Bailers will be used to collect groundwater for field observations prior to purging and sampling, in wells installed in unconfined basal aquifer conditions and are screened across the water table. These bailer samples will be collected without removing dedicated pumps. Field analysis of bailer samples will include:

- Photo-documentation, which consists of taking pictures of a clear bailer held against a white background to document evidence of signs of product or sheen.
- Groundwater headspace evaluation, as described in Section 3.3.2.

If the presence of LNAPL is observed in a monitoring well bailer, the normal groundwater analyses will not be completed. Instead portions of the water containing the sheen or product will be analyzed for fuel fingerprinting by method including saturated hydrocarbon (SHC) analysis and Petroleum Hydrocarbon Identification (PHI).

4. Methods to Evaluate Condition of Groundwater Monitoring Wells

The Navy is currently evaluating the condition of each of the groundwater monitoring wells within the Red Hill groundwater monitoring well network to ensure each is capable of producing groundwater samples that represent the conditions and quality of aquifer in which each is screened. The Navy uses dedicated pumps at each location, and the Consolidated Groundwater Sampling Program is implemented in accordance with Section 6.6 *Groundwater Sample Collection* of the DOH TGM (DOH 2023).

4.1 TGM Well Development and Sample Purging Criteria

In accordance with the DOH TGM, the following criteria are ideally achieved during well development and low-flow purging before sampling (DOH 2023):

- The well water pH stabilizes to within plus or minus (±) 0.1 pH units for three successive readings.
- Well water temperature stabilizes to within ±1 degree Celsius.
- Well water conductivity stabilizes to within ±3 percent.
- Well water oxidation-reduction potential stabilizes to within ±10 millivolts.
- Well water dissolved oxygen concentration stabilizes to within ±0.3 mg/L.
- The well water is clear to the unaided eye, in areas where the local groundwater is known to be clear, and the turbidity readings are below 10 nephelometric NTUs.
- Turbidity stabilizes to within ±10 percent at concentrations larger than 10 NTU. In areas of known turbid groundwater, the final well water may be turbid to the eye.

Well development also includes:

- Removal of at least three well bore volumes, including filter pack (assuming 30 percent porosity).
- The sediment thickness in the well is less than 1 percent of the well screen length or less than 0.1 foot for wells with screens less than 10 feet long.

Low-flow sampling also requires:

- The purge rate should be kept low enough to ensure that the level of the water in the well does not drop more than 4 inches or 10 centimeters (Puls and Barcelona 1996). Typically, a flow rate on the order of 0.1–0.5 liter per minute is used; however, this is dependent on site-specific hydrogeology.

4.2 Well Condition Evaluation and Response Actions

The Navy will review well development and purge logs at each well in the monitoring well network based on these parameters and will identify wells that have significantly different stabilization parameters during sample purging, or significant drawdown is observed during pre-sample purging at low-flow purge rates.

The Navy will work collaboratively with the RAs to confirm that the wells can be removed from the sampling program briefly while additional assessment is conducted, with the understanding that redevelopment may require some period of time before the well returns to stable conditions observed prior to redevelopment. Those wells will be scheduled for pump removal, video camera evaluation of well casing and well screens, and assessment of sedimentation thickness. If the results of the assessment indicate significant degradation that would be improved by additional well development, the Navy will work collaboratively with the RAs to schedule a time for redevelopment that would not interfere with data gathering during the Consolidated Groundwater Sampling Program.

If, necessary, well redevelopment would follow standard operating procedures in accordance with Procedure I-C-2, *Monitoring Well Development* (DON 2015). Well development will consist of a combination of surging and bailing techniques, and pumping groundwater with a submersible pump until fine sediment particles have been removed and the water clarifies. This ensures that formation water enters the well and that the water affected by drilling is removed. The parameters of DO, ORP, pH, temperature, specific conductance, and turbidity will be monitored during the development cycle. Because DO and ORP are affected by the agitation of surging and pumping, the values obtained for these parameters during development may vary and are not representative of the aquifer water. If the development water is not relatively clear and sediment free after ten well volumes, development will be considered complete. The well development activities will be documented in the field book and on computer-generated well development forms.

5. Summary of Changes

Overall, the extensive groundwater data sets provide useful information for confirming that the COPC list (EPA Region 9 and DOH 2016) remains appropriate for groundwater monitoring at the Red Hill Bulk Fuel Storage Facility and should continue to be used in this Consolidated Groundwater Sampling Program.

The Navy has revised and consolidated the current groundwater sampling program to include the following:

1. **Monitoring Wells.** Table 2 and Figure 1 respectively update and illustrate the monitoring locations included in this Consolidated Groundwater Sampling Program. Attachment 1 explains the rationale for the well locations included in the consolidated program.
2. **Analytes.** Table 1 summarizes the parameters that will be analyzed in the Consolidated Groundwater Sampling Program.
3. **Frequency.** Table 2 summarizes the wells and frequency of sampling for each sampling program and GAC operation scenarios, and specifically includes twice per month sampling for reduced operation at RHS. In addition, NPDES sampling of RHS discharge water will occur when pumping at RHS resumes after being off for 24 hours or more, as detailed in the *Red Hill Shaft Recovery Plan NPDES Compliance Sampling Protocol*, March 27, 2023 (IDWST 2023).
4. **Sampling Methods.** Sampling of the monitoring wells and RHS will use the low-flow sampling methods recommended in the DOH TGM (DOH 2023), consistent with the quarterly GW LTM program. Bailers will continue to be used prior to purging and sampling to conduct field observations (including photo-documentation) in monitoring wells installed in unconfined conditions.
5. **Methods for Evaluating Uncontrolled Offsite Migration During Reduced RHS Pumping Rates.** Section 3 references methods for evaluating data and establishes lines of evidence that may indicate uncontrolled offsite migration of contaminants that may present an unacceptable risk to human health or the environment.

No other changes are made to the sampling program at this time. The scope and frequency of data collection may change, based on data obtained and additional work to identify the nature and extent of the fuel releases

~~in the environment. When conditions allow, the Navy will consult with the RAs to potentially transition the consolidated sampling program to normal quarterly sampling, consistent with the GW LTM program.~~

~~6.~~5. References

Air Force Center for Engineering and the Environment (AFCEE). 1995. *Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater*. November 11.

Department of Health, State of Hawaii (DOH). 2023. *Technical Guidance Manual for the Implementation of the Hawaii State Contingency Plan*. Interim Final. Honolulu, HI: Hazard Evaluation and Emergency Response Office. Latest Update: July 2023.

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———. 2017. *Sampling and Analysis Plan, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor-Hickam, O‘ahu, Hawai‘i; April 20, 2017, Revision 01*. Prepared by AECOM Technical Services, Inc., Honolulu, HI. Prepared for Defense Logistics Agency Energy, Fort Belvoir, VA, under Naval Facilities Engineering Command, Hawaii, JBPHH HI.

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Environmental Protection Agency, United States, Region 9; and Department of Health, State of Hawaii (EPA Region 9 and DOH). 2016. *Final Scoping for AOC SOW Sections 6 and 7, and Navy's Proposed Chemical of Potential Concern (COPC) Recommendations*. Letter from: Bob Pallarino, EPA Red Hill Project Coordinator, and Steven Chang, Hawaii DOH Red Hill Project Coordinator, to: James A. K. Miyamoto, Naval Facilities Engineering Command, Hawaii, Joint Base Pearl Harbor-Hickam. February 4.

Interagency Drinking Water System Team (IDWST). 2023. *Red Hill Shaft Recovery Plan NPDES Compliance Sampling Protocol, Red Hill Shaft GAC Water Treatment Unit, Joint Base Pearl Harbor-Hickam, Oahu, HI; March 27, 2023, V.03*. Update of V.1 Presented in IDWST January 2022, Red Hill Shaft Recovery and Monitoring Plan (RHSRMP), JBPHH, O‘ahu, Hawai‘i.

Puls, R. W., and M. J. Barcelona. 1996. "Ground Water Issue: Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures," April.

Attachment 1: Justification for Monitoring Location Changes

Location	Description of Change	Reason For Change
Adit 3 Sump	Removal of monitoring location from the Consolidated Program	Not a basal groundwater location. Location was appropriate initially during the emergency response phase of the NOI for source investigation, but not appropriate for assessing risk since the NOI has transitioned to groundwater monitoring. The sump water is sourced by drainage from the tunnel and vadose zone and water samples from the sump are not representative of groundwater. Contribution to detects at Adit 3 Sump are not necessarily attributed to fuel and instead are from external sources unrelated to the fuel stored at the Facility. Sump sampling may occur intermittently during site characterization and remediation activities, as necessary.
RHMW01	Removal of monitoring well from the Consolidated Program; replaced with RHMW01R	Duplicate well with better alternative available. RHMW01 is submerged while 01R is screened across water table. RHMW01R was installed to replace RHMW01 and provide a well that can also be used to measure for the presence/absence of light nonaqueous-phase liquid.
RHMW07	Removal of monitoring well from Consolidated Program; replaced with RHMW16	Not representative; better alternative at RHMW16. Well is screened in a zone lacking strong hydraulic connection with surrounding basal aquifer, as evidenced by elevated water levels and muted response to pumping and barometric pressure changes. RHMW16, located very close to RHMW07, will be included in the sampling program and is installed in a deeper zone with a strong connection to the basal aquifer.
RHMW10	Add monitoring well to Consolidated Program	RHMW10 fills in a potential gap to the southeast from the center of the tank farm; GW LTM program already samples this well.
RHMW16A	Removal of monitoring well from the Consolidated Program	Duplicate well: RHMW16 is screened in a deeper zone with a strong hydraulic connection to the basal aquifer, while 16A is above the water table.
Hālawa Deep HDMW 2253-03	Add monitoring well to the Consolidated Program	Sampling in the vicinity of Halawa Quarry can assess whether any potential COPC migration to the northwest toward Hālawa Shaft is occurring; GW LTM program already samples this well.
OWDFMW03A and OWDFMW08A	Add monitoring wells to the Consolidated Program	These Oily Waste Disposal Facility (OWDF) wells are screened relatively close to the basal water table and are located to provide information about the quality of groundwater migrating off the northwestern boundary of the Facility.
RHP Wells	Add RHP Wells to the Consolidated Program	Red Hill Plume Delineation (“RHP”) Wells have been installed both on and off the Red Hill Facility property to expand the groundwater monitoring network and evaluate the horizontal extent of fuel impacts that were observed following the November 2021 release.
Sentinel Wells	Add Sentinel Wells to the Consolidated Program	Similar to RHP Wells, Sentinel Wells have been installed on and off the Red Hill Facility property to characterize potential contaminant migration following the November 2021 release and to understand the surrounding geology.