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Summary of TPH Monitoring Conducted at 100-NR-2- 2008 through 2010

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September 2010



Pacific Northwest
NATIONAL LABORATORY

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Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

Corrosion of diesel fuel transfer lines connecting the large storage tanks and day use tanks resulted in several releases of diesel contamination between 1966 and 1985. Approximately 302,832 L (82,000 gal) of diesel fuel was lost to the vadose zone and aquifer during this time period. The loss of the diesel fuel occurred between 100 and 150 meters from the edge of the Columbia River. An interim solution involved construction of a trench along the shoreline to intercept and accumulate the migrating diesel. Periodically, the fuel was ignited and allowed to burn in order to remove as much of the diesel as possible before it could enter into the river. Now, a Tri-Party Agreement (TPA) milestone exists to remediate the contaminated groundwater of the 100-NR-2 operable unit to concentrations below the drinking water standard. This report summarizes the results of preliminary investigations conducted to characterize the concentrations of diesel fuel and associated contaminants within the 100-NR-2 operable unit near the Columbia River.

The work conducted for this characterization included soil sampling, water sampling, biota sampling, microbial sampling and passive measurements of in-situ parameters. Water samples were collected along the shoreline, as well as at near-shore groundwater monitoring wells. Soil samples were collected along the shoreline, as well as from a single near-shore borehole. Clam and periphyton samples were collected along the shoreline. Soil samples were analyzed and evaluated for microbial activity. Dissolved oxygen, temperature, specific conductance and water table head elevation were measured in near-shore groundwater monitoring wells. This characterization data has resulted in some insights to the current extent and magnitude of the contamination present in the near shore region that resulted from the diesel fuel spills.

No water samples were collected along the Columbia River shoreline with detectable concentrations of any suspected contaminants. For water samples collected from the near-shore groundwater monitoring wells, benzene and toluene are the only contaminants originating from the diesel fuel spill that appear to approach or exceed any applicable standards. No sediment samples collected as part of this project had concentrations of any contaminants that exceeded any applicable standards. There are several lines of evidence that microbial degradation of the diesel fuel contamination is occurring; there were very low levels of dissolved oxygen measured in the near-shore region, there were low concentrations of nitrate high concentrations and dissolved iron in water samples collected in the near-shore region (resulting from microbial activity), and laboratory studies using site soil confirmed the presence of microbial species capable of degrading diesel.

The general conclusion from this initial characterization is that the concentrations of contaminants associated with the diesel fuel spill may not exceed any applicable regulatory threshold concentrations. Based on this initial characterization, the recommendations for immediate implementation are: a conceptual model should be developed to provide a more complete picture of the contaminant fate and transport; work with regulators to establish the point-of-compliance for the TPH contaminant plume within the 100-NR-2 OU; consider quarterly monitoring of TPH (diesel fraction) as well as volatile organics and PAHs at wells within the suspected boundary of the contaminant plume, consider additional monitoring wells within the suspected boundary of the contaminant plume. Some of these recommendations were initiated in FY2010, and discussed in Appendix D and E.

Recommendations from the original characterization report were implemented in FY2010; a summary of the findings are included in Appendix D and E of this revised report. Appendix D includes a preliminary conceptual model, a summary of more extensive TPH monitoring (including at a number of wells drilled since August 2009), and a list of some potential remediation strategies that might prove capable of reducing TPH concentrations in the groundwater at 100-N. Also included (Appendix E) is a laboratory study that provides confirmation of the presence of diesel degrading bacteria, and some evaluation of enhancements that may be beneficial for in-situ remediation strategies. The conclusions from the FY2010 work are that in-situ microbial degradation of TPH is occurring naturally within the plume footprint, and that the aged and weathered nature of the hydrocarbons is a significant factor affecting the contaminant transport and selection of a remedial technology strategy. After screening a number of remedial strategies, the ones that appear to have the most potential for success at 100-N are *In Situ* Chemical Oxidation (Fenton's oxidation), Enhanced biodegradation, Monitored natural attenuation (MNA), and Initially enhanced monitored natural attenuation.

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1.0 Introduction

The Hanford Site, located in southeastern Washington State, was once home to Cold War weapons grade plutonium production. Over the last fifteen years, the Site's function has shifted from production and operation to remediation and decontamination. At the 100-N Area, the 100-NR-1 operable unit (OU) contains all the source waste sites located within the main industrial area around the 100-N Reactor and the Hanford Generating Plant, and includes the surface sediments and shallow subsurface soil associated with the disposal trenches. The 100-NR-2 OU contains the contaminated groundwater and aquifer. One contaminant still unaddressed in the 100-NR-2 OU is residual diesel contamination and associated contaminants. During operation of the 100-N reactor, number 2 diesel fuel was used for firing igniters in boilers and the operation of different types of machinery. Diesel was transferred from these large storage tanks daily via a four inch transfer pipe to smaller day use tanks. Corrosion of the transfer lines connecting the large storage tanks and day use tanks resulted in several incidents that occurred between 1966 and 1985; release of approximately 302,832 L (82,000 gal) of diesel fuel. These unplanned releases are documented in the *Waste Information Data System* database with the following identification numbers: UPR-100-N-17, UPR-100-N-19, and UPR-100-N-20. The leak was identified by a discrepancy in the inventory of diesel. Two other documented spills (in 1973 and 1985) resulted in approximately 200 additional gallons of diesel fuel being lost to the environment.

The loss of the diesel fuel occurred between 100 and 150 meters from the edge of the Columbia River. Some time later diesel was observed to be entering the river. In order to alleviate this problem, a trench was excavated along the shoreline to intercept and accumulate the migrating diesel. Periodically, the fuel was ignited and allowed to burn in order to remove as much of the diesel as possible before it could enter into the river.

Although some mitigating actions have taken place since the initial leak, sediment and groundwater in the vicinity of the 100 N reactor have been found to be contaminated with diesel fuel and its associated breakdown products. In recent years, some limited environmental monitoring for total petroleum hydrocarbons (TPH) and other organic contaminants occurred along the Columbia River shoreline in the vicinity of the 100-NR-2 operable unit. The 100-NR-2 is the operable unit that encompasses the groundwater beneath and near the 100 N reactor.

A shoreline risk assessment was performed 2005, but has not yet been published. This investigation evaluated radiological, metal and organic contaminants in sediment, water and biota. No detectable levels of TPH were found in the water samples collected near the riverbed surface, but low concentrations were detected in some sediment samples.

In February 2007, aquifer tubes were installed along the Columbia River shoreline within the suspected TPH plume discharge area (Mendoza et al. 2007). One round of water samples were collected and analyzed for TPH-Dx (diesel fraction). Concentrations ranged from undetected (<0.1 mg/L) to 0.63 mg/L. These preliminary samples provided evidence for the location of the TPH plume centerline.

A Tri-Party Agreement (TPA) milestone exists to remediate the contaminated groundwater of the 100-NR-2 operable unit to concentrations below the drinking water standard. This report summarizes the results of preliminary investigations conducted to identify potential non-radiological contaminants of concern.

2.0 Project Activities

Under this project, a variety of activities were conducted in order to assess the extent of the TPH plume, improve the understanding of contaminant fate and transport, and to begin to assess the potential impact of this contamination to the river. Each activity is discussed separately in the following sections, with a discussion of the integrated results at the end.

2.1 Shoreline Sampling

2.1.1 Water sampling

Two water sampling events were conducted along the shoreline during FY08. These sampling events occurred May 19 and September 25, 2008. Samples were collected from 11 aquifer tubes along the shore (Table 1) and the Columbia River. Typical aquifer tube sampling procedures were used (Mendoza et al. 2007). These samples were analyzed for a number of constituents (Appendix A). Samples were collected as bulk water in amber glass jars and immediately placed on ice; acidification of the sample occurred within 24 hours for analytes requiring acidification. Field parameters (specific conductance, temperature, dissolved oxygen, etc.) were also measured with hand held instruments and recorded for all samples collected. Although some samples collected had measured specific conductance and dissolved oxygen levels typical of groundwater, all 24 samples analyzed in FY08 had concentrations of organic constituents below detectable concentrations.

Table 1. Sampling Locations for Water Samples Collected in 2008 (not all locations sampled each time)

Aquifer Tube Name	Latitude	Longitude	Screen Elevation (m)
N0A-US25-167cm	46.67670	-119.56980	116.0
N-116mARRAY-0A-50cm	46.67707	-119.56975	117.2
N-116mARRAY-0A-81cm	46.67707	-119.56975	116.8
N-116mARRAY-0A	46.67707	-119.56975	116.0
N-116mARRAY-0A-250cm	46.67707	-119.56975	115.2
N-116mARRAY-0B-60cm	46.67709	-119.56980	116.0
N0A-DS15-80cm	46.67715	-119.56966	116.8
N0A-DS15-160cm	46.67715	-119.56966	116.0
N0A-DS15B-60cm	46.67717	-119.56970	115.9
N0A-DS25-76cm	46.67723	-119.56958	116.8
N0A-DS25-149cm	46.67723	-119.56958	116.1
N0A-DS25-223cm	46.67723	-119.56958	115.3
N0A-DS50-149cm	46.67742	-119.56939	116.0
Columbia River (~10 ft offshore)	NA	NA	~116.5

2.1.2 Soil Sampling

Soil samples were collected at various depths along the Columbia River shoreline in FY09. These samples were analyzed for the presence of Diesel Range Organics (DRO), metals, and volatile organic compounds. The raw data for these samples is included in Appendix A. Nine samples were collected at four locations, with samples being collected from multiple depths at some of the locations (Table 2). A coring tool (Marco-Core, Geoprobe[®], Salins, KS) was used for sample collection. This tool collected a 2-inch core in a polyethylene core liner. After collection, the sample was immediately transferred to appropriate sample containers for the various analytes, as provided by the sub-contracted analytical laboratory. The sample containers were then placed on ice prior to shipment to the analytical laboratory for analysis.

None of the compounds detected in shoreline soil exceeded the Model Toxics Control Act (MTCA) Method A soil cleanup levels for unrestricted use (Table 740-1, WAC 173-340-740). Only TPH exceeded 25% of the MTCA Method A values (Table 3; Appendix B), indicating it is likely the only compound that could possibly exceed the soil threshold concentration along the Columbia River shoreline.

Table 2. Shoreline Soil Sampling Names and Locations

Sediment Sample ID	Latitude	Longitude	Sample Elevation (m)
TPHA1-2ft	46.677027	119.569626	118.8
TPHA2-1.5ft	46.677033	119.569646	118.3
TPHA2-4ft	46.677033	119.569646	117.5
TPHA2-5ft	46.677033	119.569646	117.2
TPHA3-2ft	46.677048	119.569686	117.3
TPHA3-4ft	46.677048	119.569686	116.7
TPHB1-2ft	46.677096	119.569555	118.1
TPHB1-4ft	46.677096	119.569555	117.5
TPHB1-5ft	46.677096	119.569555	117.2

Table 3. Maximum Measured Concentrations in Sediment Samples Collected Along the 100-N Shoreline and Associated MTCA Concentrations

Compound	Maximum Concentration (mg/kg)	MTCA Clean-up Level ^(a) (mg/kg)
Benzene	0.0032	0.03
Ethylbenzene	0.00013	6
Lead	6.4	250
MTBE	0.000083	0.1
Fluoranthene	0.015	0.1 ^(b)
Pyrene	0.024	0.1 ^(b)
Toluene	0.00073	7
TPH- DRO	1200	2000
Xylenes ^(c)	0.00072	9

(a) Method A Unrestricted Land Use Cleanup Levels. From Table 740-1 of WAC Code 173-340-740

(b) Value for Benzo(a)pyrene used for all PAH's, as instructed in the WAC Code

(c) Sum of m,p and o xylenes

2.2 Installation of Monitoring Well

A monitoring well (199-N-173) was installed at the river's edge to assess the vertical extent of contaminated soil. No other contaminant concentration in soil data was available in the area where the TPH contamination plume is assumed to discharge to the river. Water samples and soil samples were collected at various depths below ground surface during well installation (Table 4). The well was completed with a 6-inch inner casing, and screened between 10.1 and 25.1 feet below ground surface. The results of the sampling indicate that the TPH contamination was primarily limited to the top portion of the aquifer and the "smear zone," or the portion of the vadose zone that is occasionally saturated as a result of a fluctuating river stage.

Table 4. Depths of samples collected during installation of monitoring well 199-N-173

Soil Core Sample Collection Depths (ft bgs)	Water Sample Collection Depths (ft bgs)
9.9 – 12	19 ^a
12.5 – 14.5	23.2
15 – 16.5 ^(a)	33
17.5 – 20	43
24.5 – 27	
30 – 31.5	
34.5 – 37	
39.5 – 42	
44.6 – 47.1	

(a) duplicate sample collected at this depth

2.2.1 Soil Samples

Two types of soil samples were collected during the drilling of 199-N-173; grab samples and core samples. Grab samples were collected nominally every 2.5 feet between 9.5 and 45 feet below ground surface (bgs). Grab samples were analyzed for TPH using a field screening kit that detected a positive presence of diesel above 15 mg/kg. These screening kits only provided an indication of TPH above the threshold; there was no estimate of the relative concentration provided by the screening kit. Two foot long core samples were collected continuously between 10 and 20 feet bgs, then every 5 feet between 25- and 45-foot bgs. Core samples were analyzed for TPH, metals, and volatile organic compounds by the Waste Sampling and Characterization Facility (WSCF) (Appendix B).

The field screening for TPH indicated the presence of diesel contamination between 9.5 and 20 feet bgs at concentrations exceeding 15 mg/kg. This was consistent with the results from the core samples (Figure 1). The core sample results indicate that the concentrations increased with depth up to 20 feet bgs. Below 20 feet bgs, the TPH concentrations in sediment were below detectable concentrations (~4 mg/kg). The metals concentrations observed in core samples collected from 199-N-173 appeared to vary some with depth; however, the variation was probably associated with lithological changes rather than the presence of contaminants (Appendix C). Core samples were analyzed for 99 organic compounds; only 7 were measured at detectable concentrations in any of the core samples (Table 5, Appendix B). These concentrations were at or below the MTCA Method A soil cleanup levels for unrestricted use (Table 740-1, WAC 173-340-740) for the detectable compounds. It should be emphasized that the data presented here is for a handful of samples collected from a single location; further sampling from boreholes in this area may reveal different information.

Pictures of the core samples indicated some irregularities at 20 feet bgs. Primarily, the color of the soil became grey and had a slimy appearance (Figure 2). However, the grain size distribution did not appear significantly different. This same grey color was observed in several soil samples collected along the shoreline. During drilling, there was a diesel odor noticed at the 20 foot depth (Appendix C). This was consistent with diesel odor associated with grey discoloration noted in samples collected along the Columbia River shoreline.

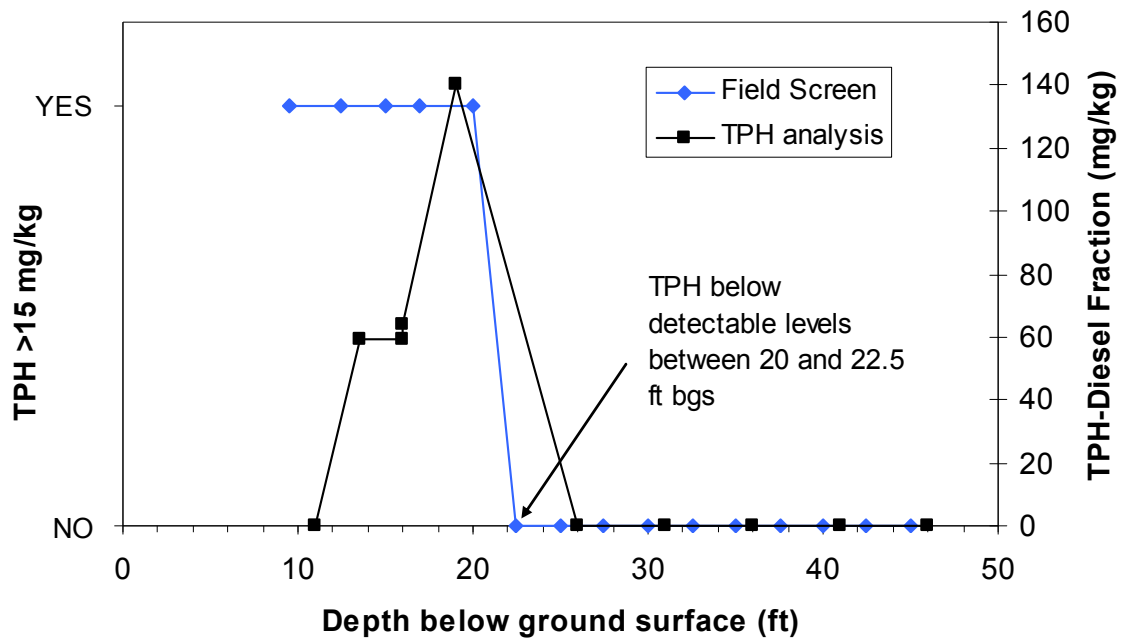


Figure 1. Concentrations and Screening Results for TPH Measured in Samples Collected During Drilling of Monitoring Well 199-N-173

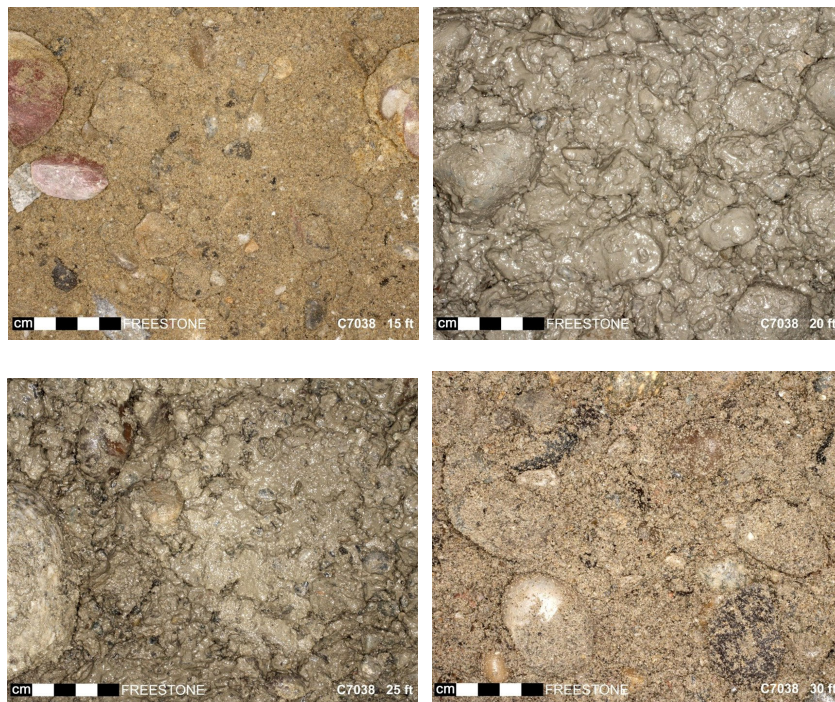


Figure 2. Pictures of core samples collected during drilling of 199-N-173

Table 5. Maximum Measured Concentrations in Soil Samples Collected During Drilling of Monitoring Well 199-N-173 and Associated MTCA Concentrations

Compound	Maximum Concentration (mg/kg)	Depth of Maximum (ft bgs)	MTCA Clean-up Level ^(a) (mg/kg)
TPH- DRO	140	17.5 – 20	2000
Benzene	0.003	15 – 16.5	0.03
Ethylbenzene	0.0025	39.5 – 42	6
Toluene	0.005	15 – 16.5	7
2-Butanone (MEK)	0.0073	15 – 20 ^(b)	NA
Bis(2-Ethylhexyl)phthalate	1.4	15 – 20 ^(b)	NA
Styrene	0.0067	15 – 16.5	NA
Xylenes ^(c)	<0.001	NA	9

(a) Method A Unrestricted Land Use Cleanup Levels. From Table 740-1 of WAC Code 173-340-740

(b) Similar concentrations at 15-16.5 and 17.5-20 foot intervals

(c) Sum of m,p and o xylenes

2.2.2 Water Samples

Five aqueous samples were collected during drilling activities. These samples were collected from the top of the water table (2 samples), and then at various depths (Appendix B). For evaluation, results from three depths were evaluated; results from the two samples at the top of the aquifer were averaged into a single result, and the sample at the bottom of the well was from a different lithologic material, and was not considered representative. In general, chemical analysis of samples collected from the top of the aquifer identified the presence of TPH and provided evidence of microbial activity, and deeper samples indicated a decrease of TPH contamination with depth (Figure 3). At the top of the aquifer, TPH, iron, and manganese were elevated relative to the lower portion of the aquifer. The high iron and manganese concentrations are indicative of microbial activity; aqueous iron concentrations increase as bacteria use Fe(III) as an electron acceptor and reduce it to Fe(II), which is soluble in water. Manganese can be reduced in a similar manner, but is not present in sediment at the same quantity as iron. Microbial use of iron and manganese as an electron acceptor is not as thermodynamically favorable as the use of oxygen and nitrate. Dissolved oxygen levels in groundwater have been shown to be quite low (see section 3.3). Similarly, nitrate concentrations were very low at the top of the aquifer, and increased with depth. These data all indicate that bacteria are actively using the TPH contamination near the top of the aquifer as a carbon source. As the TPH concentrations decrease, the microbial activity also decreases, as evidenced by higher measured nitrate concentrations, and lower iron and manganese concentrations with increasing depth. Microbial activity and TPH degradation were confirmed by slurry reactor tests (see Section 3.4).

Other contaminants were also detected in aqueous samples collected from 199-N-173 during drilling. Several of these contaminants were detected at concentrations that approach or exceed the Groundwater Quality Criteria or Drinking Water Standards established by the WAC Code (173-200-040 and 246-290-310, respectively) (Table 6). Several of these contaminants do not originate from the diesel fuel spill (nitrate, sulfate, specific conductance, strontium-90), and iron is likely only high because of microbial activity (this iron would be insoluble in oxygenated water). It is also important to note that

having sample results that exceed the concentrations established by the WAC Code does not necessarily mean that the standard is being exceeded at this point in time. These were depth discrete samples from an uncompleted well collected for characterization purposes; future sample collection efforts will use appropriate sampling methodology from the fully screened well to determine compliance.

Table 6. Maximum Measured Concentrations in Water Samples Collected During Drilling of Monitoring Well 199-N-173 and Associated Regulatory Standards

Constituent	Groundwater Quality Criteria (mg/L) ^(a)	Drinking Water MCL (mg/L) ^(b)	Maximum Concentration (mg/L) ^(c)	Depth of Maximum (ft)
Benzene	0.001	0.005	0.0033	19
Nitrate (as N)	10	10	11.8	33
Iron	0.3	0.3	42	19
Sulfate	250	250	306	19
Toluene	NA	1	2.6	19
Xylene's (total)	NA	10	ND (< 0.001)	ND
Ethylbenzene	NA	0.7	ND (< 0.001)	ND
TPH- Dx	NA	NA	4.3	19
Sp. Conductance	NA	700 μ S/cm	1420 μ S/cm	19
Strontium-90 ^(d)	8 pCi/L	8 pCi/L	23 pCi/L	19

(a) WAC Code 173-200-040-Table 1

(b) WAC Code 246-290-310-Table 4, 40 CFR 141.61, 40 CFR 141.66

(c) Measured in 199-N-173 during drilling

(d) Radiological analysis conducted was, but is not discussed in this report

NA no value provided for this contaminant

ND concentration below the analytical detection limit

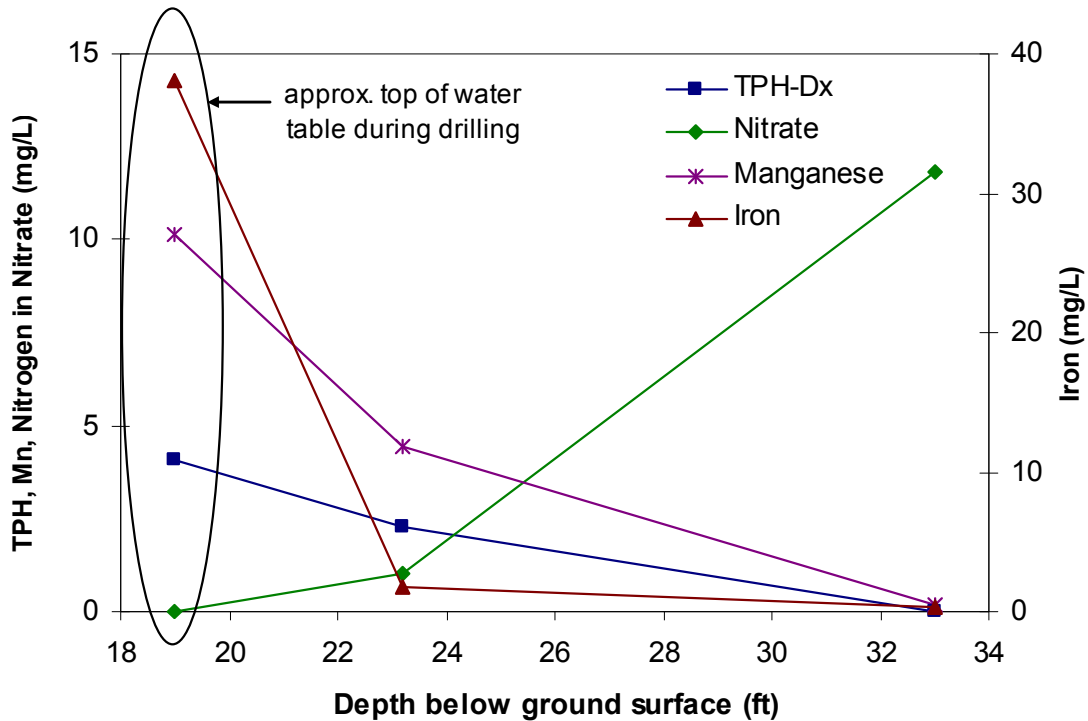


Figure 3. Concentrations of Selected Compounds Measured in Water Samples Collected During Drilling of Monitoring Well 199-N-173

2.3 Passive Down Hole Monitoring

2.3.1 Water Level

Five groundwater wells in the vicinity of the TPH contaminant plume were instrumented with water level sensors (Figure 4). This was done to gain a better understanding of the groundwater gradient in this portion of the 100-N Area, and to evaluate the influence of fluctuating river stage at various distances away from the river. The instruments were PT2X temperature/pressure sensors housed within a self-contained data logger (Instrumentation Northwest, Kirkland, WA). Measurements were recorded every 15 minutes, beginning in early January 2009. Water depth was converted to head elevation by collecting periodic depth to water readings from vertically controlled points (top-of-casing). Hourly river stage elevation measurements were obtained from the Hanford Site Virtual Library. The data indicate that the water head elevation in all of the wells responded to changes in river stage, even 330 meters inland from the river (199-N-56). As expected, the wells closer to the river responded very rapidly to changes in river stage, while wells farther from the river responded slower, and with a dampened response (Figure 5).

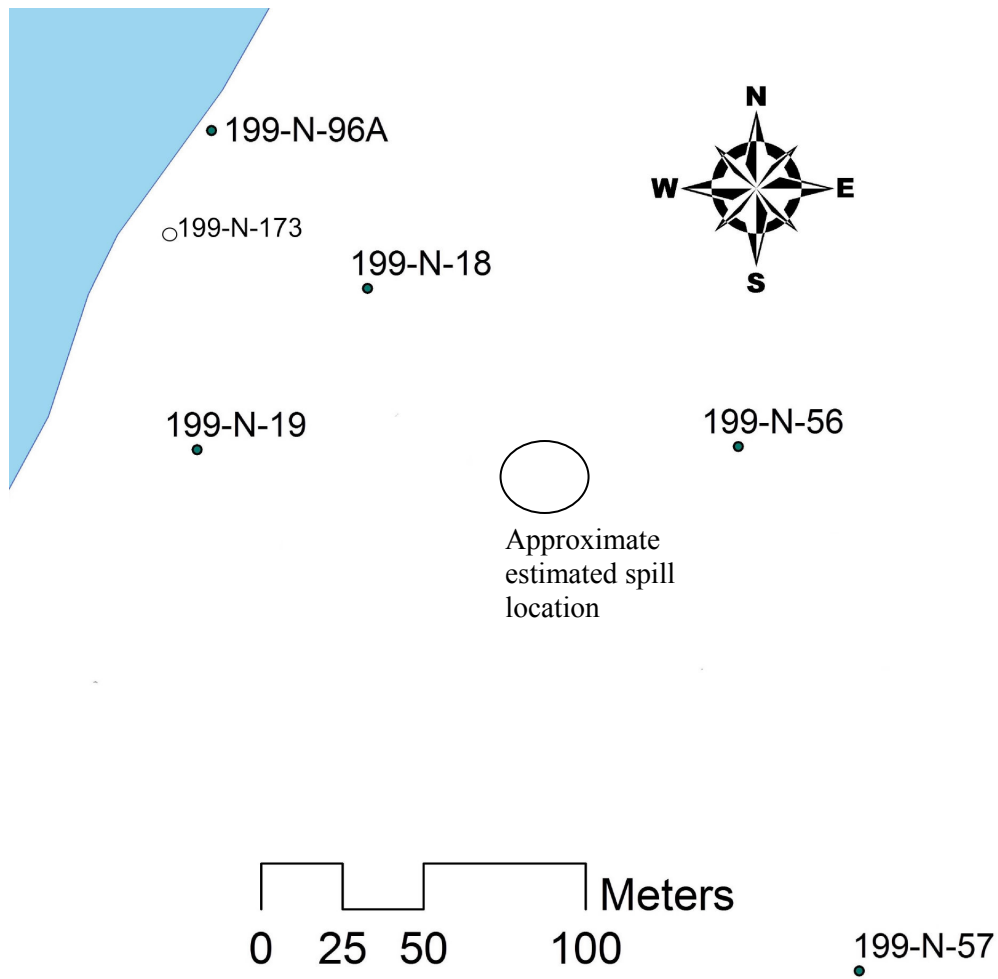


Figure 4. Locations with Water Level Monitoring Instrumentation Installed in 2008 (199-N-173 shown for reference only; water level monitoring began summer 2009).

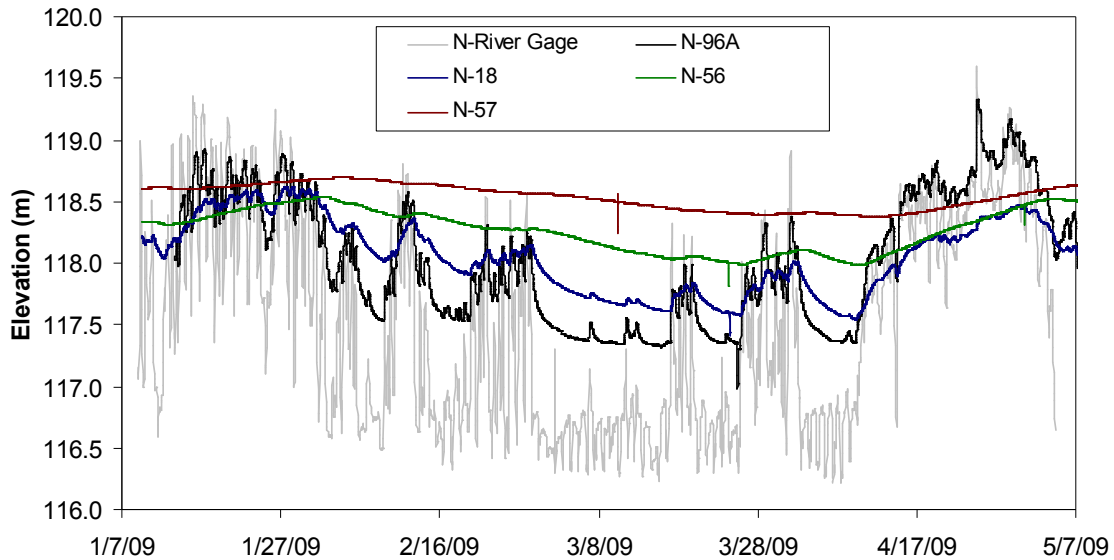


Figure 5. Groundwater Head Elevation Measured in the Vicinity of the Diesel Contamination Plume. Data from 199-N-19 not shown as it was nearly identical to data from 199-N-18.

2.3.2 Dissolved Oxygen

Dissolved oxygen concentrations were monitored in-situ at several locations within the contaminant plume during FY08 and FY09. The largest data set was collected at 199-N-96A between July 2008 and February 2009. Other monitoring points included a piezometer installed along the shoreline and monitoring well 199-N-173. The results clearly indicate the presence of groundwater with low dissolved oxygen concentrations. For example, in 199-N-173, the dissolved oxygen concentration was below 0.1 mg/L for the entire four week monitoring period. The concentrations of dissolved oxygen measured at the two monitoring wells are lower than typically observed in near-shore groundwater wells within the 100-N Area. The low DO concentrations observed likely indicate that microbial activity is occurring. The dissolved oxygen concentrations observed in the near shore piezometer (nominally 8 mg/L) were typical of mixed river water and groundwater. No evidence of reduced dissolved oxygen concentration was observed at the shoreline; however, the piezometer was likely not placed far enough into the river. When river stage dropped low enough for potential groundwater discharge to the river, the piezometer was dry.

In 199-N-96A it is evident that the dissolved oxygen concentrations are impacted by seasonal river stage conditions as well as hourly river stage conditions (Figure 6). During the late summer, when the river stage is beginning to descend from the yearly high, dissolved oxygen concentrations were moderately high, indicating intrusion of oxygenated river water. This is supported by the lower specific conductance observed during this time. As the river stage decreased, the specific conductance increased, indicating a higher groundwater to river water mixing ratio. During this time, the dissolved oxygen concentration decreased below 1 mg/L. Although the seasonal pattern of dissolved oxygen response to river stage is typical (high river stage = high dissolved oxygen), the hourly fluctuations of dissolved oxygen are inversely proportional. When river stage increases, the dissolved oxygen concentration decreases.

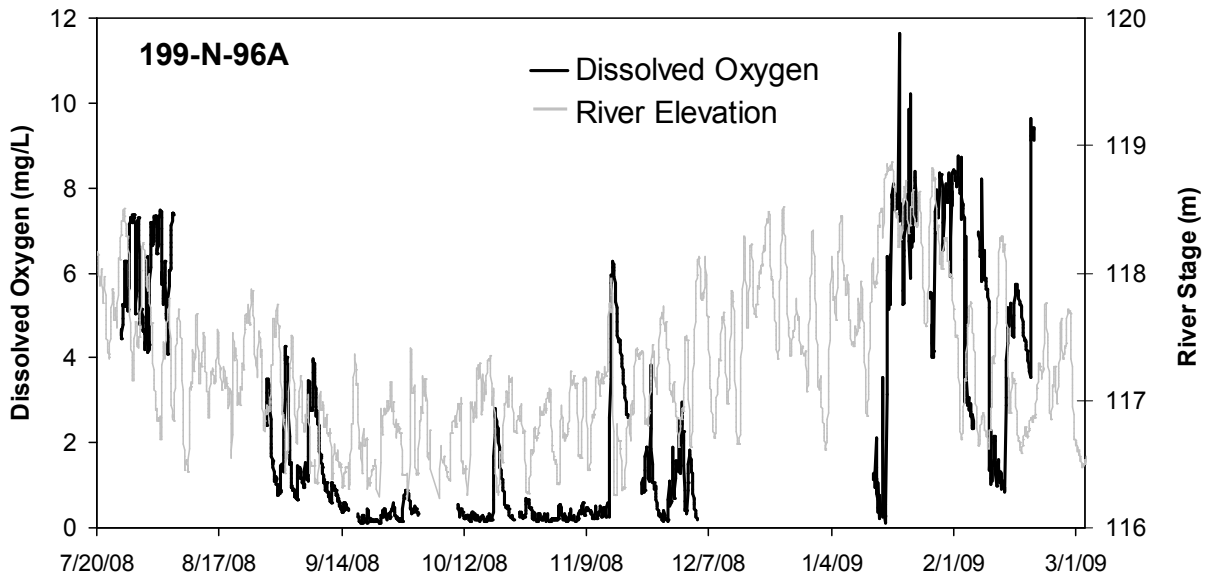


Figure 6. Dissolved Oxygen Concentrations Measured in 199-N-96

This unusual pattern was further investigated by installing a pair of dissolved oxygen sensors in 199-N-96A; one near the bottom of the screen, and one near the top of the water table. During most time periods, the dissolved oxygen concentration was the same at the top and bottom of the screened interval (Figure 7). During some periods of rapid decrease in river stage, the top sensor measured an increase in dissolved oxygen concentration. The bottom sensor only measured a significant change in dissolved oxygen concentration a couple of times. One possible explanation for this unusual behavior is that 199 N-96A is on the very edge of the diesel contamination plume. During stable hydraulic conditions, microbial activity results in low dissolved oxygen concentrations. During rapid decreases in river stage, the hydraulic gradient changes such that water from outside of the diesel contamination plume (higher dissolved oxygen) moves into the well, primarily near the top of the water table.

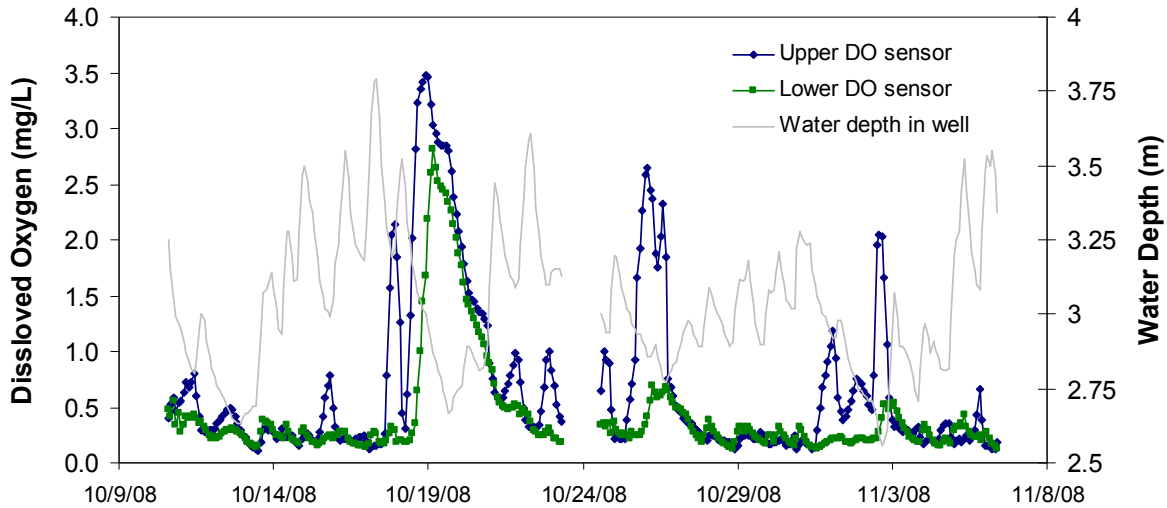


Figure 7. Dissolved Oxygen Measured at Two Locations in 199-N-96A; Near the Top and Bottom of the Screened Interval

2.4 Microbial Assessment

Several sediments samples from well 199-N-173 that were found to be contaminated with TPH were sent to Washington State University, Pullman to look at microbial populations and species. The objective was to determine if diesel-degrading microorganisms are present and if so, to test the microorganisms ability to break down TPH.

2.4.1 Presence of Diesel degrading Bacteria

Samples that appeared to have a substantial amount of TPH present were examined for diesel-degrading microorganisms and total heterotrophs using a modified most probable number (MPN) method. Assessment includes the use of “mini plates” (volume of agar = 1 mL) in which serial dilutions of diesel laden soil were added. Plates that had positive growth were used to determine bacterial numbers based on the relative growth to dilution and were compared to standard tables used by the food and drug administration (Blodgett 2003). The two plates chosen to do the MPN test had sample material collected at depths of 15 ft bgs and 17.5-20 ft bgs. The populations were averaged over five samples, and the results indicate that bacteria which have an ability to degrade diesel fuel are present (Table 7).

Table 7. Most Probable Number (MPN) Results for Bacteria Growth Using Two Sediment Samples Collected During Drilling of Monitoring Well 199-N-173

Sample Depth (ft)	MPN (number of diesel degrading bacteria per gram of soil)	Lower Confidence Interval ($\alpha = 0.05$)	Upper Confidence Interval ($\alpha = 0.05$)
17.5 - 20	3.5×10^4	1.0×10^4	1.1×10^5
15	5.4×10^3	1.5×10^3	1.7×10^4

In order to gain a better understanding of the morphology of the bacteria, regular agar plates were used to grow the bacteria. All bacteria were grown in the presence of diesel fuel (0.05 g per plate). The plates were inoculated with a sediment suspension from each of the monitoring well samples and allowed to dry. Diesel fuel was then spread thinly over the agar plate to act as a carbon and energy source. The diesel fuel was obtained from a local gas station. The plates were then incubated for approximately 30 days at 30° C under aerobic conditions. After completion of the incubation, the agar plates were assessed for positive results. Numerous plates indicated the presence of bacteria (Figure 8). The upper left plate is bacteria grown from the 35 ft bgs sediment, upper right is from sediment collected 17 ft bgs, lower left was inoculated with sediment from 15 ft bgs, and the lower right sample used sediment from 17.5-20 ft bgs. Clearing zones appeared around all the colonies indicating diesel degradation had occurred (Figure 8). The white bacteria growth on plates A and B (Figure 8) demonstrate the production of rhamnolipids, which are natural surfactants produced by some bacteria to aid in the mobilization of organics. The rhamnolipids make the organic compounds more readily available for biodegradation by the bacteria. The presence of rhamnolipid producing bacteria also likely explains the foamy water observed purging of well 199-N-173 (Appendix C).

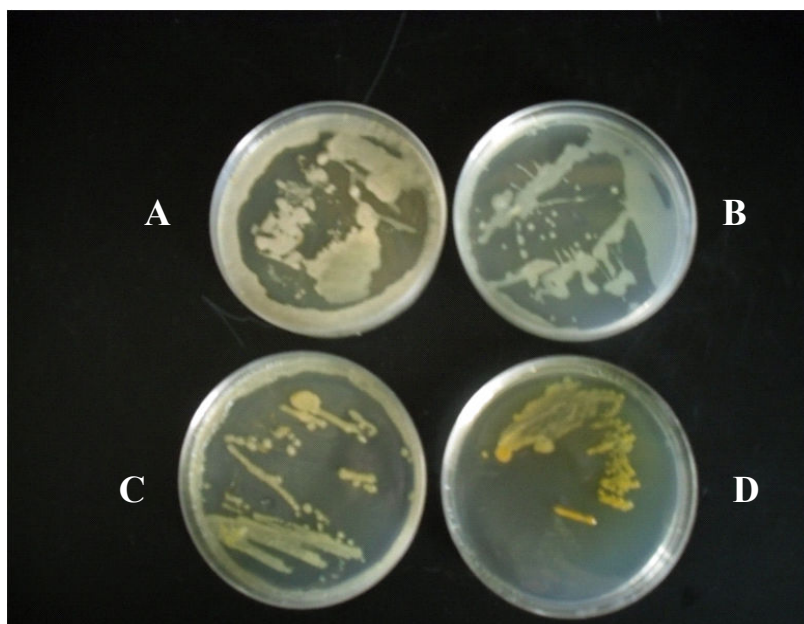


Figure 8. Agar Plates with Bacteria Growing on Them. Diesel fuel was the sole carbon source; sediment from: A-35 ft bgs, B- 17 ft, C- 15 ft, D- 17.5 to 20 ft.

The two tests indicated that bacteria, capable of using diesel as the sole carbon source, are present in the soil. The use of the mini-plate was meant to enumerate all diesel degrading species that may have been present while the larger agar plate provides a qualitative indication of the types of bacteria present.

2.4.2 Slurry Reactors

Slurry reactors were used to determine the rate at which the bacteria could degrade diesel. Sediment from the 20 ft bgs sample was used. Seven grams of soil (wet weight) and 110 mL of sterile (autoclaved) tap water were added to the reactors. A number of reactors were prepared and separated into different groups. The first group was used as a control; phosphate and ammonia (0.62mM and 3.8 mM

respectively) were added along with 0.1 M sodium azide to prevent bacterial growth. Other groups of reactors were prepared with nutrients (ammonia and phosphate), with nutrients and an additional carbon source (ammonia, phosphate and 500 mg/L molasses) and without nutrients. Reactors from different groups were sacrificed and total concentration of soil-phase diesel range organics (DRO) were determined by extraction/concentration in methylene chloride with quantification by gas chromatography/flame ionization detector (FID). The control and ammonia/phosphate reactors were prepared on March 2, 2009. Ammonia levels were maintained at constant levels throughout the experiment by monitoring ammonia concentrations and adding additional mass to maintain the target concentration.

After 17 days of incubation, the reactors were analyzed for diesel concentrations. The DRO concentrations were compared to the DRO concentrations in the sterile control reactors (Figure 9). Initial results demonstrate a reduction in diesel concentration for the reactors with nutrient addition relative to the control and the no-nutrient amendment. Repeat analysis reactors showed that the small apparent benefit of nutrient addition was not statistically significant relative to the no-nutrient tests. However, all of the slurry reactors demonstrated a statistically significant decrease in diesel concentration relative to the control. This indicates that natural attenuation of the diesel by microbial activity is occurring within the soil, enhancement or stimulation of the degradation process with the nutrients tried here would not be successful.

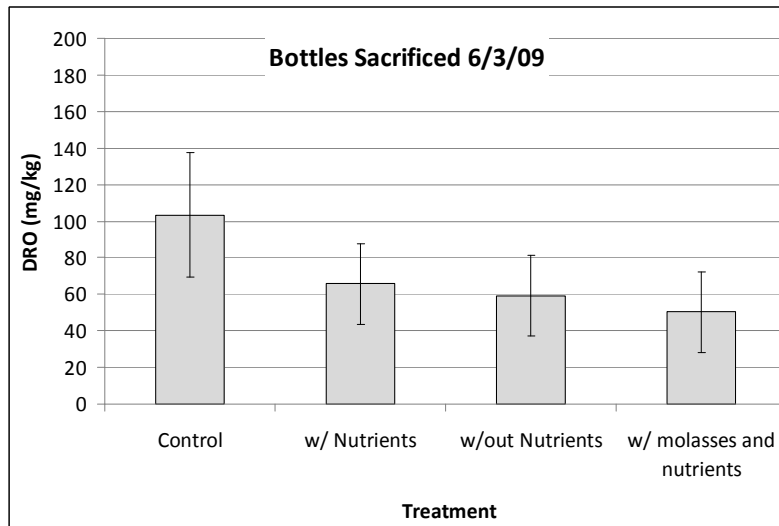
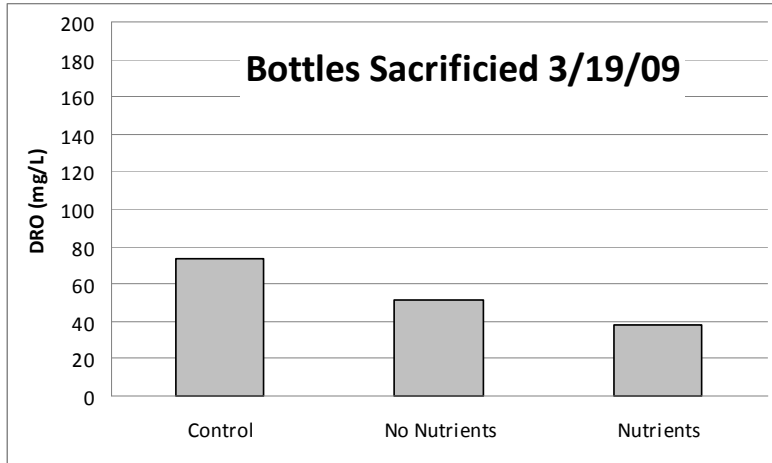


Figure 9. Results for Multiple Sets of Slurry Reactor Tests

2.5 Biota Assessment of TPH Plume

Aquatic biota have been used to evaluate potential exposure to groundwater contaminants entering into a riverine environment. In particular, clams and periphyton have been used in the Hanford area to qualitatively determine if contaminated groundwater is entering into the Columbia River by analysis of body tissue for contaminants.

Periphyton and clam samples were collected from four locations along the 100-N shoreline within the perceived TPH plume discharge boundary. Three periphyton and three clam samples were also collected at a reference location directly upstream of the plume (Figure 10). All samples were collected at the same river depth at the green line. The green line is the minimum river stage elevation along this stretch of the Columbia River (nominally 117 m). The rocks on which the periphyton grow are always submerged, making for a high biological productivity area. The periphyton were scraped from the rocks immediately after the rocks were removed from the river. Clam samples were collected by plucking clams from the river bed. All samples were placed on ice after collection. The soft body tissues from 15-20 clams from each sampling location were removed from their shells in the laboratory within 6 hours of collection.

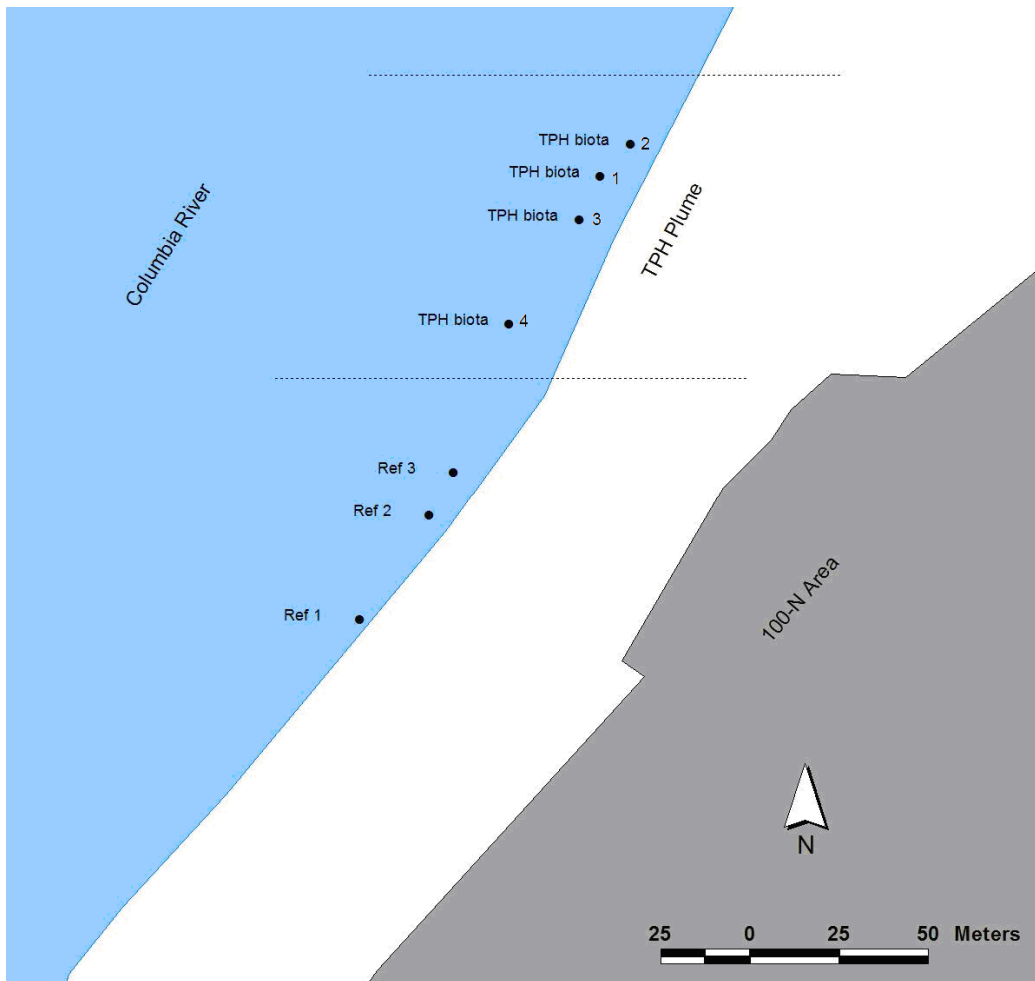


Figure 10. Periphyton and Clam Sampling Locations – September 2008

Periphyton and clam tissue samples were analyzed for polycyclic aromatic hydrocarbons (PAH), a known byproduct of diesel fuel (ATSDR 1995). PAHs often attach to soil and sediment and are known to bioaccumulate in aquatic organisms, including invertebrates and periphyton (ATSDR 1995). Samples were submitted for analysis using EPA method 8720C. The PAHs that were analyzed are listed in Appendix A.

2.5.1 Periphyton Results

Three periphyton samples from the upstream reference location and four from the TPH plume were analyzed for PAHs. In most cases, results for individual PAHs were below detection (0.5 ug/kg). In all cases, average concentration results from the upstream reference area were the same as or higher than the average concentrations measured in periphyton samples collected from the suspected TPH plume discharge area (Table 8). This appears to be a result of the reference samples not being collected far enough upstream. For most of the periphyton results, the PAH concentrations reported at TPH location 4 and Reference location 1 were significantly higher than concentrations reported at the other five sampling locations. For example, fluoranthene concentrations at these two locations were approximately 10 times higher than the concentration measured at the other five sampling locations (Figure 11). This trend was similar for all the PAHs measured at detectable concentrations.

Table 8. Average PAH Results for Periphyton Samples Collected within the 100 N TPH Plume and at an Upstream Reference Location – September 2008 (ug/kg wet weight)

Analyte	Reference Location ^a	TPH Plume ^(a)
Anthracene	2.3 (n=1)	1.2 (n=1)
Benz(a)anthracene	0.56 - 5.1 (n=3)	0.52 - 4.9 (n=2)
Benzo(a)pyrene	3.2 (n=1)	3.1 (n=1)
Benzo(b)fluoranthene	0.57 - 5 (n=3)	0.52 - 4.2 (n=3)
Benzo(g,h,i)perylene	2.1 (n=1)	1.4 (n=1)
Benzo(k)fluoranthene	2 (n=1)	2 (n=1)
Chrysene	0.54 - 6 (n=3)	0.58 - 5 (n=2)
Fluoranthene	0.93 - 12 (n=3)	0.75 - 7.3 (n=4)
Indeno(1,2,3-cd)pyrene	2.3 (n=1)	1.8 (n=1)
Phenanthrene	0.57 - 7.2 (n=3)	0.68 - 1.4 (n=4)
Pyrene	0.69 - 11 (n=3)	0.59 - 7.4 (n=3)

(a) The number of composite samples at the Reference Location was three, and at the TPH plume was four.
NOTE: n = number of samples where analyte was above the detection limit (0.5 ug/kg)



Figure 11. Fluorathene Concentrations Measured in Periphyton Samples Collected Along the 100-N Shoreline. Trend was similar for other PAHs.

2.5.2 Clam Results

Three clam tissue samples from the upstream reference location and four from the TPH plume were analyzed for PAHs (Table 9). One of the clam samples collected within the TPH plume had elevated levels of benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, chrysene, and dibenzofuran compared to other clam samples collected in the TPH plume and at the upstream reference location. With the exception of dibenzofuran, the PAH levels for this clam sample were less than levels reported from the periphyton samples collected at the reference location and at the TPH plume. Dibenzofuran was only detected in the clam sample from the TPH plume (location 3). Four other compounds were measured at detectable concentrations at TPH location 4, but not detected at any of the reference locations. Unlike the periphyton results, concentrations measured in clams were similar at all sampling locations for those compounds with detectable concentrations at the reference locations. This implies that clams respond differently to PAHs than periphyton, as there is no strong evidence of increased PAH concentrations along the portion of shoreline sampled.

Table 9. Average PAH Results for Clam Tissue Samples Collected within the 100 N TPH Plume and at an Upstream Reference Location – September 2008 (ug/kg wet weight)

Analyte	Reference Location ^a	TPH Plume ^(a)
Benz(a)anthracene	ND	0.79 (n=1)
Benzo(a)pyrene	ND	0.64 (n=1)
Benzo(b)fluoranthene	ND	0.62 (n=1)
Chrysene	ND	0.71 (n=1)
Dibenzofuran	ND	1.3 (n=1)
Fluoranthene	2.8 - 4.1 (n=3)	2.4 - 4 (n=4)
Phenanthrene	1.3 - 1.4 (n=3)	0.88 - 1.4 (n=4)
Pyrene	0.69 - 0.7 (n=2)	0.79 - 1.2 (n=4)

(a) The number of composite samples at the Reference Location was three, and at the TPH plume was four.
 NOTE: n = number of samples where analyte was above the detection limit (0.5 ug/kg)
 ND = not detected

2.5.3 Biota Assessment Discussion

Periphyton and clam samples are relatively easy to collect, abundant and can provide a useful indication of elevated levels of contaminants at one point in time. Biota samples, such as clams and periphyton, provide a good indicator of environmental exposure because these organisms live at the point where the groundwater contamination is highest as it enters the riverine environment. Many of the TPH constituents included in the PAH analyses are known to impact aquatic organisms in sediments and are regulated (EPA 2006). Uptake of PAHs in periphyton and clams indicate exposure of the organisms to the constituent through the water pathway. In addition, clams consume periphyton, and thus accumulation of PAHs in the clam is an indication of exposure through the food pathway.

With the exception of dibenzofuran, the PAHs that were detected in either the clams or the periphyton samples from the TPH plume were also detected in periphyton and clam samples from the upstream reference location. These results indicate that PAHs are accumulating in biota tissue in the 100-N riverine environment. While the periphyton results indicate a potential groundwater source of PAHs, these results do not provide sufficient spatial or temporal coverage to delineate the source of the PAHs. The two periphyton samples with elevated PAH concentrations were collected along a stretch of shore with a strong eddy. The results could be an indication of increased PAH accumulation along that stretch of shore as a result of sediment accumulation caused by the eddy.

3.0 Discussion

3.1 Comparison of Well and Shoreline Core Results

The concentrations of diesel in sediment measured in core samples from N-173 were compared against the concentrations measured along the shoreline. When compared spatially, the concentrations are relatively consistent at the two locations (Figure 12). The concentrations typically increase at lower elevations. The highest concentration measured at 199-N-173 was 140 mg/kg and occurred between 118.1 and 117.4 meters elevation. The two shoreline cores collected within this elevation range had measured diesel concentrations of 91 and 130 mg/kg. However, TPH results from the shoreline core samples and from the well are not necessarily directly comparable. The well samples were bulk material, whereas the samples collected from shoreline cores were size selective; material larger than ~5 mm was removed from the sample prior to analysis. For gravelly sediment, this could have biased the results from shoreline samples high.

Based on the field screening, the diesel concentration dropped below 15 mg/kg below 116.6 m elevation. The maximum sediment contamination may have been missed in 199-N-173 between 116.6 and 117.4 meters. This is the elevation range where the maximum TPH concentrations were measured in the shoreline core samples. However, the water sample collected at 116.4 m had lower measured diesel concentrations than the sample collected at 117.7 m. It is also worth noting that 116.6 m is at approximately the 5th percentile river state elevation; in other words, in the vicinity of 100-N, the river elevation only drops below 116.6 meters elevation about 5% of the time.

When all of these results are evaluated together, it would appear to indicate that the diesel contamination is confined to the ‘smear zone’, or that portion of the vadose zone that is occasionally saturated. This is not too surprising since diesel has a lower specific gravity than water. It would tend to float on top of the water table, making it less likely for sorption onto sediment to occur below the low water table elevation. It is important to note that the water samples collected along the shoreline were collected at elevations ranging between 116 and 117 meters, or likely near the bottom edge of the vertical extent of diesel contamination.

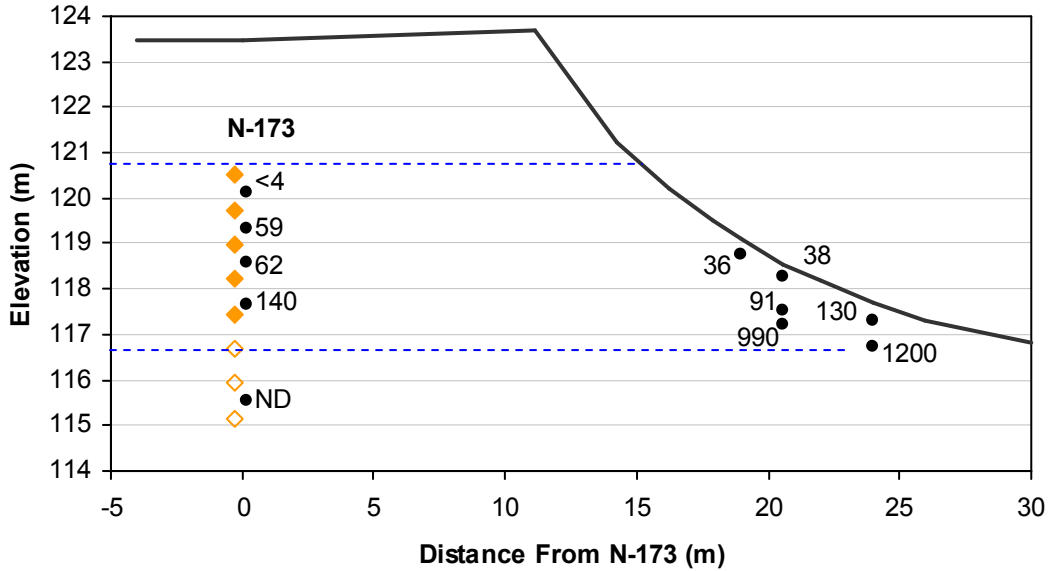


Figure 12. Concentrations of TPH-Dx measured in Sediment Samples Collected during Drilling of 199-N-173 and Along the Shoreline. Orange diamonds indicate where screening samples were collected (solid= detected, hollow= undetected). The blue lines represent nominal high and low water table elevations.

3.2 Comparison of Water Concentrations

The results of water samples collected from well 199-N-173 during drilling were compared to historical results from the two closest groundwater monitoring wells (199-N-96A and 199-N-18). These two wells are located 45 meters cross gradient and 75 meters up-gradient from 199-N-173, respectively. The measured diesel concentrations in water were significantly higher in 199-N-18 than in wells 199-N-173 and -96A (Table 10). Well 199-N-18 is located up-gradient from well 199-N-173, nominally halfway between the river and the plume origin. The significant decrease in diesel concentration between well 199-N-18 and the two other monitoring wells indicates that biological degradation of the diesel is likely occurring. Ethylbenzene and xylene concentrations were also lower at 199-N-173 than in 199-N-18, although the concentrations in 199-N-173 were not detectable. This could be a result of biological activity reducing ethylbenzene and xylene concentrations. Wells 199-N-173 and 199-N-18 had similar measured concentrations of iron, benzene. 199-N-96A had lower concentrations of iron, and no reported results for volatile compounds. On the other hand, 199-N-96A and 199-N-173 had similar concentrations of sulfate and nitrate, while 199-N-18 had much lower concentrations of these compounds. This is likely a result of a desalination effluent plume that is known to exist along that portion of the Columbia River shoreline (Mendoza et al. 2007). Although there is a minimal amount of analytical data available for contaminants in this plume, it would appear that by the time the plume reaches the near shore region, microbial activity has destroyed much of the diesel contamination. On the other hand, it would appear that benzene, and toluene concentrations are reduced at a slow rate through natural process.

Table 10. Average Measured Concentrations of Several Key Analytes from Samples Collected in Recent Years in Monitoring Wells within the Suspected Footprint of the Diesel Contamination Plume (mg/L)

Constituent	199-N-173	199-N-96A	199-N-18
TPH-Dx	3.2	1	632
Iron	38	0.085	42
Sulfate	154	76	7.8
Nitrate	7.7	18	0.2
Benzene	3	NS	0.95
Toluene	2.5	NS	0.14
Ethylbenzene	<1	NS	3.9
Xylene	<1	NS	3.7

3.3 Comparison of Water, Sediment and Biota Concentrations

Although there were several PAH compounds were detected in the biota samples, the only compounds measured at detectable concentrations in both biota and sediment samples were pyrene and fluoranthene. No PAHs were detected in any water samples collected by this project. While pyrene and fluoranthene were detected in one sediment sample each (although not the same sample) collected along the shoreline, the concentrations were below applicable standards. However, the elevated concentrations of PAHs measured in periphyton collected near the sediment samples appear to indicate a real source. There are several explanations for the elevated concentrations of PAHs identified upstream of 199-N-173 at the two periphyton sampling locations: 1) the diesel plume center is upstream of 199-N-173, 2) the PAHs moved towards the Columbia River along a different path than the diesel contamination, 3) the elevated PAH concentrations in periphyton are caused by a different groundwater source than the diesel spill, 4) elevated PAH concentrations in periphyton are a result of a contaminated Columbia River sediment (e.g., accumulation of sediment in an eddy). Further monitoring will be necessary to resolve this.

4.0 Conclusions/Recommendations

This report summarizes a number of monitoring activities conducted around the known diesel contamination. It appears that microbial degradation of the diesel fuel contamination is occurring; the low dissolved oxygen and nitrate concentrations, the elevated soluble iron concentrations, the presence of rhamnolipid producing bacteria and the decrease in TPH concentrations observed in the slurry reactors all indicate that microbial activity is occurring within the footprint of the diesel contaminant plume. Since there are no other carbon sources, the bacteria must be using the residual contamination as a food source. It also appears that the concentrations of all contaminants in sediment and water are near or below applicable standards. However, the current data set is limited; monitoring for the key analytes needs to be conducted over several years to provide a better characterization of the concentrations. Also, the spatial distribution of the monitoring points is not adequate to characterize the average plume concentration, or to even identify the center and edges of the plume. For instance, the periphyton samples collected along the shoreline indicate that the plume centerline may be further upstream than previously suspected. Nevertheless, it is possible that (once a point-of-compliance is established) concentrations of contaminants within this plume will not exceed regulatory threshold concentrations. Therefore, the recommendations for immediate implementation are: a detailed conceptual model should be developed to provide a more complete picture of the contaminant fate and transport; work with regulators to establish the point-of-compliance for the TPH contaminant plume within the 100-NR-2 OU; consider quarterly monitoring of TPH (diesel fraction) as well as volatile organics and PAHs at wells within the suspected boundary of the contaminant plume, consider additional monitoring wells within the suspected boundary of the contaminant plume.

5.0 Reference

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Appendix A
Compounds Analyzed

Table A.1. Analytical Methods Used for Sample Analysis

Analyte	Method	Matrix	Maximum Hold Time	Detection Limit
TPH-Dx ^(a)	NWTPH-Dx	Water/Sediment	14 days	0.5 mg/L or 10 mg/kg
TPH-Dx ^(b)	EPA 8015	Water/Sediment	14 days	0.5 mg/L or 10 mg/kg
VOC	EPA 8260	Water	14 days	1 mg/L
SVOC	EPA 8270	Water/Sediment	14 days	1 mg/L or 10 mg/kg
BTEX/MTBE	EPA 8021B	Water/Sediment	14 days	1 mg/L or 10 mg/kg
Anions	EPA 300.0	Water	45 days	1 mg/L
Metals	EPA 200.8	Water	60days	1 mg/L
Metals	EPA 6020	Sediment	60 days	5 mg/kg
PAH's	EPA 8270C	Water/Sediment	14 days	1 mg/L or 10 mg/kg
PAH's	EPA 3541/ EPA 8270C	Biota	14 days	1 ug/kg wet wt
PCB's	EPA 608/8082	Water/Sediment	14 days	1 mg/L or 10 mg/kg

(a) shoreline samples

(b) well samples

Table A.2. Compounds Analyzed for During the Various Sampling Efforts. Analytes with bolded text were measured at detectable concentrations in at least one sample collected for this study.

Well Water & Sediment Analytes	Near-Shore Water Analytes	Near-Shore Sediment Analytes	Clam & Periphyton Analytes
1,1,1-Trichloroethane	1,1,1-Trichloroethane	1,2,4-Trichlorobenzene	acenaphthene
1,1,2,2-Tetrachloroethane	1,1,2-Trichloroethane	1,3-Dichlorobenzene	acenaphthylene
1,1,2-Trichloroethane	1,1-Dichloroethane	1,4-Dichlorobenzene	anthracene
1,1-Dichloroethane	1,1-Dichloroethene	2,4,5-Trichlorophenol	benz[a]anthracene
1,1-Dichloroethene	1,2-Dichloroethane	2,4,6-Trichlorophenol	benzo[a]pyrene
1,2,4-Trichlorobenzene	1,4-Dichlorobenzene	2,4-Dichlorophenol	benzo[e]pyrene
1,2-Dichlorobenzene	1,4-Dioxane	2,4-Dimethylphenol	benzo[b]fluoranthene
1,2-Dichloroethane	1-Butanol	2,4-Dinitrophenol	benzo[g,h,i]perylene
1,2-Dichloroethene (Total)	1-Methylnaphthalene	2,4-Dinitrotoluene	benzo[j]fluoranthene
1,2-Dichloropropane	2-Butanone	2,6-Dinitrotoluene	benzo[k]fluoranthene
1,3-Dichlorobenzene	2-Methylnaphthalene	2-Chloronaphthalene	chrysene
1,4-Dichlorobenzene	2-Pentanone, 4-Methyl	2-Chlorophenol	dibenz[a,h]anthracene

Table A.2. contd

Well Water & Sediment Analytes	Near-Shore Water Analytes	Near-Shore Sediment Analytes	Clam & Periphyton Analytes
2,4,5-Trichlorophenol	Acenaphthene	2-Methylnaphthalene	fluoranthene
2,4,6-Trichlorophenol	Acenaphthylene	2-Methylphenol	fluorene
2,4-Dichlorophenol	Acetone	2-Nitroaniline	phenanthrene
2,4-Dimethylphenol	Anthracene	2-Nitrophenol	pyrene
2,4-Dinitrophenol	Aroclor 1016	3,3'-Dichlorobenzidine	indeno[1,2,3-c,d]pyrene
2,4-Dinitrotoluene	Aroclor 1221	3-Nitroaniline	Dibenzofuran
2,6-Dinitrotoluene	Aroclor 1232	4,6-Dinitro-2-methylphenol	
2-Butanone	Aroclor 1248	4-Bromophenylphenyl ether	
2-Chloronaphthalene	Aroclor 1254	4-Chloro-3-methylphenol	
2-Chlorophenol	Aroclor 1260	4-Chloroaniline	
2-Hexanone	Benzene	4-Chlorophenylphenyl ether	
2-Methylnaphthalene	Benzo(a)anthracene	4-Methylphenol	
2-Methylphenol (cresol, o-)	Benzo(a)pyrene	4-Nitroaniline	
2-Nitroaniline	Benzo(b)fluoranthene	4-Nitrophenol	
2-Nitrophenol	Benzo(ghi)perylene	Acenaphthene	
2-Pentanone, 4-Methyl	Benzo(k)fluoranthene	Acenaphthylene	
3 & 4 Methylphenol Total	Carbon disulfide	Aluminum	
3,3'-Dichlorobenzidine	Carbon tetrachloride	Aniline	
3-Nitroaniline	Chloroform	Anthracene	
4,6-Dinitro-2-methylphenol	Chrysene	Benzene	
4-Bromophenylphenyl ether	cis-1,2-Dichloroethylene	Benzo(a)anthracene	
4-Chloro-3-methylphenol	Dibenzo(a,h)anthracene	Benzo(a)pyrene	
4-Chloroaniline	Ethyl cyanide	Benzo(b)fluoranthene	
4-Chlorophenylphenyl ether	Ethylbenzene	Benzo(ghi)perylene	
4-Nitroaniline	Fluoranthene	Benzo(k)fluoranthene	
4-Nitrophenol	Fluorene	Benzoic Acid	
Acenaphthene	Indeno(1,2,3-cd)pyrene	Benzyl Alcohol	
Acenaphthylene	Methylene chloride	Bis(2-Chloroethoxy)methane	
Acetone	Naphthalene	Bis(2-chloroethyl) Ether	
Anthracene	TPH-Dx	Bis(2-chloroisopropyl) Ether	

Table A.2. contd

Well Water & Sediment Analytes	Near-Shore Water Analytes	Near-Shore Sediment Analytes	Clam & Periphyton Analytes
Antimony	Phenanthrene	Bis(2-Ethylhexyl)phthalate	
Benzene	Pyrene	Butylbenzylphthalate	
Benzo(a)anthracene	Tetrachloroethene	Chrysene	
Benzo(a)pyrene	Tetrahydrofuran	Cobalt	
Benzo(b)fluoranthene	Toluene	Copper	
Benzo(ghi)perylene	trans-1,2-Dichloroethylene	Dibenz(a,h)anthracene	
Benzo(k)fluoranthene	Trichloroethene	Dibenzofuran	
Bis(2-Chloro-1-methylethyl)ether	Vinyl chloride	Diesel Range Organics (DRO)	
Bis(2-Chloroethoxy)methane	Xylenes (total)	Diethylphthalate	
Bis(2-chloroethyl) ether		Dimethyl phthalate	
Bis(2-Ethylhexyl)phthalate		Di-n-butylphthalate	
Bromodichloromethane		Di-n-octylphthalate	
Bromoform		Ethylbenzene	
Bromomethane		Fluoranthene	
Butylbenzylphthalate		Fluorene	
Carbazole		Hexachlorobenzene	
Carbon disulfide		Hexachlorobutadiene	
Carbon tetrachloride		Hexachlorocyclopentadiene	
Chlorobenzene		Hexachloroethane	
Chloroethane		Ideno(1,2,3-cd)pyrene	
Chloroform		Iron	
Chloromethane		Isophorone	
Chrysene		Lead	
cis-1,3-Dichloropropene		m,p-Xylenes	
Cobalt-60		Methyl-tert Butyl Ether	
Dibenz(a,h)anthracene		Naphthalene	
Dibenzofuran		Nickel	
Dibromochloromethane		Nitrobenzene	
Diethylphthalate		N-Nitrosodimethylamine	
Dimethyl phthalate		n-Nitrosodi-n-propylamine	

Table A.2. contd

Well Water & Sediment Analytes	Near-Shore Water Analytes	Near-Shore Sediment Analytes	Clam & Periphyton Analytes
Di-n-butylphthalate		n-Nitrosodiphenylamine	
Di-n-octylphthalate		o-Xylenes	
Ethylbenzene		Pentachlorophenol	
Fluoranthene		Phenanthrene	
Fluorene		Phenol	
Hexachlorobenzene		Potassium	
Hexachlorobutadiene		Pyrene	
Hexachlorocyclopentadiene		Residual Range Organics	
Hexachloroethane		Sodium	
Ideno(1,2,3-cd)pyrene		Toluene	
Iron			
Isophorone			
Magnesium			
Manganese			
Methylene Chloride			
Naphthalene			
Nickel			
Nitrate in Nitrogen			
Nitrite in Nitrogen			
Nitrobenzene			
n-Nitrosodi-n-dipropylamine			
n-Nitrosodiphenylamine			
Pentachlorophenol			
Phenanthrene			
Phenol			
Phosphorus in Phosphate			
Pyrene			
Strontium-89/90			
Styrene			
Sulfate			
Technetium-99			
Tetrachloroethene			
Toluene			

Table A.2. contd

Well Water & Sediment Analytes	Near-Shore Water Analytes	Near-Shore Sediment Analytes	Clam & Periphyton Analytes
TPH- diesel range			
TPH- kerosene range			
trans-1,3-Dichloropropene			
Trichloroethene			
Trichlorofluoromethane			
Tritium			
Vinyl chloride			
Xylenes (Total)			

Appendix B
Analytical Results

This appendix lists the raw analytical results. All results shown have no associated QC qualifiers. Samples with undetectable concentrations are reported here as 'ND'.

Table B.1. Shoreline Soil Samples

Analytes- results on a dry wt basis (mg/kg)	TPHA1 2 ft	TPHA2 1.5 ft	TPHA2 4 ft	TPHA2 5 ft	TPHA3 2 ft	TPHA3 4 ft	TPHB1 2 ft	TPHB1 4 ft	TPHB1 5 ft
Sample Elevation (m)	118.8	118.3	117.5	117.2	117.3	116.7	118.1	117.5	117.2
Aluminum	6170	8660	4520	5310	5710	5070	4510	4810	5270
Cobalt	4.8	8.1	3.5	4.6	4.7	4.3	7.3	5.6	5.4
Copper	11.5	13.3	9.9	10.4	11.9	13	11.1	18.7	11.8
Iron	13300	16900	11700	12900	15200	13700	23400	20900	14700
Lead	3.1	2.4	3.9	3.5	6.4	3.8	3	5.1	3.6
Nickel	12.1	21.9	8.2	10	15	9.5	8.1	6.7	13.7
Potassium	948	1220	746	900	645	567	404	465	688
Sodium	115	484	153	184	293	267	239	262	218
TPH-Dx	36	38	91	990	130	1200	320	350	690
residual range organics	14	8.7	12	23	6.9	20	15	16	21
Methyl tert-butyl ether	ND	0.083	ND	ND	ND	ND	ND	ND	ND
Benzene	0.00071	0.0032	ND	0.00037	0.0025	0.00016	0.0011	0.00018	0.00034
Toluene	0.00035	0.00068	0.00032	0.00073	0.00065	0.00038	0.00053	0.00021	0.00046
Ethylbenzene	0.000059	0.000092	ND	ND	ND	ND	0.000076	ND	0.00013
m,p xylenes	0.00018	0.0004	0.00021	0.00047	0.00037	0.00032	0.00033	0.00011	0.00025
o xylene	ND	0.00016	ND	0.00025	0.00017	ND	ND	ND	ND
Fluoranthene	ND	ND	ND	NS	ND	ND	ND	ND	0.015
Pyrene	ND	ND	ND	NS	ND	0.024	ND	ND	ND
Bis(2-ethylhexyl) Phthalate	0.034	ND	0.047	NS	ND	ND	ND	0.056	0.076

B.1

Table B.2. Well Soil Samples

Analytes- results on a dry wt basis (mg/kg)	Average ^(a)								
	B1YDD6/ B1YDD8	B1YDF0/ B1YDF2	B1YDF4/B1YDF6 B1YDH0/B1YDF8	B1YDH2/ B1YDH4	B1YDH6/ B1YDH8	B1YDJ0/ B1YDJ2	B1YDJ4/ B1YDJ6	B1YDJ8/ B1YDK0	B1YDK2/ 1YDK4
Depth (ft bgs)	9.9 - 12	12.5 - 14.5	15 - 16.5	17.5 - 20	24.5 - 27	30 - 31.5	34.5 - 37	39.5 - 42	44.6 - 47.1
Elevation (middle of core)	120.1	119.3	118.6	117.7	115.5	114.0	112.5	111.0	109.4
Iron	8750	15800	15150	14400	14000	7170	6020	14600	17900
Magnesium	2350	3850	3425	2790	2150	2500	2690	2960	6660
Manganese	92.5	165	198	158	178	145	0.0100	70.1	122
Nickel	8.78	14.5	14.8	31.2	10.1	13.7	<0.00196	4.10	16.2
TPH- Diesel	<i>ND</i> <3.1	59	61.5	140	<i>ND</i> <3.2	<i>ND</i> <3.7	<i>ND</i> <3.8	<i>ND</i> <3.3	<i>ND</i> <3.6
Bis(2-Ethylhexyl) phthalate	<i>ND</i>	<i>ND</i>	1.4	1.4	0.47	0.19	0.68	0.35	0.33
Benzene	<i>ND</i>	0.0028	0.003	<i>ND</i>	<i>ND</i>	<i>ND</i>	<i>ND</i>	<i>ND</i>	<i>ND</i>
Toluene	<i>ND</i>	0.0024	0.005	<i>ND</i>	<i>ND</i>	<i>ND</i>	<i>ND</i>	<i>ND</i>	0.0028
Ethylbenzene	<i>ND</i>	<i>ND</i>	<i>ND</i>	<i>ND</i>	<i>ND</i>	<i>ND</i>	<i>ND</i>	0.0025	<i>ND</i>
Xylenes	<i>ND</i>	<i>ND</i>	<i>ND</i>	<i>ND</i>	<i>ND</i>	<i>ND</i>	<i>ND</i>	<i>ND</i>	<i>ND</i>
Styrene	0.0034	0.0031	0.0067	0.0036	<i>ND</i>	0.0033	0.0035	0.0028	0.0039
2-Butanone	<i>ND</i>	<i>ND</i>	0.0073	0.0072	<i>ND</i>	<i>ND</i>	<i>ND</i>	<i>ND</i>	<i>ND</i>

(a)- Duplicate sample. Average of two samples is shown.

ND- Concentration reported below minimum detectable concentration. Detection Limit shown for TPH results.

Table B.3. Water Samples

Constituent	HEIS Sample ID				
	B1YK44	B1YK46	B1YK48	B1YK50	B1YK54
Depth bgs (ft)	19	19	23.2	33	43
Sp. Cond. ($\mu\text{S}/\text{cm}$)	1420	1420	1216	1243	834
TPH-Dx (mg/L)	3.9	4.3	2.3	<0.07	<0.07
Iron (mg/L)	42.2	33.9	1.8	0.389	19
Magnesium (mg/L)	48.8	52.7	27.2	20.4	25.3

Appendix C

Drilling Information for Monitoring Well 199-N-173

BOREHOLE LOG					Page 1 of 3
					Date: 1/28/09
Well ID: C7038		Well Name: 199-N-173		Location: 50m South of 199-N-138	
Project: CO-NR-2 TPH Monitoring well			Reference Measuring Point: Ground Surface		
Depth (Ft.)	Sample		Graphic Log	Sample Description	Comments
	Type No.	Blows Recovery			
0				0-1', crushed gravel fill for drill pad	Drilling Method: Cable Tool with Drive Barrel; Grab samples for archive every 5 feet
1				1-9', sandy GRAVEL (sG): 60% gravel, 35% sand, 5% silt; Gul: predominantly basalt, 0.5-6cm, SA-SR; sand: 50% basalt, 50% other, f-m grained; slight rxn HCl; 10YR 5/2 grayish brown (moist)	
5	Grab	(archive)			5.5', encountered large rock
9	Grab				8.5', Dry, color is 2.5Y 4/2
9-10	grab (BIVD09)	9-5.5, 250 blows, 100% recovery		9-20', sandy GRAVEL (sG): 30% gravel, 70% sand; Gul: 10% basalt, 90% other, 0.5-3cm, SA-SR; sand: 10% basalt, 90% other, m-c grained; no rxn HCl; 2.5Y 6/3 light yellowish brown (moist)	light brownish gray 9', Hanford/Ringold contact(?)
11	grab (BIVD10)	11-12.0			11', gul ↑ to 40%, driving harder DR↓ (poor recovery)
12	grab (BIVD11)	12.5-4.5, 344 blows, 100% recovery			
13	grab (BIVD12)	13.5-4.5, 344 blows, 100% recovery			
14	grab (BIVD13)	14.5-4.5, 344 blows, 100% recovery			
15	grab (BIVD14)	15.0-5.4, 500 blows, 100% recovery		Same lithology as above, though sand is f-m grained, and color is 2.5Y 5/3 light olive brown (moist)	
16	grab (BIVD15)	16.5-4.4, 700 blows, 100% recovery			
17	grab (BIVD16)	17.5-4.4, 700 blows, 100% recovery			
18	grab (BIVD17)	18.5-4.4, 700 blows, 100% recovery			
19	grab (BIVD18)	19.5-4.4, 700 blows, 100% recovery			
Reported By: Patrick Cabbage			Reviewed By: L. D. Walker		
Title: Geologist			Title: Geologist		
Signature: Patrick Cabbage		Date: 1/28/09	Signature: L. D. Walker		Date: 3/16/09

A-6003-642 (03/03)

Figure C.1. Borehole Log for 199-N-173

BOREHOLE LOG					Page 2 of 3
Well ID: C7038		Well Name: 199-N-173		Location: 50m South of 199-N-133	
Project: 100-NR-2 TPH Monitoring well			Reference Measuring Point: Ground Surface		
Depth (Ft.)	Sample		Graphic Log	Sample Description	Comments
	Type No.	Blows Recovery			
20	grab (BIVDL2)	20.0		20-30', silty sandy (GRAVEL (ms.G): 40% gul, 50% sand, 10% silt; Gul is same as above; sand is same as above; no rxn HCl; 2.5Y 5/1 grey	20', strong diesel odor, ITH monitors ~1 ppm inside casing
21					
23	grab water (BIVL48)			24.5-25.5, 314 blows, 100% recovery HEIS: BIVDH5, BIVDH6, BIVDH7, BIVDH8	Same lith. as above; color is 2.5Y 4/2 dark grayish brown
25	grab (BIVDL4)				
27	grab (BIVDL5)	27.0		30-44', sandy (GRAVEL (SG): 40% gul, 60% sand; lith for gul and sand is same as above; no rxn HCl; color is 2.5Y 5/2 grayish brown	28', sand m-vc; color is same as above 28.5', oxidation present
28					
30	grab (BIVDL6)	30.0-35.0		34.5-35.5, 254 blows, 100% recovery HEIS: BIVDS3, BIVDS4, BIVDS5, BIVDS6	Same lith. as above, though gul 50%, sand 50%
35	grab water (BIVL50)				
37	grab (BIVDLA)	37.0			

Reported By: Patrick Cabbage
 Title: Geology PT
 Signature: Patrick Cabbage
 Date: 2/2/09

Reviewed By: L.D. Walker
 Title: Geologist
 Signature: L.D. Walker
 Date: 3/16/09

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Figure C.1. contd

BOREHOLE LOG					Page 3 of 3
Well ID: C7038					Date: 2/5/09
Well Name: 199-N-173			Location: 50m South of 199-N-138		
Project: 100-NR-2 TPH Monitoring Well			Reference Measuring Point: Ground Surface		
Depth (Ft.)	Sample		Graphic Log	Sample Description	Comments
	Type No.	Blows Recovery			
40	Grab grab (BYDM0)	39.5-53.274 Blows, 100% recovery HEIS: 81Y0J7 81Y0J8 81Y0J9 81Y0K0		30-44', sandy GRAVEL (SG): 40% sil, 60% sand; sil: 10% basalt, 90% other, 0.5-3mm, SA-SR; ind: 10% basalt, 90% other, m-c grained; no rxn HCl; 2.5Y 6/3 light yellowish brown (moist)	40', more mica present
41					
42					
43	Grab grab (BYDM1)	42.0			
44	Grab grab (BYDM2)	44.6-54.154 Blows, 100% recovery HEIS: 81Y0K1 81Y0K2 81Y0K3 81Y0K4		44-45', clay: 100% clay; no rxn HCl; 2.5YR 4/2 pinkish white (dry) 45', 100% silt/clay; no rxn HCl; 2.5Y 6/2 light brownish gray	44', sharp contact with possible ash layer 45', RUM contact
45					TD: 45.2' bgs (2/5/09)
46					
47					
48					
49					
50					
51					
52					
53					
54					
55					
56					
57					
58					
59					
Reported By: Patrick Cabbage			Reviewed By: L.D. Walker		
Title: Geologist			Title: Geologist		
Signature: Patrick Cabbage		Date: 2/5/09	Signature: L.D. Walker		Date: 2/16/09

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Figure C.1. contd

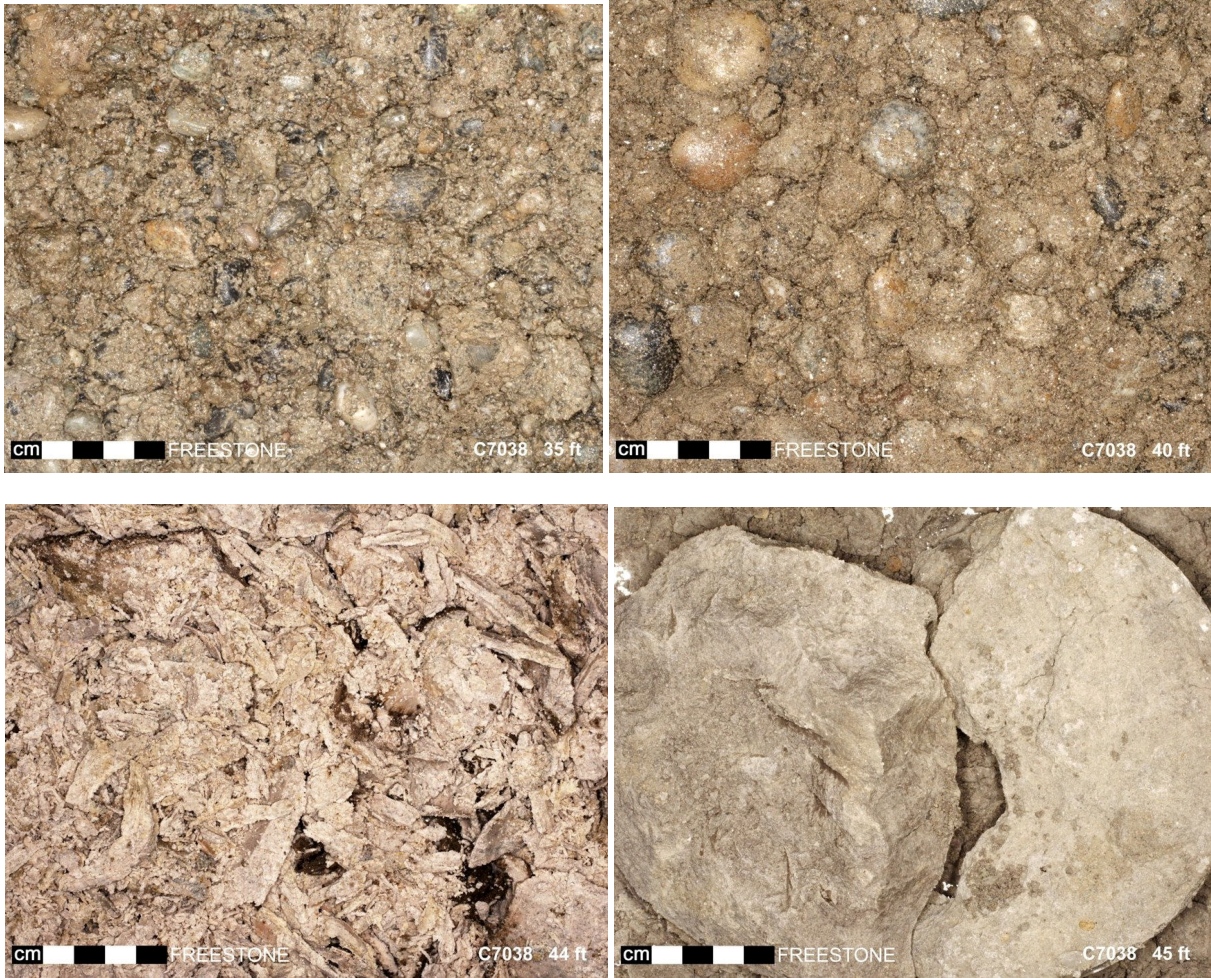


Figure C.2. Additional Pictures of Core Samples Collected From Monitoring Well 199-N-173



Figure C.3. Examples of the Unusual Foamy Water Observed During Drilling and Development of Monitoring Well 199-N-173

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