Final
First Quarter 2016 - Quarterly Groundwater Monitoring Report Inside Tunnel Wells

Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, Oahu, Hawaii

DOH Facility ID No.: 9-102271
DOH Release ID Nos.: 990051, 010011, 020028, and 140010

March 2016

NAVFAC
Naval Facilities Engineering Command
NAVFAC HAWAII

Contract Number N62742-14-D-1884, CTO 0014

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Approval Signature: 28 March 2016
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ACRONYMS AND ABBREVIATIONS

ACRONYMS/ ABBREVIATIONS	DEFINITION / MEANING
bgs	below ground surface
COC	Chain-of-Custody
COPC	Contaminant of Potential Concern
CTO	Contract Task Order
DLNR	State of Hawaii Department of Land and Natural Resources
DoD	Department of Defense
DOH	State of Hawaii Department of Health
DON	Department of the Navy
DQO	Decision Quality Objective
E2	Element Environmental, LLC
EAL	Environmental Action Level
EPA	Environmental Protection Agency
ESI	Environmental Science International, Inc.
F-76	Marine Diesel Fuel
ID	Identification
JBPHH	Joint Base Pearl Harbor-Hickam
JP-5	Jet Fuel Propellant-5
JP-8	Jet Fuel Propellant-8
LCS	Laboratory Control Sample
LCSD	Laboratory Control Sample Duplicate
LOD	Limit of Detection
LOQ	Limit of Quantitation
µg/L	microgram per liter
MDL	Method Detection Limit
MS	Matrix Spike
MSD	Matrix Spike Duplicate
NAVFAC	Naval Facilities Engineering Command
NAVSUP FLC	Naval Supply Systems Command Fleet Logistics Center
ND	Not Detected
PAH	Polycyclic Aromatic Hydrocarbons
PARCCS	Precision, Accuracy, Representativeness, Completeness, Comparability, and Sensitivity
pH	potential of hydrogen
QC	Quality Control
QSM	Quality Systems Manual
RHSF	Red Hill Bulk Fuel Storage Facility
RPD	Relative Percent Difference
SAP	Sampling and Analysis Plan
SSRBL	Site-Specific Risk-Based Level
TEC	The Environmental Company, Inc.
TPH	Total Petroleum Hydrocarbons
TPH-d	Total Petroleum Hydrocarbons as diesel
TPH-g	Total Petroleum Hydrocarbons as gasoline
TPH-o	Total Petroleum Hydrocarbons as oil
U.S.	United States
UST	Underground Storage Tank

VOC	Volatile Organic Compound
WP	Work Plan

EXECUTIVE SUMMARY

This quarterly groundwater monitoring report presents the results of the First Quarter 2016 groundwater sampling event, conducted on 20 January 2016, at the Red Hill Bulk Fuel Storage Facility (RHSF), Joint Base Pearl Harbor-Hickam (JBPHH), Hawaii. The RHSF is located in Halawa Heights on the island of Oahu. There are 18 active and 2 inactive Underground Storage Tanks (USTs) located at the RHSF. The State of Hawaii Department of Health (DOH) Facility Identification (ID) number is 9-102271. The DOH Release ID numbers are 990051, 010011, 020028, and 140010.

The groundwater sampling was conducted as part of the long-term groundwater and soil vapor monitoring program at the RHSF and concurrent with release response activities initiated at Tank 5 in January 2014, for Naval Supply Systems Command Fleet Logistics Center (NAVSUP FLC) Pearl Harbor (formerly Fleet and Industrial Supply Center), under Naval Facilities Engineering Command (NAVFAC) Contract Number N62742-14-D-1884, Contract Task Order (CTO) 0014. The sampling was conducted in accordance with the approved *Work Plan/Sampling and Analysis Plan (WP/SAP*) prepared by Element Environmental, LLC (E2, 2015).

On 20 January 2016, E2 personnel collected groundwater samples from four monitoring wells at the RHSF (RHMW01, RHMW02, RHMW03, and RHMW05) and one sampling point at the Red Hill Shaft (RHMW2254-01) during the First Quarter 2016 groundwater monitoring event. In addition, one duplicate sample was collected from well RHMW05.

The analyte list for the RHSF groundwater monitoring has been reduced to ten contaminants of potential concern (COPCs) as documented in the United States (U.S.) Environmental Protection Agency (EPA)/DOH letter, Enclosure A, Analytes and Action Levels, dated February 4, 2016 (Appendix D). Groundwater samples from existing wells are no longer going to be analyzed for analytes that have not been detected at significant concentrations during previous events, including lead scavengers 1,2-dibromoethane and 1,2-dichloroethane.

Analytical results from the First Quarter 2016 groundwater monitoring event were compared to the DOH Tier 1 Environmental Action Levels (EALs) listed in the U.S. EPA/DOH letter, Enclosure A dated February 4, 2016 (Appendix D). Analytical results for wells RHMW01, RHMW02, and RHMW03 were also compared to the Site-Specific Risk-Based Levels (SSRBLs) for total petroleum hydrocarbons as diesel fuel (TPH-d) (4,500 micrograms per liter [µg/L]) and benzene (750 µg/L), established in the RHSF *Final Groundwater Protection Plan (TEC, 2008a)*.

A summary of the analytical results is provided below:

- **RHMW01** –COPCs detected in groundwater sample ERH024 collected from RHMW01 were total petroleum hydrocarbons as diesel fuel (TPH-d) (430 µg/L) and TPH as oil (TPH-o) (60 µg/L); polycyclic aromatic hydrocarbons (PAHs) 1-methylnaphthalene (0.029 µg/L), 2-methylnaphthalene (0.023 µg/L), and naphthalene (0.18 µg/L); and volatile organic compound (VOC) toluene (0.17 µg/L). The concentration of TPH-d exceeded the DOH Tier 1

EAL, but did not exceed the SSRBL. TPH-d concentrations have increased over the past two events, but have shown an overall decreasing trend from a high of 1,500 µg/L in February 2005. Toluene was also detected in the associated trip blank at a similar concentration and is likely the result of laboratory contamination.

- **RHMW02** – COPCs detected in groundwater sample ERH025 collected from well RHMW02 included TPH as gasoline (TPH-g) (36 µg/L), TPH-d (6,500 µg/L), and TPH-o (340 µg/L); PAHs 1-methylnaphthalene (48 µg/L), 2-methylnaphthalene (7.9 µg/L), and naphthalene (120 µg/L); and VOCs benzene (0.080 µg/L), ethylbenzene (0.014 µg/L), toluene (0.070 µg/L), and total xylenes (0.21 µg/L). TPH-d, TPH-o, 1-methylnaphthalene, and naphthalene were detected at concentrations exceeding their respective DOH Tier 1 EALs, with concentrations of TPH-d exceeding the SSRBL of 4,500 µg/L. Toluene was also detected in the associated trip blank at a higher concentration and is likely the result of laboratory contamination.
- **RHMW03** – COPCs detected in groundwater sample ERH026 collected from well RHMW03 were TPH-d (150 µg/L) and TPH-o (160 µg/L); and the VOC toluene (0.14 µg/L). Concentrations of TPH-d and TPH-o exceeded their respective DOH Tier 1 EALs, but TPH-d did not exceed the SSRBL. Toluene was also detected in the associated trip blank at a similar concentration and is likely the result of laboratory contamination.
- **RHMW05** – COPCs detected in groundwater sample ERH021 collected from well RHMW05 were TPH-d (27 µg/L) and TPH-o (45 µg/L), the PAH 2-methylnaphthalene (0.0031 µg/L), and the VOC toluene (0.18 µg/L). None of the detected concentrations exceeded the DOH Tier 1 EALs. Toluene was also detected in the associated trip blank at a similar concentration and is likely the result of laboratory contamination.
- **RHMW2254-01** – COPCs detected in groundwater sample ERH021 collected from sampling point RHMW2254-01 were TPH-d (21 µg/L) and the VOC toluene (0.16 µg/L), neither of which exceeded the DOH Tier 1 EALs. TPH-d and TPH-o were detected in the method blank, likely indicating laboratory contamination. The TPH-o result is presented as not detected (ND) in the data summary tables since the reported concentration was below the concentration detected in the method blank. Toluene was also detected in the associated trip blank at a similar concentration and is likely the result of laboratory contamination.

During this quarterly event, the concentrations of TPH-d in RHMW01, RHMW02, and RHMW03; TPH-o in RHMW02 and RHMW03; and 1-methylnaphthalene and naphthalene in RHMW02 were detected at concentrations exceeding the DOH Tier 1 EALs. Concentrations of TPH-d in RHMW02 were above the SSRBL. Groundwater contaminant concentrations in RHMW05 and RHMW2254-01 remained at low concentrations and did not change significantly from the previous event, or were ND.

Concentrations of 1-methylnaphthalene, 2-methylnaphthalene, and naphthalene in RHMW02 decreased since the July 2015 event, but continue to be elevated and have shown a generally increasing trend since March 2014. During the April 2015 event, the concentration of TPH-d in RHMW02 increased to its highest level since October 2008 and to a level similar to that reached in January 2014. During the October 2015 event, the TPH-d concentration increased to its highest level since monitoring began in 2005 and exceeded the SSRBL. During the January 2016 event, the concentration of TPH-d again exceeded the SSRBL and was higher than the concentration detected during the October 2015 event. All other analytical results were generally consistent with historical data.

Based on the groundwater monitoring results and the reported release at Tank 5 in January 2014, continued groundwater monitoring at the wells inside the RHSF tunnel is recommended. The next quarterly event is tentatively scheduled for April 2016.

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SECTION 1 – INTRODUCTION

This quarterly groundwater monitoring report presents the results of the First Quarter 2016 groundwater sampling conducted by Element Environmental, LLC (E2) on 20 January 2016 at the Red Hill Bulk Fuel Storage Facility (RHSF), Joint Base Pearl Harbor-Hickam (JBPHH), Hawaii. The RHSF is located in Halawa Heights on the island of Oahu. The purpose of the sampling is to (1) assess the condition of groundwater beneath the RHSF with respect to chemical constituents associated with jet fuel propellant and marine diesel fuel, and (2) to ensure the Navy remains in compliance with State of Hawaii Department of Health (DOH) Underground Storage Tank (UST) release response requirements as described in Hawaii Administrative Rules Chapter 11-281 Subchapter 7, *Release Response Action* (DOH, 2013). The DOH Facility identification (ID) number for the RHSF is 9-102271. The DOH Release ID numbers are 990051, 010011, 020028, and 140010.

The groundwater sampling was conducted as part of the long-term groundwater and soil vapor monitoring program at the RHSF for the Naval Supply Systems Command Fleet Logistics Center (NAVSUP FLC) Pearl Harbor, under Naval Facilities Engineering Command (NAVFAC) Contract Number N62742-14-D-1884, Contract Task Order (CTO) 0014. The sampling was conducted in accordance with the approved *Work Plan/Sampling and Analysis Plan (WP/SAP)* prepared by E2 (E2, 2015).

1.1 SITE DESCRIPTION

The RHSF is located on federal government land (zoned F-1 Military and Federal Preservation), in Halawa Heights, approximately 2.5 miles northeast of Pearl Harbor. It is located on a low ridge on the western edge of the Koolau Mountain Range that divides Halawa Valley from Moanalua Valley. The RHSF is bordered on the north by Halawa Correctional Facility and private businesses, on the southwest by the United States (U.S.) Coast Guard reservation, on the south by residential neighborhoods, and on the east by Moanalua Valley. A quarry is located less than a quarter mile away to the northwest. The RHSF occupies 144 acres of land and the majority of the site is at an elevation ranging from approximately 200 to 500 feet above mean sea level.

The RHSF contains 18 active and 2 inactive USTs that are operated by NAVSUP FLC Pearl Harbor. Each UST has a capacity of approximately 12.5 million gallons. The RHSF is located approximately 100 feet above the basal aquifer. The USTs contain Jet Fuel Propellant-5 (JP-5), Jet Fuel Propellant-8 (JP-8), and Marine Diesel Fuel (F-76). The current status of each UST is summarized in Table 1.1.

Four groundwater monitoring wells (RHMW01, RHMW02, RHMW03, and RHMW05) and one sampling point at the Red Hill Shaft (RHMW2254-01) are located within the RHSF lower access tunnel. Five groundwater monitoring wells (HDMW2253-03, OWDFMW01, RHMW04, RHMW06, and RHMW07) are located outside of the RHSF tunnel system. Monitoring data for the five wells located outside the tunnel are included in a separate report.

As noted, monitoring wells RHMW01, RHMW02, RHMW03, and RHMW05 are located inside the underground tunnels. Sampling point RHMW2254-01 is located inside the infiltration gallery of the Department of the Navy (DON) drinking water supply Well 2254-01, which is located approximately 2,400 feet down-gradient of the USTs. It provides potable water to the JBPHH Water System, which serves approximately 65,200 military customers. NAVFAC Hawaii Public Works Department operates and maintains the infiltration gallery and DON Well 2254-01.

TABLE 1.1
Current Status of the USTs
Red Hill Bulk Fuel Storage Facility

Tank Identification	Fuel Type	Status	Capacity
F-1	None	Inactive	12.5 million gallons
F-2	JP-8	Active	12.5 million gallons
F-3	JP-8	Active	12.5 million gallons
F-4	JP-8	Active	12.5 million gallons
F-5	JP-8	Active	12.5 million gallons
F-6	JP-8	Active	12.5 million gallons
F-7	JP-5	Active	12.5 million gallons
F-8	JP-5	Active	12.5 million gallons
F-9	JP-5	Active	12.5 million gallons
F-10	JP-5	Active	12.5 million gallons
F-11	JP-5	Active	12.5 million gallons
F-12	JP-5	Active	12.5 million gallons
F-13	F-76	Active	12.5 million gallons
F-14	F-76	Active	12.5 million gallons
F-15	F-76	Active	12.5 million gallons
F-16	F-76	Active	12.5 million gallons
F-17	JP-5	Active	12.5 million gallons
F-18	JP-5	Active	12.5 million gallons
F-19	None	Inactive	12.5 million gallons
F-20	JP-5	Active	12.5 million gallons

F-76	Marine Diesel Fuel
JP-5	Jet Fuel Propellant-5
JP-8	Jet Fuel Propellant-8

1.2 PHYSICAL SETTING

Climatological conditions in the area of the RHSF consist of warm to moderate temperatures and low to moderate rainfall. The RHSF is leeward of the prevailing northeasterly trade winds. The average annual precipitation is approximately 40 inches, which occurs mainly between November and April (State of Hawaii Department of Land and Natural Resources [DLNR], 1986). Annual pan evaporation is approximately 75 inches (DLNR, 1985). Average temperatures range from the low 60s to high 80s (degrees Fahrenheit) (Atlas of Hawaii, 1983).

Oahu consists of the eroded remnants of two shield volcanoes, Waianae and Koolau. The RHSF is located on the southwest flank of the Koolau Volcanic Shield. Lavas erupted during the shield-building phase of the volcano belong to the *Koolau Volcanic Series* (Stearns and Vaksvik, 1935). Following formation of the Koolau Shield, a long period of volcanic quiescence occurred, during which the shield was deeply eroded. Following this erosional period, eruptive activity resumed. Lavas and pyroclastic material erupted during this period belong to the *Honolulu Volcanic Series* (Stearns and Vaksvik, 1935).

In the immediate area of the RHSF, Koolau Volcanic Series lavas dominate, although there are consolidated and unconsolidated non-calcareous deposits in the vicinity that consist of alluvium generated during erosion of the Koolau Volcanic Shield. South-southwest of the RHSF, and in isolated exposures to the west, are pyroclastic deposits formed during eruptions from three *Honolulu Volcanic Series* vents – Salt Lake, Aliamanu, and Makalapa (Stearns and Vaksvik, 1935). Based on established geology and records of wells drilled at the RHSF (Stearns and Vaksvik, 1938), the RHSF is underlain by *Koolau Volcanic Series* basalts. The area of the RHSF is classified as *Rock Land*, where 25-90% of the land surface is covered by exposed rock and there are only shallow soils (Foote, et al., 1972).

Groundwater in Hawaii exists in two principal aquifer types. The first and most important type, in terms of drinking water resources, is the basal aquifer. The basal aquifer exists as a lens of fresh water floating on and displacing seawater within the pore spaces, fractures, and voids of the basalt that forms the underlying mass of each Hawaiian island. In parts of Oahu, groundwater in the basal aquifer is confined by the overlying caprock and is under pressure. Waters that flow freely to the surface from wells that tap the basal aquifer are referred to as *artesian*.

The second type of aquifer is the caprock aquifer, which consists of various kinds of unconfined and semi-confined groundwater. Commonly, the caprock consists of a thick sequence of nearly impermeable clays, coral, and basalt that separates the caprock aquifer from the basal aquifer. The impermeable nature of these materials and the artesian nature of the basal aquifer severely restrict the downward migration of groundwater from the upper caprock aquifer. However, in the area of the RHSF, there is no discernible caprock.

Groundwater in the area of the RHSF is part of the *Waimalu Aquifer System* of the *Pearl Harbor Aquifer Sector. T*he aquifer is classified as a basal, unconfined, flank-type; and is currently used as a drinking water source. The aquifer is considered fresh, with less than 250 milligrams per liter of chloride, and is considered an irreplaceable resource with a high vulnerability to contamination (Mink and Lau, 1990).

The nearest drinking water supply well is DON Well 2254-01, located in the infiltration gallery within the RHSF lower tunnel. The DON Well 2254-01 is located approximately 2,400 feet hydraulically and topographically down-gradient of the USTs.

The nearest body of surface water is Halawa Stream, an ephemeral stream that is present along the north side of the RHSF. Except for the portion to the east of the Halawa Correctional Facility, the stream is contained by a concrete culvert. The stream is usually dry, but flows after periods of significant rainfall.

1.3 BACKGROUND

The RHSF, consisting of twenty USTs and a series of tunnels, was constructed by the U.S. Government in the early 1940s. The USTs were constructed of steel, and in the past, have stored DON special fuel oil, DON distillate, aviation gasoline, and motor gasoline (Environet, 2010). The tanks currently contain JP-5, JP-8, and F-76. The fueling system is a self-contained underground unit that was installed into native rock comprised primarily of basalt with some interbedded tuffs and breccias (Environet, 2010). Each UST measures approximately 250 feet in height and 100 feet in diameter. The upper domes of the tanks lie at a depth varying between 100 feet and 200 feet below ground surface (bgs).

In 1998, Earth Tech conducted a Phase II Remedial Investigation/Feasibility Study for the Oily Waste Disposal Facility located within the RHSF. The study included the installation of well OWDFMW01 (which was originally identified as MW08) (Earth Tech, 1999).

In February 2001, the DON installed groundwater monitoring well RHMW01 to monitor for contamination in the basal aquifer beneath the RHSF. Well RHMW01 was installed approximately 100 feet below grade within the lower access tunnel. The depth to water was measured at 86 feet below the tunnel floor at the time of the well completion. In February 2001, a groundwater sample was collected from the well. Total petroleum hydrocarbons (TPH) and total lead were detected in the sample. Total lead was detected at a concentration above the DOH Tier 1 groundwater environmental action level (EAL) of 5.6 micrograms per liter (µg/L) (The Environmental Company, Inc. [TEC], 2009; DOH, 2000).

In 2005, the RHSF groundwater monitoring program was initiated. It involved routine groundwater sampling of well RHMW01 and sampling point RHMW2254-01. Samples were collected in February, June, September, and December of 2005. Lead was detected at concentrations above the DOH Tier 1 EAL of 5.6 µg/L in samples collected in February and June. The samples collected in February and June were not filtered prior to analysis, whereas the samples collected in September and December were filtered prior to analysis. Since the samples collected in February and June were not filtered prior to analysis, the lead results were not considered appropriate for a risk assessment (TEC, 2008a).

Between June and September 2005, TEC installed three additional groundwater monitoring wells (RHMW02, RHMW03, and RHMW04) (TEC, 2008a). Well RHMW04 was installed hydraulically up-gradient of the USTs to provide background geochemistry information for water moving through the basal aquifer beneath the RHSF. Wells RHMW02 and RHMW03 were installed approximately 125 feet below grade within the RHSF lower tunnel and well RHMW04 was installed to a depth of approximately 300 feet bgs outside of the RHSF tunnels. In September 2005, groundwater samples were collected from the three newly installed groundwater monitoring wells (RHMW02, RHMW03, and RHMW04) along with the existing well RHMW01 and sampling point RHMW2254-01. The contaminants of potential concern (COPCs) with concentrations that exceeded current DOH EALs are summarized below.

- **RHMW01** – TPH as diesel (TPH-d) was detected at concentrations exceeding the DOH EALs.
- **RHMW02** – TPH as gasoline (TPH-g), TPH-d, naphthalene, trichloroethylene, 1-methylnaphthalene, and 2-methylnaphthalene were detected at concentrations exceeding their respective DOH EALs.
- **RHMW03** – TPH-d was detected at concentrations exceeding the DOH EALs.

In 2006, TEC installed dedicated sampling pumps in the four wells (RHMW01, RHMW02, RHMW03, and RHMW04) and one sampling point (RHMW2254-01). In July and December, groundwater samples were collected from the four wells and the sampling point. COPCs with concentrations that exceeded current DOH EALs are summarized below.

- **RHMW01** – TPH-d and naphthalene.
- **RHMW02** – TPH-g, TPH-d, and naphthalene.
- **RHMW03** – TPH-d.

In 2007, site-specific risk-based levels (SSRBLs) were established for TPH-d (4,500 µg/L) and benzene (750 µg/L) based on the solubility of JP-5 and JP-8 in water (TEC, 2007). Groundwater samples were collected from wells RHMW01, RHMW02, and RHMW03, and sampling point RHMW2254-01 in March, June, and September. The COPCs with concentrations that exceeded current DOH EALs are summarized below.

- **RHMW01** – TPH-d. However, the concentrations did not exceed the SSRBL.
- **RHMW02** – TPH-g, TPH-d, naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene. However, the TPH-d concentrations did not exceed the SSRBL.
- **RHMW03** – TPH-d. However, the concentrations did not exceed the SSRBL.

In 2008, groundwater samples were collected from wells RHMW01, RHMW02, and RHMW03, and sampling point RHMW2254-01. In addition, a *Groundwater Protection Plan* (TEC, 2008a) was prepared. Samples were collected in January, April, July, and October. The COPCs with concentrations that exceeded current DOH EALs are summarized below.

- **RHMW01** – TPH-d. However, the concentrations did not exceed the SSRBL.
- **RHMW02** – TPH-d, naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene. In addition, the TPH-d concentrations detected in October 2008 exceeded the SSRBL.
- **RHMW03** – TPH-d. However, the concentrations did not exceed the SSRBL.
- **RHMW2254-01** – Preliminary analytical results from the January 2008 sampling event indicated TPH-d was detected at an estimated concentration of 102 µg/l and above the DOH EAL. Upon review of the analytical data, the result was reported in the March 2008 *Quarterly Groundwater Monitoring Report* (TEC, 2008b) as rejected due to laboratory contamination observed in the associated laboratory blank. Sampling point RHMW2254-01 was re-sampled,

and split samples were sent to two laboratories (SGS Environmental Services in Anchorage, Alaska and Accutest Laboratories in Orlando, Florida) for analysis. Analytical results from both laboratories indicated TPH-d was ND above the respective method detection limits of the laboratories, which were equal to or less than the DOH EAL.

Although rejected in the March 2008 *Quarterly Groundwater Monitoring Report*, the January 2008 TPH-d concentration has previously been reported as an estimated 102 µg/l, as reported by the analytical laboratory. With the *Second Quarter 2015 Quarterly Groundwater Monitoring Report, Inside Tunnel Wells*, the January 2008 result was re-validated based on DON Procedure II-H, *Standard and Full Data Validation for Extractable Total Petroleum Hydrocarbons by SW-846 8015B,* (DON, 2007) and changed to "ND" with a Limit of Detection (LOD) of 102 µg/l.

In April 2009, groundwater monitoring well RHMW05 was installed down-gradient of the USTs, within the lower access tunnel between RHMW01 and RHMW2254-01. It was installed to identify the extent of contamination hydraulically down-gradient of the USTs. Well RHMW05 was added to the quarterly groundwater sampling program. In 2009, quarterly groundwater samples were collected from wells RHMW01, RHMW02, RHMW03, and RHMW05, and sampling point RHMW2254-01. Samples were collected in February, May, July, and October. In addition, the *Groundwater Protection Plan* was revised to include well RHMW05 (TEC, 2008a). The COPCs with concentrations that exceeded current DOH EALs are summarized below.

- **RHMW01** – TPH-d and 1-methylnaphthalene. However, the TPH-d concentrations did not exceed the SSRBL.
- **RHMW02** – TPH-d, naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene. However, the TPH-d concentrations did not exceed the SSRBL.
- **RHMW03** – TPH-d. However, the concentrations did not exceed the SSRBL.
- **RHMW05** – TPH-d. However, the concentrations did not exceed the SSRBL.

In 2010, groundwater samples were collected from wells RHMW01, RHMW02, RHMW03, and RHMW05, and sampling point RHMW2254-01. Samples were collected in January, April, July, and October. The COPCs with concentrations that exceeded current DOH EALs are summarized below.

- **RHMW01** – TPH-d. However, the concentrations did not exceed the SSRBL.
- **RHMW02** – TPH-g, TPH-d, naphthalene, and 1-methylnaphthalene. However, the TPH-d concentrations did not exceed the SSRBL.
- **RHMW03** – TPH-d. However, the concentrations did not exceed the SSRBL.
- **RHMW05** – TPH-d. However, the concentrations did not exceed the SSRBL.

In 2011, quarterly groundwater samples were collected from wells RHMW01, RHMW02, RHMW03, and RHMW05, and sampling point RHMW2254-01. Samples were collected in January, April, July, and October. In Fall 2011, the DOH EALs were revised. The drinking water toxicity EAL for TPH-d decreased from 210 to 190 µg/L (DOH, 2011). The COPCs with concentrations that exceeded current DOH EALs are summarized below.

- **RHMW01** – TPH-d. However, the concentrations did not exceed the SSRBL.
- **RHMW02** – TPH-d, naphthalene, and 1-methylnaphthalene. However, the TPH-d concentrations did not exceed the SSRBL.

In 2012, quarterly groundwater samples were collected from wells RHMW01, RHMW02, RHMW03, and RHMW05, and sampling point RHMW2254-01. Samples were collected in February, April, July, and October (ESI, 2013a, respectively). The COPCs with concentrations that exceeded current DOH EALs are summarized below.

- **RHMW01** – TPH-d. However, the concentrations did not exceed the SSRBL.
- **RHMW02** – TPH-d, TPH-g, naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene. However, the TPH-d concentrations did not exceed the SSRBL.

In 2013, quarterly groundwater samples were collected from wells RHMW01, RHMW02, RHMW03, and RHMW05, and sampling point RHMW2254-01. Samples were collected in January, April, July, and October (ESI, 2013b, 2013c, 2013d, and 2014a, respectively). The COPCs with concentrations that exceeded current DOH EALs are summarized below.

- **RHMW01** – TPH-d. However, the concentrations did not exceed the SSRBL.
- **RHMW02** – TPH-d, TPH-g, naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene. However, the TPH-d concentrations did not exceed the SSRBL.

In 2014, quarterly groundwater samples were collected from wells RHMW01, RHMW02, RHMW03, and RHMW05, and sampling point RHMW2254-01. Samples were collected in January, April, July, and October (ESI, 2014e, 2014h, 2014k, and 2015a, respectively). The COPCs with concentrations that exceeded current DOH EALs are summarized below.

- **RHMW01** – TPH-d. However, the concentrations did not exceed the SSRBL.
- **RHMW02** – TPH-d, naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene. However, the TPH-d concentrations did not exceed the SSRBL.

Between January and June 2014, additional groundwater sampling (ESI, 2014b) was conducted at wells RHMW01, RHMW02, RHMW05, and sampling point RHMW2254-01 in response to a reported release from Tank 5. The COPCs with concentrations that exceeded current DOH EALs are summarized below.

- **RHMW01** – TPH-d. However, the concentrations did not exceed the SSRBL.

- **RHMW02** – TPH-d, 1-methylnaphthalene, and naphthalene. However, the TPH-d concentrations did not exceed the SSRBL.

Between August and October 2014, wells RHMW06 and RHMW07 were installed outside the RHSF tunnel system in order to develop a more robust groundwater monitoring network at the site (Battelle, 2015). The wells were sampled in October 2014 and January 2015, and subsequently included in the quarterly sampling conducted as part of the long-term groundwater and soil vapor monitoring program at the RHSF. Monitoring data for these wells are included in a separate report.

In January 2015, quarterly groundwater samples were collected from wells RHMW01, RHMW02, RHMW03, and RHMW05, and sampling point RHMW2254-01 (ESI, 2015b). The COPCs with concentrations that exceeded current DOH EALs are summarized below.

- **RHMW02** – TPH-d, naphthalene, and 1-methylnaphthalene. However, the TPH-d concentrations did not exceed the SSRBL.

In April 2015, quarterly groundwater samples were collected from wells RHMW01, RHMW02, RHMW03, and RHMW05, and sampling point RHMW2254-01 (ESI, 2015c). The COPCs with concentrations that exceeded current DOH EALs are summarized below.

- **RHMW01** – TPH-d. However, the concentration did not exceed the SSRBL.
- **RHMW02** – TPH-d, TPH as oil (TPH-oil), naphthalene, and 1-methylnaphthalene. In addition, the TPH-d concentration exceeded the SSRBL.
- **RHMW03** – TPH-d and TPH-o. However, the concentrations did not exceed the SSRBL.

On 25 June 2015, groundwater samples were collected from wells RHMW01, RHMW02, and RHMW05 at the RHSF as part of an additional groundwater sampling event in response to the results of the April 2015 groundwater sampling event. The samples were analyzed for TPH-d, TPH-o, 1-methylnaphthalene, 2-methylnaphthalene, and naphthalene. The COPCs with concentrations that exceeded current DOH EALs are summarized below.

- **RHMW01** – TPH-d. However, the concentrations did not exceed the SSRBL.
- **RHMW02** – TPH-d, TPH-o, naphthalene, 1-methylnaphthalene, 2-methylnaphthalene, and naphthalene. In addition, the TPH concentrations did not exceed the SSRBL.

On 20 and 21 July 2015, ESI personnel collected groundwater samples from wells RHMW01, RHMW02, RHMW03, and RHMW05, and sampling point RHMW2254-01 during the Third Quarter 2015 groundwater monitoring event (ESI 2015d). The COPCs with concentrations that exceeded current DOH EALs are summarized below.

- **RHMW01** – TPH-d. However, the concentration did not exceed the SSRBL.

- **RHMW02** – TPH-d, TPH-o, 1-methylnaphthalene, 2-methylnaphthalene, and naphthalene (in both the primary and duplicate samples). However, the concentrations of TPH did not exceed the SSRBL.
- **RHMW03** – TPH-d and TPH-o. However, the concentrations did not exceed the SSRBL.

On 20 October 2015, E2 personnel collected groundwater samples from wells RHMW01, RHMW02, RHMW03, and RHMW05, and sampling point RHMW2254-01 during the Fourth Quarter 2015 groundwater monitoring event. The COPCs with concentrations that exceeded current DOH EALs are summarized below.

- **RHMW01** – TPH-d. However, the concentration but did not exceed the SSRBL.
- **RHMW02** –TPH-d, TPH-o, 1-methylnaphthalene, 2-methylnaphthalene, and naphthalene (in both the primary and duplicate samples). In addition, the concentrations of TPH exceeded the SSRBL.
- **RHMW03** –TPH-d and TPH-o. However, the concentrations did not exceed the SSRBL.

1.3.1 Previous Reports

The following groundwater monitoring reports for wells located inside the underground tunnels and infiltration gallery were previously submitted to DOH:

1. Groundwater Sampling Report, February 2005 (submitted April 2005).
2. Groundwater Sampling Report, June 2005 (submitted August 2005).
3. Groundwater Sampling Report, September 2005 (submitted November 2005).
4. Groundwater Sampling Report, December 2005 (submitted February 2006).
5. Groundwater Monitoring Results, July 2006 (submitted September 2006).
6. Groundwater Monitoring Results, December 2006 (submitted January 2007).
7. Groundwater Monitoring Results, March 2007 (submitted May 2007).
8. Groundwater Monitoring Results, June 2007 (submitted August 2007).
9. Groundwater Monitoring Results, September 2007 (submitted October 2007).
10. Groundwater Monitoring Report, January 2008 (submitted March 2008).
11. Groundwater Monitoring Report, April 2008 (submitted May 2008).
12. Groundwater Monitoring Report, July 2008 (submitted October 2008).
13. Groundwater Monitoring Report, October and December 2008 (submitted February 2009).
14. Groundwater Monitoring Report, February 2009 (submitted May 2009).
15. Groundwater Monitoring Report, May 2009 (submitted July 2009).
16. Groundwater Monitoring Report, July 2009 (submitted September 2009).

17. Groundwater Monitoring Report, October 2009 (submitted December 2009).
18. Groundwater Monitoring Report, January, February, and March 2010 (submitted April 2010).
19. Groundwater Monitoring Report, April 2010 (submitted May 2010).
20. Groundwater Monitoring Report, July 2010 (submitted August 2010).
21. Groundwater Monitoring Report, October 2010 (submitted December 2010).
22. Groundwater Monitoring Report, January 2011 (submitted March 2011).
23. Groundwater Monitoring Report, April 2011 (submitted June 2011).
24. Groundwater Monitoring Report, July 2011 (submitted September 2011).
25. Groundwater Monitoring Report, October 2011 (submitted December 2011).
26. Groundwater Monitoring Report, January and February 2012 (submitted March 2012).
27. Groundwater Monitoring Report, April 2012 (submitted July 2012).
28. Groundwater Monitoring Report, October 2012 (submitted January 2013).
29. Groundwater Monitoring Report, January 2013 (submitted April 2013).
30. Groundwater Monitoring Report, April 2013 (submitted July 2013).
31. Groundwater Monitoring Report, July 2013 (submitted September 2013).
32. Groundwater Monitoring Report, October 2013 (submitted January 2014).
33. Groundwater Sampling Report for Additional Sampling, January 2014 (submitted January 2014).
34. Groundwater Monitoring Report, January 2014 (submitted April 2014).
35. Groundwater Sampling Report for Tank 5 Release Response on March 5 and 6, 2014 (submitted March 2014).
36. Groundwater Sampling Report for Tank 5 Release Response on March 10, 2014 (submitted March 2014).
37. Groundwater Sampling Report for Tank 5 Release Response on March 25 and 26, 2014 (submitted April 2014).
38. Groundwater Sampling Report for Tank 5 Release Response on April 7, 2014 (submitted April 2014).
39. Groundwater Monitoring Report, April 2014 (submitted June 2014).
40. Groundwater Sampling Report for Tank 5 Release Response on May 27 and 28, 2014 (submitted June 2014).
41. Groundwater Sampling Report for Tank 5 Release Response on June 23 and 24, 2014 (submitted July 2014).
42. Groundwater Monitoring Report, July 2014 (submitted September 2014).

43. Groundwater Monitoring Report, October 2014 (submitted January 2015).

44. Groundwater Monitoring Report, January 2015 (submitted March 2015).

45. Groundwater Monitoring Report, April 2015 (submitted August 2015).

46. Groundwater Monitoring Report, July 2015 (submitted November 2015).

47. Groundwater Monitoring Report, October 2015 (submitted February 2016).

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SECTION 2 – GROUNDWATER SAMPLING

On 20 January 2016, E2 personnel collected groundwater samples from four monitoring wells at the RHSF (RHMW01, RHMW02, RHMW03, and RHMW05) and one sampling point at the Red Hill Shaft (RHMW2254-01). All samples were collected in accordance with the approved WP/SAP (E2, 2015), which is consistent with DOH UST release response requirements (DOH, 2000); DON Procedure I-C-3, *Monitoring Well Sampling* (DON, 2007); and the Interim Update, RHSF *Final Groundwater Protection Plan* (HDR, 2014). Prior to purging and sampling, the depth to groundwater in the wells were measured using a Geotech oil/water interface probe. No measurable product, sheen, or petroleum hydrocarbon odor was detected in any of the wells.

2.1 GROUNDWATER SAMPLING

Prior to collecting groundwater samples, the monitoring wells were purged of standing water in the well casings. Each well, with the exception of RHMW01, contains a dedicated bladder pump, which was used to purge the well and to collect samples. RHMW01 was purged and sampled using a portable bladder pump, dedicated bladder and tubing. The groundwater wells were purged at a flow rate of approximately 0.5 liter per minute.

To operate the pump, a portable air compressor with an in-line filter was connected to a QED MP50 MicroPurge® Basics Controller box, which was then connected to the pump. The compressor was turned on to power the pump and the controller was used to adjust the pumping rate to less than one liter of water per minute.

Water quality parameters were monitored periodically during well purging. The water quality parameters that were measured included hydrogen activity (pH), temperature, conductivity, dissolved oxygen, and oxidation reduction potential. The water quality parameters were evaluated to assess whether the natural characteristics of the aquifer formation water were present within the monitoring wells before collecting the samples. At least four readings were collected during the purging process. Purging was considered complete when at least three consecutive water quality measurements stabilized within approximately 10%. The readings were recorded on Groundwater Sampling Logs, which are included in Appendix A. In addition, field notes were taken to document the sampling event. The field notes are included in Appendix B.

When the water quality parameters stabilized, groundwater samples were collected from the wells using the bladder pumps. The groundwater samples were collected immediately after (no more than two hours after) purging was completed to decrease groundwater interaction with the monitoring well casing and atmosphere. Prior to collecting the sample, the water level in the monitoring wells was measured and recorded to ensure that excessive drawn down had not occurred. Samples collected for dissolved lead analysis were filtered in the field using new, dedicated, 0.45-micron filters.

All samples were labeled and logged on the Sample Inventory Log, placed in resealable bags, and sealed, custody sealed, sealed with tape, placed in a cooler with wet ice, and logged onto the

Chain-of-Custody (COC) Form. The samples were labeled and logged in accordance with DON Procedure III-E, *Record Keeping, Sample Labeling, and Chain-of-Custody Procedures* (DON, 2007). All samples were shipped under COC to the analytical laboratory and analyzed for the COPCs as described below in Section 2.2.

2.2 ANALYTICAL RESULTS

The samples were analyzed for TPH-g, TPH-d, and TPH-o using Environmental Protection Agency (EPA) Method 8015C; volatile organic compounds (VOCs) using EPA Methods 8260C, 8260-SIM, and 8011; and polycyclic aromatic hydrocarbons (PAHs) using EPA Method 8270D SIM. A copy of the laboratory report is included as Appendix C.

Analytical results were compared to the EALs listed in the EPA/DOH letter, Enclosure A, dated February 4, 2016. A copy of Enclosure A (including the list of COPCs and their respective EALs) is included in Appendix D. Analytical results for wells RHMW01, RHMW02, and RHMW03 were also compared to the SSRBLs for TPH (4,500 µg/L) and benzene (750 µg/L), established in the 2008 RHSF *Final Groundwater Protection Plan* (TEC, 2008a). The results of the first quarter groundwater sampling event are summarized in Table 2.1 and described below. A description of laboratory data qualifiers, definitions of the terms Method Detection Limit (MDL), Limit of Detection (LOD), and Limit of Quantitation (LOQ), and basic concepts of those terms are presented in the Fact Sheet included as Appendix E.

- **RHMW01** – COPCs detected in groundwater sample ERH024 collected from RHMW01 were TPH-d (430 µg/L) and TPH-o (60 µg/L); PAHs 1-methylnaphthalene (0.029 µg/L), 2-methylnaphthalene (0.023 µg/L), and naphthalene (0.18 µg/L); and VOC toluene (0.17 µg/L). The concentration of TPH-d exceeded the DOH Tier 1 EAL, but did not exceed the SSRBL. TPH-d concentrations have increased over the past two events, but have shown an overall decreasing trend from a high of 1,500 µg/L in February 2005. Toluene was also detected in the associated trip blank at a similar concentration and is likely the result of laboratory contamination.
- **RHMW02** – COPCs detected in groundwater sample ERH025 collected from well RHMW02 included TPH-g (36 µg/L), TPH-d (6,500 µg/L), and TPH-o (340 µg/L); PAHs 1-methylnaphthalene (48 µg/L), 2-methylnaphthalene (7.9 µg/L), and naphthalene (120 µg/L); and VOCs benzene (0.080 µg/L), ethylbenzene (0.014 µg/L), toluene (0.070 µg/L), and total xylenes (0.21 µg/L). TPH-d, TPH-o, 1-methylnaphthalene, and naphthalene were detected at concentrations exceeding their respective DOH Tier 1 EALs, with concentrations of TPH-d exceeding the SSRBL of 4,500 µg/L. Toluene was also detected in the associated trip blank at a higher concentration and is likely the result of laboratory contamination.
- **RHMW03** – COPCs detected in groundwater sample ERH026 collected from well RHMW03 were TPH-d (150 µg/L) and TPH-o (160 µg/L); and the VOC toluene (0.14 µg/L). Concentrations of TPH-d and TPH-o exceeded their respective DOH Tier 1 EALs, but TPH-d did not exceed the SSRBL. Toluene was also detected in the associated trip blank at a similar concentration and is likely the result of laboratory contamination.

- **RHMW05** – COPCs detected in groundwater sample ERH021 collected from well RHMW05 were TPH-d (27 µg/L) and TPH-o (45 µg/L), the PAH 2-methylnaphthalene (0.0031 µg/L), and the VOC toluene (0.18 µg/L). None of the detected concentrations exceeded the DOH Tier 1 EALs. Toluene was also detected in the associated trip blank at a similar concentration and is likely the result of laboratory contamination.
- **RHMW2254-01** – COPCs detected in groundwater sample ERH021 collected from sampling point RHMW2254-01 were TPH-d (21 µg/L) and the VOC toluene (0.16 µg/L), neither of which exceeded the DOH Tier 1 EALs. TPH-d and TPH-o were detected in the method blank, likely indicating laboratory contamination. The TPH-o result is presented as not detected (ND) in the data summary tables since the reported concentration was below the concentration detected in the method blank. Toluene was also detected in the associated trip blank at a similar concentration and is likely the result of laboratory contamination.

2.3 GROUNDWATER CONTAMINANT TRENDS

The historical groundwater contaminant concentration trends for TPH-g, TPH-d, and COPCs that exceeded the DOH Tier 1 EALs are illustrated in Appendix F. A summary of groundwater contaminant trends is provided below.

- **RHMW01** – The COPCs detected during this round of quarterly sampling were consistent with the historical data for RHMW01. TPH-d has historically been detected at concentrations above the DOH Tier 1 EAL. TPH-d concentrations have increased over the past two events, but have shown an overall decreasing trend from a high of 1,500 µg/L in February 2005.
- **RHMW02** – The COPCs detected during this round of quarterly sampling were generally consistent with the historical data for RHMW02. TPH-g, TPH-d, 1-methylnaphthalene, 2-methylnaphthalene, and naphthalene have historically been detected at concentrations above the DOH Tier 1 EALs. During the January 2016 event, concentrations of TPH-d were again detected exceeding the SSRBL and found at its highest concentration since 2008. Concentrations of 1-methylnaphthalene, 2-methylnaphthalene, and naphthalene in RHMW02 decreased since the July 2015 event, but continue to be elevated and have shown a generally increasing trend since March 2014. The concentrations of TPH-g remained below the DOH Tier 1 EALs and were comparable to the concentrations detected during the previous event.
- **RHMW03** – COPCs detected during this round of quarterly sampling were consistent with the historical data for RHMW03. TPH-d has historically been detected at concentrations above the DOH Tier 1 EALs. The TPH-d concentration detected in RHMW03 during this event (150 µg/L) exceeded the DOH Tier 1 EAL and was the highest concentration detected since October 2010.
- **RHMW05** – COPCs detected during this round of quarterly sampling were consistent with the historical data for RHMW05. TPH-d has historically been detected in RHMW05 at concentrations above the DOH Tier 1 EAL; however, it has not been detected at concentrations above the DOH Tier 1 EAL since January 2010.
- **RHMW2254-01** – COPCs detected during this round of quarterly sampling were consistent with the historical data for RHMW2254-01. Although the method reporting limits for TPH-d were

above the DOH Tier 1 EAL in several results prior to August 2010, TPH-d has not been detected in RHMW2254-01 at concentrations above the DOH Tier 1 EAL.

2.4 WASTE DISPOSAL

The purged groundwater and decontamination water generated during sampling of the inside tunnel wells were placed in two 55-gallon drums along with the purged water and decontamination water generated during sampling of the outside tunnel wells. The drums will be properly profiled and manifested following the next quarterly sampling event, or when they reach 90% full.

TABLE 2.1
Analytical Results for Groundwater Sampling (20 January 2016)
Red Hill Bulk Fuel Storage Facility - Inside Tunnel Wells and Sampling Point
January 2016 Quarterly Monitoring Report

Well/Sampling Point (EPA / Field Sample ID):				RHMW01 (ERH024)					RHMW02 (ERH025)					RHMW03 (ERH026)					RHMW05 (ERH022)					RHMW2254-01 (ERH021)				
Method	**Analyte**	**DOH EAL**	**SSRBL**	**Result**	**Q**	**LOQ**	**LOD**	**DL**	**Result**	**Q**	**LOQ**	**LOD**	**DL**	**Result**	**Q**	**LOQ**	**LOD**	**DL**	**Result**	**Q**	**LOQ**	**LOD**	**DL**	**Result**	**Q**	**LOQ**	**LOD**	**DL**
EPA 8015C	TPH-g	100		ND	U	50	25	8.3	36	J	50	25	8.3	ND	U	50	25	13	ND	U	50	25	8.3	ND	U	50	25	8.3
	TPH-d	100	4,500	**430**	B,Y	57	23	13	**6,500**	B,Y	54	22	12	**150**	B,Y	54	22	12	27	B,J	54	22	12	21	B,J	54	22	12
	TPH-o	100		60	B,J	120	57	22	**340**	B,L	110	54	21	**160**	B,L	110	54	21	45	B,J	110	54	21	ND	B,U	110	54	21
EPA 8270D SIM	1-Methylnaphthalene	4.7		0.029	X	0.02	0.0050	0.0035	**48**	D	0.099	0.025	0.018	ND	U	0.020	0.0050	0.0035	ND	U	0.020	0.0050	0.0035	ND	U	0.020	0.0050	0.0035
	2-Methylnaphthalene	10		0.023	X	0.02	0.0050	0.0023	7.9	D	0.099	0.025	0.012	ND	U	0.020	0.0050	0.0023	0.0031	J	0.020	0.0050	0.0023	ND	U	0.020	0.0050	0.0023
	Naphthalene	17		0.18		0.02	0.0050	0.0038	**120**	D	0.99	0.25	0.19	ND	U	0.020	0.0050	0.0038	ND	U	0.020	0.0050	0.0038	ND	U	0.020	0.0050	0.0038
EPA 8260C / 8260-SIM / 8011	1,2-Dibromoethane (EDB)	0.04		ND	U	0.0097	0.0040	0.0030	ND	U	0.0097	0.0040	0.0030	ND	U	0.0097	0.0040	0.0030	ND	U	0.0097	0.0040	0.0030	ND	U	0.0097	0.0040	0.0030
	1,2-Dichloroethane (DCA)	5		ND	U	20	15	5.8	ND	U	20	15	5.8	ND	U	20	15	5.8	ND	U	20	15	5.8	ND	U	20	15	5.8
	Benzene	5	750	ND	U	0.50	0.10	0.062	0.080	J	0.50	0.10	0.062	ND	U	0.50	0.10	0.062	ND	U	0.50	0.10	0.062	ND	U	0.50	0.10	0.062
	Ethylbenzene	30		ND	U	0.50	0.10	0.050	0.014	J	0.50	0.10	0.050	ND	U	0.50	0.10	0.050	ND	U	0.50	0.10	0.050	ND	U	0.50	0.10	0.050
	Toluene	40		0.17	Tb, J	0.50	0.10	0.054	0.070	Tb, J	0.50	0.10	0.054	0.14	Tb, J	0.50	0.10	0.054	0.18	Tb, J	0.50	0.10	0.054	0.16	Tb, J	0.50	0.10	0.054
	Xylenes, Total	20		ND	U	1.0	0.20	0.18	0.21	J	1.0	0.20	0.18	ND	U	1.0	0.20	0.18	ND	U	1.0	0.20	0.18	ND	U	1.0	0.20	0.18

Only COPCs listed in the EPA/DOH Letter, Enclosure A, dated February 4, 2016 and 1,2-dibromoethane and 1,2-dichloroethane are included in this table.
Bold, shaded values exceeded the DOH Tier 1 EALs and/or SSRBLs
Data are reported in µg/L.

DOH EAL	Department of Health Tier 1 Environmental Action Levels for groundwater where groundwater is a current drinking water source (DOH, Fall 2011).
DL	Detection Limit
EPA	Environmental Protection Agency
LOD	Limit of Detection
LOQ	Limit of Quantitation
ND	Not Detected
Q	Qualifiers (listed below)
B	Compound identified during validation in the method blank. Result was changed to ND if the reported concentration was below the concentration detected in the method blank. Results remain reported in the laboratory provided report.
D	The reported result is from a dilution.
J	The result is an estimated value.
L	The chromatographic fingerprint of the sample resembles a petroleum product, but the elution pattern indicates the presence of a greater amount of lighter molecular weight constituents than the calibration standard.
U	The analyte was analyzed for, but was not detected ("Non-detect") at or above the MRL/MDL.
X	The results reported for several analytes in sample ERH024 may contain a slight bias. The chromatogram indicated the presence of non-target background components. The matrix interference may have resulted in a slight high bias in the affected samples. The results were flagged with “X” to indicate the issue.
Tb	The analyte was also detected in the associated trip blank at a similar concentration.
Y	The chromatographic fingerprint of the sample resembles a petroleum product eluting in approximately the correct carbon range, but the elution pattern does not match the calibration standard.

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SECTION 3 – DATA QUALITY ASSESSMENT

A data quality assessment, which consists of a review of the overall groundwater sample collection and analysis process, was performed in order to determine whether the analytical data generated met the decision quality objectives (DQOs) for the project. The data quality assessment was performed in accordance with the approved WP/SAP (E2, 2015). The field quality control (QC) program consisted of standardized sample collection and management procedures, and the collection of field duplicate samples and matrix spike (MS)/MS duplicate (MSD) samples. The laboratory quality assurance program consisted of the use of standard analytical methods and the preparation and analyses of MS/MSD samples, surrogate spikes, blanks, and laboratory control samples [LCSs]/LCS Duplicates (LCSDs) and trip blank samples.

3.1 DATA VALIDATION AND ASSESSMENT

The objective of data validation is to ensure the data provided is of known quality for project decisions. Data quality is judged in terms of Precision, Accuracy, Representativeness, Completeness, Comparability, and Sensitivity (PARCCS). A number of factors may affect the quality of data, including: sample collection methods, sample analysis methods, and adherence to established procedures for sample collection, preservation, management, shipment, and analysis.

Precision

Precision is defined as the reproducibility of replicate measurements. Precision is evaluated by Relative Percentage Difference (RPD) of field duplicates, LCS/LCSD, and MS/MSD results. Field duplicate and MS/MSD samples were collected at a rate of approximately 10% of primary samples. Field duplicates were sent to the laboratory under fictitious sample IDs, along with the primary samples.

The RPDs of detected analytes for the primary and field duplicate samples (ERH022 and ERH023 collected from well RHMW05) are provided in Table 3.1. An RPD of less than 50% for duplicate pairs is required by the DON *Project Procedures Manual* to be considered acceptable (DON, 2007). All RPDs fell within the acceptable limit of less than 50%.

RPDs for MS/MSD and LCS/LCSD pairs for all other analytes were within the control limits, and the data precision is considered acceptable with the exception of the MS/MSD for PAHs by 8270C SIM. Due to a laboratory error, the replicate MS/MSD KWG1600624-1 and KWG1600624-2 were not spiked with the compounds of interest. The recoveries in the replicate LCS/LCSD KWG1600624-3 and KWG1600624-4 were acceptable, which indicated the analytical batch was in control. No further corrective action was necessary.

Accuracy

Accuracy is defined as the degree of conformity of a measurement to a standard or true value. Accuracy is evaluated through measurement of the percent recovery of an analyte in a reference standard or spiked sample. Accuracy limits for surrogates, LCS, MS, and MSD samples are either prescribed by the Department of Defense (DoD) or established by the individual laboratory. The acceptance criteria for accuracy are dependent on the analytical method and are based on historical laboratory or DoD data.

Between July 2006 and July 2010, naphthalene was analyzed by both EPA Methods 8260B and 8270C, and both results were reported. In the September 2005 event and in all events beginning in October 2010, only results using EPA Method 8270C were reported. Naphthalene has historically only been detected at concentrations above the DOH Tier 1 EALs in well RHMW02. In this well, concentrations of naphthalene detected in each sample by EPA Method 8260B were generally two to three times higher than those detected by EPA Method 8270C. This is likely due to the better preservation of VOCs associated with the use of EPA Method 8260B. This suggests that the naphthalene results provided by EPA Method 8270C may be biased low. Since March 2014, naphthalene concentrations in RHMW02 have exceeded the DOH Tier 1 EAL. Therefore, a low bias is unlikely to affect project decisions.

Similarly, the large error inherent to the analysis of TPH-d and TPH-o by EPA Method 8015 should be considered when results are compared to each other, to action levels, and to results from previous sampling events. Any comparative analysis of the results should take into consideration the fairly wide method acceptance limits (36-132%) as per DoD Quality Systems Manual (QSM) Version 5.0 (DoD, 2013).

Results for TPH-d in samples ERH024 (RHMW01), ERH025 (RHMW02), and ERH026 (RHMW03) were flagged “Y” to indicate that the chromatographic fingerprint of the samples resembled a petroleum product, but did not match the calibration standard. Results for TPH-o in samples ERH025 (RHMW02) and ERH026 (RHMW03) were additionally flagged “L” to indicate that the results in this range were likely due to tailing of the diesel range product into the heavier oil range, and not due to the presence of an oil range petroleum product. Mismatches of this type are not uncommon and a review of sample chromatograms confirmed the flagging applied by the laboratory. The chromatograms of groundwater samples from sample ERH025 (RHMW02) did not indicate any significant changes in the type of petroleum product present in the well compared to data from previous sampling events.

All MS/MSD recoveries met the control limit criteria, indicating that negative matrix effects were negligible with all analysis with the exception explained above under the *Precision* subsection. Additionally, the results reported for 1-methylnaphthalene and 2-methylnaphthalene in sample ERH024 (RHMW01) may contain a slight bias. The chromatogram indicated the presence of non-target background components. The matrix interference may have resulted in a slight high bias in the affected samples. The results were flagged with “X” to indicate the issue.

All surrogate spike recoveries met the control limit criteria indicating that laboratory procedures were meeting method analyte recovery criteria with the following exceptions:

- For EPA Method 8260C SIM, the control criteria were exceeded for toluene-d8 in LCS KWG1600798-3, and KWG1600835-3 and MS/MSD Batch QC. The associated MS recoveries of target compounds were in control, indicating the analysis was in control. The surrogate outlier was flagged accordingly. No further corrective action was appropriate.

The data accuracy for this monitoring event is considered acceptable.

Representativeness

Representativeness is the degree that data accurately and precisely represents a characteristic of a population, parameter variations at a sampling point, or an environmental condition. Representativeness was achieved by conducting sampling in accordance with the sample collection procedures described in the approved WP/SAP, which included standardized sample collection methods (E2, 2015).

Representativeness is also evaluated through the compliance with the standardized sample holding time and sample preservation methods, and through the analysis of blank samples, including method blank and trip blank samples. For this sampling event, all sample holding times and sample preservation were consistent with EPA guidance.

For this sampling event, one trip blank was included with the cooler containing samples for VOC and TPH-g analyses to assess the potential for contamination during sample transport. Toluene was detected in the trip blank at a concentration below the LOQ. Subsequently, toluene results for primary samples were flagged "Tb" in Tables 2.1 and 3.1.

Additionally, TPH-d and TPH-o were detected in the method blank at concentrations below their respective LOQs. Presence of these compounds at comparable levels in project samples likely indicate positive interference from laboratory procedures (laboratory contamination). Subsequently, detections for compounds identified in the method blank were changed to ND in Tables 2.1 and 3.1 if the reported concentration was below the concentration detected in the method blank.

With the exceptions noted above, the groundwater sample data are considered representative of the groundwater quality at the site. A summary of the trip blank results is provided in Table 3.1.

Completeness

Completeness is defined as the overall percentage of valid analytical results (including estimated results) compared to the total number of analytical results reported by the analytical laboratory. No data were rejected for this project, and therefore the completeness goal for this project (90%) was successfully met.

Comparability

Comparability expresses the confidence with which one data set can be compared to another data set. Comparability can be related to accuracy and precision because these quantities are measures of data reliability. Data with acceptable precision and accuracy are considered comparable if collection techniques, analytical procedures, methods, and reporting are equivalent.

For this monitoring event, the samples were collected using approaches consistent with those in the previous events, and the same analytical methods/procedures were used to measure the concentration of COPCs. The field and laboratory personnel followed standard operating procedures. With the exceptions noted below, the results are considered comparable within this data set and with the data collected from previous sampling events.

All samples collected from October 2010 to and including the February 2015 event were analyzed by Calscience Environmental Laboratories located in Garden Grove, CA (now known as Eurofins Calscience). Samples collected during April 2015 were analyzed by ALS Environmental located in Kelso, WA. Analytical MDLs, LODs, and LOQs for most analytes were lower than they had been during previous events and several VOCs and PAHs were detected during the April 2015 event at concentrations that would have been below previous LODs and therefore ND. The method used to analyze 1,2-dichloroethane, bromodichloromethane, dibromochloromethane, and 1,1,2,2-tetrachloroethane was changed from EPA Method 8260 to EPA Method 8260-SIM to improve sensitivity. Correspondingly, analysis of 1,2-dibromo-3-chloropropane and 1,2-dibromoethane was switched from EPA Method 8260 to EPA Method 8011 for the same reason. The significantly improved reporting limits should be considered when results are compared to data from previous events.

Additionally, during the April 2015 event, TPH-o was added to the analyte list. There are very few previous TPH-o results to compare this data to.

The TPH-g analysis of samples through July 2010 was performed using EPA Method 8015. Between October 2010 and January 2015, TPH-g analysis was performed using EPA Method 8260. Beginning in April 2015, the use of EPA Method 8015 was reestablished. There was no event where both methods were used; consequently, there is no way to directly compare the results obtained by the two methods and to assess potential bias. However, there is no reason to believe that using either method should bias the data significantly, and the TPH-g data for all events should be comparable with respect to the limits of the analytical method.

Other than the lower detection limits, the addition of TPH-o to the analyte list, the large uncertainty inherent to EPA Method 8015, and the naphthalene bias discussed above, no other issues with comparability were identified. The results are considered comparable within this data set and with the data collected from recent sampling events.

Sensitivity

The LOQs are established by the laboratory based on the LODs or instrument detection limits, historical data, and EPA limits established for the various methods. The LOQs and LODs for samples may require adjustment by the laboratory due to matrix interference or if high levels of target analytes necessitate dilution before analysis. Matrix interference and sample dilutions have the effect of decreasing sensitivity and increasing the LOQs/LODs. There are no results with increased LOQs or LODs in this data set that have impacted sensitivity and data usability.

All LODs were sufficiently low to satisfy project DQOs. The limits for several analytes were significantly lower than in historical sampling events. The impact on comparability of the data to historical data is described in the comparability section of this report. The laboratory, in several cases, indicated issues with relative response factors determined for initial calibrations or calibration verifications of certain VOCs. In every case, the laboratory verified that the sensitivity was sufficient to detect the affected compounds at their respective LOQs. All LOQs for the affected analytes were below the EALs, indicating that any potential impact on sensitivity was minor and irrelevant in terms of project decisions.

3.2 DATA ASSESSMENT AND USABILITY CONCLUSIONS

The PARCCS criteria were evaluated, and with some exceptions, all criteria were met. Results associated with QC data that failed acceptance criteria are discussed in detail above in Section 3.1. Data quality issues that need to be taken into account for project decisions are summarized below.

Finally, it should be noted that analytical MDLs, LODs, and LOQs decreased for the April and July 2015 sampling events compared to monitoring data from October 2010 through February 2015 due to a change of laboratories and the utilization of alternative methods. Analytes that were detected during the current event and were ND at or above the higher MDLs during past events include acenaphthene, benzo[a]anthracene, fluorene, phenanthrene, naphthalene, 1-methylnaphthalene, and 2-methlynaphthelene in RHMW01; 1,2,3-trichloropropane, benzene, and toluene in RHMW02; benzo[a]anthracene, phenanthrene, and lead in RHMW03; and naphthalene, 1-methylnaphthalene, 2-methlynaphthelene, and lead in RHMW05. Consequently, these analytes may have been present at the currently detected concentrations during previous events without being detected and do not necessarily indicate any trend. These compounds were also identified in the method blank and may indicate that at these very low levels, laboratory contamination may lead to false low level hits. Furthermore, it should be noted that, in general, detections below the LOQ in primary samples, laboratory method blanks and trip blanks should be subject to scrutiny as they could be false low level hits resulting from positive interference from laboratory analytical processes (i.e., laboratory contamination).

The data assessment concludes that all data generated during this event are usable for the intended purpose, with the limitations described above.

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TABLE 3.1
Quality Control Results for Groundwater Sampling (20 January 2016)
Red Hill Bulk Fuel Storage Facility - Inside Tunnel Wells and Sampling Point
January 2016 Quarterly Monitoring Report

Well/Sampling Point (EPA / Field Sample ID):				RHMW05 (ERH0022) Primary					RHMW05 (ERH023) Field Duplicate					RPD Duplicate %	Trip Blank				
Method	**Analyte**	**DOH EAL**	**SSRBL**	**Result**	**Q**	**LOQ**	**LOD**	**DL**	**Result**	**Q**	**LOQ**	**LOD**	**DL**		**Result**	**Q**	**LOQ**	**LOD**	**DL**
EPA 8015C	TPH-g	100		ND	U	50	25	8.3	ND	U	50	25	8.3	NA	-	-	-	-	-
	TPH-d	100	4,500	27	B,J	54	22	12	26	B,J	54	22	12	3.8%	-	-	-	-	-
	TPH-o	100		45	B,J	110	54	21	44	B,J	110	54	21	2.2%	-	-	-	-	-
EPA 8270D SIM	1-Methylnaphthalene	4.7		ND	U	0.02	0.01	0.0035	ND	U	0.02	0.01	0.004	NA	-	-	-	-	-
	2-Methylnaphthalene	10		0.0031	J	0.02	0.01	0.0023	0.0039	J	0.02	0.01	0.0023	22.9%	-	-	-	-	-
	Naphthalene	17		ND	U	0.02	0.01	0.0038	0.0046	J	0.02	0.01	0.0038	NA	-	-	-	-	-
EPA 8260C / 8260-SIM / 8011	1,2-Dibromoethane (EDB)	0.04		ND	U	0.010	0.004	0.0030	ND	U	0.0097	0.0040	0.0030	NA	ND	U	2.0	0.20	0.10
	1,2-Dichloroethane (DCA)	5		ND	U	20.000	15	5.8	ND	U	20	15	5.8	NA	ND	U	0.020	0.02	0.0058
	Benzene	5	750	ND	U	0.50	0.10	0.062	ND	U	0.50	0.10	0.062	NA	ND	U	0.50	0.10	0.062
	Ethylbenzene	30		ND	U	0.50	0.10	0.05	ND	U	0.50	0.10	0.050	NA	ND	U	0.50	0.10	0.050
	Toluene	40		0.18	Tb, J	0.50	0.10	0.054	0.12	Tb, J	0.50	0.10	0.054	-40.0%	0.19	J	0.50	0.10	0.054
	Xylenes, Total	20		ND	U	1.0	0.20	0.18	ND	U	1.0	0.20	0.18	NA	ND	U	1.0	0.20	0.18

Only COPCs listed in the EPA/DOH Letter, Enclosure A, dated February 4, 2016 and 1,2-dibromoethane and 1,2-dichloroethane are included in this table.
Data are reported in µg/L.

-	Not analyzed
DOH EAL	Department of Health Tier 1 Environmental Action Levels for groundwater is a current drinking water source (DOH, Fall 2011).
DL	Detection Limit
EPA	Environmental Protection Agency
LOD	Limit of Detection
LOQ	Limit of Quantitation
NA	Not Available
ND	Not Detected
Q	Qualifiers (listed below)
B	Compound identified during validation in the blank. Result was changed to ND if the reported concentration was below the concentration detected in the method blank. Results remain reported in the laboratory provided report.
J	The result is an estimated value.
Tb	The analyte was also detected in the associated trip blank at a similar concentration.
U	The analyte was analyzed for, but was not detected ("Non-detect") at or above the MRL/MDL.

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SECTION 4 – SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

On 20 January 2016, E2 personnel collected groundwater samples from four monitoring wells at the RHSF (RHMW01, RHMW02, RHMW03, and RHMW05) and one sampling point at the Red Hill Shaft (RHMW2254-01).

The groundwater sampling was conducted as part of the long-term groundwater and soil vapor monitoring program at the RHSF for NAVSUP FLC Pearl Harbor, under NAVFAC Contract Number N62742-14-D-1844, CTO 0014. The sampling was conducted in accordance with the approved WP/SAP (E2, 2015). A summary of the analytical results is provided below:

- **RHMW01** – COPCs detected in groundwater sample ERH024 collected from RHMW01 were TPH-d (430 µg/L) and TPH-o (60 µg/L); PAHs 1-methylnaphthalene (0.029 µg/L), 2-methylnaphthalene (0.023 µg/L), and naphthalene (0.18 µg/L); and VOC toluene (0.17 µg/L). The concentration of TPH-d exceeded the DOH Tier 1 EAL, but did not exceed the SSRBL. TPH-d concentrations have increased over the past two events, but have shown an overall decreasing trend from a high of 1,500 µg/L in February 2005. Toluene was also detected in the associated trip blank at a similar concentration and is likely the result of laboratory contamination.
- **RHMW02** – COPCs detected in groundwater sample ERH025 collected from well RHMW02 included TPH-g (36 µg/L), TPH-d (6,500 µg/L), and TPH-o (340 µg/L); PAHs 1-methylnaphthalene (48 µg/L), 2-methylnaphthalene (7.9 µg/L), and naphthalene (120 µg/L); and VOCs benzene (0.080 µg/L), ethylbenzene (0.014 µg/L), toluene (0.070 µg/L), and total xylenes (0.21 µg/L). TPH-d, TPH-o, 1-methylnaphthalene, and naphthalene were detected at concentrations exceeding their respective DOH Tier 1 EALs, with concentrations of TPH-d exceeding the SSRBL of 4,500 µg/L. Toluene was also detected in the associated trip blank at a similar concentration and is likely the result of laboratory contamination.
- **RHMW03** – COPCs detected in groundwater sample ERH026 collected from well RHMW03 were TPH-d (150 µg/L) and TPH-o (160 µg/L); and the VOC toluene (0.14 µg/L). Concentrations of TPH-d and TPH-o exceeded their respective DOH Tier 1 EALs, but TPH-d did not exceed the SSRBL. Toluene was also detected in the associated trip blank at a similar concentration and is likely the result of laboratory contamination.
- **RHMW05** – COPCs detected in groundwater sample ERH021 collected from well RHMW05 were TPH-d (27 µg/L) and TPH-o (45 µg/L), the PAH 2-methylnaphthalene (0.0031 µg/L), and the VOC toluene (0.18 µg/L). None of the detected concentrations exceeded the DOH Tier 1 EALs. Toluene was also detected in the associated trip blank at a similar concentration and is likely the result of laboratory contamination.
- **RHMW2254-01** – COPCs detected in groundwater sample ERH021 collected from sampling point RHMW2254-01 were TPH-d (21 µg/L) and the VOC toluene (0.16 µg/L), neither of which exceeded the DOH Tier 1 EALs. TPH-d and TPH-o were detected in the method blank, likely indicating laboratory contamination. The TPH-o result is presented as not detected (ND) in the

data summary tables since the reported concentration was below the concentration detected in the method blank. Toluene was also detected in the associated trip blank at a similar concentration and is likely the result of laboratory contamination.

The historical groundwater contaminant concentration trends for TPH-g, TPH-d, and COPCs that exceeded the DOH Tier 1 EALs are illustrated in Appendix F. A summary of groundwater contaminant trends is provided below.

- **RHMW01** – The COPCs detected during this round of quarterly sampling were consistent with the historical data for RHMW01. TPH-d has historically been detected at concentrations above the DOH Tier 1 EAL. TPH-d concentrations have increased over the past two events, but have shown an overall decreasing trend from a high of 1,500 µg/L in February 2005.
- **RHMW02** – The COPCs detected during this round of quarterly sampling were generally consistent with the historical data for RHMW02. TPH-g, TPH-d, 1-methylnaphthalene, 2-methylnaphthalene, and naphthalene have historically been detected at concentrations above the DOH Tier 1 EALs. During the January 2016 event, concentrations of TPH-d were again detected exceeding the SSRBL and found at its highest concentration since 2008. Concentrations of 1-methylnaphthalene, 2-methylnaphthalene, and naphthalene in RHMW02 decreased since the July 2015 event, but continue to be elevated and have shown a generally increasing trend since March 2014. The concentrations of TPH-g remained below the DOH Tier 1 EALs and were comparable to the concentrations detected during the previous event.
- **RHMW03** – COPCs detected during this round of quarterly sampling were consistent with the historical data for RHMW03. TPH-d has historically been detected at concentrations above the DOH Tier 1 EALs. The TPH-d concentration detected in RHMW03 during this event (150 µg/L) exceeded the DOH Tier 1 EAL and was the highest concentration detected since October 2010.
- **RHMW05** – COPCs detected during this round of quarterly sampling were consistent with the historical data for RHMW05. TPH-d has historically been detected in RHMW05 at concentrations above the DOH Tier 1 EAL; however, it has not been detected at concentrations above the DOH Tier 1 EAL since January 2010.
- **RHMW2254-01** – COPCs detected during this round of quarterly sampling were consistent with the historical data for RHMW2254-01. Although the method reporting limits for TPH-d were above the DOH Tier 1 EAL in several results prior to August 2010, TPH-d has not been detected in RHMW2254-01 at concentrations above the DOH Tier 1 EAL.

Conclusions and Recommendations

During the sampling event conducted on 20 January 2016, TPH-d in RHMW01, RHMW02, and RHMW03; TPH-o in RHMW02 and RHMW03; and 1-methylnaphthalene and naphthalene in RHMW02 were detected at concentrations exceeding the respective DOH Tier 1 EALs. In addition, the concentration of TPH-d in RHMW02 exceeded the SSRBL. Groundwater contaminant concentrations in RHMW05 and RHMW2254-01 remained at low concentrations and did not change significantly from the previous event, or were ND.

Concentrations of 1-methylnaphthalene, 2-methylnaphthalene, and naphthalene in RHMW02 decreased compared to those obtained in the April 2015 event, but have shown a generally increasing trend since March 2014. The concentration of TPH-d in RHMW02 increased during the January 2016 event (6,500 µg/L) to its highest level since October 2008 (6,300 µg/L). All other analytical results were generally consistent with historical data.

Lead scavengers 1,2-dibromoethane and 1,2-dichloroethane have not been detected at concentrations above their respective DOH Tier 1 EALs for four consecutive quarters. Subsequently, and in accordance with the EPA/DOH letter, Enclosure A, Analytes and Action Levels dated February 4, 2016, analysis for lead scavengers and all but the ten COPCs listed in Enclosure A, will be discontinued.

Based on the January 2016 groundwater monitoring results and the reported release at Tank 5 in January 2014, continued groundwater monitoring at the wells inside the RHSF tunnel is recommended.

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SECTION 5 – FUTURE WORK

Future work includes the Second Quarter 2016 groundwater monitoring that is tentatively scheduled for April 2016. A quarterly groundwater monitoring report will be prepared to document the sampling event.

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APPENDIX A

Groundwater Sampling Logs

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GROUNDWATER SAMPLING LOG

WELL NO. RHMW01
LOCATION: RHFS
PROJECT NO. 150037
DATE: 1/20/2016 TIME: 1225
CLIMATIC CONDITIONS: N/A
TIDAL CONDITIONS: Rising ☐ Falling ☐
HIGH TIDE:
LOW TIDE:
CURRENT TIDE:

STATIC WATER LEVEL (FT.) and TIME: 83.31 @1230
TOTAL DEPTH (FT.):
WELL PURGING:
LENGTH OF SATURATED ZONE: LINEAR FT.
a
VOLUME OF WATER TO BE EVACUATED: GALS. (Gals/Linear ft. X linear feet of saturation X 3-casing volumes)
METHOD OF REMOVAL: BLADDER PUMP
PUMPING RATE: mL/min

WELL PURGE DATA:

DATE/ TIME	DTW	GALLONS REMOVED	TDS (g/L)	pH	SP. COND. (µS/cm)	D.O. (mg/L)	TURB. (NTU)	TEMP. (°C)	ORP (mV)	SAL (ppt)
1/20/16 @ 1258	83.31	0.5	0.22	6.91	338.1	1.75	1.5	23.9	-74.1	0.16
1300	83.31	0.75	0.22	6.84	338.6	1.31	1.5	23.8	-75.2	0.16
1304	83.31	1.25	0.22	6.77	339.5	0.89	1.5	23.5	-78.1	0.16
1306	83.21	1.5	0.22	6.76	339.7	0.82	1.5	23.4	-78.0	0.16
1308	83.31	1.75	0.22	6.75	339.8	0.77	1.5	23.4	-78.0	0.16

SAMPLE WITHDRAWAL METHOD: BLADDER PUMP
APPEARANCE OF SAMPLE: COLOR: clear
SEDIMENT: None
OTHER: No odor/sheen
LABORATORY ANALYSIS PARAMETERS AND PRESERVATIVES TPH-DRO/ORO/GRO (HCl), VOCs (HCl), PAHs (NONE), ~~TOT~~ DISSOLVED LEAD (HNO_3), EDB ($Na_2S_2O_7$)
NUMBER AND TYPES OF SAMPLE CONTAINERS USED: 1 x L AMBER, 2 x 500 mL AMBERS, 1 x 500 mL POLY, 7 x 40 mL VOAs (TOTAL = 11)
SAMPLE IDENTIFICATION NUMBER(S) ERH024 @ 1315, ALSO COLLECTED 1/21/2016 ERH027 SOURCE BLANK @ 0800 ERH028 EQUIP. RINSE. BLANK @ 0830
DECONTAMINATION PROCEDURES: NAVY PPM I-F
NOTES: SAMPLES ~~WAS~~ WERE FIELD FILTERED FOR DISSOLVED LEAD.
SAMPLED BY: AL, BB
SAMPLES DELIVERED TO: ALS, KELSO, WA
TRANSPORTER: TRACIE SOBBER, ALS
DATE: 1/21/2016 TIME: 0900

CAPACITY OF CASING (GALLONS/LINEAR FOOT)
2"-0.16•4"-0.65•6"-1.47•8"-2.61•10"-4.08•12"-5.87

Figure I-C-3-1: Groundwater Sampling Log

GROUNDWATER SAMPLING LOG

WELL NO. RHMW02 LOCATION: RHFS PROJECT NO. 150037

DATE: 1/20/2016 TIME: 1400 CLIMATIC CONDITIONS: N/A

TIDAL CONDITIONS: Rising ☐ Falling ☐ HIGH TIDE: LOW TIDE: CURRENT TIDE:

STATIC WATER LEVEL (FT.) and TIME: 85.97 @ 1407 TOTAL DEPTH (FT.):

WELL PURGING: LENGTH OF SATURATED ZONE: LINEAR FT.

a VOLUME OF WATER TO BE EVACUATED: GALS. (Gals/Linear ft. X linear feet of saturation X 3-casing volumes)

METHOD OF REMOVAL: Dedicated Submersible Bladder Pump PUMPING RATE: mL/min

WELL PURGE DATA:

DATE/ TIME	DTW	GALLONS REMOVED	TDS (g/L)	pH	SP. COND. (µS/cm)	D.O. (mg/L)	TURB. (NTU)	TEMP. (°C)	ORP (mV)	SAL (ppt)
1/20/16 @ 1420	85.97	0.5	0.37	6.21	564	0.50	3.6	23.7	-32.7	0.27
1423	85.97	0.75	0.37	6.12	564	0.41	2.6	23.7	-23.1	0.27
1425	85.97	1.0	0.37	6.06	565	0.38	2.2	23.9	-16.9	0.27
1427	85.97	1.25	0.37	6.02	565	0.40	2.3	24.0	-14.9	0.27
1429	85.97	1.50	0.37	5.97	566	0.40	2.3	24.1	-8.1	0.27
1431	85.97	1.75	0.37	5.95	566	0.43	2.5	24.2	-3.2	0.27
1433	85.97	2.00	0.37	5.93	566	0.46	2.3	24.4	0.5	0.27

SAMPLE WITHDRAWAL METHOD: Dedicated Submersible Bladder Pump

APPEARANCE OF SAMPLE: COLOR: clear

SEDIMENT: none

OTHER: light odor

LABORATORY ANALYSIS PARAMETERS AND PRESERVATIVES TPH-DRO/ORO/GRO (HCl), VOCs (HCl), PAHs (NONE), DISSOLVED LEAD (HNO3), EDB ($Na_2S_2O_3$)

NUMBER AND TYPES OF SAMPLE CONTAINERS USED: 1 x 1L AMBER, 2 x 500mL AMBERS, 1x500 mL POLY, 7x40mL VOAs (TOTAL = 11)

SAMPLE IDENTIFICATION NUMBER(S) ERH025 @ 1440

DECONTAMINATION PROCEDURES: NAVY PPM I-F

NOTES: SAMPLE WAS FIELD FILTERED FOR DISSOLVED LEAD

SAMPLED BY: AL, BB

SAMPLES DELIVERED TO: ALS, KELSO, WA TRANSPORTER: TRACIE SOBER, ALS

DATE: 1/21/2016 TIME: 0900

CAPACITY OF CASING (GALLONS/LINEAR FOOT)
2"-0.16•4"-0.65•6"-1.47•8"-2.61•10"-4.08•12"-5.87

Figure I-C-3-1: Groundwater Sampling Log

GROUNDWATER SAMPLING LOG

WELL NO. RHMW03 LOCATION: RHFS PROJECT NO. 150037

DATE: 1/20/2016 TIME: 1455 CLIMATIC CONDITIONS: N/A

TIDAL CONDITIONS: Rising ☐ Falling ☐ HIGH TIDE: LOW TIDE: CURRENT TIDE:

STATIC WATER LEVEL (FT.) and TIME: 102.21 @1516 TOTAL DEPTH (FT.):

WELL PURGING: LENGTH OF SATURATED ZONE: LINEAR FT.

a VOLUME OF WATER TO BE EVACUATED: GALS. (Gals/Linear ft. X linear feet of saturation X 3-casing volumes)

METHOD OF REMOVAL: Dedicated Submersible Bladder Pump PUMPING RATE: mL/min

WELL PURGE DATA:

DATE/ TIME	DTW	GALLONS REMOVED	TDS (g/L)	pH	SP. COND. (µS/cm)	D.O. (mg/L)	TURB. (NTU)	TEMP. (°C)	ORP (mV)	SAL (ppt)
1/20/16 @ 1526	102.21	0.25	0.55	6.30	849	1.58	2.6	26.7	117.2	0.41
1528	102.21	0.50	0.55	6.40	849	1.40	3.2	26.5	111.7	0.41
1530	102.21	0.75	0.55	6.44	849	1.30	3.6	26.6	107.2	0.41
1532	102.21	1.00	0.55	6.46	847	1.29	3.1	26.7	96.3	0.41
1534	102.21	1.25	0.55	6.45	847	1.29	2.9	26.8	93.6	0.41
1536	102.21	1.50	0.55	6.46	844	1.32	2.8	26.8	84.9	0.41

SAMPLE WITHDRAWAL METHOD: Dedicated Submersible Bladder Pump

APPEARANCE OF SAMPLE: COLOR: clear

SEDIMENT: none

OTHER: no odor

LABORATORY ANALYSIS PARAMETERS AND PRESERVATIVES TPH-DRO / ORO / GRO (HCl), VOCs (HCl), PAHs (NONE), DISSOLVED LEAD (HNO_3), EDB ($Na_2S_2O_7$)

NUMBER AND TYPES OF SAMPLE CONTAINERS USED: 1x1L AMBER, 2 x500mL AMBERS, 1x500mL POLY, 7x40mL VOAs (TOTAL = 11)

SAMPLE IDENTIFICATION NUMBER(S) ERH026 @ 1545

DECONTAMINATION PROCEDURES: NAVY PPM

NOTES: SAMPLE WAS FIELD FILTERED FOR DISSOLVED LEAD

SAMPLED BY: AL, BB

SAMPLES DELIVERED TO: ALS, KELSO, WA TRANSPORTER: TRACIE SOBER, ALS

DATE: 1/21/2016 TIME: 0900

CAPACITY OF CASING (GALLONS/LINEAR FOOT)
2"-0.16•4"-0.65•6"-1.47•8"-2.61•10"-4.08•12"-5.87

Figure I-C-3-1: Groundwater Sampling Log

GROUNDWATER SAMPLING LOG

WELL NO. RHMW05 LOCATION: RHFS PROJECT NO. 150037

DATE: 1/20/2016 TIME: 1120 CLIMATIC CONDITIONS: N/A

TIDAL CONDITIONS: Rising ☐ Falling ☐ HIGH TIDE: LOW TIDE: CURRENT TIDE:

STATIC WATER LEVEL (FT.) and TIME: TOTAL DEPTH (FT.): COULD NOT BE MEASURED (OBSTRUCTION IN WELL)

WELL PURGING: LENGTH OF SATURATED ZONE: LINEAR FT.

a VOLUME OF WATER TO BE EVACUATED: GALS. (Gals/Linear ft. X linear feet of saturation X 3-casing volumes)

METHOD OF REMOVAL: Dedicated Submersible Bladder Pump PUMPING RATE: mL/min

WELL PURGE DATA:

DATE/ TIME	DTW	GALLONS REMOVED	TDS (g/L)	pH	SP. COND. (µS/cm)	D.O. (mg/L)	TURB. (NTU)	TEMP. (°C)	ORP (mV)	SAL (ppt)
1/20/16 @ 1146	N/A	0.5	0.62	7.07	954	8.41	8.6	23.7	112.8	0.47
1148	N/A	0.75	0.62	7.34	956	8.42	5.6	23.7	110.8	0.47
1150	N/A	1.0	0.62	7.45	956	8.42	4.8	23.7	113	0.47
1152	N/A	1.50	0.62	7.48	957	8.41	4.7	23.7	114.3	0.47

SAMPLE WITHDRAWAL METHOD: Dedicated Submersible Bladder Pump

APPEARANCE OF SAMPLE: COLOR: clear

SEDIMENT: None

OTHER: No odor

LABORATORY ANALYSIS PARAMETERS AND PRESERVATIVES TPH-DRO/ORO/GRO (HCl), VOCs (HCl), PAHs (NONE), DISSOLVED LEAD (HNO_3), EDB ($Na_2S_2O_7$)

NUMBER AND TYPES OF SAMPLE CONTAINERS USED: 1x1L AMBER, 2 x 500mL AMBERS, 1x500 mL POLY, 7x40 mL VOAS (TOTAL = 11)

SAMPLE IDENTIFICATION NUMBER(S) ERH022 @ 1200, ALSO COLLECTED DUPLICATE ERH023 " @ 1230 "

DECONTAMINATION PROCEDURES: NAVY PPM I-F

NOTES: SAMPLES ~~WAS~~ WERE FIELD FILTERED FOR ~~TOTAL~~ DISSOLVED LEAD.

SAMPLED BY: AL, BB

SAMPLES DELIVERED TO: ALS, KELSO, WA TRANSPORTER: TRACIE SOBER, ALS

DATE: 1/21/2016 TIME: 0900

CAPACITY OF CASING (GALLONS/LINEAR FOOT)
2"-0.16•4"-0.65•6"-1.47•8"-2.61•10"-4.08•12"-5.87

Figure I-C-3-1: Groundwater Sampling Log

GROUNDWATER SAMPLING LOG

WELL NO. RHMW2254-01 LOCATION: RHFS PROJECT NO. 150037

DATE: 1/20/2016 TIME: 0925 CLIMATIC CONDITIONS: N/A

TIDAL CONDITIONS: Rising ☐ Falling ☐ HIGH TIDE: LOW TIDE: CURRENT TIDE:

STATIC WATER LEVEL (FT.) and TIME: 81.00 @09:50 TOTAL DEPTH (FT.): N/A

WELL PURGING: LENGTH OF SATURATED ZONE: LINEAR FT.

a VOLUME OF WATER TO BE EVACUATED: GALS. (Gals/Linear ft. X linear feet of saturation X 3-casing volumes)

METHOD OF REMOVAL: Dedicated submersible bladder pump PUMPING RATE: mL/min

WELL PURGE DATA:

DATE/ TIME	DTW	GALLONS REMOVED	TDS (g/L)	pH	SP. COND. (μS/cm)	D.O. (mg/L)	TURB. (NTU)	TEMP. (°C)	ORP (mV)	SAL (ppt)
1/20/16 @ 1010	81.00	0.25	0.38	6.41	578	8.47	0.3	22.2	130.2	0.28
1012	81.00	0.50	0.38	6.52	583	8.60	1.3	22.2	126.5	0.28
1014	81.00	0.75	0.38	6.61	584	8.64	1.1	21.6	126.3	0.28
1016	81.00	1.25	0.38	6.72	583	8.64	0.6	21.6	126.0	0.28

SAMPLE WITHDRAWAL METHOD: Dedicated submersible bladder pump

APPEARANCE OF SAMPLE: COLOR: clear

SEDIMENT: None

OTHER: no odor / sheen

LABORATORY ANALYSIS PARAMETERS AND PRESERVATIVES TPH-DRO/ORO/GRO (HCl), VOCs (HCl), PAHs (NONE), TOTAL / ~~DISSOLVED~~ LEAD (HNO_3), EDB ($Na_2S_2O_3$)

NUMBER AND TYPES OF SAMPLE CONTAINERS USED: 1 x 1L AMBER, 2 x 500 mL AMBERS, 1 x 500 mL POLY, 7 x 40 mL VOAs (TOTAL = 11)

SAMPLE IDENTIFICATION NUMBER(S) ERH021 @ 1020

DECONTAMINATION PROCEDURES: Navy PPM I-F

NOTES: SAMPLE WAS NOT FIELD FILTERED FOR TOTAL LEAD.

SAMPLED BY: AL, BB

SAMPLES DELIVERED TO: ALS KELSO, WA TRANSPORTER: TRACIE SOBBER, ALS

DATE: 1/21/2016 TIME: 0900

CAPACITY OF CASING (GALLONS/LINEAR FOOT)
2"-0.16•4"-0.65•6"-1.47•8"-2.61•10"-4.08•12"-5.87

Figure I-C-3-1: Groundwater Sampling Log

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APPENDIX B

Field Notes

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1-20-2016 WEDNESDAY

ACTIVITY: GW MONITORING (INSIDE WELLS)
FUEL PRODUCT MONITORING
TEAM: AUSTIN LUTEY, E2
BERNICE BALETE, E2
DARREN UCHIMA, NAVFAC HI (ESCORT)
PPE LEVEL: D
WEATHER: 72°F, MOSTLY CLOUDY, 81% HUMIDITY, NO WIND
REFERENCES: WP/SAP, HSP
NAVY PPM

0815 AL ARRIVES ONSITE (DU ALREADY ONSITE)
0830 BB ARRIVES ONSITE & DRIVES VAN TO ADIT 3
AL/DU DRIVE TO ADIT 5 TO RETRIEVE GOLF CART
0900 AL/DU ARRIVE @ ADIT 3
0905 H&S BRIEFING
0910 PACK SUPPLIES/EQUIPMENT FOR 1st WELL
0920 HALAWA SHAFT POC ARRIVES TO OPEN PUMP ROOM DOOR
0921 ARRIVE @ MW <u>RHMW2254-01</u> & SETUP (DEDICATED SUBMERSIBLE
* BB DROPPED FITTING INTO WATER BLADDER PUMP)
1001 START PURGING (WL = 81.00' @ 0950)

PUMP_PRESSURE 55 PSI
-DISCHARGE TIME 20 SEC
-FILL TIME 20 SEC
CO_2 TANK·PRESSURE 150 PSI

1020 END PURGING AND COLLECT SAMPLE <u>ERH021</u>
1040 CLEAN-UP, LEAVE WELL, LOCK DOOR.
1050 GATHER EQUIPMENT/SUPPLIES FOR REMAINDER OF WELLS
1105 BACK INSIDE / PACK EQUIPMENT/SUPPLIES ONTO GOLF CART

1120 ARRIVE @ MW <u>RHMW05</u> AND SETUP (DEDICATED SUBMERSIBLE BLADDER PUMP)
1130 COULD NOT MEASURE GW LEVEL DUE TO OBSTRUCTION IN THE WELL
1140 START PURGING (USE CONTINUOUS FLOW CELL)

PUMP-PRESSURE ~~55~~ 60 PSI BB
-DISCHARGE TIME 25 SEC
-FILL TIME ~~20~~ 25 SEC BB
CO_2 TANK-PRESSURE 150 PSI

WEDNESDAY 1-20-2016

SAMPLE LOG:

EPA ID:	SAMPLE ID:	DATE:	TIME:	# CONT:
ERH021	RH-MW2254-GW116	01-20-16	1020	11
ERH022	RH-MW05-GW116	01-20-16	1200	11
ERH023	RH-MW05-GW116-DUP	01-20-16	1230	11
ERH024	RH-MW01-GW116	01-20-16	1315	11
ERH025	RH-MW02-GW116	01-20-16	1440	11
ERH026	RH-MW03-GW116	01-20-16	1545	11
ERH027	* RH-SB-GW116	01-~~20~~ 21-16	0800	11
ERH028	† * RH-ERB-GW116	01-~~20~~ 21-16 DB	0830	11

* MENEHUNE WATER, CO. STEAMED DISTILLED WATER

† BLADDER PUMP USED @ RHMW01

1-20-2016 WEDNESDAY

1155 END PURGING
1200 COLLECT SAMPLE ERH022 AND DUPLICATE ERH023
(1230) TIME GIVEN TO DUPLICATE SAMPLE
1220 LEAVE WELL

1221 ARRIVE @ MW RHMW01 AND SETUP (THE WELL IS FURTHER EAST,
CLOSER TO ADIT 5) USED OUR OWN TUBING AND SMALL ϕ BLADDER (0.85")
1251 START PURGING (USE CONTINUOUS FLOW CELL), WL = 83.3' @ 1230

PUMP-PRESSURE 50 PSI
-DISCHARGE TIME 10 SEC
-FILL TIME 15 SEC
CO_2 TANK PRESSURE - 150 PSI

1310 END PURGING
1315 COLLECT SAMPLE ERH024
EAT LUNCH WHILE JARS ARE SLOWLY BEING FILLED
1357 LEAVE WELL

1358 ARRIVE @ MW RHMW02 AND SETUP (DEDICATED SUBMERSIBLE BLADDER PUMP)
1407 WL = 85.97'
1417 START PURGING

PUMP-PRESSURE 60 PSI
- DISCHARGE TIME 30 SEC
- FILL TIME 25 SEC
CO_2 TANK PRESSURE - 150 PSI

1435 END PURGING
1440 COLLECT SAMPLE ERH025
1452 LEAVE WELL

1455 ARRIVE AT MW RHMW03 AND SETUP (DEDICATED SUBMERSIBLE BLADDER PUMP)
1516 WL = 102.21'
1518 START PURGING

PUMP-PRESSURE 60 PSI
-DISCHARGE TIME 40 SEC
-FILL TIME 25 SEC
CO_2 TANK PRESSURE - 150 PSI

1540 END PURGING

1545 COLLECT SAMPLE ERM026

1557 LEAVE WELL

PACK UP, USE FREIGHT ELEVATOR TO TAKE EQUIPMENT UP

1620 EXIT TUNNELS AT ADIT 5

1630 EMPTY 10W INTO NEW DRUM-002 AND SECURE TARP COVER WITH BUNGY CORDS

1640 BB LEAVES SITE

1650 AL/OU RETURN TO MW RHMW04 TO ~~CHECK AIR LINE AND~~ ADD AN EXTENSION BB TO THE WATER DISHARGE LINE

1710 AL/OU LEAVE SITE

1/20/16

APPENDIX C

Laboratory Report
(included on attached CD)

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APPENDIX D

EPA/DOH Letter, Enclosure A, Analytes and Action Levels, February 4, 2016

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ENCLOSURE A
ANALYTES AND ACTION LEVELS

TABLE 1
ANALYTES AND ACTION LEVELS FOR RED HILL MONITORING WELLS RHMW01, RHMW02, AND RHMW03

ANALYTE	Environmental Action Level µg/L	SSRBL µg/L
TPH-g	100	NA
TPH-d	100	4500
TPH-o	100	NA
Benzene	5	750
Ethylbenzene	30	NA
Toluene	40	NA
Total Xylenes	20	NA
Naphthalene	17	NA
1-Methylnaphthalene	4.7	NA
2-Methylnaphthalene	10	NA

NA – Not Applicable

TABLE 2
ANALYTES AND ACTION LEVELS FOR RED HILL MONITORING WELLS RHMW04, RHMW05, RHMW06, RHMW07, RHMW2254-01, HDMW2253, AND OWDFMW01

ANALYTE	Environmental Action Level µg/L
TPH-g	100
TPH-d	100
TPH-o	100
Benzene	5.0
Ethylbenzene	30
Toulene	40
Total Xylenes	20
Naphthalene	17
1-Methylnaphthalene	4.7
2-Methylnaphthalene	10

ENCLOSURE A
ANALYTES AND ACTION LEVELS

TABLE 3
ANALYTES AND ACTION LEVELS FOR FUTURE RED HILL MONITORING WELLS RHMW08, RHMW09, RHMW10, AND RHMW11

ANALYTE	Environmental Action Level µg/L
TPH-g	100.0
TPH-d	100.0
TPH-o	100.0
Benzene	5.0
Ethylbenzene	30.0
Toulene	40.0
Total Xylenes	20.0
Naphthalene	17.0
1-Methylnaphthalene	4.7
2-Methylnaphthalene	10.0
1,2 Dichloroethane*	5.0
1,2 Dibromoethane*	0.04

*Lead Scavengers can be discontinued after one year of sampling if all samples result in non-detection.

APPENDIX E

Fact Sheet, Quantitation & Detection

Fact Sheet: Detection and Quantitation — What Project Managers and Data Users Need to Know

As a Project Manager or decision-maker, you may use environmental data to accomplish one or more of the following tasks:

- Determine whether a chemical substance is present in an environmental sample at or above some threshold value or action level;
- Verify that a pollutant concentration remains below a permit limit;
- Evaluate potential risks to human health or the environment;
- Monitor changes in concentrations of contaminants; or
- Determine the effectiveness of remediation activities.

Making correct decisions in these cases often depends on the ability of an analytical method to detect and measure extremely low concentrations of a substance.

This fact sheet has been prepared to: 1) provide Project Managers and data users with basic information about detection and quantitation concepts; and 2) acquaint the reader with detection and quantitation terminology and requirements contained in the *DoD Quality Systems Manual for Environmental Laboratories (DoD QSM)*, Version 4.1. This information should help clarify the uncertainty associated with reporting low-concentration data. It should also help project teams understand the importance of selecting analytical methods that are sensitive enough for their intended uses, i.e., capable of generating reliable data (data of known precision and bias) at the project-specific decision levels.

Measures of Sensitivity — Basic Concepts

The following terms are used to describe the routine sensitivity of analytical procedures:

- DL – Detection Limit
- LOD – Limit of Detection
- LOQ – Limit of Quantitation

All measures of sensitivity are specific to the analyte, sample matrix, test method, instrumentation, and analyst/laboratory performance. Therefore, analytical performance must be demonstrated for each variable (e.g., it is possible that two “identical” instruments from the same manufacturer may exhibit different sensitivities).

The Detection Limit (DL) is the smallest analyte concentration that can be demonstrated to be different from zero or a blank concentration at the 99% level of confidence. In other words, if a substance is detected at or above the DL, it can be reliably stated (with 99% confidence) that the analyte is present (there is a 1% chance that the analyte is not present (a false positive)). Note that for reporting purposes, any result at or above the DL must also meet qualitative identification criteria required by the test method. Although a result at or above the DL indicates that the analyte is present, the absence of a result at or above the DL is inconclusive (i.e., one cannot confidently state whether the analyte is present or absent), because the false negative rate at the DL is 50%.

The Limit of Detection (LOD) is the smallest amount or concentration of a substance that must be present in a sample in order to be detected at a 99% confidence level. In other words, if a sample has a true concentration at the LOD, there is a minimum probability of 99% of reporting a “detection” (a measured value ≥ DL) and a 1% chance of reporting a non-detect (a false negative).

The failure to obtain a “detection” should be reported as “<LOD,” because the false negative rate at the LOD is 1%. Reporting the sample result as “<DL” is inappropriate because, as stated above, the false negative rate at the DL is 50%.

The Limit of Quantitation (LOQ) is the lowest concentration of a substance that produces a quantitative result within specified limits of precision and bias. The LOQ is typically larger than the LOD (but may be equal to the LOD, depending upon the acceptance limits for precision and bias); therefore, the following is true:

$$\text{DL} < \text{LOD} \leq \text{LOQ}$$

Quantitative results can only be achieved at or above the LOQ. Measurements between the DL and the LOQ assure the *presence* of the analyte with confidence, but their numeric values are estimates.

Types of Procedures for Estimating Sensitivity

Numerical estimates of the DL, LOD, or LOQ for a specific analyte, matrix, and method can be calculated using various statistical procedures, which involve spiking reagent water or other specific matrix with low concentrations of the analyte of interest. At this time, unfortunately, universally accepted statistical procedures do not exist.

The estimator that has been most commonly used by environmental laboratories is the EPA Method Detection Limit (MDL), which is an approximation of the DL. EPA has defined the MDL as the "minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero, and is determined from analysis of a sample in a given matrix containing the analyte."[1] Calculating the MDL at 99% confidence means there is a 1% probability that a sample having a result at or above the MDL is a false positive. The EPA MDL was designed to protect against false positives.

Uses and Limitations of the MDL

When performed correctly and consistently, MDLs determined using the EPA procedure can be useful for comparing different laboratories' performance using the same methods, or the performance of different methods within the same laboratory. Laboratories typically determine the MDL in reagent water, resulting in a "best-case" MDL, which provides limited information about method performance on real-world samples.

The EPA MDL procedure has been criticized as a poor estimator of the DL for the following reasons:

1. It is a single laboratory, short-term estimator that fails to account for analytical bias, changing instrument conditions, or analyst skill.
2. It assumes uniform variance across all possible spike concentrations, failing to account for the fact that variance increases at higher concentrations.
3. It assumes that measured values at the spike concentration are normally distributed. By using this procedure and spiking at very low concentrations, laboratories have been able to calculate MDLs that cannot be achieved in practice.

DoD QSM Requirements

For the reasons discussed in the previous paragraph, the DoD QSM requires that laboratories verify measures of method sensitivity, in terms of the LOD and LOQ, at least quarterly. Requirements for the LOD and the LOQ are contained in DoD QSM Boxes D-13 and D-14, respectively, which follow:

---

[1] 40 Code of Federal Regulations (CFR) Part 136, Appendix B, rev. 1.11.

Box D-13

Limit of Detection (LOD): Determination and Verification (Requirement)

A laboratory shall establish a detection limit (DL) using a scientifically valid and documented procedure for each suite of analyte-matrix-method, including surrogates. The detection limit shall be used to determine the LOD for each analyte and matrix as well as for all preparatory and cleanup methods routinely used on samples, as follows:

After each detection limit determination, the laboratory must immediately establish the LOD by spiking a quality system matrix at approximately two to three times the detection limit (for a single-analyte standard) or one to four times the detection limit (for a multi-analyte standard). This spike concentration establishes the LOD. It is specific to each combination of analyte, matrix, method (including sample preparation), and instrument configuration. The LOD must be verified quarterly. The following requirements apply to the initial detection limit/LOD determinations and to the quarterly LOD verifications.

- The apparent signal to noise ratio at the LOD must be at least three and the results must meet all method requirements for analyte identification (e.g., ion abundance, second-column confirmation, or pattern recognition.) For data systems that do not provide a measure of noise, the signal produced by the verification sample must produce a result that is at least three standard deviations greater than the mean method blank concentrations.
- If a laboratory uses multiple instruments for a given method the LOD must be verified on each.
- If the LOD verification fails, then the laboratory must repeat the detection limit determination and LOD verification at a higher concentration or perform and pass two consecutive LOD verifications at a higher concentration and set the LOD at the higher concentration.
- The laboratory shall maintain documentation for all detection limit determinations and LOD verifications.

Box D-14

Limit of Quantitation (LOQ): Establishment and Verification of LOQ (Requirement)

For DoD projects, the LOQ must be set within the calibration range prior to sample analysis. At a minimum, the LOQ must be verified quarterly.

The laboratory procedure for establishing the LOQ must empirically demonstrate precision and bias at the LOQ. The LOQ and associated precision and bias must meet client requirements and must be reported. If the method is modified, precision and bias at the new LOQ must be demonstrated and reported.

Establishing Project-Specific Requirements for Method Sensitivity

Project teams should establish their project-specific requirements for method sensitivity in terms of a Reporting Limit (RL) for each analyte and matrix. As defined in the DoD QSM, the RL is the lowest concentration value specified by the client that meets project requirements for reporting quantitative data with known precision and bias for a specific analyte in a specific matrix. The LOQ cannot be greater than the RL, if precision and bias of the RL and LOQ are the same. If the LOQ for a particular analytical method or laboratory cannot meet the RL, then a project team has three options:

1. Improve analyst performance or modify the method to achieve a lower LOQ.
2. Select a different method with an LOQ less than or equal to the RL.
3. Raise the RL.

Please note that precision and bias must be taken into consideration when assessing the LOQ versus the RL. Also note that data below the RL can be reported; however they are estimated values if less than the LOQ.

Reporting and Flagging Analytical Data

Although data reporting and flagging requirements are project-specific, all reported LOD and LOQ shall be adjusted for the size of sample aliquots, concentration/dilution factors, and percent solids. In addition, the following example (based on Box 47 of DoD QSM Version 4.1) illustrates the proper use of the "U" and "J" data qualifier flags for non-detect and estimated analytical results, respectively.

U – Analyte was not detected and is reported as less than the LOD or as defined by the client. The LOD has been adjusted for any dilution or concentration of the sample (* see Example, below).

J – The reported result is an estimated value (e.g., matrix interference was observed or the analyte was detected at a concentration outside the quantitation range, see Box 33).

Example: DL = 2, LOD = 4, LOQ = 20, and RL = 30 with the precision and bias of the LOQ meeting those of the RL and all samples are undiluted.

Sample #1:	Analytical result: Non-detect	Reported result: <4 U
Sample #2:	Analytical result: 3	Reported result: 3 J
Sample #3:	Analytical result: 10	Reported result: 10 J
Sample #4:	Analytical result: 20	Reported result: 20
Sample #5:	Analytical result: 30	Reported result: 30

Understanding and Documenting Uncertainty for Low-Concentration Data

As mentioned above, detection and quantitation limits are laboratory specific. Following are some steps Project Managers can take to document measurement uncertainty for low concentration data.

- As part of the laboratory selection process, provide the laboratory with project-specific RLs, including precision and bias, for each analyte and matrix. Ask the laboratory to provide its DL, LOD, and LOQ with associated precision and bias for each target analyte, in each matrix of concern (e.g., reagent water, clean sand, etc.), and verify that these values meet project-specific RLs. Request laboratory SOPs for establishing the DL and for establishing and verifying the LOD and LOQ.
- Ask the laboratory to verify the LOD by processing an LOD verification check sample with each batch of samples. This is a quality control sample that is spiked at a concentration at or slightly above the LOD to evaluate whether the analyte of interest is in fact "detectable" in the matrix of interest. To confidently report non-detects, set the reporting for non-detects to less than the LOD.
- If the project involves the collection of unusual or difficult matrices, or if the project-specific RL is near the LOQ, ask the laboratory to verify the LOQ in the project-specific matrix by analyzing a minimum of four replicate samples with known concentrations at the LOQ.
- Review the raw data (e.g., chromatograms) for low-concentration data. If a result is reported above the DL, make sure that the signal-to-noise ratio is at least 3.
- Compare sample results with blank results. If sample results (including chromatograms) cannot be distinguished from blank results, then they are not meaningful.

APPENDIX F

Historical Groundwater Exceedance Trends

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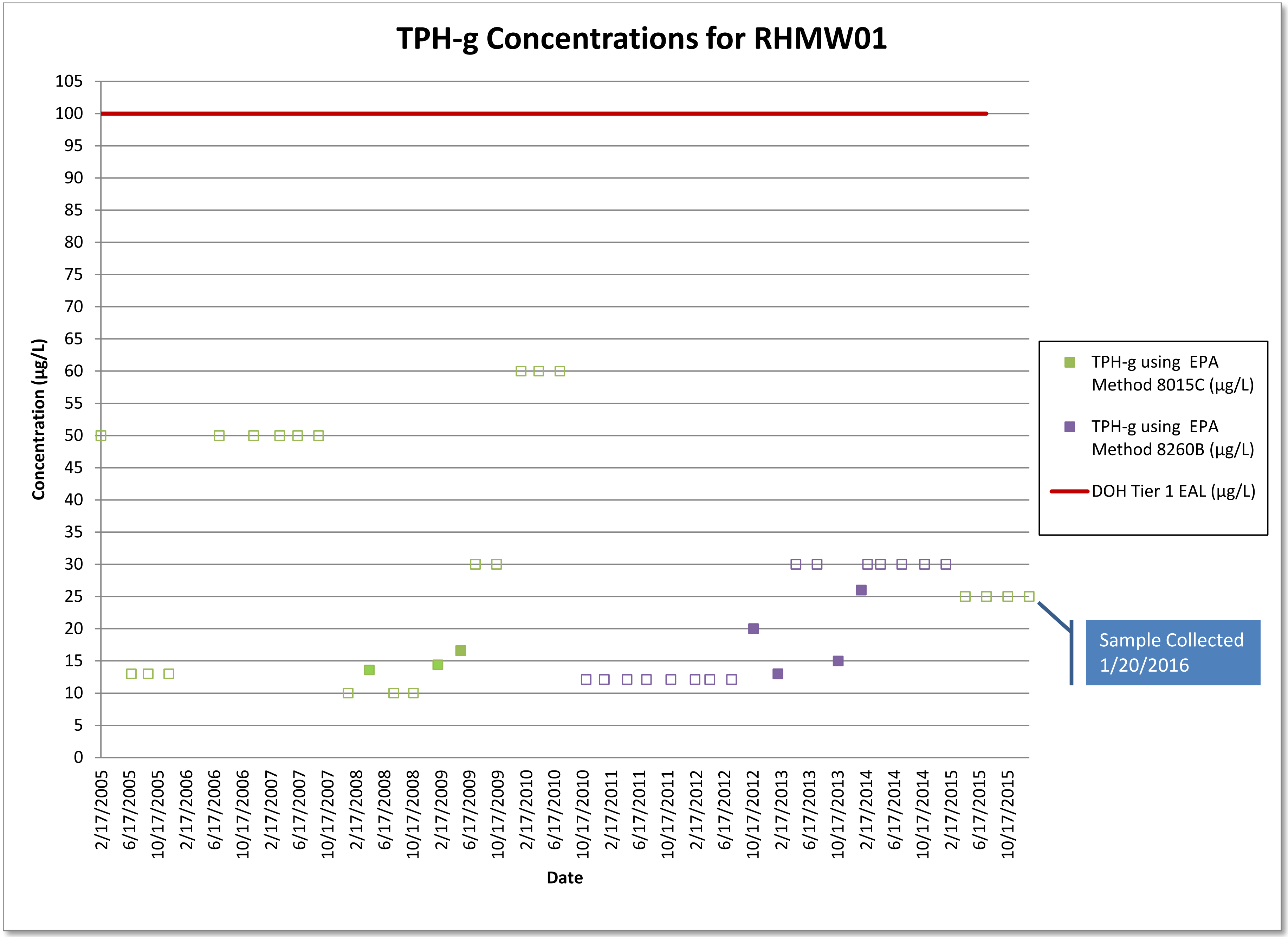
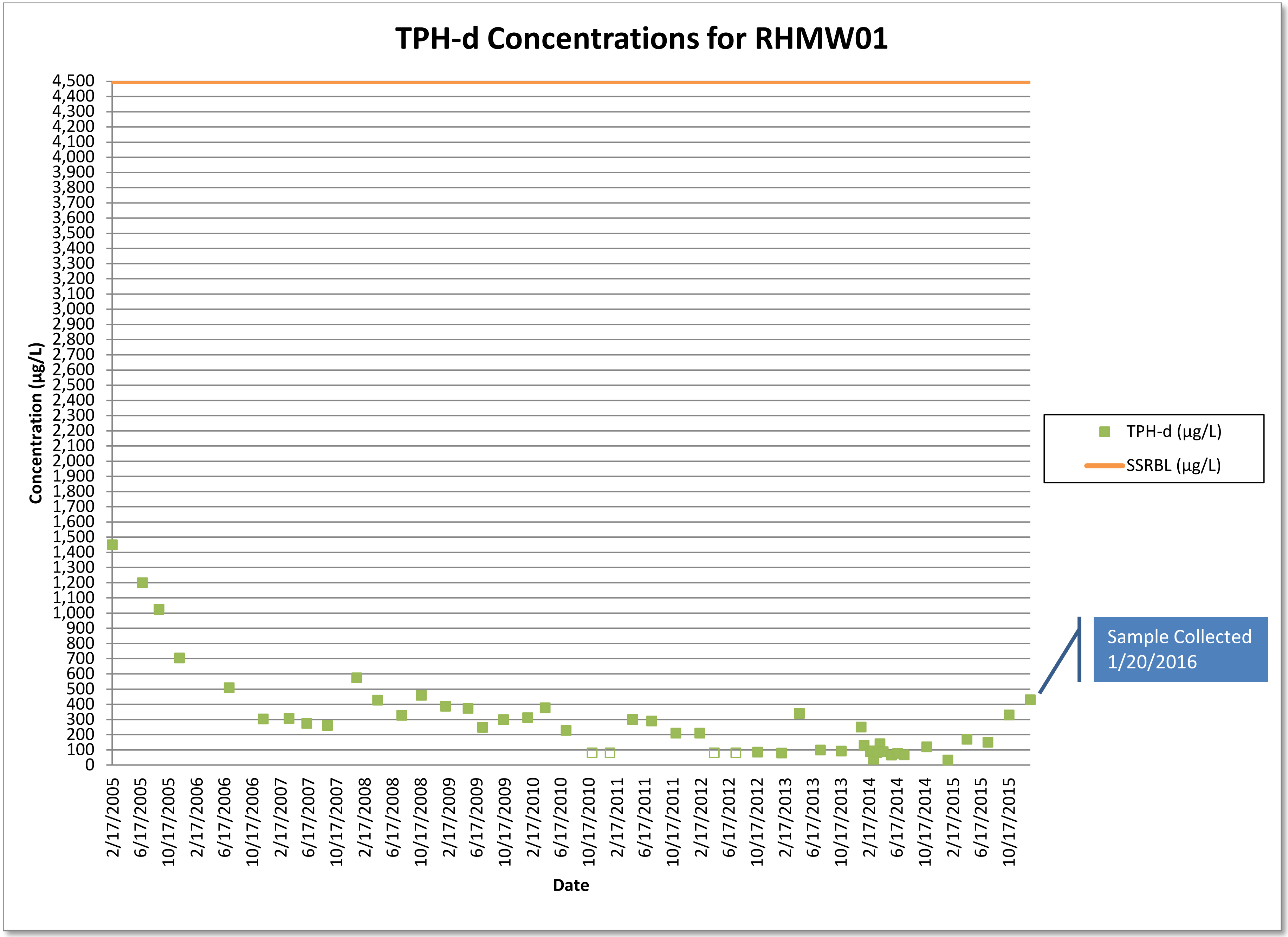
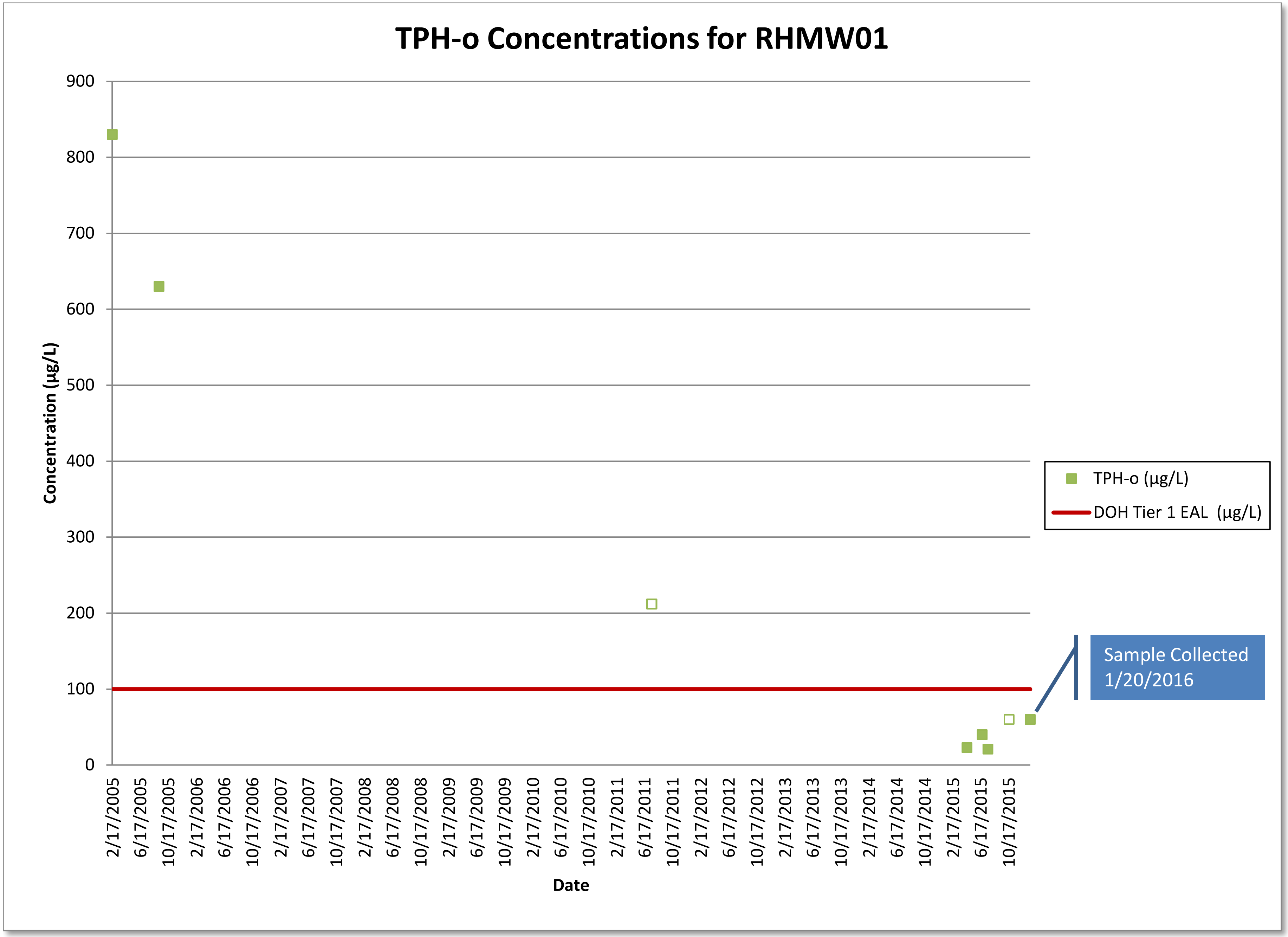


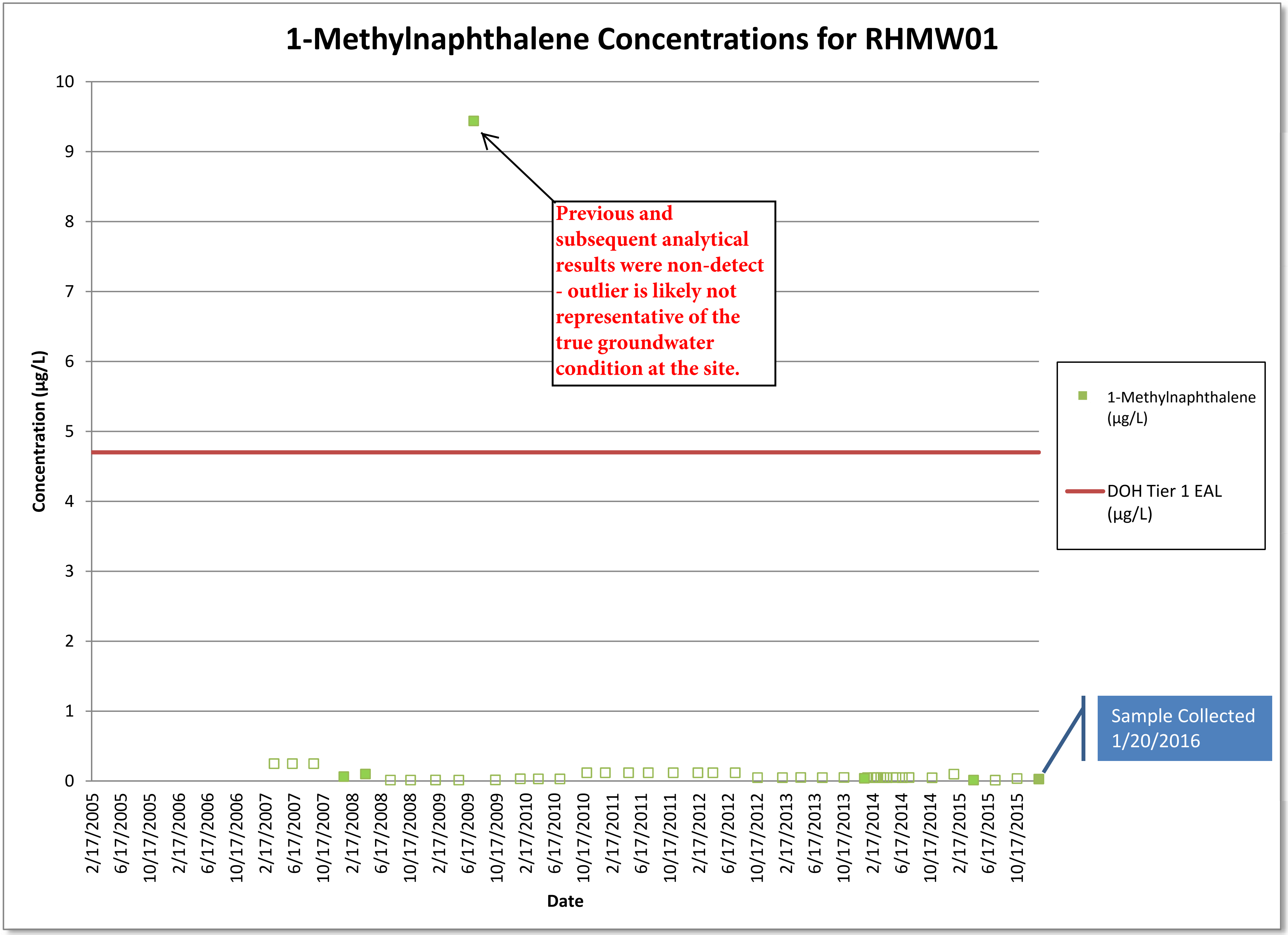
Unfilled boxes indicate non-detections. Data points for 2/17/2005 through 9/8/2005 and 12/6/2005 are the average of the primary and duplicate samples. Possible laboratory contamination for 10/22/2012, 10/21/2013, and 1/28/2014 sampling events. Method reporting limits (MRLs) are shown for February 2005, method detection limits (MDLs) are shown for June 2005 through October 2009, and limits of detection (LODs) are shown from January 2010 on.



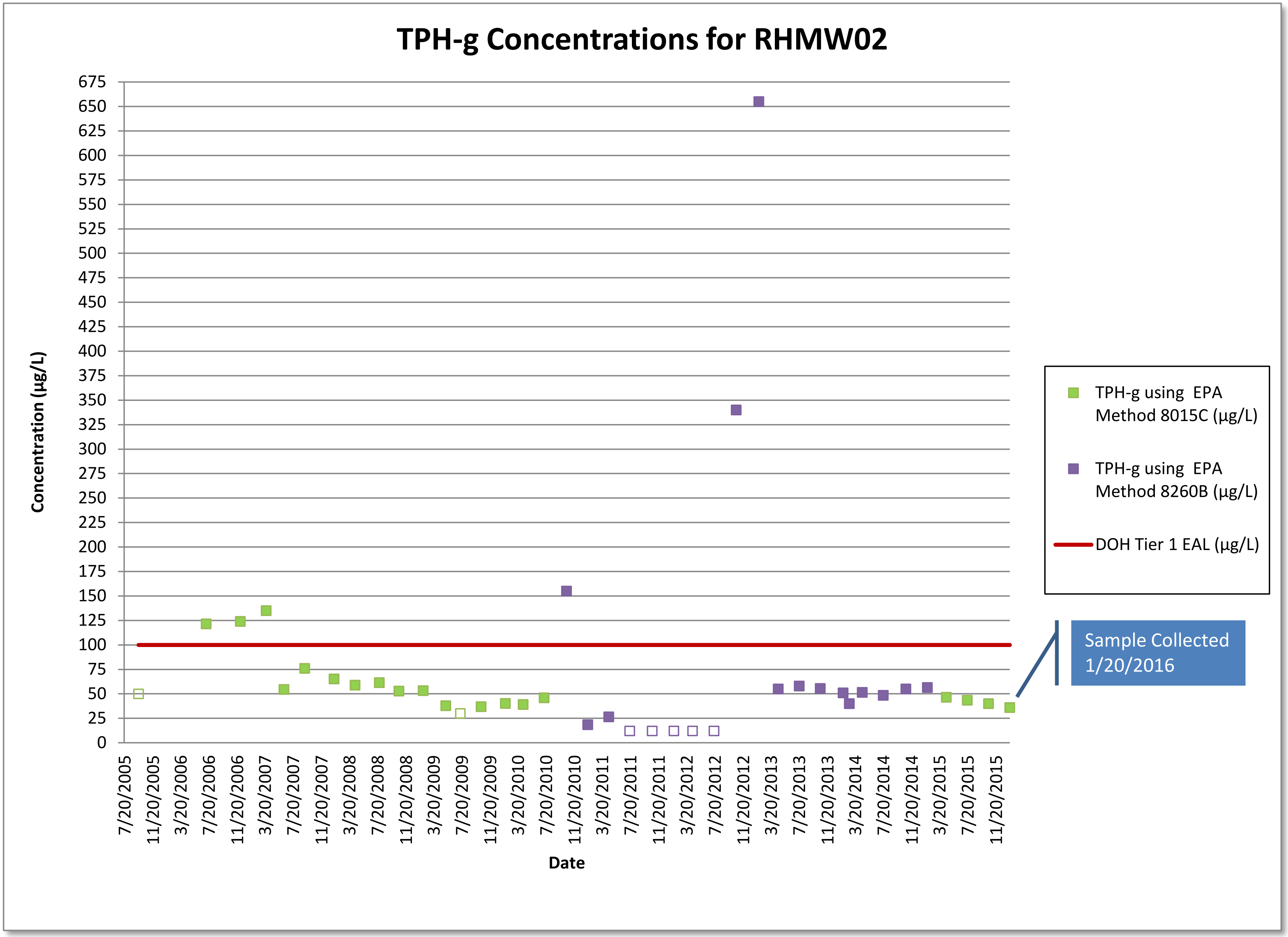
Unfilled boxes indicate non-detections. LODs are shown. Numerous sample results had a chromatographic pattern that did not match the calibration standard. The relatively high TPH-d values may not necessarily be indicative that there is diesel fuel or other petroleum products in the well. Data points for 2/17/2005 through 9/8/2005 and 12/6/2005 are the average of the primary and duplicate samples.



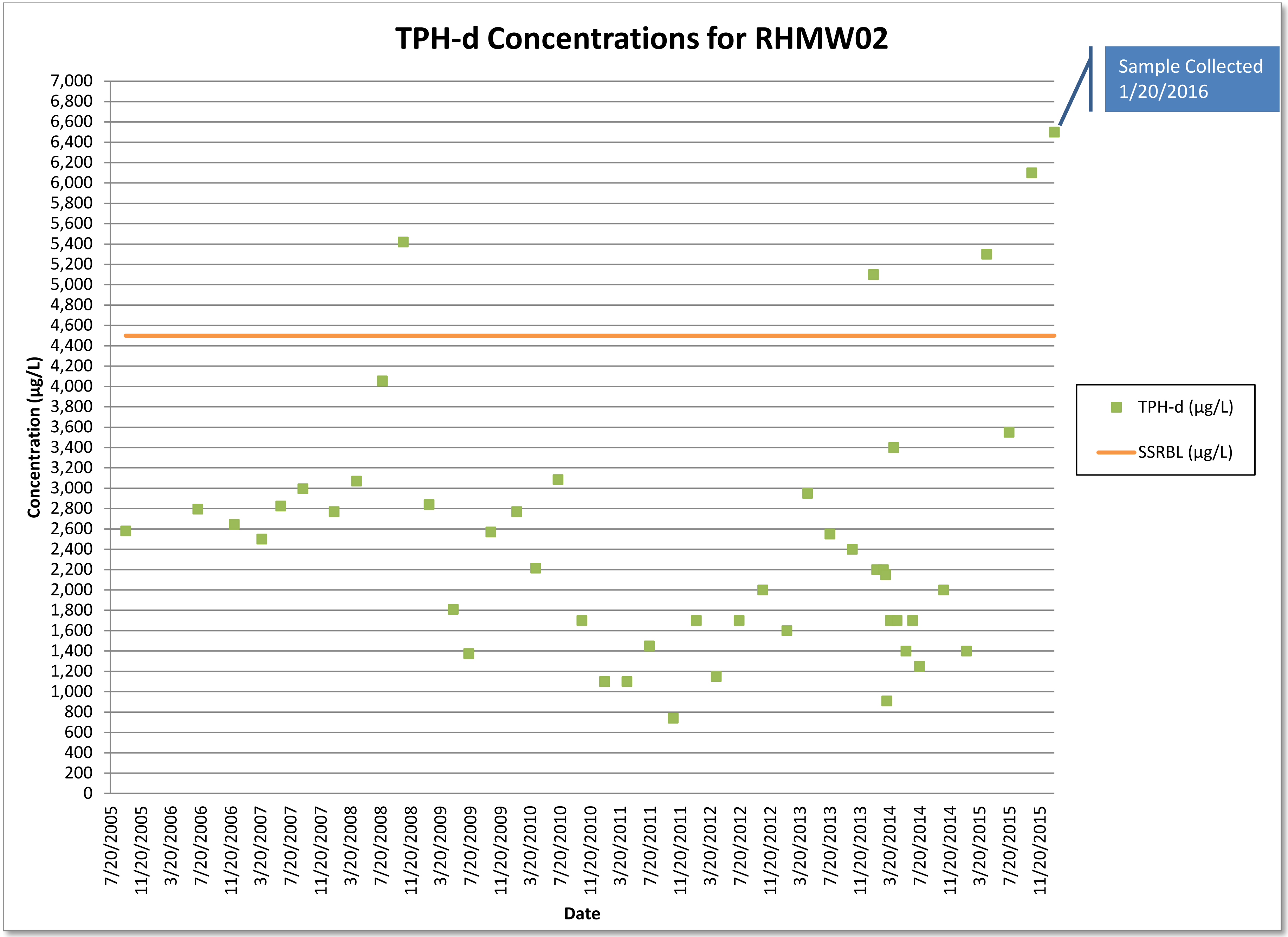
Unfilled boxes indicate non-detections.



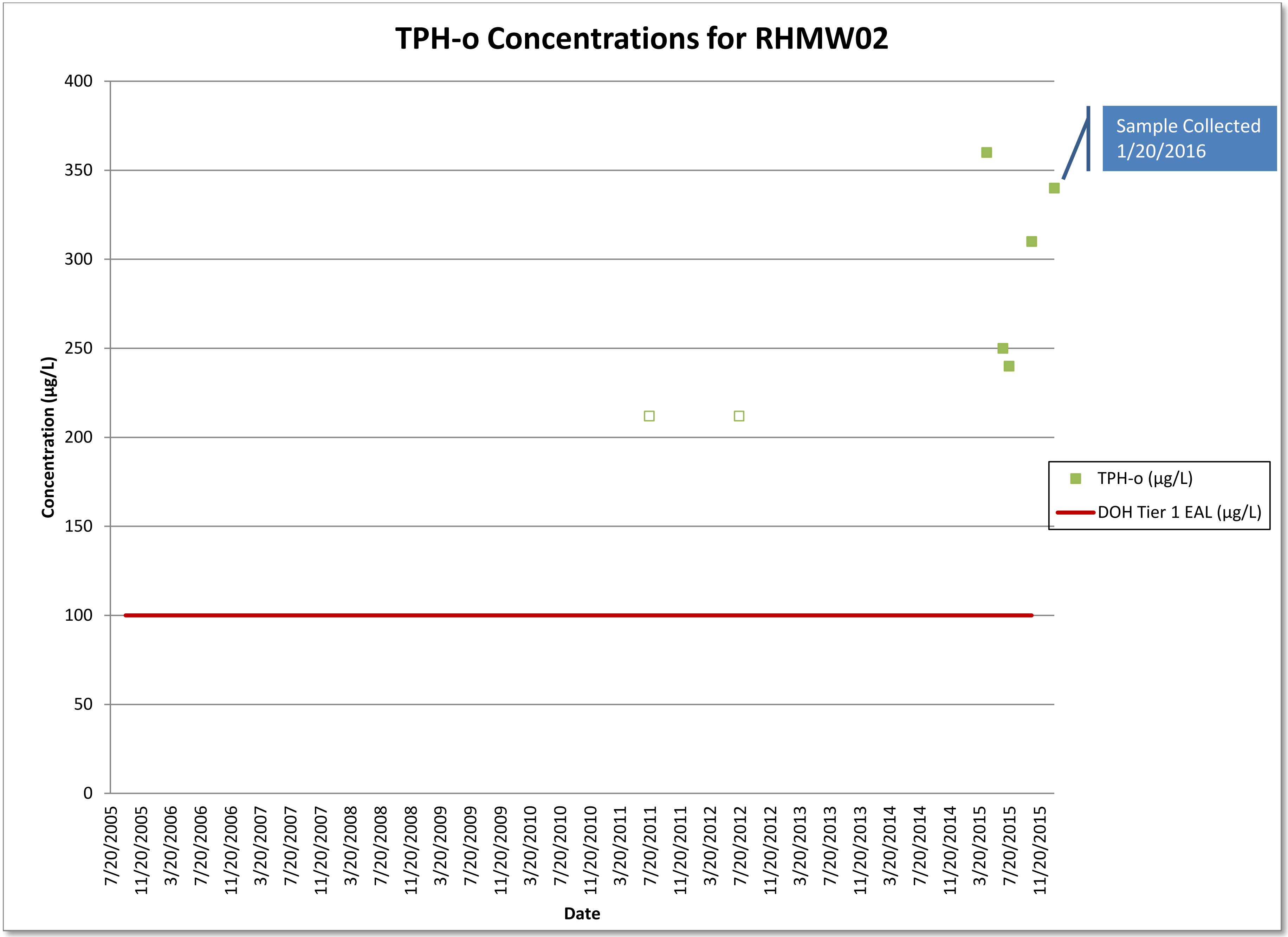
Unfilled boxes indicate non-detections. MDLs are shown for June 2005 through October 2009 and LODs are shown from January 2010 on.



Unfilled boxes indicate non-detections. Data points for 9/20/2005 through 4/21/2014 are the average of the primary and duplicate samples. Possible laboratory contamination for 10/21/2013 and 1/28/2014 sampling events. MDLs are shown for July 2009, and LODs are shown for September 2005 and from July 2011 on. Primary sample results are shown for 1/26/2012 and 7/18/2012; all other concentrations are the average of the primary and duplicate sample results.

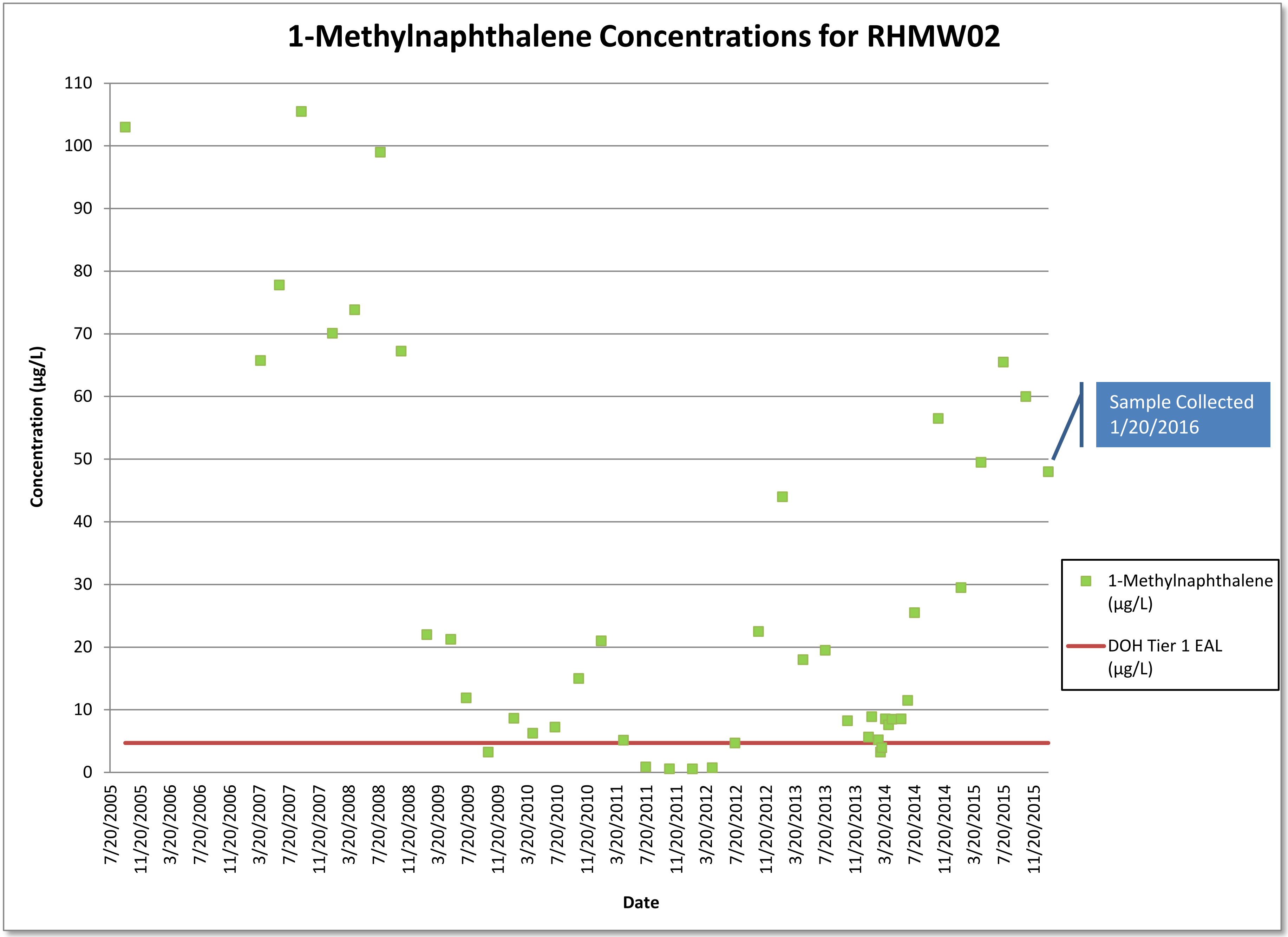


Data points for 9/20/2005 through 4/21/2014 are the average of the primary and duplicate samples.
Numerous sample results had a chromatographic pattern that did not match the calibration standard.
The relatively high TPH-d values may not necessarily be indicative that there is diesel fuel or other petroleum products in the well.

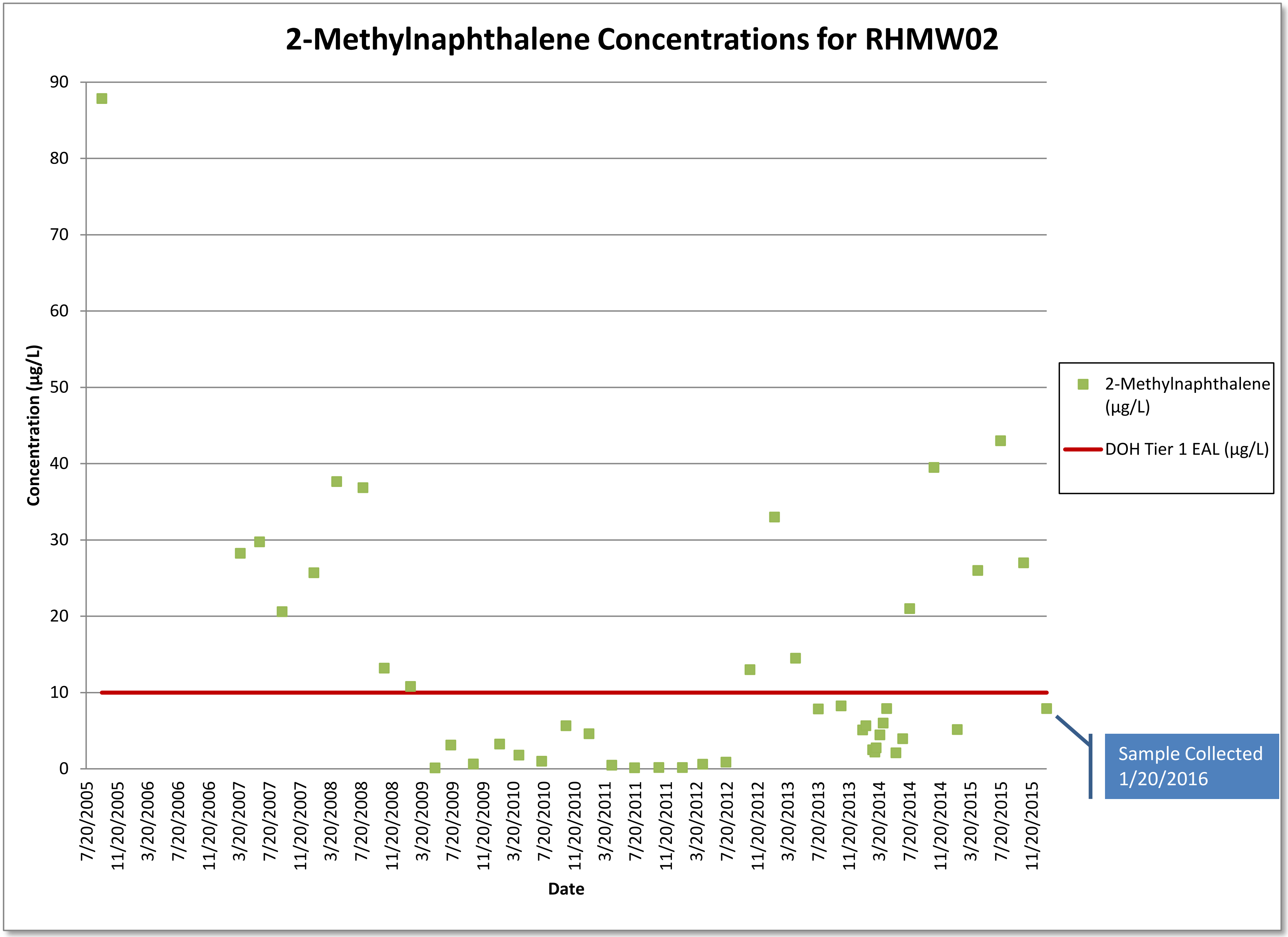


Unfilled boxes indicate non-detections.

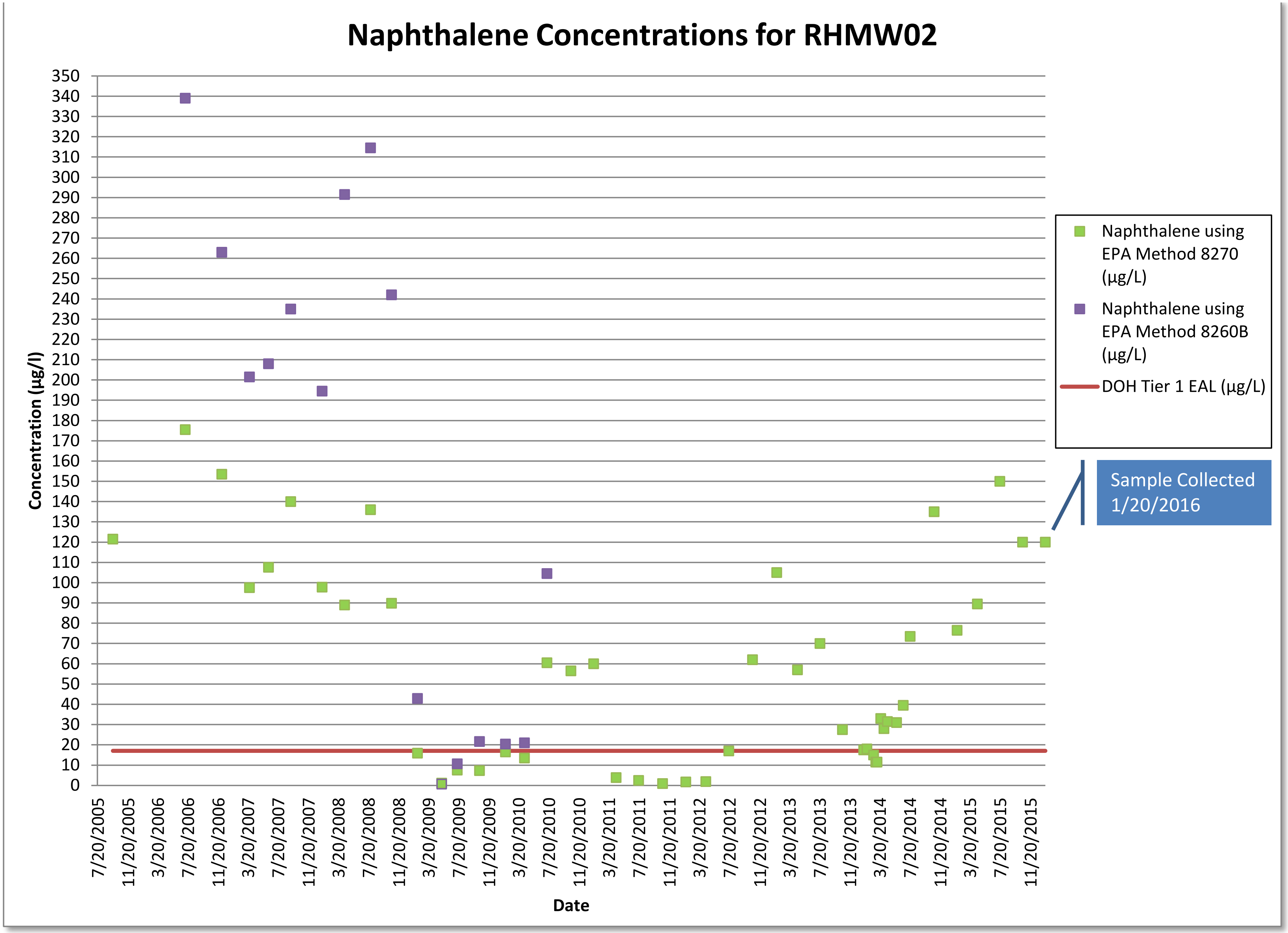
January 2016 data was flagged "L", meaning the chromatographic fingerprint of the sample resembled a petroleum product, but the elution pattern indicated the presence of a greater amount of lighter molecular weight constituents than the calibration standard.



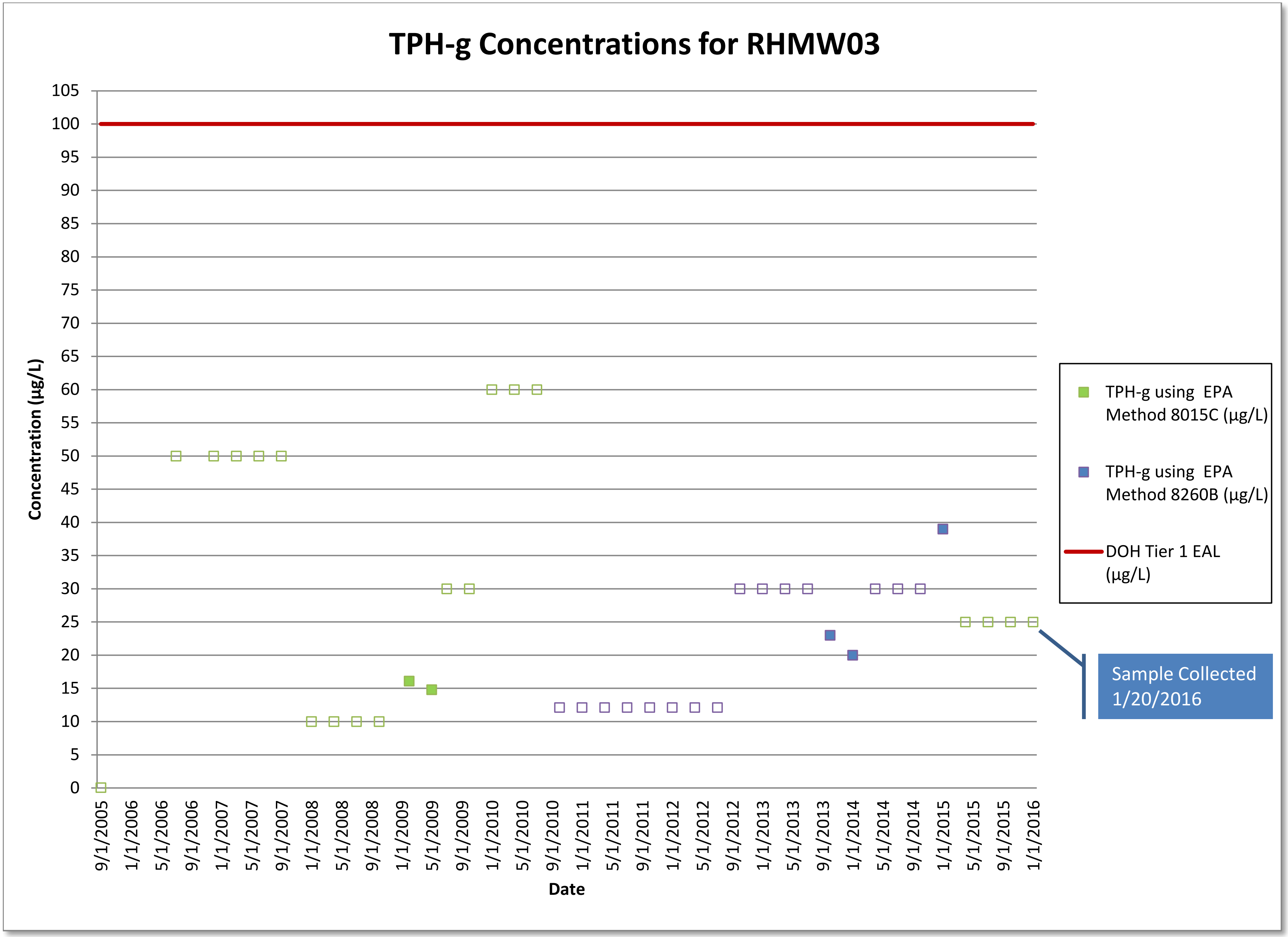
Data points for 9/20/2005 and 3/27/2007 through 4/21/2014 are the average of the primary and duplicate sample results.



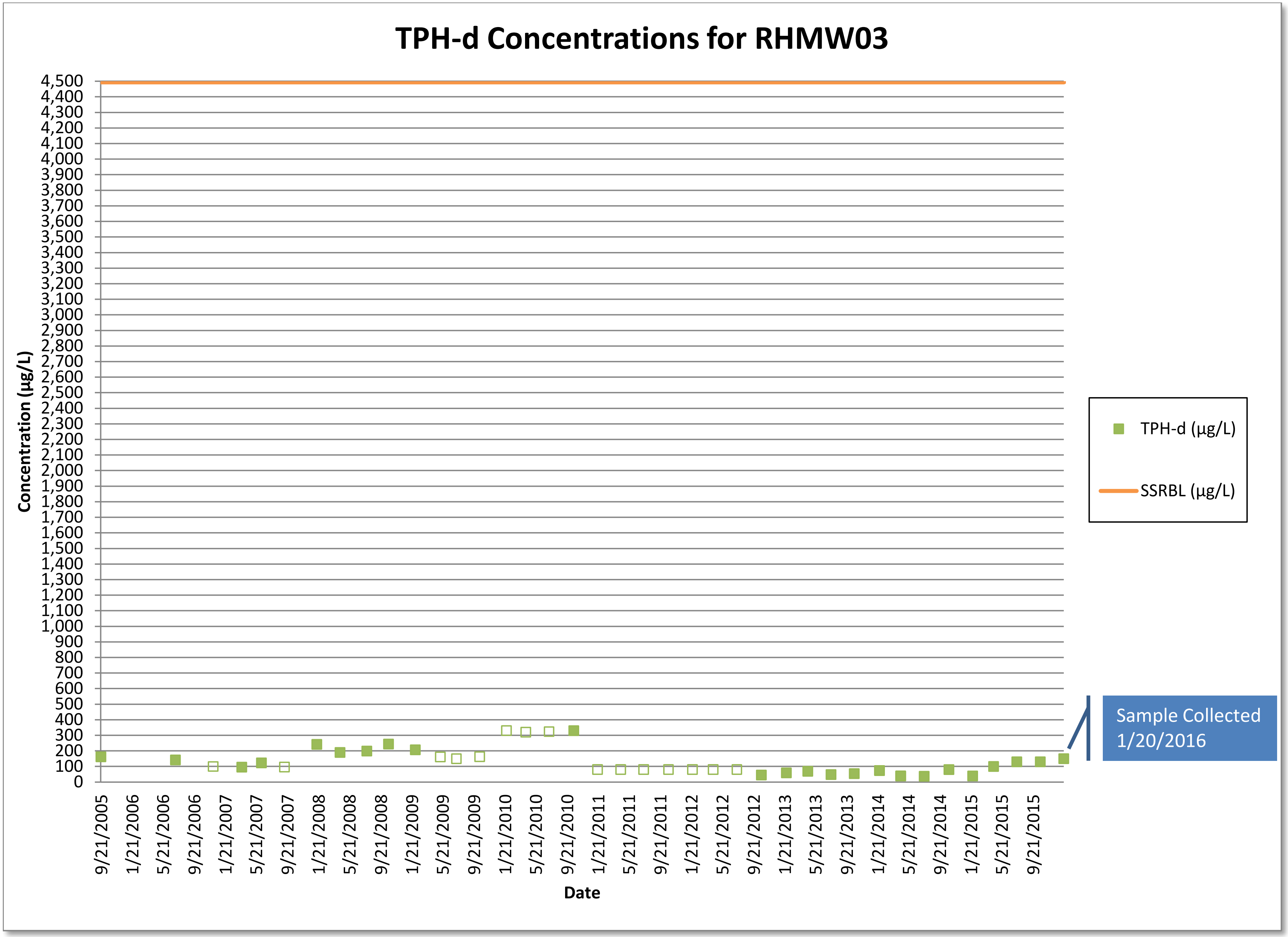
Data points for 9/20/2005 and 3/27/2007 through 4/21/2014 are the average of the primary and duplicate sample results.
Unfilled boxes indicate non-detections.



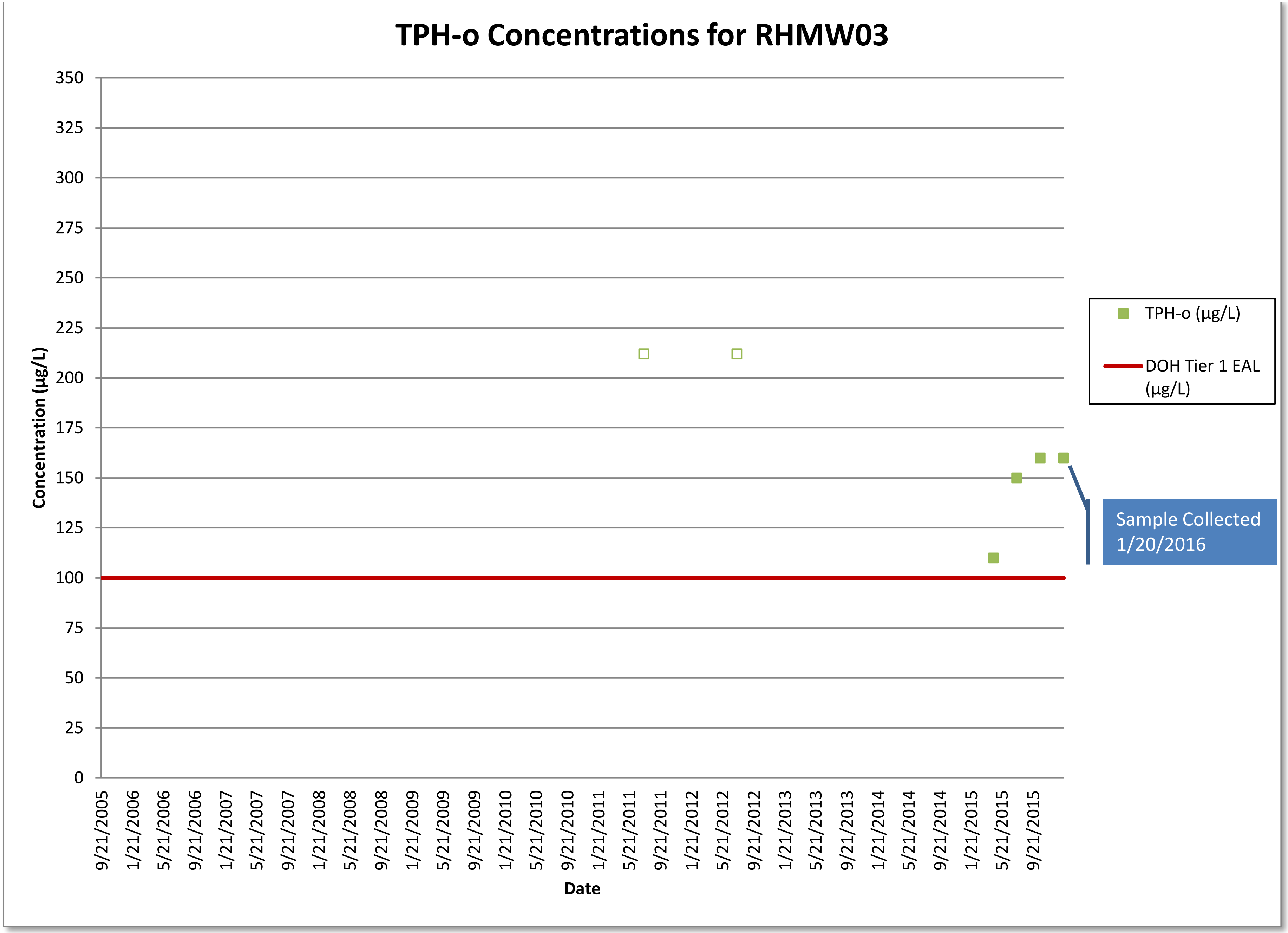
Possible laboratory contamination for 10/21/2013 and 1/28/2014 sampling events.
Unfilled boxes indicate non-detections. LODs are shown.



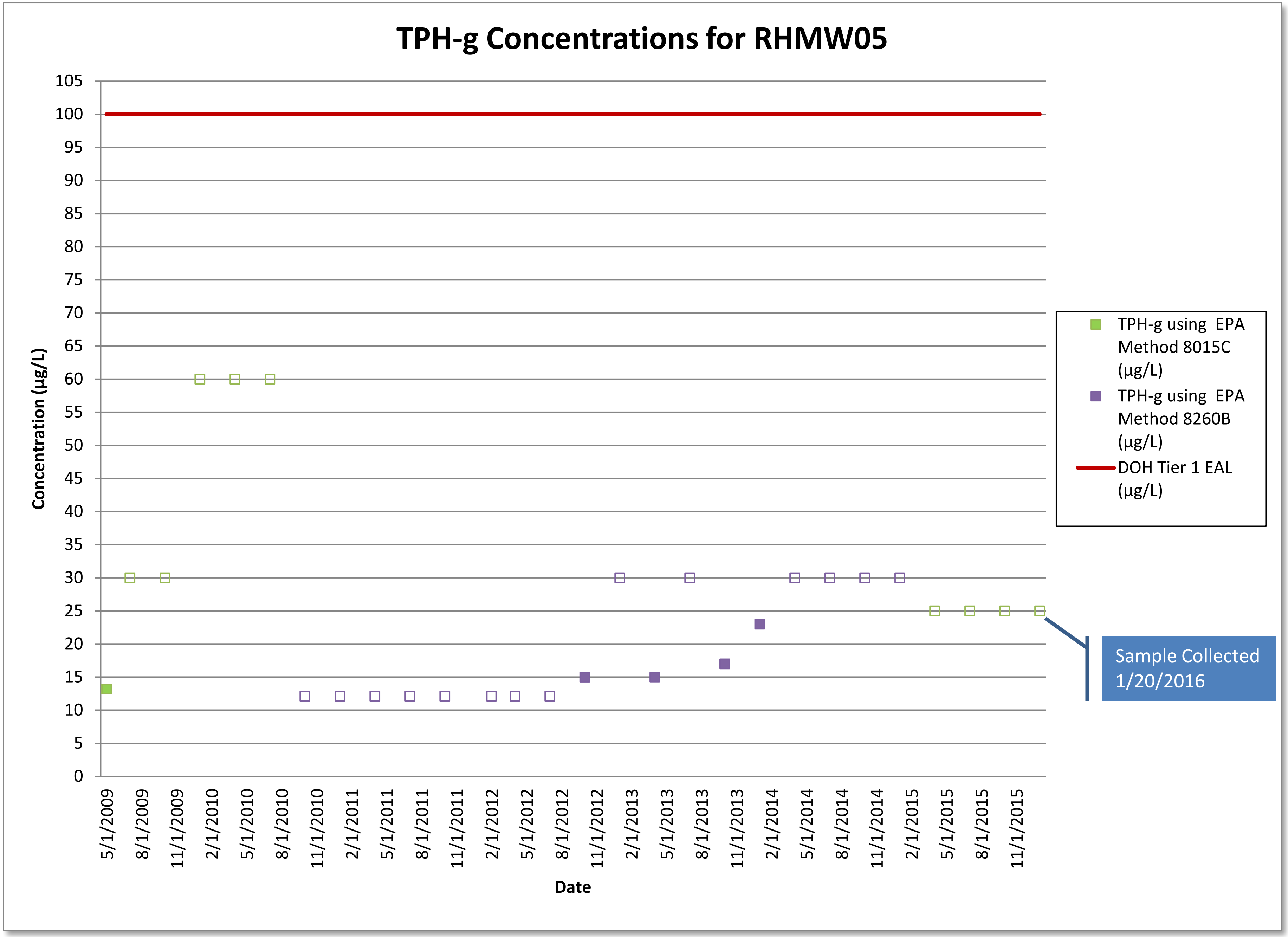
Possible laboratory contamination for 10/21/2013 and 1/28/2014 sampling events.
Unfilled boxes indicate non-detections. MDLs are shown for July 2006 through October 2009, and LODs are shown for September 2005 and from January 2010 on.



Unfilled boxes indicate non-detections. MDLs are shown for December 2006 through October 2009, and LODs are shown for September 2005 and from January 2010 on. Numerous sample results had a chromatographic pattern that didn't match the calibration standard. The relatively high TPH-d values may not necessarily be indicative that there is diesel fuel or other petroleum products in the well.

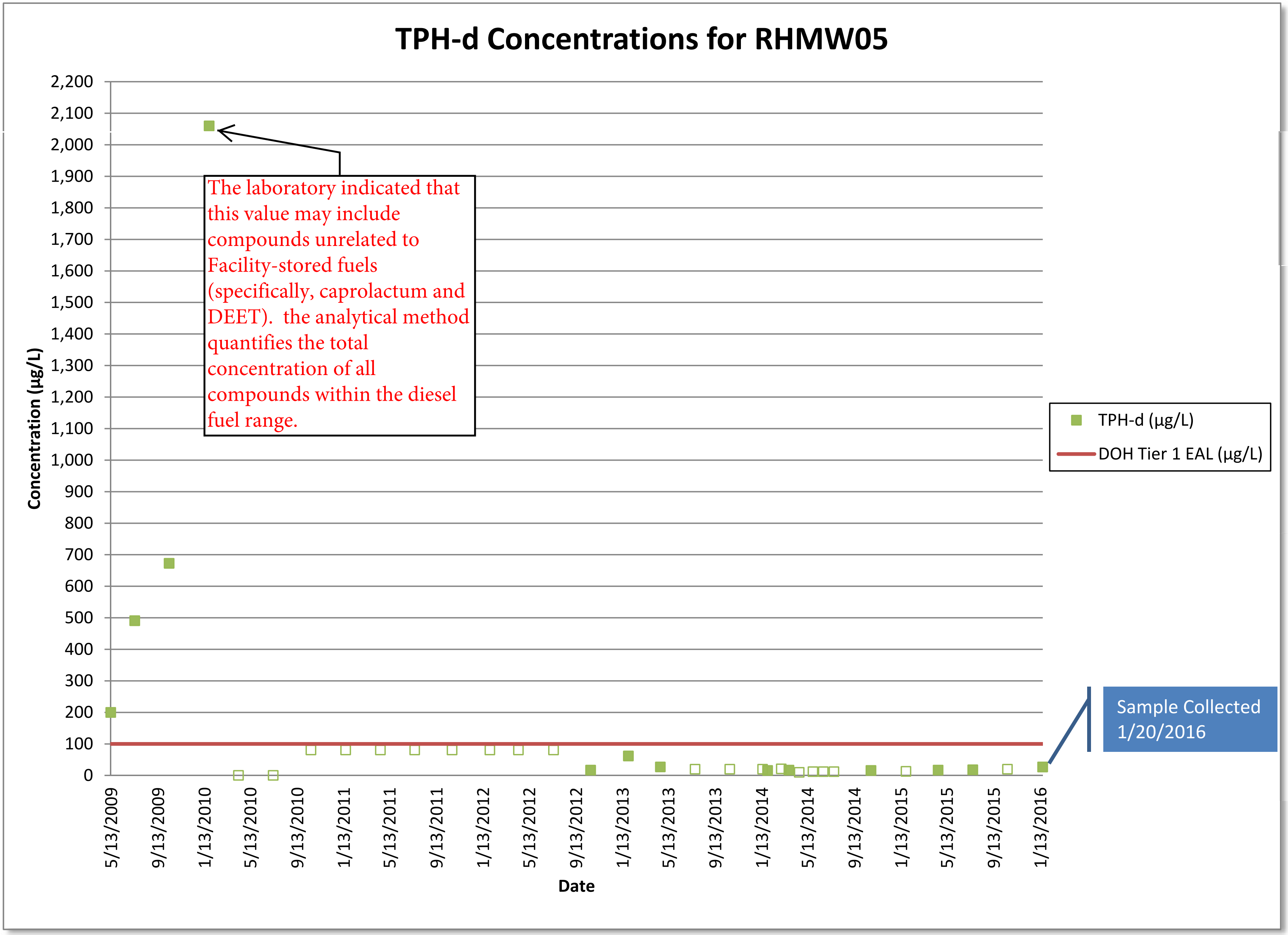


January 2016 data was flagged "L", meaning the chromatographic fingerprint of the sample resembled a petroleum product, but the elution pattern indicated the presence of a greater amount of lighter molecular weight constituents than the calibration standard.
Unfilled boxes indicate non-detections.



Unfilled boxes indicate non-detections. Data point for 7/17/2012 is the average of the primary and duplicate samples. MDLs are shown for July and October 2009, and LODs are shown from January 2010 on.

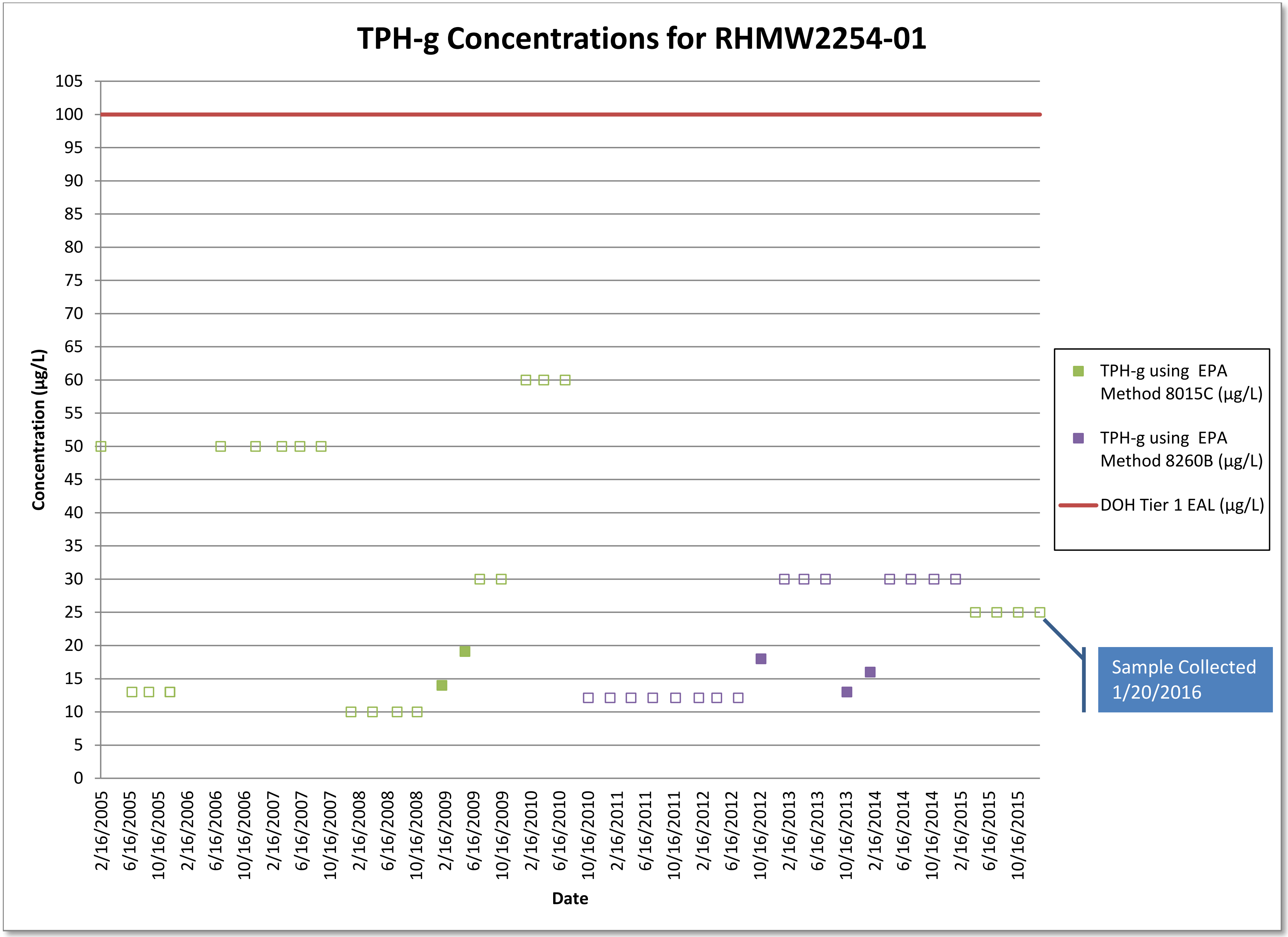
Possible laboratory contamination for 10/22/2012, 10/22/2013, and 1/29/2014 sampling events.



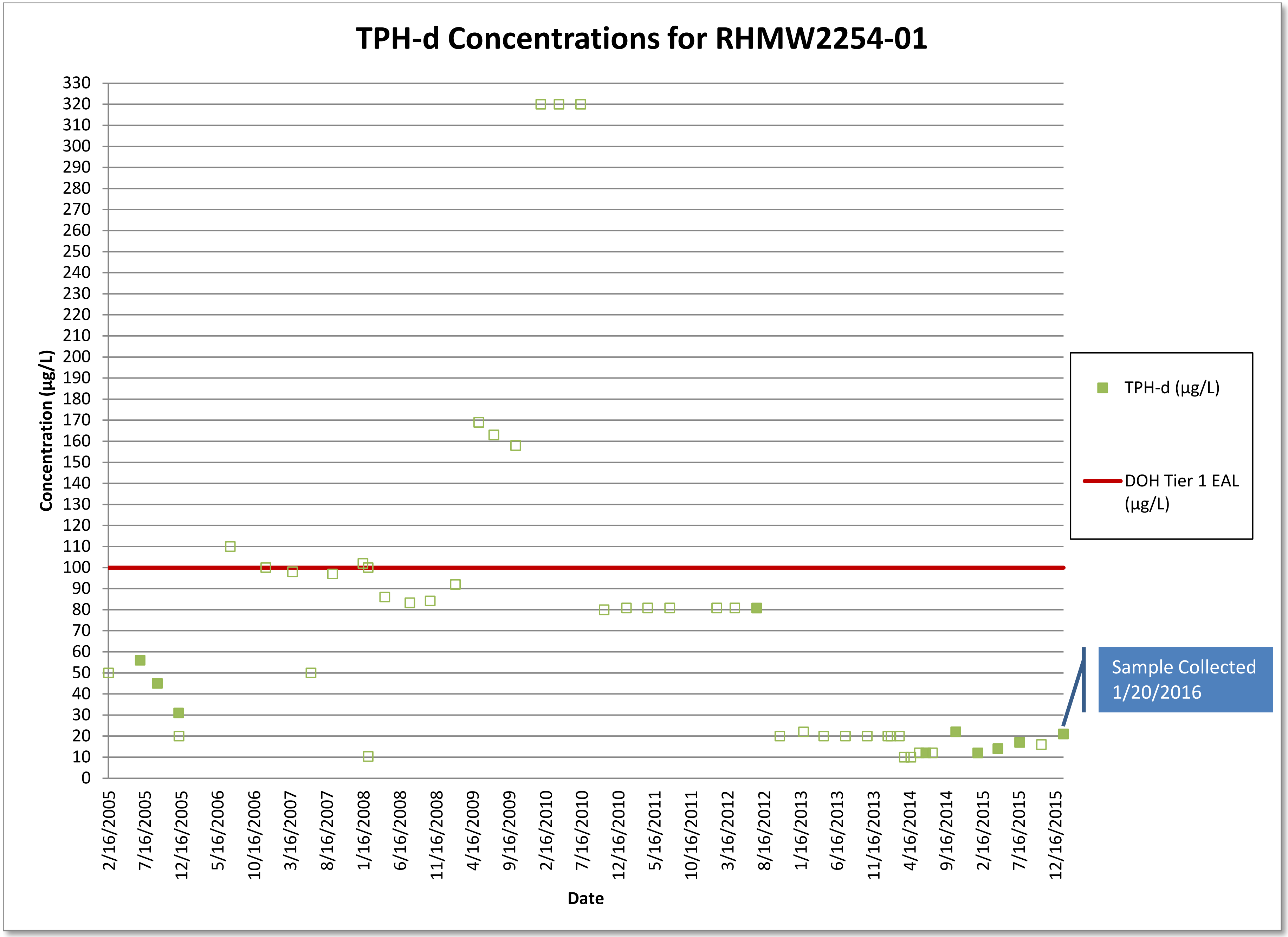
The laboratory indicated that this value may include compounds unrelated to Facility-stored fuels (specifically, caprolactum and DEET). the analytical method quantifies the total concentration of all compounds within the diesel fuel range.

Sample Collected 1/20/2016

Unfilled boxes indicate non-detections. LODs are shown. Data point for 7/17/2012 is the average of the primary and duplicate samples. Numerous sample results had a chromatographic pattern that did not match the calibration standard. The relatively high TPH-d values may not necessarily be indicative that there is diesel fuel or other petroleum products in the well.



Unfilled boxes indicate non-detections. MRLs are shown for February 2005, MDLs are shown for June 2005 through October 2009, and LODs are shown from January 2010 on. Possible laboratory contamination for 10/22/2012, 10/22/2013, and 1/29/2014 sampling events.



Unfilled boxes indicate non-detections. MRLs are shown for February 2005, MDLs are shown for December 2005 through October 2009, and LODs are shown from January 2010 on. Laboratory data rejected for 1/15/2008 sampling event. Numerous sample results had a chromatographic pattern that did not match the calibration standard. The relatively high TPH-d values may not necessarily be indicative that there is diesel fuel or other petroleum products in the well.