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Annual Operations and Monitoring Report for UPR-100-N-17: March 2015- February 2016

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

P.O. Box 1600
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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Executive Summary

This annual summary report describes the routine operation of the bioventing system at the UPR-100-N-17 waste site from March 2015 through February 2016 and includes a summary of performance for the bioremediation remedy. Biodegradation rates calculated from respirometry testing exhibited a declining trend from the initial rates calculated in March 2010 of approximately 0.97 mg/kg-day down to 0.19 mg/kg-day calculated in February 2016. Calculations using the respirometry data indicate that approximately 594 mg/kg of petroleum have been removed from impacted soils since startup of the bioventing system in November 2012.

Bioremediation of deep vadose zone petroleum contamination at the UPR-100-N-17 waste site, located within the 100-NR-1 Operable Unit, was initiated in November 2012. The *Interim Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*[1] identified in situ bioremediation as the selected remedy for cleanup of petroleum located below 4.6 m (15 ft) of surrounding grade. Using bioremediation, oxygen is supplied to the deep vadose zone at the UPR-100-N-17 waste site in the 100-NR-1 Operable Unit to provide a source of energy for aerobic hydrocarbon degrading bacteria to metabolize petroleum contamination. Implementation of the bioremediation project began with the drilling, construction, and sampling of seven pilot test bioventing wells to provide access to deep zone vadose petroleum contamination. These activities were completed in 2009 and documented in WCH-370, *Bioremediation Well Borehole Soil Sampling and Data Analysis Summary Report for the 100-N Area Bioremediation Project (UPR-100-N-17)*[2]. Drilling, well construction, and sampling were followed by Phase I pilot testing of the bioremediation system from February 2010 through May 2011 (WCH-490, *UPR-100-N-17: Bioventing Pilot Plant Performance Report*[3]).

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[1] EPA/ROD/R10-99/112, 1999, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Region 10, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Seattle, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D9177845

[2] WCH-370, 2009, *Bioremediation Well Borehole Soil Sampling and Data Analysis Summary Report for the 100-N Area Bioremediation Project (UPR-100-N-17)*, Rev. 0, Washington Closure Hanford, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0084017.

[3] WCH-490, 2011, *UPR-100-N-17: Bioventing Pilot Plant Performance Report*, Rev. 0, Washington Closure Hanford, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0093690.

Pilot testing consisted of collecting baseline measurements at the seven bioremediation wells, a respirometry test, an air injection radius of influence test, and a 6-month operational test period. Results from the pilot testing indicate that deep-vadose-zone hydrocarbon-impacted soils are amenable to bioventing enhanced in situ bioremediation.

Phase II testing was initiated in November 2012. During this phase, the bioventing system operated to supply approximately 250 ft^3/min of air to the subsurface via two injection wells, 199-N-167 and 199-N-172. Based on previous studies, the radius of influence for each injection well is approximately 61 m (200 ft). Phase II testing of the bioventing system was in continuous operation from November 2012 through September 2014, with the exception of periodic short-term shutdowns for maintenance and respirometry test events.

The operation and maintenance of the system transitioned from Washington Closure Hanford to CH2M HILL Plateau Remediation Company (CHPRC) on October 1, 2014, and began the period of routine operation of the system. The bioventing system was shut down from September 30, 2014, through December 3, 2014, while CHPRC completed activities to bring the system current with contractor electrical and mechanical requirements, developed procedures, and implemented training to support full-scale operation of the system. The transition period to the start of routine monitoring is documented in DOE/RL-2015-20, *Annual Operations and Monitoring Report for UPR-100-N-17: March 2014 – February 2015*[4].

The respirometry rates associated with the bioremediation remedy over the reporting period are generally below the literature values for recommending bioventing as a viable option. However, there is clear evidence that oxygen is a limiting factor for microbial degradation of petroleum hydrocarbons in the deep vadose zone and that bioventing will help maintain this degradation, albeit at a somewhat low rate.

The following recommendations are made regarding system operations and performance monitoring:

- Operate the bioventing system in a pulse mode (e.g., 1 week on, 3 weeks off). Respirometry testing indicates that this operational protocol is expected to maintain sufficient oxygen levels in the subsurface while substantially reducing costs for power consumption.

[4] DOE/RL-2015-20, 2015, *Annual Operation and Monitoring Report for UPR-100-N-17: March 2014-February 2015*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0080062H

- Continue semi-annual respirometry testing to evaluate remediation progress and the effect of seasonal variability on the measured biodegradation rates.
- Collect and evaluate soil samples at the site to determine progress toward achievement of cleanup criteria with respect to hydrocarbons in soil.
- Evaluate use of an additional treatment technology (e.g., sparging) to treat hydrocarbon-impacted groundwater and saturated zone soils in order to accelerate the overall cleanup time frame.
- Collect soil and groundwater samples to measure numbers of hydrocarbon-degrading bacteria prior to commencement of a biosparging pilot test. Other geochemical and nutrient parameters should also be measured in soil and groundwater.

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Contents

1 Introduction 1-1

1.1 Site Location 1-1
1.2 Site History 1-1
1.3 Delineation of Impacted Soils 1-3

2 Bioventing System Description 2-1

2.1 Bioremediation Wells 2-2

3 Bioventing System Operation and Performance 3-1

3.1 System Downtime 3-1
3.2 System Maintenance 3-1
3.3 Monthly Injection Well Measurements 3-2
3.4 Monthly Soil Gas Measurements 3-3
3.5 Respirometry Tests 3-4
3.6 Bioventing System Costs 3-7

4 Groundwater Monitoring 4-1

4.1 Groundwater Sampling 4-1
4.1.1 Geochemical Indicators 4-1
4.1.2 Groundwater Concentrations 4-2

5 Conclusions and Recommendations 5-1

6 References 6-1

Appendices

A June – August 2015 Respirometry Testing ..... A-i

B January - February 2016 Respirometry Testing ..... B-i

Figures

Figure 1-1. Map Showing the Locations of the 100-N Area Petroleum Waste Sites 1-2
Figure 1-2. Conceptual Model of Petroleum Contamination at the 100-N Area 1-3
Figure 1-3. Aerial View of the UPR-100-N-17 Bioventing System Location (January 2014) 1-4
Figure 1-4. Aerial View of the 100-N Area after Backfill and Revegetation (December 2014) 1-4
Figure 2-1. Bioventing System Conex Box 2-1
Figure 2-2. Interior of Bioventing System Conex Box 2-2
Figure 2-3. Locations of the Bioventing System Wells and Aquifer Tubes 2-4
Figure 3-1. Chart of Monthly Soil Vapor Monitoring Results 3-6
Figure 3-2. Bioventing System Cost ($274,200) Breakdown (by Percentage) 3-8
Figure 4-1. Summary of Groundwater Oxidation and Reduction Species, July 2015 4-36
Figure 4-2. Summary of Groundwater Oxidation and Reduction Species, February 2016 4-37
Figure 4-3. Petroleum Plume Distribution in Groundwater at the 100-NR-2 OU, July 2015 4-38
Figure 4-4. Petroleum Plume Distribution in Groundwater at the 100-NR-2 OU, December 2015 4-39

Tables

Table 2-1. Bioventing Well Information 2-3
Table 3-1. UPR-100-N-17 Bioventing System Operating Times (March 2015 – February 2016) 3-1
Table 3-2. Monthly Air Injection Well Measurements 3-2
Table 3-3. Monthly Vapor Monitoring Data 3-3
Table 3-4. Comparison of Biodegradation Rates Calculated from In Situ Respiration Testing 3-7
Table 4-1. Bioventing Sample Schedule and Analytical Parameters 4-4
Table 4-2. Groundwater Sample Results for Petroleum Hydrocarbons (July 2015) 4-5
Table 4-3. Groundwater Sample Results for Petroleum Hydrocarbons (February 2016) 4-6
Table 4-4. Groundwater Sample Results for Anions (July 2015) 4-7
Table 4-5. Groundwater Sample Results for Anions (February 2016) 4-10
Table 4-6. Groundwater Sample Results for Metals (July 2015) 4-13
Table 4-7. Groundwater Sample Results for Metals (January 2016) 4-20
Table 4-8. Groundwater Sample Results for Organics (July 2015) 4-26
Table 4-9. Groundwater Sample Results for Organics (February 2016) 4-31
Table 4-10. Groundwater Elevations during Sampling Events 4-35

Terms

bgs	below ground surface
CHPRC	CH2M HILL Plateau Remediation Company
N/A	not applicable
OU	operable unit
ppmv	parts per million by volume
PQL	practical quantitation limit
PVC	polyvinyl chloride
TPH	total petroleum hydrocarbon
WCH	Washington Closure Hanford

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1 Introduction

CH2M HILL Plateau Remediation Company (CHPRC) provides operation, maintenance, and monitoring for the UPR-100-N-17 bioventing system at the Hanford Site 100-N Area. The bioventing system was transitioned on October 1, 2014, from Washington Closure Hanford (WCH) as a Phase II testing operation to CHPRC for routine operation.

This annual report summarizes the bioventing system operations and monitoring for the period from March 2015 through February 2016. System operations were conducted at the 100-N Area using WCH-576, *Operations and Maintenance Manual, Phase II Testing – Bioremediation Design for Deep Zone Petroleum Contamination (UPR-100-N-17)*. Monitoring activities were conducted in accordance with DOE/RL-2005-93, *Remedial Design Report/Remedial Action Work Plan for the 100-N Area*, Appendix H, "Phase II Testing/Performance Monitoring Plan for the UPR-100-N-17 Bioremediation," and included semiannual groundwater sampling and analysis, collecting monthly soil gas measurements, and performing semiannual in situ respirometry tests. Report EPA/ROD/R10-99/112, *Interim Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*, identifies in situ bioremediation (using supplied oxygen, bacteria, and nutrients) as the selected remedy for cleanup of petroleum located below 4.6 m (15 ft) of surrounding grade. Currently, only oxygen is supplied to the vadose zone, providing a source of energy for aerobic hydrocarbon degrading bacteria to metabolize petroleum contamination.

The previous annual report is documented in DOE/RL-2015-20, *Annual Operation and Monitoring Report for UPR-100-N-17: March 2014-February 2015*.

1.1 Site Location

The UPR-100-N-17 waste site is located within the Hanford Site 100-NR-1 Operable Unit (OU), approximately 192 m (630 ft) northeast of the N Reactor (Figure 1-1). The site is an unplanned release of diesel oil that occurred at the 166-N Tank Farm sometime between August 1965 and September 1966. The diesel fuel release was from a 10 cm (4 in.) pipeline in the tank farm and was located approximately 140 m (460 ft) from the Columbia River. The presence of light, nonaqueous-phase liquid was discovered beneath the facility in March 1967, when evidence of oil was observed at the bank of the Columbia River (100-N-65 waste site), approximately 100 m (328 ft) northwest of the 166-N Tank Farm. Additional releases of both diesel and Bunker C fuel occurred during operations. The location of documented petroleum releases is shown in Figure 1-1.

1.2 Site History

The bioventing system was installed at the UPR-100-N-17 waste site to remediate deep vadose zone petroleum-contaminated soils identified within the 100-NR-1 OU. The Phase II bioventing system was started on November 27, 2012. The system was transitioned to CHPRC on October 1, 2014, for routine operations.

Groundwater at the site is also contaminated and is addressed as part of the 100-NR-2 OU. A detailed history of the waste site is provided in DOE/RL-2005-93.

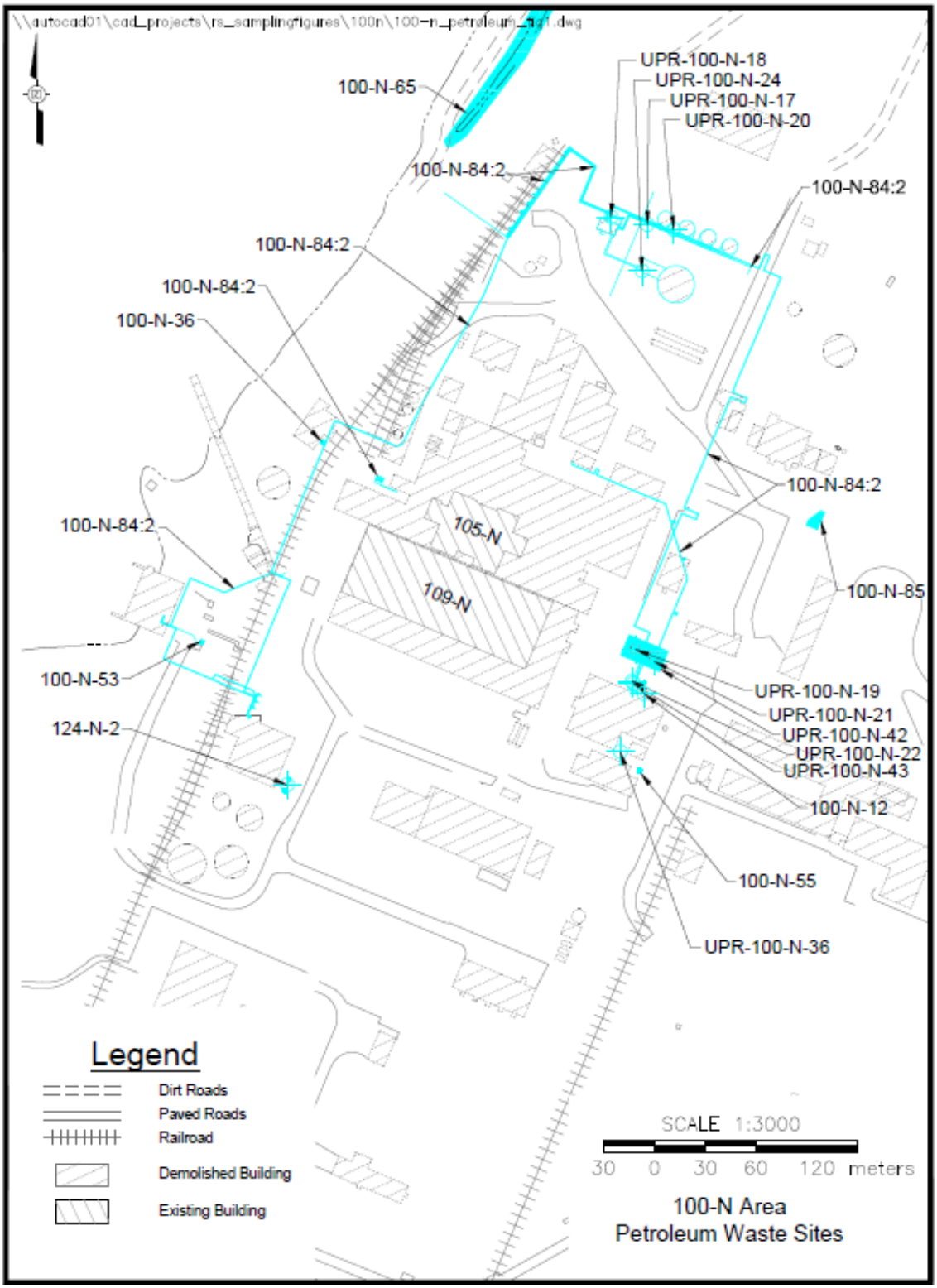


Figure 1-1. Map Showing the Locations of the 100-N Area Petroleum Waste Sites

1.3 Delineation of Impacted Soils

Prior to construction of the Phase II bioventing system, the extent of petroleum-contaminated soil was based on historical information, including that provided in DOE/RL-95-111, *Corrective Measures Study for the 100-NR-1 and 100-NR-2 Operable Units*; the results of sampling during installation of seven pilot test bioventing wells (WCH-370, *Bioremediation Well Borehole Soil Sampling and Data Analysis Summary Report for the 100-N Area Bioremediation Project (UPR-100-N-17)*); and the Phase I bioventing pilot study (WCH-490, *UPR-100-N-17: Bioventing Pilot Plant Performance Report*). Field observations and sampling performed during removal and remediation of the 100-N-84:2 Bunker C and diesel pipelines during 2012 and 2013 provided additional information regarding the extent of petroleum-impacted soil. Figure 1-2 provides a conceptual model for the site. An estimated 58,349 bank cubic meters of petroleum-contaminated soil was removed from petroleum-contaminated waste sites at the 100-N Area excavated to a depth of 4.6 m (15 ft) and disposed at the Environmental Restoration Disposal Facility.

Figure 1-3 shows the extent of excavation and soil removal that WCH performed near the UPR-100-N-17 waste site. Backfill of these excavations was initiated in July 2014 and was completed in September 2014, with revegetation completed in December 2014 (Figure 1-4).

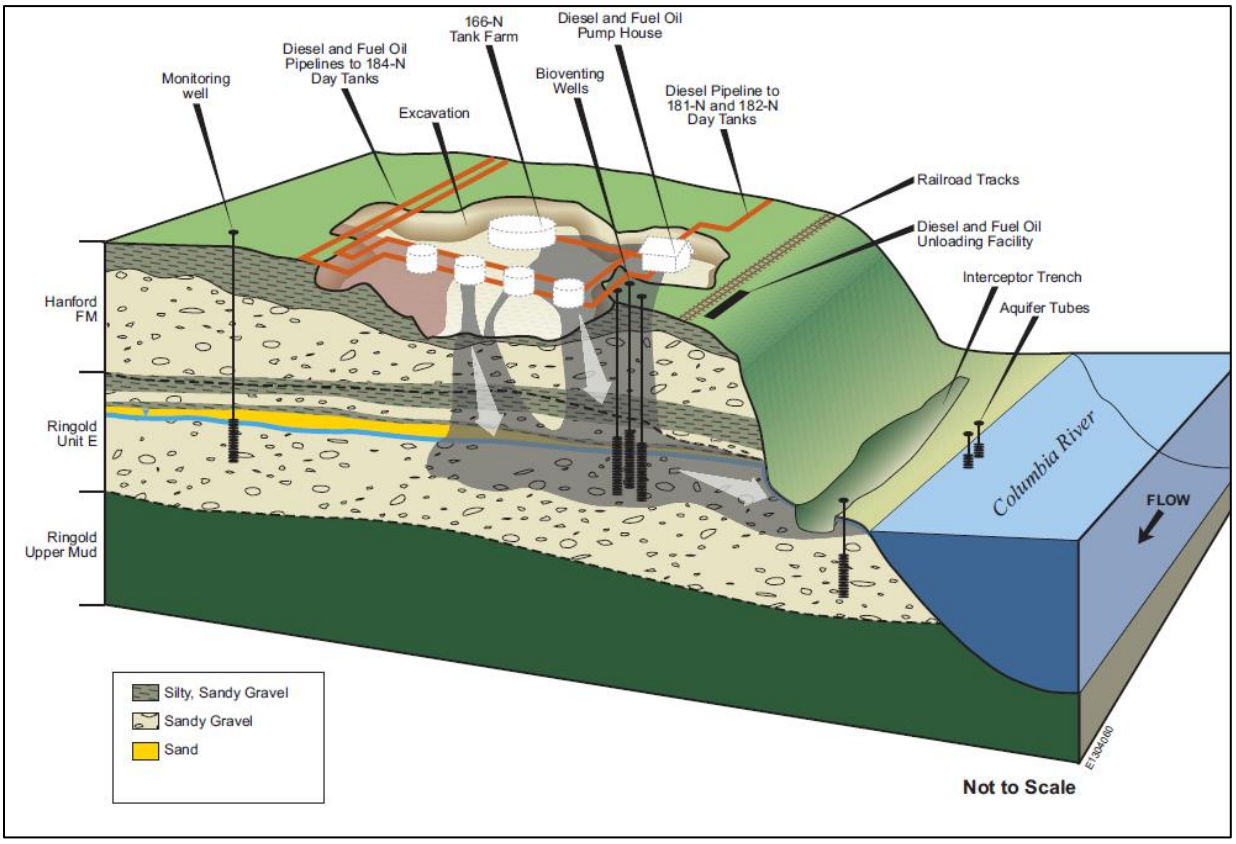


Figure 1-2. Conceptual Model of Petroleum Contamination at the 100-N Area

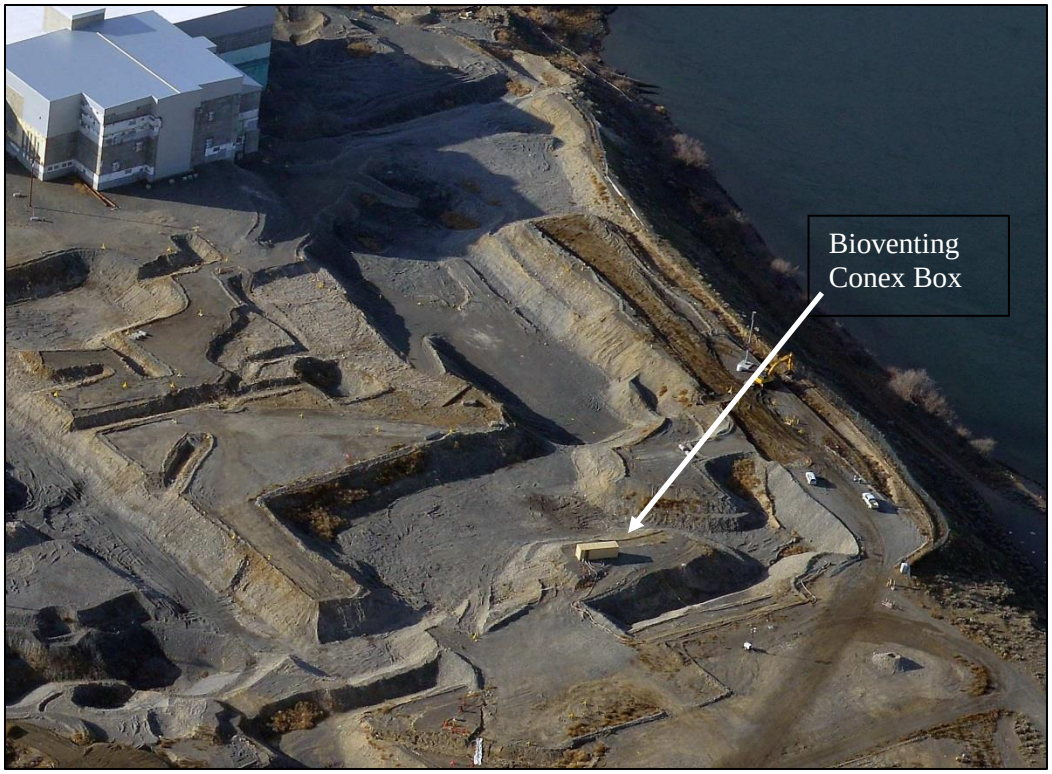


Figure 1-3. Aerial View of the UPR-100-N-17 Bioventing System Location (January 2014)

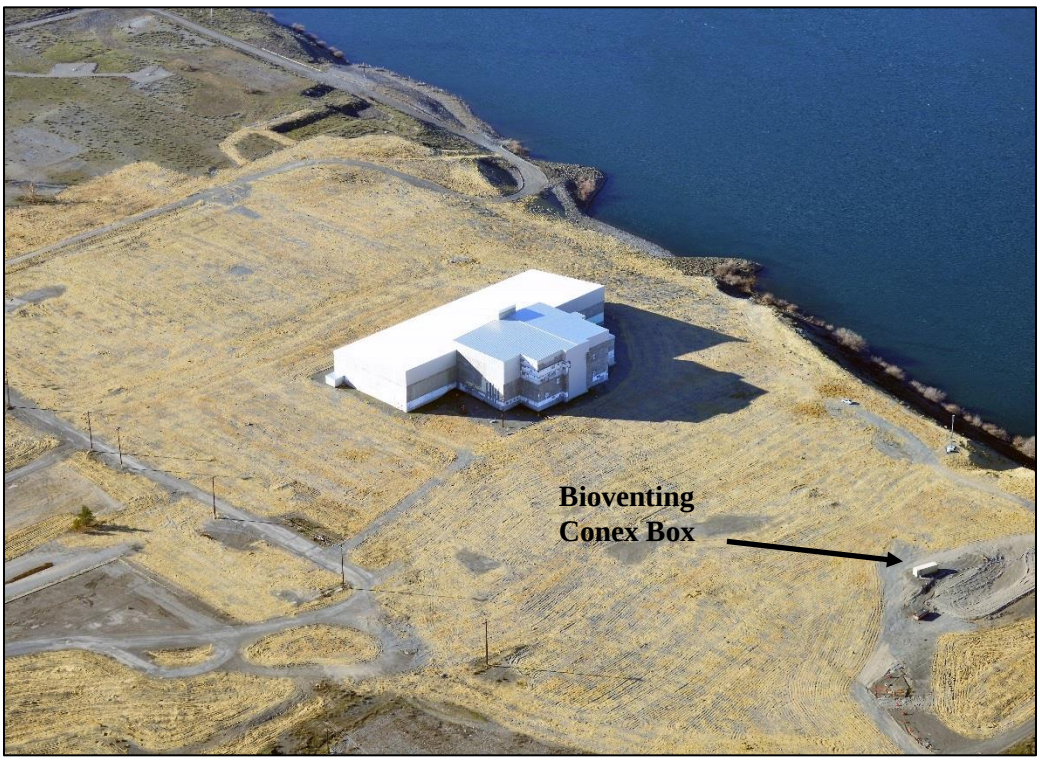


Figure 1-4. Aerial View of the 100-N Area after Backfill and Revegetation (December 2014)

2 Bioventing System Description

The bioremediation system at the UPR-100-N-17 waste site consists of a blower system housed within a conex container that can operate 24 h/d continuously. The airflow induced by the blower system enhances the biodegradation of the petroleum-contaminated soils. Details on the design criteria and equipment selection are provided in WCH-576.

Three Rotron®[5] model DR808AY72MX blowers supply air to the two injection wells. Each blower is a 7.5 horsepower, 208-230/480 volt, alternating-current regenerative blower. Each blower is connected to a header pipeline that connects to a main airline, leading to each of the treatment wells, 199-N-167 and 199-N-172. The injection wells are constructed of 4 in. Schedule 40 polyvinyl chloride (PVC) and are screened from approximately 16.8 to 22.9 m (55 to 75 ft). Photographs of the bioventing system are provided in Figures 2-1 and 2-2.

Other system components include the following:

- Pressure, vacuum, and temperature gauges
- In-line air filters
- A remote telemetry and alarm messaging system
- A 480-V control panel

Figure 2-1. Bioventing System Conex Box

[5] Rotron is a registered trademark of Ametek, Inc.

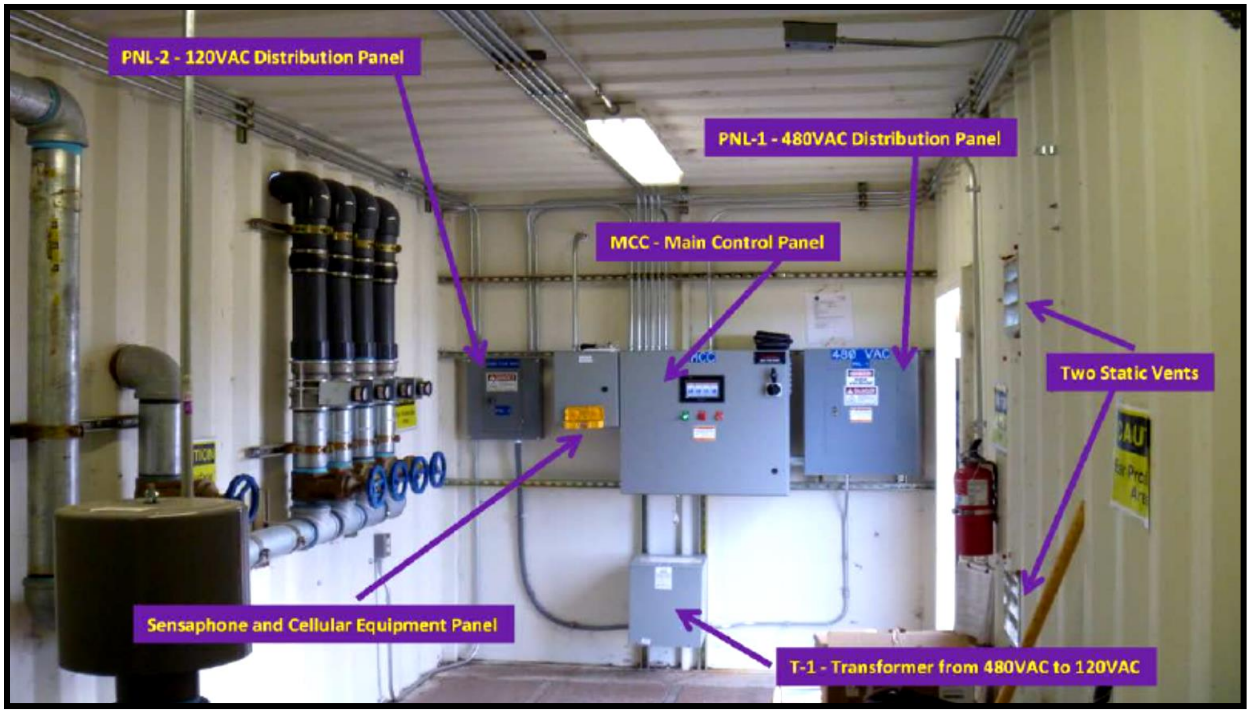


Figure 2-2. Interior of Bioventing System Conex Box

2.1 Bioremediation Wells

Seven bioventing wells were drilled and constructed in 2009. Five of the wells were drilled to a depth of approximately 25 m (82 ft) below surface grade and completed as deep vadose zone wells, with well screens from approximately 16.8 to 22.9 m (55 to 75 ft). Two of the wells were drilled to 10.1 m (33 ft) depth and completed as shallow wells, with well screens from 3 to 10 m (10 to 33 ft) (WCH-370). Table 2-1 provides a summary of the Phase I bioremediation well construction details. Figure 2-3 shows the locations of the bioventing wells and groundwater monitoring wells.

The Phase II bioventing system uses wells 199-N-167 and 199-N-172 as air injection wells. Two of the bioremediation wells (199-N-169 and 199-N-171) are used for soil gas monitoring.

Table 2-1. Bioventing Well Information

Well Name	Depth (ft bgs)	Top of Screen (ft bgs)	Bottom of Screen (ft bgs)	Depth to Groundwater (ft bgs)
199-N-166 (SIW-1)	33.0	10	30	N/A
199-N-167 (DIW-1)[a]	83.0	53	78	73[d]
199-N-168 (SMP-1)	33.0	10	30	N/A
199-N-169 (DMP-1)[b]	83.0	53	78	73.3[d]
199-N-170 (DMP-2)[c]	83.0	54	79	70.2[e]
199-N-171 (DMP-3)[b]	82.4	55	80	74[d]
199-N-172 (DMP-4)[a]	82.0	57	77	72.8[d]

a. This well is an injection well for bioventing.

b. This well is a monitoring well for bioventing.

c. This well was decommissioned to support shallow zone remediation work.

d. Measured on February 17, 2016.

e. Measured on May 20, 2011.

bgs = below ground surface
N/A = not applicable
DIW = deep injection well
SIW = shallow injection well
DMP = deep monitoring well
SMP = shallow monitoring well

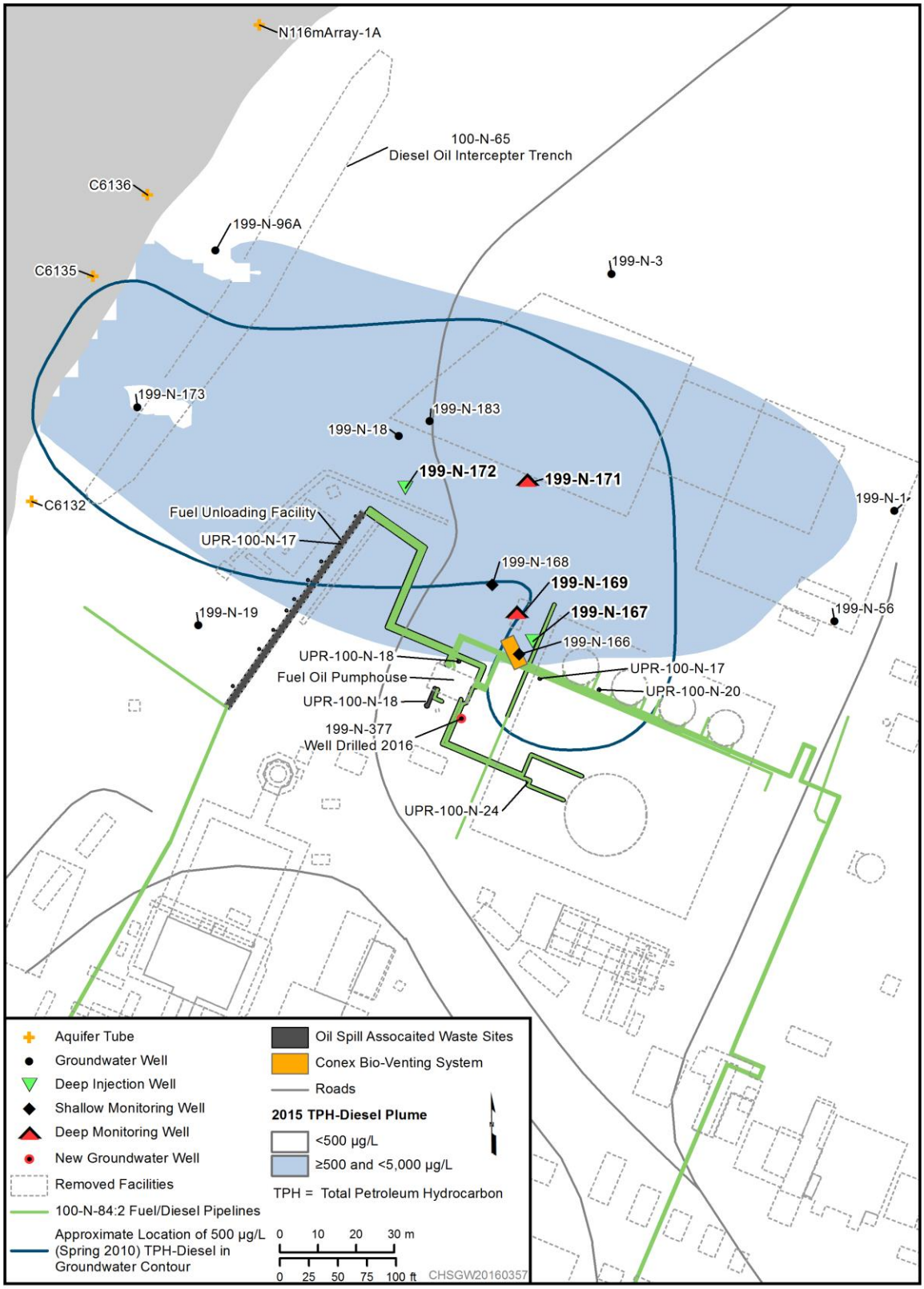


Figure 2-3. Locations of the Bioventing System Wells and Aquifer Tubes

3 Bioventing System Operation and Performance

This chapter describes the startup and operations of the bioventing system and the monthly soil gas measurements, as well as two respirometry tests that were conducted (one test from June 22 through August 3, 2015, and the second test from January 11 through February 22, 2016).

3.1 System Downtime

The operating times of the bioventing system from March 1, 2015, through February 29, 2016, are presented in Table 3-1. The system ran for a total of 6,738 hours. From March through June 2015, the system ran continuously with no shutdowns occurring. The system was offline for 1,010 hours for the June 2015 respirometry test and for 1,013 hours for the January 2016 respirometry test. Downtime for system maintenance is described in Section 3.2. The system was also offline on December 3, 2015, for 1 hour and December 28, 2015, for 1 hour for preventive maintenance.

Table 3-1. UPR-100-N-17 Bioventing System Operating Times (March 2015 – February 2016)

Date On	Time On	Date Off	Time Off	Blower Operational Hours Between Time On and Time Off*	Total Blower Operational Hours	Comments
03/01/15	—	06/22/15	1000	2,722	2,722	System shut down on 06/22/15 to perform June 2015 respirometry test.
System shut off from June 22 through August 3, 2015 (1,010 hours) to support June 2015 respirometry test.						
08/03/15	1200	12/03/15	1300	2,917	5,639	
System shut off on December 3, 2015, for 1 hour for preventive maintenance.						
12/03/15	1400	12/28/15	1000	596	6,235	
System shut off on December 28, 2015, for 1 hour for preventive maintenance.						
12/28/16	1100	01/11/16	1000	335	6,570	System shut down on 01/11/16 to perform February 2016 respirometry test.
System shut off on January 11 through February 22, 2016 (1,013 hours) to support respirometry test.						
02/22/16	1500	02/29/16	1500	168	6,738	Continuously running since 02/29/16.
				Total hours	**6,738**	03/01/2015 through 02/29/16.

* Time estimated to nearest hour.

3.2 System Maintenance

In December 2015, the hoses to the pressure gauges on injection wells 199-N-167 and 199-N-169 were found to be cracked, and the hoses were replaced.

The system was offline on December 3, 2015, for 1 hour and December 28, 2015, for 1 hour for preventive maintenance. Routine maintenance and inspections were conducted according to the recommended schedule for maintenance activities described in WCH-576.

3.3 Monthly Injection Well Measurements

Table 3-2 provides a summary of the monthly airflow rates and pressure readings for the two injection wells, 199-N-167 and 199-N-172.

Table 3-2. Monthly Air Injection Well Measurements

Date	Time	Pressure Gauge Reading (in. H_2O)	Air Flow Rate at Manifold Valve (ft^3/min)
Injection Well 199-N-167			
03/25/15	0801	20	200
04/29/15	0815	20	200
05/26/15	0818	20	220
System shut off from June 22 through August 3, 2015, (1,757 hours) to support June 2015 respirometry test.			
08/27/15	0814	25	280
09/30/15	0829	23	240
10/29/15	0852	23	250
11/30/15	1353	22	250
12/22/2015	0829	005 (gauge broken)	250
System shut off on January 11 through February 22, 2016, (1,013 hours) to support respirometry test.			
02/29/16	0827	45 (gauge sticks)	250
Injection Well 199-N-172			
03/25/15	0802	43	240
04/29/15	0820	14	240
05/26/15	0839	45	250
System shut off from June 22 through August 3, 2015, (1,757 hours) to support June 2015 respirometry test.			
08/27/15	0814	48	250
09/30/15	0859	47	245
10/29/15	0914	46	255
11/30/15	1415	20	250
12/22/15	0829	008 (gauge broken)	250
System shut off on January 11 through February 22, 2016, (1,013 hours) to support respirometry test.			
02/29/16	0826	23 (gauge housing broken)	250

3.4 Monthly Soil Gas Measurements

Two monitoring wells, 199-N-169 and 199-N-171, were installed as deep vadose bioremediation monitoring wells. The monitoring wells were installed to measure vapor concentrations of oxygen, carbon dioxide, methane, total organic hydrocarbons, and injection pressure in the vadose zone. The monitoring wells are fitted with a connection for a vacuum sampling pump. These wells are constructed of 2 in. diameter PVC with slotted screen, from 16.3 to 23.9 m (53.5 to 78.4 ft) below surface grade for well 199-N-169 and 16.7 to 24.3 m (54.8 to 79.7 ft) below surface grade for well 199-N-171. Clean silica sand was used to fill the annular space around the screen. Above the screen, hydrated bentonite, followed by a grout seal, was placed to isolate the screens from the surface.

The monitoring wells are sampled monthly, with the results reported in the monthly unit managers' meeting minutes. Table 3-3 provides a summary of the monthly measurements for soil gas collected for the monitoring wells. Figure 3-1 displays a graph of the oxygen and carbon dioxide measurement data. Monthly measurements do not indicate significant biodegradation activity at well 199-N-169 where CO_2 concentrations have remained near atmospheric concentrations of about 400 ppm. However, the biodegradation rates calculated for well 199-N-169 based on the respirometry testing presented in Section 3.5 show a biodegradation rate similar to that observed at well 199-N-171. This suggests that pulsing the air injection rather than continuous air injection may improve monitoring of biodegration performance. Respirometry testing indicates 1 week on and three weeks off for injection would maintain sufficient oxygen levels in the subsurface and provide for improvements in performance monitoring. Pulse mode operation of the bioventing system would also reduce costs in terms of power consumption.

No monthly measurements were taken during the time that the bioventing system was shut off for respirometry testing.

Table 3-3. Monthly Vapor Monitoring Data

Date	Time	Barometric Pressure (in. Hg)	Temperature (°F)	O_2 %	CO_2 (ppm)	VOC (ppmv)	Methane (% LEL)	Pressure (in. H_2O)*
Monitoring Well 199-N-169								
03/25/15	0813	29.80	44	20.9	15.6	0.2	0	53.8
04/29/15	0851	29.63	52	20.9	410	0.5	0	55.9
05/26/15	0833	29.44	62.6	20.9	460	0	0	54.2
08/27/15	0910	29.49	65.1	21.4	330	0	0	54.9
09/30/15	0852	29.45	46	20.9	530	0.2	0	56.0
10/29/15	0909	29.52	47	20.9	360	0	0	57.6
11/30/15	1409	29.84	25	20.9	460	0	0	57.8
12/22/15	0849	29.02	25	20.9	490	0.3	0	55.4
02/29/16	0842	29.73	37	20.9	520	0.8	0	54.3
Monitoring Well 199-N-171								
03/25/15	0828	29.80	44	19.8	20,000	48.3	0	57.3

Table 3-3. Monthly Vapor Monitoring Data

Date	Time	Barometric Pressure (in. Hg)	Temperature (°F)	O_2 %	CO_2 (ppm)	VOC (ppmv)	Methane (% LEL)	Pressure (in. H_2O)*
04/29/15	0908	29.63	52	19.8	9650	46.2	0	58.3
05/26/15	0852	29.44	62.8	19.8	8260	50.7	0	57.4
08/27/15	0925	29.49	65.1	19.9	9620	17.4	0	58.4
09/30/15	0913	29.45	46	19.3	8070	19.8	0	59.5
10/29/15	0928	29.52	47	19.4	9770	46	0	60.9
11/30/15	1425	29.84	25	19.8	7200	19.9	0	60.7
12/22/15	0911	29.02	25	20	7510	11.8	0	57.9
02/29/16	0859	29.73	37	18.4	24000	34.5	0	57.3

* Pressure measurement recorded from blower pressure gauge

LEL = lower explosive limit

ppm = parts per million

ppmv = parts per million vapor

VOC = volatile organic compound

3.5 Respirometry Tests

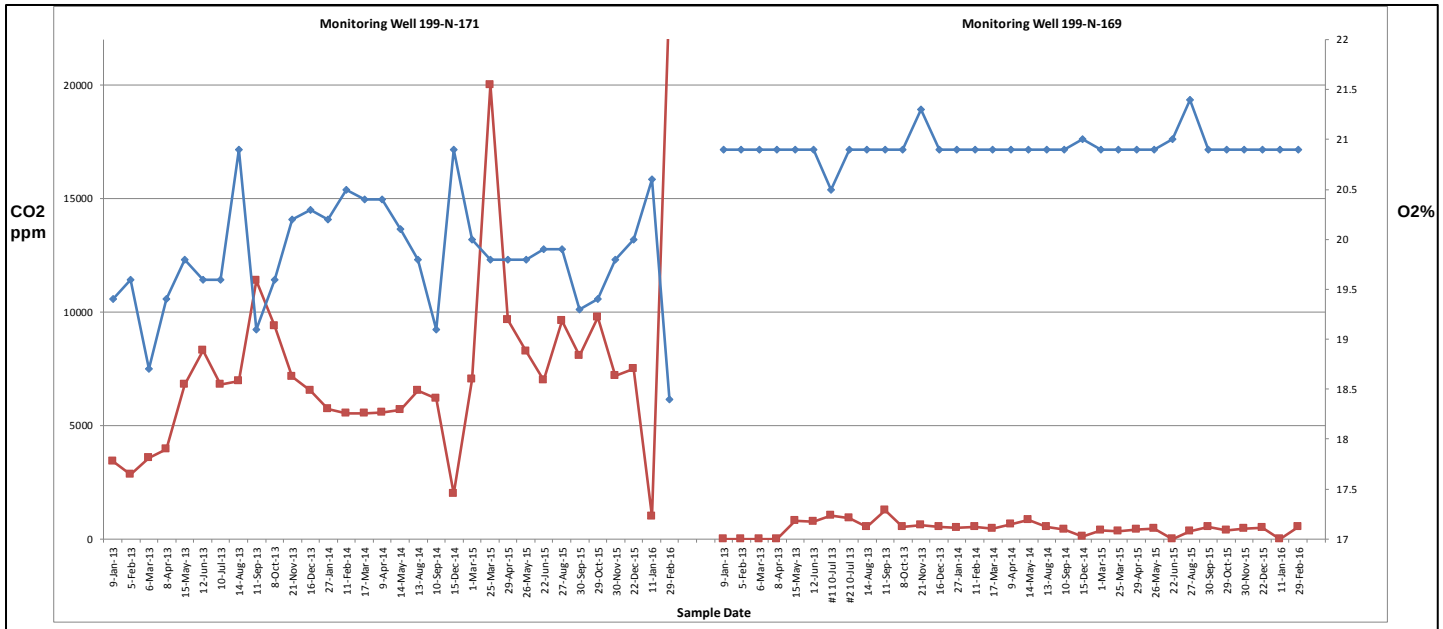
Two in situ respirometry tests were performed to measure microbial respiration rates and estimate biodegradation rates. The tests were performed from June 22 through August 3, 2015, and from January 11 through February 22, 2016, with each test initiated after the system was shut off. Field measurements of oxygen, carbon dioxide, total vapor hydrocarbons, and methane were collected from the six wells in the monitoring program:

- 199-N-167 (bioventing air injection well)
- 199-N-169 (bioventing monitoring well)
- 199-N-171 (bioventing monitoring well)
- 199-N-172 (bioventing air injection well)
- 199-N-183 (groundwater monitoring well)
- 199-N-18 (groundwater monitoring well)

The July 2015 and February 2016 respirometry tests results, including field measurements, are provided in Appendix A and Appendix B, respectively. The respirometry measurements were used to calculate biodegradation rates for each well. Table 3-4 presents a comparison of the biodegradation rates for the respirometry tests conducted in 2010 (pilot test), 2012, 2014, 2015, and 2016.

Calculations using the respirometry data indicate that approximately 594 mg/kg of petroleum have been removed from impacted soils since full-scale operation of the bioventing system in November 2012. The biodegradation rates in Table 3-4 exhibit a declining trend from the initial rates measured in 2010. This rate of decline may indicate reduction in the bio-available hydrocarbon food source in the treatment

zone to levels that no longer support significant biological activity. Changes in subsurface conditions, such as temperature, moisture, and/or nutrient availability, may also have affected the rates shown, although only minor fluctuations are expected in temperature and moisture at depth.



BIOVENTING WELL SAMPLE RESULTS

Well #	Date	O2%	CO2 ppm
199-N-171	9-Jan-13	19.4	3400
	5-Feb-13	19.6	2840
	6-Mar-13	18.7	3570
	8-Apr-13	19.4	3960
	15-May-13	19.8	6820
	12-Jun-13	19.6	8290
	10-Jul-13	19.6	6800
	14-Aug-13	20.9	6940
	11-Sep-13	19.1	11400
	8-Oct-13	19.6	9380
	21-Nov-13	20.2	7160
	16-Dec-13	20.3	6520
	27-Jan-14	20.2	5720
	11-Feb-14	20.5	5520
	17-Mar-14	20.4	5520
	9-Apr-14	20.4	5560
	14-May-14	20.1	5670
	13-Aug-14	19.8	6520
	10-Sep-14	19.1	6180
	15-Dec-14	20.9	2000
	1-Mar-15	20	7020
	25-Mar-15	19.8	20000
	29-Apr-15	19.8	9650
	26-May-15	19.8	8260
	22-Jun-15	19.9	7000
	27-Aug-15	19.9	9620
	30-Sep-15	19.3	8070
	29-Oct-15	19.4	9770
	30-Nov-15	19.8	7200
	22-Dec-15	20	7510
	11-Jan-16	20.6	1000
	29-Feb-16	18.4	24000

Well #	Date	O2%	CO2 ppm
199-N-169	9-Jan-13	20.9	0
	5-Feb-13	20.9	0
	6-Mar-13	20.9	0
	8-Apr-13	20.9	0
	15-May-13	20.9	800
	12-Jun-13	20.9	780
	#1 10-Jul 13	20.5	1020
	#2 10-Jul 13	20.9	920
	14-Aug-13	20.9	530
	11-Sep-13	20.9	1250
	8-Oct-13	20.9	550
	21-Nov-13	21.3	600
	16-Dec-13	20.9	530
	27-Jan-14	20.9	500
	11-Feb-14	20.9	550
	17-Mar-14	20.9	470
	9-Apr-14	20.9	660
	14-May-14	20.9	840
	13-Aug-14	20.9	520
	10-Sep-14	20.9	410
	15-Dec-14	21	100
	1-Mar-15	20.9	360
	25-Mar-15	20.9	325
	29-Apr-15	20.9	410
	26-May-15	20.9	460
	22-Jun-15	21	0
	27-Aug-15	21.4	330
	30-Sep-15	20.9	530
	29-Oct-15	20.9	360
	30-Nov-15	20.9	460
	22-Dec-15	20.9	490
	11-Jan-16	20.9	0
	29-Feb-16	20.9	520

Figure 3-1. Chart of Monthly Soil Vapor Monitoring Results

Table 3-4. Comparison of Biodegradation Rates Calculated from In Situ Respiration Testing

Monitoring Well	Biodegradation Rate (mg/kg-day)						
	January 2016	August 2015	January 2015	July 2014	January 2014	December 2012	March 2010
199-N-167	-0.07	-0.05	-0.05	-0.06	-0.01	-0.15	-0.99
199-N-169	-0.12	-0.12	-0.23	-0.09	-0.07	-0.28	-0.97
199-N-171	-0.19	-0.14	-0.23	-0.09	-0.05	-9.82	-0.37
199-N-172	-0.04	-0.04	-0.05	-0.02	-0.01	-0.14	-0.54
199-N-183	NA	N/A	N/A	N/A	-0.09	Not tested	Not tested
199-N-18	NA	N/A	N/A	N/A	N/A	Not tested	Not tested

N/A = not applicable; oxygen depletion insignificant and biodegradation not calculated

3.6 Bioventing System Costs

This section summarizes the costs for the UPR-100-N-17 bioventing system for March 2015 through February 2016. The primary categories of expenditures are as follows:

- **Project support:** Includes project management, reporting, and consultation, as required, during the course of operating the system.
- **Operations and maintenance:** Includes facility supplies, labor, and supervision costs associated with operating the system. It also includes the costs associated with routine field and engineering support as required during the course of the system operation and periodic maintenance.
- **Performance monitoring:** Includes system and groundwater sampling and sample analysis, as required, in accordance with the performance monitoring plan (DOE/RL-2005-93, Appendix H). It also includes respirometry testing, microbial laboratory studies, and monthly monitoring of well gases.

Figure 3-2 shows the relative costs for the bioventing system for calendar year 2015 through February 2016.

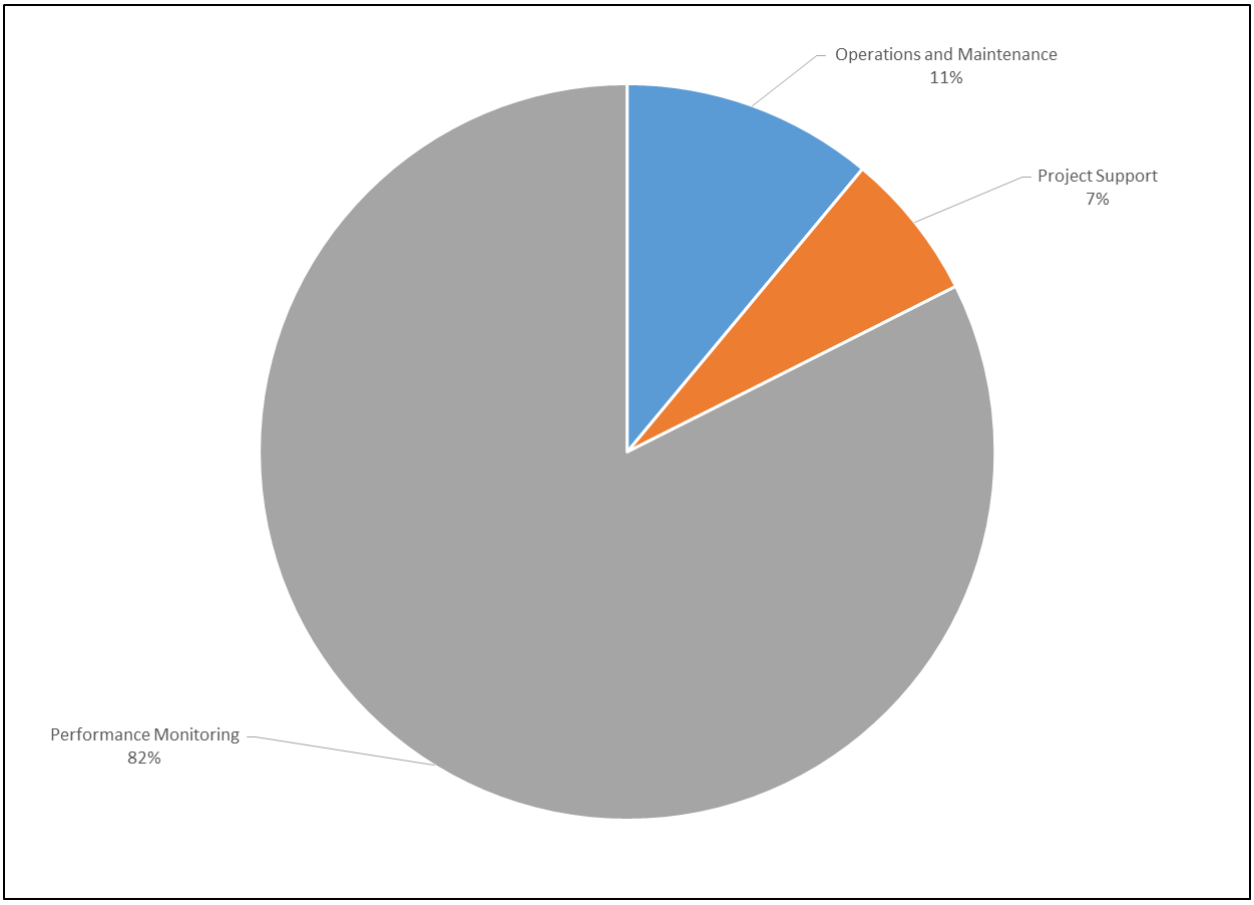


Figure 3-2. Bioventing System Cost ($274,200) Breakdown (by Percentage)

4 Groundwater Monitoring

Groundwater monitoring well sampling was performed as specified in Appendix H of DOE/RL-2005-93. The monitoring well network includes one upgradient well (100-N-56), two bioventing wells (199-N-169 and 199-N-171), five groundwater monitoring wells (199-N-19, 199-N-183, 199-N-173, 199-N-96A, and 199-N-3), and two aquifer tubes (N116-mArray-OA and C6132). Aquifer tube C6135 was not sampled because it required repairs that had not been made at the time of sample collection. The monitoring well locations are shown in Figure 2-3. The sample schedule and analytical parameters for each well and aquifer tube are provided in Table 4-1.

4.1 Groundwater Sampling

Groundwater sampling was planned for the fall and spring to account for seasonal low and high groundwater table elevations. However, seasonal changes in groundwater elevation were minimal over the recording period. The largest change (0.78 m [2.56 ft]) during the two sampling events was observed in well 199-N-96A. Less than 0.18 m (0.6 ft) of change was observed in most wells during the two sampling events. The results of the July 2015 and February 2016 groundwater sampling are provided in Tables 4-2 through 4-9. Dissolved oxygen concentrations are shown in Figure 4-1 and 4-2. Table 4-10 provides a summary of groundwater elevations for each well as measured at the time of sampling.

4.1.1 Geochemical Indicators

Geochemical variations in the groundwater sample results provide evidence of the types of biodegradation processes that are occurring in the saturated zone. In general, geochemical species serve as electron acceptors, and they are reduced during the microbial degradation (i.e., oxidation) of petroleum hydrocarbons.

During microbial degradation of petroleum, the dissolved oxygen concentrations steadily decrease until anaerobic conditions prevail. Once anaerobic conditions exist and multiple electron acceptors (i.e., oxidizers) are available, microorganisms preferentially use the electron acceptor that is thermodynamically most favorable. The general order of preference for anaerobic hydrocarbons biodegradation is as follows:

- Denitrification (reduction of nitrate), with the eventual production of molecular nitrogen
- Reduction of manganese from Mn^{4+} to Mn^{2+}
- Reduction of ferric iron (Fe^{3+}) to ferrous iron (Fe^{2+})
- Sulfate reduction, with eventual production of sulfide
- Reduction of carbon dioxide and generation of methane

These microbial processes generally segregate into distinct zones dominated by oxygen, nitrate, ferric iron, sulfate, and carbon dioxide reduction. Furthermore, given the different electron acceptors consumed and final products produced, it is theoretically possible to differentiate the “zones” of microbial processes across the smear zone.

In general, if dissolved oxygen is present in groundwater above 0.5 mg/L, then aerobic biodegradation of petroleum hydrocarbons is the dominant process. If dissolved oxygen concentrations are less than 5 mg/L but nitrate concentrations exceed 1.0 mg/L, then denitrification dominates. Because nitrite is an unstable intermediate product of denitrification, the presence of measurable nitrite concentrations is indicative of nitrate reduction. If groundwater is deprived of dissolved oxygen, nitrate, and nitrite, but concentrations of ferrous iron are greater than 0.5 mg/L, then iron reduction will be the dominant

biodegradation process. If groundwater is depleted in ferrous iron but contains concentrations of sulfate above 1.0 mg/L and hydrogen sulfide above 0.05 mg/L, then sulfate reduction will be the dominant process. Finally, if the groundwater is depleted in all the electron acceptors and byproducts, with the exception of methane greater than 0.2 mg/L, then methanogenesis is the predominant process degrading petroleum hydrocarbons. When applied at a field scale, this differentiation of microbial zones commonly encounters uncertainties, as many of the byproducts of microbial metabolism (e.g., ferric iron, hydrogen sulfide, and methane) are readily transported downgradient.

The spatial distribution of electron acceptors measured during the July 2015 and February 2016 sampling events are shown in Figures 4-1 and 4-2, respectively. Tables 4-2 through 4-9 present the groundwater sample results. Nitrate concentrations are generally higher upgradient of the petroleum plume compared to concentrations within the plume indicating denitrification is likely occurring within the bioremediation area.

The concentration of oxidation byproducts (iron and manganese) was higher within the plume compared to upgradient and downgradient conditions. This increased concentration of these dissolved-phase products indicates iron and manganese reduction of dissolved-phase petroleum hydrocarbons.

4.1.2 Groundwater Concentrations

Tables 4-2 through 4-9 present the groundwater sample results for July 2015 and February 2016. Monitoring well 199-N-171 continues to exhibit the highest concentrations of petroleum, consisting of approximately 70 to 80 percent diesel-range (C10-C20) petroleum and 20 to 30 percent motor-oil-range (C20-C36) petroleum. An increasing trend for total petroleum hydrocarbon (TPH)-diesel concentrations is observed in well 199-N-171 since 2010. Diesel-range petroleum is also relatively higher than motor-oil-range petroleum in samples collected from wells 199-N-172 and 199-N-183. These wells are all located in the center of the petroleum plume. Diesel-range concentrations are generally similar, or lower than, motor-oil-range concentrations at the boundaries of the petroleum plume.

The February 2016 groundwater sample at well 199-N-19 was greater than 500 µg/L (drinking water standard) at 2,780 µg/L. This is a suspect sample result since the value is out of trend by an order of magnitude higher than historic trends at this well and not supported by the extractable petroleum hydrocarbon analysis performed on the sample. Extractable petroleum hydrocarbon results were all non-detect or had laboratory qualifiers on the results. (Note: subsequent to the performance period covered by this report, TPH results for samples colleted at this well in July 2016 was below the 500 µg/L drinking water standard at104 µg/L).

During the February 2016 sampling event, an oily sheen was observed in groundwater sampled from well 199-N-171. Yellow to charcoal color groundwater samples and diesel odors were also observed in wells 199-N-171 and 199-N-172 during each sampling event. Figures 4-3 and 4-4 depict the petroleum contamination plume distribution in groundwater for the 100-NR-2 OU for high and low groundwater periods in 2015, respectively.

TPH-motor oil was detected at a maximum concentration of 2,040 µg/L in July 2015 and 1,990 µg/L in February 2016. The higher TPH-motor oil concentrations were detected associated with higher TPH-diesel in groundwater monitoring wells 199-N-171, 199-N-172, and 199-N-173. The concentration of TPH-motor oil in these wells ranged from 767 µg/L to 2,040 µg/L over the reporting period while 1,900 µg/L of TPH-motor oil was detected in aquifer tube N116mArray-0A in July 2015 at the river’s edge. This concentration in N116mArray-0A decreased to 96.5 µg/L in 2016.

TPH-gasoline concentrations typically do not exceed 100 µg/L in the OU. The maximum concentration detected during the reporting period was 38 µg/L in aquifer tube N116mArray-0A.

Detectable concentrations of oil and grease were present in 7 of the 12 locations sampled during the July 2015 event. Concentrations ranged from 1,320 to 4,580 µg/L. Oil and grease were only detected in well 199-N-171 during the February 2016 sampling event. The concentration detected was 3,210 µg/L.

Table 4-1. Bioventing Sample Schedule and Analytical Parameters

Analytical Parameters[a]		Bioventing Air Injection Wells		Bioventing Monitoring Wells							Aquifer Tubes			Upgradient Well
		199-N-167	199-N-172	199-N-169	199-N-171	199-N-3	199-N-183	199-N-96A	199-N-173	199-N-19	116m Array-0A	C6132	C6135	199-N-56
Laboratory Methods	TPH-diesel range	X	X	X	X	X	X	X	X	X	X	X	X	X
	TPH-gasoline range	X	X	X	X	X	X	X	X	X	X	X	X	X
	Oil and grease	X	X	X	X	X	X	X	X	X	X	X	X	X
	Anions	X	X	X	X	X	X	X	X	X	X	X	X	X
	ICP metals	X	X	X	X	X	X	X	X	X	X	X	X	X
	Alkalinity	X	X	X	X	X	X	X	X	X	X	X	X	X
	PAH	X	X	X	X	X	X	X	X	X	X	X	X	X
Field Methods	Dissolved oxygen	X	X	X	X	X	X	X	X	X	X	X	X	X
	Oxidation-reduction potential	X	X	X	X	X	X	X	X	X	X	X	X	X
	pH	X	X	X	X	X	X	X	X	X	X	X	X	X
	Conductivity	X	X	X	X	X	X	X	X	X	X	X	X	X
	Temperature	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sheen/odor[b]	X	X	X	X	X	X	X	X	X	X	X	X	X

Note: Sample collection will be semiannually occurring at low river stage and after high river stage.

a. All analyses will be performed on nonfiltered groundwater samples.

b. Prior to purging well for sample collection, a transparent bailer will be used to collect a grab sample to evaluate the presence of sheen.

ICP = inductively coupled plasma
PAH = polycyclic aromatic hydrocarbon
TPH = total petroleum hydrocarbon

Table 4-2. Groundwater Sample Results for Petroleum Hydrocarbons (July 2015)

Well Name	Sample Number	Date	Oil and Grease			TPH Gasoline			TPH -Diesel			TPH-Motor Oil		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-3	B321L4	07/28/15	1,310	U	1,310	16.7	U	16.7	47.6	TU	47.6	130	BJT	47.6
199-N-19	B321M6	07/31/15	1,310	U	1,310	16.7	U	16.7	143	JT	50	295		50
199-N-56	B321M9	07/28/15	1,310	U	1,310	16.7	U	16.7	233	T	47.6	205	BT	47.6
199-N-96A	B321M0	07/29/15	3,740	B	1,310	16.7	U	16.7	161	JT	48.1	347	BT	48.1
199-N-167	B321K2	07/29/15	1,600	B	1,320	16.7	U	16.7	927	T	47.6	645	BT	47.6
199-N-169	B321K8	07/29/15	1,700	B	1,320	16.7	U	16.7	545	T	47.6	425	BT	47.6
199-N-171	B321L1	07/29/15	2,710	B	1,310	30.8	J	16.7	4,360	DT	95.2	1,340	BDT	95.2
199-N-172	B321K5	07/29/15	3,580	B	1,320	16.7	U	16.7	4,130		47.2	2,040		47.2
199-N-173	B321M3	07/28/15	1,320	B	1,320	16.7	U	16.7	1,280	T	47.6	1,230	BT	47.6
199-N-183	B321L7	07/28/15	4,580	B	1,310	16.7	U	16.7	2,180	T	47.6	577	BT	47.6
C6132	B319J3	07/09/15	-	-	-	16.7	U	16.7	76.5	J	48.1	234		48.1
C6132	B321N5	07/29/15	1,390	U	1,390	16.7	U	16.7	82.6	J	50	183	J	50
N116mArray-0A	B319M4	06/24/15	-	-	-	38	J	10	17	UN	17	1,900		23

Note: Blank cell means no laboratory qualifier.

- \- = not applicable
- B = blank contamination
- D = analyte reported at a secondary dilution factor
- J = estimated value
- N = presumptive evidence of compound based on mass spectral library search
- PQL = practical quantitation limit
- Q = laboratory qualifier
- T = spike and or spike duplicate is outside control limits
- TPH = total petroleum hydrocarbon
- U = undetected

Table 4-3. Groundwater Sample Results for Petroleum Hydrocarbons (February 2016)

Well Name	Sample Number	Date	Oil and Grease			TPH Gasoline			TPH -Diesel			TPH-Motor Oil		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-3	B33LY4	02/17/16	1,310	U	1,310	16.7	U	16.7	47.6	U	47.6	47.6	U	47.6
199-N-19	B33LY1	02/17/16	1,330	U	1,330	18.9	J	16.7	2780		47.6	792		47.6
199-N-56	B33LY7	02/17/16	1,330	U	1,330	25.9	J	16.7	47.6	U	47.6	47.6	U	47.6
199-N-96A	B33M00	02/17/16	1,320	U	1,320	27.3	J	16.7	260		48.1	379		48.1
199-N-167	B33LW3	02/17/16	1,330	U	1,330	20.3	J	16.7	459		48.1	433		48.1
199-N-169	B33LW6	02/17/16	1,320	U	1,320	29.7	J	16.7	373		47.2	318		47.2
199-N-171	B33LW9	02/17/16	3,210	B	1,320	24.7	J	16.7	11,900	D	250	1,990	D	250
199-N-172	B33LX2	02/17/16	1,320	U	1,320	26.7	J	16.7	4,440	D	98	1,580	D	98
199-N-173	B33LX5	02/17/16	1,320	U	1,320	16.7	U	16.7	1,210	D	236	767	DJ	236
199-N-183	B33LX8	02/17/16	1,320	U	1,320	26.8	J	16.7	121	J	47.6	246		47.6
C6132	B33DN9	02/17/16	-	-	-	-	-	-	48.5	U	48.5	-	-	-
C6132	B33DP0	02/17/16	-	-	-	-	-	-	49.5	U	49.5	-	-	-
C6132	B33M03	02/17/16	1,310	U	1,320	23.3	J	16.7	70.1	J	47.2	283		47.7
N116mArray-0A	B33DV0	02/17/16	-	-	-	-	-	-	500		17	-	-	-
N116mArray-0A	B33M06	02/17/16	1,310	U	1,310	23.2	J	16.7	125	J	48.5	96.5	J	48.8

Note: Blank cell means no laboratory qualifier.

- = not applicable
D = analyte reported at a secondary dilution factor
J = estimated value
PQL = practical quantitation limit
Q = laboratory qualifier
TPH = total petroleum hydrocarbon
U = undetected

Table 4-4. Groundwater Sample Results for Anions (July 2015)

Well Name	Sample Number	Date	Alkalinity			Chloride			Fluoride			Nitrite		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-3	B321L4	07/28/15	257,000		725	-	-	-	-	-	-	-	-	-
199-N-3	B321L5	07/28/15	-	-	-	24,400	D	670	71.5	B	33	125	U	125
199-N-19	B321M6	07/31/15	171,000		725	-	-	-	-	-	-	-	-	-
199-N-19	B321M7	07/31/15	-	-	-	75,000	D	200	170	D	50	125	UD	125
199-N-56	B321M9	07/28/15	382,000		725	-	-	-	-	-	-	-	-	-
199-N-56	B321N0	07/28/15	-	-	-	34,600	D	670	57.2	B	33	125	U	125
199-N-96A	B321M0	07/29/15	445,000		1,450	-	-	-	-	-	-	-	-	-
199-N-96A	B321M1	07/29/15	-	-	-	18,900	D	670	33.4	B	33	125	U	125
199-N-167	B321K2	07/29/15	362,000		2,900	-	-	-	-	-	-	-	-	-
199-N-167	B321K3	07/29/15	-	-	-	40,900	D	670	93.1	B	33	164	B	125
199-N-169	B321K8	07/29/15	283,000		2,900	-	-	-	-	-	-	-	-	-
199-N-169	B321K9	07/29/15	-	-	-	46,700	D	670	97.9	B	33	913		125
199-N-171	B321L1	07/29/15	536,000		1,450	-	-	-	-	-	-	-	-	-
199-N-171	B321L2	07/29/15	-	-	-	31,900	D	670	62.6	B	33	125	U	125
199-N-172	B321K5	07/29/15	451,000		1,450	-	-	-	-	-	-	-	-	-
199-N-172	B321K6	07/29/15	-	-	-	68,000	D	670	102	B	33	125	U	125
199-N-173	B321M3	07/28/15	170,000		725	-	-	-	-	-	-	-	-	-
199-N-173	B321M4	07/28/15	-	-	-	57,700	D	670	126	B	33	125	U	125
199-N-183	B321L7	07/29/15	486,000		725	-	-	-	-	-	-	-	-	-
199-N-183	B321L8	07/28/15	-	-	-	32,000	D	670	73.8	B	33	381	B	125

Table 4-4. Groundwater Sample Results for Anions (July 2015)

Well Name	Sample Number	Date	Alkalinity			Chloride			Fluoride			Nitrite		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
C6132	B321N5	07/29/15	145,000		725	-	-	-	-	-	-	-	-	-
C6132	B319J5	07/09/15	-	-	-	71,400	D	200	133	D	50	125	UD	125
C6132	B321N6	07/29/15	-	-	-	40,200	D	670	133	B	33	125	U	125
N116mArray-0A	B31B19	06/24/15	-	-	-	43,600	D	200	107	D	50	125	UD	125

Well Name	Sample Number	Date	Nitrate			Phosphate			Sulfate		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-3	B321L5	07/28/15	93,400	D	1,460	205	U	205	13,7000	D	1,330
199-N-19	B321M7	07/31/15	85,400	D	310	251	UD	251	15,8000	D	625
199-N-56	B321N0	07/28/15	71,700	D	1,460	205	U	205	11,4000	D	1,330
199-N-96A	B321M1	07/29/15	7,880	D	1,460	9,540	D	2,050	37,300	D	1,330
199-N-167	B321K3	07/29/15	19,500	D	1,460	205	U	205	165,000	D	1,330
199-N-169	B321K9	07/29/15	42,000	D	1,460	205	U	205	158,000	D	1,330
199-N-171	B321L2	07/29/15	1,460	DU	1,460	205	U	205	151,000	D	1,330
199-N-172	B321K6	07/29/15	1,600	BD	1,460	205	U	205	279,000	D	3,330
199-N-173	B321M4	07/28/15	7,840	D	1,460	205	U	205	162,000	D	1,330
199-N-183	B321L8	07/28/15	2,340	BD	1,460	205	U	205	100,000	D	1,330

Table 4-4. Groundwater Sample Results for Anions (July 2015)

Well Name	Sample Number	Date	Nitrate			Phosphate			Sulfate		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
C6132	B319J5	07/09/15	69,900	D	310	251	UD	251	150,000	D	625
C6132	B321N6	07/29/15	41,200	D	1,460	205	U	205	88,300	D	1,330
N116mArray-0A	B31B19	06/24/15	124	UD	124	251	UD	251	93,000	D	250

Note: Blank cell means no laboratory qualifier.

- = not applicable
B = blank contamination
D = analyte reported at a secondary dilution factor
J = estimated value
PQL = practical quantitation limit
Q = laboratory qualifier
TPH = total petroleum hydrocarbon
U = undetected

Table 4-5. Groundwater Sample Results for Anions (February 2016)

Well Name	Sample Number	Date	Alkalinity			Chloride			Fluoride			Nitrite		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-3	B33LY4	02/17/16	238,000	-	725	-	-	-	-	-	-	-	-	-
199-N-3	B33LY5	02/17/16	-	-	-	27,000	D	200	72	BD	50	125	U	125
199-N-19	B33LY1	02/17/16	18,400	-	725	-	-	-	-	-	-	-	-	-
199-N-19	B33LY2	02/17/16	-	-	-	70,000	D	200	170	D	50	125	U	125
199-N-56	B33LY7	02/17/16	258,000		725	-	-	-	-	-	-	-	-	-
199-N-56	B33LY8	02/17/16	-	-	-	46,000	D	200	74	BD	50	125	U	125
199-N-96A	B33M00	02/17/16	307,000	-	725	-	-	-	-	-	-	-	-	-
199-N-96A	B33M01	02/17/16	-	-	-	37,000	D	200	60	BD	50	125	U	125
199-N-167	B33LW3	02/17/16	252,000	-	725	-	-	-	-	-	-	-	-	-
199-N-167	B33LW4	02/17/16	-	-	-	53,000	D	200	110	D	50	128	BD	125
199-N-169	B33LW6	02/17/16	247,000	-	725	-	-	-	-	-	-	-	-	-
199-N-169	B33LW7	02/17/16	-	-	-	50,000	D	200	100	D	50	657	D	125
199-N-171	B33LW9	02/17/16	488,000	-	725	-	-	-	-	-	-	-	-	-
199-N-171	B33LX0	02/17/16	-	-	-	36,000	D	200	97	BD	50	125	U	125
199-N-172	B33LX2	02/17/16	426,000	-	725	-	-	-	-	-	-	-	-	-
199-N-172	B33LX3	02/17/16	-	-	-	75,000	D	200	200	D	50	125	U	125
199-N-173	B33LX5	02/17/16	327,000	-	725	-	-	-	-	-	-	-	-	-
199-N-173	B33LX6	02/17/16	-	-	-	64,000	D	200	140	D	50	125	U	125
199-N-183	B33LX8	02/17/16	452,000	-	725	-	-	-	-	-	-	-	-	-
199-N-183	B33LX9	02/17/16	-	-	-	38,000	D	200	98	BD	50	125	U	125

Table 4-5. Groundwater Sample Results for Anions (February 2016)

Well Name	Sample Number	Date	Alkalinity			Chloride			Fluoride			Nitrite		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
C6132	B33M03	02/17/16	169,000	-	725	-	-	-	-	-	-	-	-	-
C6132	B33M04	02/17/16	-	-	-	76,000	D	200	110	D	50	125	U	125
N116mArray-0A	B32M06	02/17/16	53,200	-	725	-	-	-	-	-	-	-	-	-
N116mArray-0A	B33JP7	02/17/16	-	-	-	860	D	200	120	D	50	125	U	125
N116mArray-0A	B33M07	02/17/16	-	-	-	1,400	J	200	130	D	50	125	U	125

Well Name	Sample Number	Date	Nitrate			Phosphate			Sulfate		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-3	B33LY5	02/17/16	88,500	D	3,100	251	UN	251	120,000	D	6,300
199-N-19	B33LY2	02/17/16	66,400	D	620	251	UN	251	150,000	D	1,300
199-N-56	B33LY8	02/17/16	75,300	D	3,100	251	DN	251	110,000	D	6,300
199-N-96A	B33M01	02/17/16	11,500	D	124	3,680	UN	251	73,000	D	250
199-N-167	B33LW4	02/17/16	57,500	D	3,100	251	UN	251	170,000	D	6,300
199-N-169	B33LW7	02/17/16	48,700	D	3,100	251	UN	251	160,000	D	6,300
199-N-171	B33LX0	02/17/16	3,540	D	124	251	UN	251	200,000	D	6,300
199-N-172	B33LX3	02/17/16	753	D	124	251	UN	251	300,000	D	6,300
199-N-173	B33LX6	02/17/16	14,200	D	124	251	UN	251	230,000	D	6,300
199-N-183	B33LX9	02/17/16	4,210	D	124	251	UN	251	170,000	D	6,300

Table 4-5. Groundwater Sample Results for Anions (February 2016)

			Nitrate			Phosphate			Sulfate		
Well Name	**Sample Number**	**Date**	**µg/L**	**Q**	**PQL**	**µg/L**	**Q**	**PQL**	**µg/L**	**Q**	**PQL**
C6132	B33M04	02/17/16	62,000	D	3,100	251	UN	251	130,000	D	6,300
N116mArray-0A	B33JP7	02/17/16	124	U	124	-	-	-	17,000	D	250
N116mArray-0A	B33M07	02/17/16	841	D	124	251	UN	251	14,000	D	250

Note: Blank cell means no laboratory qualifier.

- = not applicable
D = analyte reported at a secondary dilution factor
PQL = practical quantitation limit
TPH = total petroleum hydrocarbon
U = undetected

Table 4-6. Groundwater Sample Results for Metals (July 2015)

Well Name	Sample Number	Date	Aluminum			Antimony			Arsenic			Barium		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-3	B321L4	07/28/15	15	U	15	1	U	1	1.7	U	1.7	135		0.6
199-N-19	B321M6	07/31/15	15	U	15	1	U	1	2.26	B	1.7	64.4		0.6
199-N-56	B321M9	07/28/15	15	U	15	1	U	1	1.7	U	1.7	123		0.6
199-N-96A	B321M0	07/29/15	30.4	B	15	1	U	1	4.77	B	1.7	36.8		0.6
199-N-167	B321K2	07/29/15	256		15	1	U	1	2.3	B	1.7	131		0.6
199-N-169	B321K8	07/29/15	170		15	1	U	1	2.69	B	1.7	113		0.6
199-N-171	B321L1	07/29/15	179		15	1	U	1	3.82	B	1.7	191		0.6
199-N-172	B321K5	07/29/15	888		15	1	U	1	4.76	B	1.7	104		0.6
199-N-173	B321M3	07/28/15	15	U	15	1	U	1	1.7	U	1.7	253		0.6
199-N-183	B321L7	07/29/15	15	U	15	1	U	1	3.36	B	1.7	173		0.6
C6132	B319J7	07/09/15	15	U	15	3.5	U	3.5	5	U	5	89.7		1
C6132	B319J3	07/09/15	71.4		15	3.5	U	3.5	5	U	5	86.1		1
C6132	B321N5	07/29/15	123		15	1.2	CB	1	1.83	B	1.7	58.7		0.6
N116mArray-0A	B319M4	06/24/15	17.3	U	17.3	3.7	U	3.7	4.1	BC	1.8	138		2.1
N116mArray-0A	B319M5	06/24/15	18.5	B	17.3	3.7	U	3.7	3.9	BC	1.8	132		2.1
Well Name	**Sample Number**	**Date**	**Beryllium**			**Boron**			**Cadmium**			**Calcium**		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-3	B321L4	07/28/15	0.2	U	0.2	30.9	B	15	0.11	U	0.11	143,000		50
199-N-19	B321M6	07/31/15	0.2	U	0.2	31.8	B	15	0.11	U	0.11	103,000		50

Table 4-6. Groundwater Sample Results for Metals (July 2015)

Well Name	Sample Number	Date	Beryllium			Boron			Cadmium			Calcium		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-56	B321M9	07/28/15	0.2	U	0.2	44.9	B	15	0.11	U	0.11	156,000		50
199-N-96A	B321M0	07/29/15	0.2	U	0.2	15	U	15	0.11	U	0.11	41,500		50
199-N-167	B321K2	07/29/15	0.2	U	0.2	25.6	B	15	0.11	U	0.11	149,000		50
199-N-169	B321K8	07/29/15	0.2	U	0.2	25.4	B	15	0.328	B	0.11	136,000		50
199-N-171	B321L1	07/29/15	0.2	U	0.2	25.1	B	15	0.437	B	0.11	194,000		50
199-N-172	B321K5	07/29/15	0.2	U	0.2	29.2	B	15	0.262	B	0.11	225,000		50
199-N-173	B321M3	07/28/15	0.2	U	0.2	22.2	B	15	0.11	U	0.11	180,000		50
199-N-183	B321L7	07/29/15	0.2	U	0.2	24.5	B	15	0.11	U	0.11	175,000		50
C6132	B319J7	07/09/15	-	-	-	-	-	-	1	U	1	101,000		50
C6132	B319J3	07/09/15	-	-	-				1	U	1	102,000		50
C6132	B321N5	07/29/15	0.2	U	0.2	26.1	B	15	0.11	U	0.11	64,900		50
N116mArray-0A	B319M4	06/24/15	-	-	-	-	-	-	0.34	U	0.34	78,600		54.2
N116mArray-0A	B319M5	06/24/15	-	-	-	-	-	-	0.34	U	0.34	77,100		54.2
Well Name	**Sample Number**	**Date**	**Chromium**			**Cobalt**			**Copper**			**Iron**		
			µg/L	**Q**	**PQL**	**µg/L**	**Q**	**PQL**	**µg/L**	**Q**	**PQL**	**µg/L**	**Q**	**PQL**
199-N-3	B321L4	07/28/15	4.87	B	2	0.1	U	0.1	0.383	B	0.35	30	U	30
199-N-19	B321M6	07/31/15	6.83	B	2	0.1	U	0.1	0.35	U	0.35	122		30
199-N-56	B321M9	07/28/15	3.1	B	2	0.109	B	0.1	0.759	B	0.35	30	U	30
199-N-96A	B321M0	07/29/15	17.4		2	0.1	U	0.1	0.971	B	0.35	34.6	B	30
199-N-167	B321K2	07/29/15	2	U	2	1.43		0.1	3.06		0.35	377		30

Table 4-6. Groundwater Sample Results for Metals (July 2015)

Well Name	Sample Number	Date	Chromium			Cobalt			Copper			Iron		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-169	B321K8	07/29/15	2.55	B	2	2.22		0.1	7.36		0.35	299		30
199-N-171	B321L1	07/29/15	2.21	B	2	0.604	B	0.1	8.8		0.35	2,080		30
199-N-172	B321K5	07/29/15	7.88	B	2	2.69		0.1	14.4		0.35	2,760		30
199-N-173	B321M3	07/28/15	2	U	2	0.673	B	0.1	9.44		0.35	30	U	30
199-N-183	B321L7	07/29/15	2	U	2	1.51		0.1	1.14		0.35	2,840		30
C6132	B319J7	07/09/15	3.86	B	1	1	U	1	3	U	3	89.4	B	30
C6132	B319J3	07/09/15	4.22	B	1	1	U	1	3	U	3	30	U	30
C6132	B321N5	07/29/15	5.21	B	2	0.139	B	0.1	0.684	B	0.35	183		30
N116mArray-0A	B319M4	06/24/15	3.4	U	3.4	4.2	B	2.7	2.7	B	2.1	5,370		12.8
N116mArray-0A	B319M5	06/24/15	3.4	U	3.4	5	B	2.7	2.1	U	2.1	4,690		12.8

Well Name	Sample Number	Date	Lead			Magnesium			Manganese			Molybdenum		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-3	B321L4	07/28/15	0.633	B	0.5	25,600		110	3.74	B	1	0.475	B	0.165
199-N-19	B321M6	07/31/15	0.5	U	0.5	21,100		110	11.4		1	1.1		0.165
199-N-56	B321M9	07/28/15	0.5	U	0.5	26,900		110	2.03	B	1	0.312	B	0.165
199-N-96A	B321M0	07/29/15	0.5	U	0.5	9,210		110	6.92		1	0.869		0.165
199-N-167	B321K2	07/29/15	0.554	B	0.5	29,500		110	730		1	1.68		0.165
199-N-169	B321K8	07/29/15	1.7	B	0.5	25,700		110	1,060	D	25	1.79		0.165
199-N-171	B321L1	07/29/15	2.44		0.5	37,500		110	4,090	D	100	4.52		0.165
199-N-172	B321K5	07/29/15	3.25		0.5	44,700		110	2,660	D	10	6.84		0.165

Table 4-6. Groundwater Sample Results for Metals (July 2015)

Well Name	Sample Number	Date	Lead			Magnesium			Manganese			Molybdenum		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-173	B321M3	07/28/15	3.26		0.5	31,600		110	2,570	D	100	0.858		0.165
199-N-183	B321L7	07/29/15	0.5	U	0.5	33,700		110	3,440	D	10	2.35		0.165
C6132	B319J7	07/09/15	3.3	U	3.3	19,300		110	5	B	2	2	U	2
C6132	B319J3	07/09/15	3.3	U	3.3	19,000		110	6.57	B	2	2	U	2
C6132	B321N5	07/29/15	0.5	U	0.5	12,500		110	14.8	C	1	1		0.165
N116mArray-0A	B319M4	06/24/15	3.7	B	0.6	15,000		50.5	13,500	D	10	1.9	U	1.9
N116mArray-0A	B319M5	06/24/15	2.5	B	0.6	15,600		50.5	12,600	D	10	1.9	U	1.9

Well Name	Sample Number	Date	Nickel			Phosphorus			Potassium			Selenium		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-3	B321L4	07/28/15	1.8	B	0.5	76.5	B	60	4,360		50	1.5	U	1.5
199-N-19	B321M6	07/31/15	1.56	B	0.5	60	U	60	6,150		50	1.53	B	1.5
199-N-56	B321M9	07/28/15	2.1		0.5	60	U	60	5,900		50	1.5	U	1.5
199-N-96A	B321M0	07/29/15	0.805	B	0.5	3,390		60	2,040		50	1.5	U	1.5
199-N-167	B321K2	07/29/15	2.33		0.5	67.8	B	60	6,650		50	1.5	U	1.5
199-N-169	B321K8	07/29/15	3.7		0.5	81.9	B	60	5,770		50	1.5	U	1.5
199-N-171	B321L1	07/29/15	1.89	B	0.5	115	B	60	5,790		50	1.5	U	1.5
199-N-172	B321K5	07/29/15	4.48		0.5	163		60	7,130		50	1.5	U	1.5
199-N-173	B321M3	07/28/15	1.62	B	0.5	60	U	60	6,520		50	1.5	U	1.5
199-N-183	B321L7	07/29/15	1.64	B	0.5	85.7	B	60	5,640		50	1.5	U	1.5
C6132	B319J7	07/09/15	1.5	U	1.5	41.5	B	15	5,610		50	-	-	-

Table 4-6. Groundwater Sample Results for Metals (July 2015)

Well Name	Sample Number	Date	Nickel			Phosphorus			Potassium			Selenium		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
C6132	B319J3	07/09/15	1.5	U	1.5	36.2	B	15	5,550		50	-	-	-
C6132	B321N5	07/29/15	0.514	B	0.5	62	B	60	4,470		50	1.5	U	1.5
N116mArray-0A	B319M4	06/24/15	7.4	B	2.6	132	C	10.4	3,380	B	456	-	-	-
N116mArray-0A	B319M5	06/24/15	7.4	B	2.6	120	C	10.4	3,560	B	456	-	-	-

Well Name	Sample Number	Date	Silicon			Silver			Sodium			Strontium		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-3	B321L4	07/28/15	10,800		25	0.2	U	0.2	22,900		100	593		2
199-N-19	B321M6	07/31/15	12,400		25	0.2	U	0.2	71,800		100	467		2
199-N-56	B321M9	07/28/15	12,700		25	0.2	U	0.2	55,700		100	748		2
199-N-96A	B321M0	07/29/15	9,230		25	0.2	U	0.2	49,100		100	170		2
199-N-167	B321K2	07/29/15	15,800		25	0.2	U	0.2	46,900		100	664		2
199-N-169	B321K8	07/29/15	13,900		25	0.859	B	0.2	42,200		100	634		2
199-N-171	B321L1	07/29/15	15,000		25	0.2	U	0.2	39,000		100	848		2
199-N-172	B321K5	07/29/15	17,000		25	0.2	U	0.2	60,700		100	891		2
199-N-173	B321M3	07/28/15	14,100		25	0.2	U	0.2	55,600		100	936		2
199-N-183	B321L7	07/29/15	15,100		25	0.2	U	0.2	41,200		100	779		2
C6132	B319J7	07/09/15	-	-	-	1	U	1	70,500		100	455		1
C6132	B319J3	07/09/15	-	-	-	1	U	1	69,600		100	456		1
C6132	B321N5	07/29/15	9,430		25	0.2	U	0.2	55,300		100	302		2
N116mArray-0A	B319M4	06/24/15	-	-	-	1.8	B	0.99	6,450		105	444		0.24

Table 4-6. Groundwater Sample Results for Metals (July 2015)

Well Name	Sample Number	Date	Silicon			Silver			Sodium			Strontium		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
N116mArray-0A	B319M5	06/24/15	-	-		1	B	0.99	7,110		105	420		0.24
Well Name	**Sample Number**	**Date**	**Thallium**			**Tin**			**Uranium**			**Vanadium**		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-3	B321L4	07/28/15	0.45	U	0.45	1	U	1	6.5		0.067	2.17	B	1
199-N-19	B321M6	07/31/15	0.45	U	0.45	1	U	1	5.16		0.067	4.13	B	1
199-N-56	B321M9	07/28/15	0.45	U	0.45	1	U	1	7.99		0.067	1.83	B	1
199-N-96A	B321M0	07/29/15	0.45	U	0.45	1	U	1	0.403		0.067	4.35	B	1
199-N-167	B321K2	07/29/15	0.45	U	0.45	1	U	1	3.51		0.067	3.83	B	1
199-N-169	B321K8	07/29/15	0.45	U	0.45	1	U	1	2.45		0.067	5.17		1
199-N-171	B321L1	07/29/15	0.45	U	0.45	1	U	1	3.28		0.067	2.97	B	1
199-N-172	B321K5	07/29/15	0.45	U	0.45	1.7	B	1	5.68		0.067	3.98	B	1
199-N-173	B321M3	07/28/15	0.45	U	0.45	1	U	1	3.45		0.067	1	U	1
199-N-183	B321L7	07/29/15	0.45	U	0.45	1	U	1	2.08		0.067	1	U	1
C6132	B319J7	07/09/15	-	-	-	-	-	-	-	-	-	3.21	B	1
C6132	B319J3	07/09/15	-	-	-	-	-	-	-	-	-	2.89	B	1
C6132	B321N5	07/29/15	0.45	U	0.45	1	U	1	3.7		0.067	3.4	B	1
N116mArray-0A	B319M4	06/24/15	-	-	-	-	-	-	-	-	-	5	B	4.4
N116mArray-0A	B319M5	06/24/15	-	-	-	-	-	-	-	-	-	4.4	U	4.4

Table 4-6. Groundwater Sample Results for Metals (July 2015)

Well Name	Sample Number	Date	Zinc		
			µg/L	Q	PQL
199-N-3	B321L4	07/28/15	7.88	B	3.5
199-N-19	B321M6	07/31/15	3.5	U	3.5
199-N-56	B321M9	07/28/15	5.47	B	3.5
199-N-96A	B321M0	07/29/15	3.5	U	3.5
199-N-167	B321K2	07/29/15	10.6		3.5
199-N-169	B321K8	07/29/15	31.5		3.5
199-N-171	B321L1	07/29/15	6.88	B	3.5
199-N-172	B321K5	07/29/15	222		3.5
199-N-173	B321M3	07/28/15	24.2		3.5
199-N-183	B321L7	07/29/15	3.5	U	3.5
C6132	B319J7	07/09/15	3.3	U	3.3
C6132	B319J3	07/09/15	3.3	U	3.3
C6132	B321N5	07/29/15	3.5	U	3.5
N116mArray-0A	B319M4	06/24/15	8.3	U	8.3
N116mArray-0A	B319M5	06/24/15	8.3	U	8.3

Note: Blank cell means no laboratory qualifier.

- = not applicable
B = blank contamination
C = analyte was detected in both the sample and the quality control blank
D = analyte reported at a secondary dilution factor
PQL = practical quantitation limit
Q = laboratory qualifier
TPH = total petroleum hydrocarbon
U = undetected

Table 4-7. Groundwater Sample Results for Metals (January 2016)

Well Name	Sample Number	Date	Aluminum			Antimony			Arsenic			Barium		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-3	B33LY4	02/17/16	15	U	15	1	U	1	1.81	B	1.7	139		0.6
199-N-19	B33LY1	02/17/16	45.9	B	15	1	U	1	2.33	B	1.7	63.8		0.6
199-N-56	B33LY7	02/17/16	15	U	15	1	U	1	1.7	U	1.7	120	D	3
199-N-96A	B33M00	02/17/16	36.7	B	15	1	U	1	4.79	B	1.7	71.1		0.6
199-N-167	B33LW3	02/17/16	204		15	1	U	1	2.19	B	1.7	139		0.6
199-N-169	B33LW6	02/17/16	436		15	1	U	1	2.55	B	1.7	116		0.6
199-N-171	B33LW9	02/17/16	29.3	B	15	1	U	1	1.85	B	1.7	149		0.6
199-N-172	B33LX2	02/17/16	942		15	1	U	1	3.68	B	1.7	86.8		0.6
199-N-173	B33LX5	02/17/16	15	U	15	1	U	1	1.7	U	1.7	205		0.6
199-N-183	B33LX8	02/17/16	15	U	15	1	U	1	3.29	B	1.7	213	D	3
C6132	B33M03	02/17/16	15	U	15	1	U	1	1.92	B	1.7	87.3		0.6
N116mArray-0A	B33M06	02/17/16	15	U	15	1	U	1	1.7	U	1.7	21.9		0.6
Well Name	**Sample Number**	**Date**	**Beryllium**			**Boron**			**Cadmium**			**Calcium**		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-3	B33LY4	02/17/16	0.2	U	0.2	1	U	15	0.11	U	1	137,000		50
199-N-19	B33LY1	02/17/16	0.2	U	0.2	1	U	15	0.11	U	1	98,900		50
199-N-56	B33LY7	02/17/16	0.2	U	0.2	30.5	B	15	0.11	U	1	124,000		50
199-N-96A	B33M00	02/17/16	0.2	U	0.2	30.6	B	15	0.11	U	1	90,000		50
199-N-167	B33LW3	02/17/16	0.2	U	0.2	39.1	B	15	0.11	U	1	143,000		50
199-N-169	B33LW6	02/17/16	0.2	U	0.2	17.5	B	15	0.233	B	1	134,000		50

Table 4-7. Groundwater Sample Results for Metals (January 2016)

Well Name	Sample Number	Date	Beryllium			Boron			Cadmium			Calcium		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-171	B33LW9	02/17/16	0.2	U	0.2	22.5	B	15	0.174	B	1	171,000		50
199-N-172	B33LX2	02/17/16	0.2	U	0.2	23.9	B	15	0.11	U	1	215,000		50
199-N-173	B33LX5	02/17/16	0.2	U	0.2	23.9	B	15	0.11	U	1	201,000		50
199-N-183	B33LX8	02/17/16	0.2	U	0.2	30.2	B	15	0.11	U	1	192,000		50
C6132	B33M03	02/17/16	0.2	U	0.2	25.7	B	15	0.11	U	1	105,000		50
N116mArray-0A	B33M06	02/17/16	0.2	U	0.2	23.6	B	15	0.11	U	1	16,100		50
Well Name	**Sample Number**	**Date**	**Chromium**			**Cobalt**			**Copper**			**Iron**		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-3	B33LY4	02/17/16	4.43	B	2	0.1	U	0.1	0.409	B	0.35	76.2	B	30
199-N-19	B33LY1	02/17/16	6.76	B	0.2	0.272	B	0.1	1.26		0.35	157		30
199-N-56	B33LY7	02/17/16	6.64	B	0.2	0.258	B	0.1	1.42		0.35	30	U	30
199-N-96A	B33M00	02/17/16	11		0.2	0.1	U	0.1	2.62		0.35	56.4	B	30
199-N-167	B33LW3	02/17/16	2	U	0.2	1.35		0.1	2.16		0.35	351		30
199-N-169	B33LW6	02/17/16	2.38	B	0.2	2.3		0.1	8.5		0.35	601		30
199-N-171	B33LW9	02/17/16	2	U	0.2	0.215	B	0.1	2.91		0.35	607		30
199-N-172	B33LX2	02/17/16	3.45	B	0.2	1.3		0.1	7.56		0.35	2,300		30
199-N-173	B33LX5	02/17/16	2	U	0.2	0.425	B	0.1	6.75		0.35	30	U	30
199-N-183	B33LX8	02/17/16	2.16	B	0.2	1.74		0.1	1.88		0.35	2550		30
C6132	B33M03	02/17/16	4.04	B	0.2	0.1	U	0.1	0.35	U	0.35	48.6	B	30
N116mArray-0A	B33M06	02/17/16	2	U	0.2	0.1	U	0.1	0.393	B	0.35	559		30

Table 4-7. Groundwater Sample Results for Metals (January 2016)

Well Name	Sample Number	Date	Lead			Magnesium			Manganese			Molybdenum		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-3	B33LY4	02/17/16	0.5	U	0.5	24,400	U	110	9.27		1	0.408	CB	0.165
199-N-19	B33LY1	02/17/16	0.5	U	0.5	20,700	B	110	25.1		1	1.23		0.165
199-N-56	B33LY7	02/17/16	0.5	U	0.5	21,200	B	110	1	U	1	0.421	B	0.165
199-N-96A	B33M00	02/17/16	0.5	U	0.5	19,600	U	110	11.9		1	1.72	C	0.165
199-N-167	B33LW3	02/17/16	0.601	B	0.5	25,300		110	428		1	0.946	C	0.165
199-N-169	B33LW6	02/17/16	1.6	B	0.5	24,300		110	565		1	1.41	C	0.165
199-N-171	B33LW9	02/17/16	0.785	B	0.5	31,400	B	110	3,240	D	20	2.02	C	0.165
199-N-172	B33LX2	02/17/16	1.69	B	0.5	45,400		110	2,240	D	20	2.99	C	0.165
199-N-173	B33LX5	02/17/16	1.64	B	0.5	34,400	B	110	1,740	D	20	0.898	C	0.165
199-N-183	B33LX8	02/17/16	0.5	U	0.5	36,900		110	3,660	D	50	2.75		0.165
C6132	B33M03	02/17/16	0.5	U	0.5	20,400	U	110	2.68	B	1	0.653	C	0.165
N116mArray-0A	B33M06	02/17/16	0.5	U	0.5	5,130	U	110	136		1	0.223	CB	0.165
Well Name	**Sample Number**	**Date**	**Nickel**			**Phosphorus**			**Potassium**			**Selenium**		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-3	B33LY4	02/17/16	1.81	B	0.5	65.4	B	60	4,050		50	1.89	B	1.5
199-N-19	B33LY1	02/17/16	3.18		0.5	60	U	60	6,350		50	1.85	B	1.5
199-N-56	B33LY7	02/17/16	4.03		0.5	60	U	60	5,200		50	1.84	B	1.5
199-N-96A	B33M00	02/17/16	1.36	B	0.5	3540		60	3,390		50	1.5	U	1.5
199-N-167	B33LW3	02/17/16	2.05		0.5	62.8	B	60	6,260		50	1.5	U	1.5
199-N-169	B33LW6	02/17/16	2.71		0.5	81.2	B	60	5,900		50	1.5	U	1.5

Table 4-7. Groundwater Sample Results for Metals (January 2016)

Well Name	Sample Number	Date	Nickel			Phosphorus			Potassium			Selenium		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-171	B33LW9	02/17/16	0.889	B	0.5	60	U	60	5,600		50	1.5	U	1.5
199-N-172	B33LX2	02/17/16	2.23		0.5	115	B	60	6,630		50	1.5	U	1.5
199-N-173	B33LX5	02/17/16	1.26	B	0.5	60	U	60	6,780		50	1.5	U	1.5
199-N-183	B33LX8	02/17/16	5.27		0.5	73.7	B	60	5,650		50	1.5	U	1.5
C6132	B33M03	02/17/16	0.5	U	0.5	60	U	60	4,940		50	1.86	B	1.5
N116mArray-0A	B33M06	02/17/16	0.5	U	0.5	60	U	60	803		50	1.5	U	1.5
Well Name	**Sample Number**	**Date**	**Silicon**			**Silver**			**Sodium**			**Strontium**		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-3	B33LY4	02/17/16	10,800	M	25	0.2	U	0.2	21,800		100	579	D	40
199-N-19	B33LY1	02/17/16	13,000		25	0.2	U	0.2	77,200		100	496		2
199-N-56	B33LY7	02/17/16	12,700		25	0.2	U	0.2	62,200		100	624		2
199-N-96A	B33M00	02/17/16	11,500	M	25	0.2	U	0.2	64,300		100	347	D	20
199-N-167	B33LW3	02/17/16	15,900	M	25	0.2	U	0.2	40,400		100	617	D	20
199-N-169	B33LW6	02/17/16	15,100	M	25	0.2	U	0.2	41,200		100	582	D	40
199-N-171	B33LW9	02/17/16	14,900	M	25	0.2	U	0.2	38,000		100	709	D	40
199-N-172	B33LX2	02/17/16	19,200	M	25	0.2	U	0.2	63,000		100	878	D	40
199-N-173	B33LX5	02/17/16	14,800	M	25	0.2	U	0.2	56,600		100	950	D	40
199-N-183	B33LX8	02/17/16	14,900		25	0.2	U	0.2	41,700		100	888		2

Table 4-7. Groundwater Sample Results for Metals (January 2016)

Well Name	Sample Number	Date	Silicon			Silver			Sodium			Strontium		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
C6132	B33M03	02/17/16	9,220	M	25	0.2	U	0.2	60,400		100	469	D	40
N116mArray-0A	B33M06	02/17/16	4,840	M	25	0.2	U	0.2	2,020	C	100	69.2	D	2

Well Name	Sample Number	Date	Thallium			Tin			Uranium			Vanadium		
			µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
199-N-3	B33LY4	02/17/16	0.45	U	0.45	1	U	1	5.02		0.067	1.97	B	1
199-N-19	B33LY1	02/17/16	0.851	CB	0.45	1	U	1	6.35		0.067	4.39	B	1
199-N-56	B33LY7	02/17/16	0.45	U	0.45	1	U	1	5.07		0.067	1.82	B	1
199-N-96A	B33M00	02/17/16	0.45	U	0.45	1	U	1	1.91		0.067	5.26		1
199-N-167	B33LW3	02/17/16	0.45	U	0.45	1	U	1	2.05		0.067	4.73	B	1
199-N-169	B33LW6	02/17/16	0.45	U	0.45	1	U	1	2.69		0.067	4.51	B	1
199-N-171	B33LW9	02/17/16	0.45	U	0.45	1	U	1	2.32		0.067	2.02	B	1
199-N-172	B33LX2	02/17/16	0.45	U	0.45	1.46	CB	1	3.52		0.067	2.98	B	1
199-N-173	B33LX5	02/17/16	0.45	U	0.45	1	U	1	3.97		0.067	1	U	1
199-N-183	B33LX8	02/17/16	0.45	U	0.45	1	U	1	2.46		0.067	1	U	1
C6132	B33M03	02/17/16	0.45	U	0.45	1	U	1	5.17		0.067	2.17	B	1
N116mArray-0A	B33M06	02/17/16	0.45	U	0.45	1	U	1	0.067	U	0.067	1	U	1

Table 4-7. Groundwater Sample Results for Metals (January 2016)

Well Name	Sample Number	Date	Zinc		
			µg/L	Q	PQL
199-N-3	B33LY4	02/17/16	9.27	B	3.5
199-N-19	B33LY1	02/17/16	3.5	U	3.5
199-N-56	B33LY7	02/17/16	4.61	B	3.5
199-N-96A	B33M00	02/17/16	3.98	B	3.5
199-N-167	B33LW3	02/17/16	9.48	B	3.5
199-N-169	B33LW6	02/17/16	6.92	B	3.5
199-N-171	B33LW9	02/17/16	3.5	U	3.5
199-N-172	B33LX2	02/17/16	27.8		3.5
199-N-173	B33LX5	02/17/16	17		3.5
199-N-183	B33LX8	02/17/16	3.5	U	3.5
C6132	B33M03	02/17/16	3.5	U	3.5
N116mArray-0A	B33M06	02/17/16	3.5	U	3.5

Note: Blank cell means no laboratory qualifier.

- = not applicable
B = blank contamination
C = analyte was detected in both the sample and the quality control blank
D = analyte reported at a secondary dilution factor
M = duplicate precision criteria not met
PQL = practical quantitation limit
Q = laboratory qualifier
TPH = total petroleum hydrocarbon
U = undetected

Table 4-8. Groundwater Sample Results for Organics (July 2015)

Sample Number	B321L4			B321M6			B321M9			B321M0			B321K2			B321K8		
Well Name	199-N-3			199-N-19			199-N-56			199-N-96A			199-N-167			199-N-169		
	07/28/15			07/31/15			07/28/15			07/29/15			07/29/15			07/29/15		
Constituent	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
Polycyclic Aromatic Hydrocarbons																		
Acenaphthene	0.28	U	0.28	0.3	U	0.3	0.28	U	0.28	0.28	U	0.28	0.625	U	0.625	0.652	U	0.652
Acenaphthylene	0.28	U	0.28	0.3	U	0.3	0.28	U	0.28	0.28	U	0.28	0.625	U	0.625	0.652	U	0.652
Anthracene	0.28	U	0.28	0.3	U	0.3	0.28	U	0.28	0.28	U	0.28	0.625	U	0.625	0.652	U	0.652
Benzo(a)anthracene	0.28	U	0.28	0.3	U	0.3	0.28	U	0.28	0.28	U	0.28	0.625	U	0.625	0.652	U	0.652
Benzo(a)pyrene	0.28	U	0.28	0.3	U	0.3	0.28	U	0.28	0.28	U	0.28	0.625	U	0.625	0.652	U	0.652
Benzo(b)fluoranthene	0.28	U	0.28	0.3	U	0.3	0.28	U	0.28	0.28	U	0.28	0.625	U	0.625	0.652	U	0.652
Benzo(ghi)perylene	0.28	U	0.28	0.3	U	0.3	0.28	U	0.28	0.28	U	0.28	0.625	U	0.625	0.652	U	0.652
Benzo(k)fluoranthene	0.28	U	0.28	0.3	U	0.3	0.28	U	0.28	0.28	U	0.28	0.625	U	0.625	0.652	U	0.652
Chrysene	0.28	U	0.28	0.3	U	0.3	0.28	U	0.28	0.28	U	0.28	0.625	U	0.625	0.652	U	0.652
Dibenz[a,h]anthracene	0.28	U	0.28	0.3	U	0.3	0.28	U	0.28	0.28	U	0.28	0.625	U	0.625	0.652	U	0.652
Fluoranthene	0.28	U	0.28	0.3	U	0.3	0.28	U	0.28	0.28	U	0.28	0.625	U	0.625	0.652	U	0.652
Fluorene	0.28	U	0.28	0.3	U	0.3	0.28	U	0.28	0.28	U	0.28	0.625	U	0.625	0.652	U	0.652
Indeno(1,2,3-cd)pyrene	0.28	U	0.28	0.3	U	0.3	0.28	U	0.28	0.28	U	0.28	0.625	U	0.625	0.652	U	0.652
Naphthalene	0.28	U	0.28	0.3	U	0.3	0.28	U	0.28	0.28	U	0.28	0.625	U	0.625	0.652	U	0.652
Phenanthrene	0.28	U	0.28	0.3	U	0.3	0.28	U	0.28	0.28	U	0.28	0.625	U	0.625	0.652	U	0.652
Pyrene	0.28	U	0.28	0.3	U	0.3	0.28	U	0.28	0.28	U	0.28	0.625	U	0.625	0.652	U	0.652
Volatile Organic Compounds																		
1,1,1-Trichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,1,2-Trichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,1-Dichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3

Table 4-8. Groundwater Sample Results for Organics (July 2015)

Sample Number	B321L4			B321M6			B321M9			B321M0			B321K2			B321K8		
Well Name	199-N-3			199-N-19			199-N-56			199-N-96A			199-N-167			199-N-169		
	07/28/15			07/31/15			07/28/15			07/29/15			07/29/15			07/29/15		
Constituent	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
Volatile Organic Compounds																		
1,1-Dichloroethene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,2-Dichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
2-Butanone	3	TU	3	3	TU	3	3	TU	3	3	TU	3	3	TU	3	3	TU	3
4-Methyl-2-pentanone	3	U	3	3	U	3	3	U	3	3	U	3	3	U	3	3	U	3
Acetone	3	TU	3	3	TU	3	3	TU	3	3	TU	3	3	TU	3	3	TU	3
Benzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Carbon disulfide	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6
Carbon tetrachloride	0.3	TU	0.3	0.3	TU	0.3	0.3	TU	0.3	0.3	TU	0.3	0.3	TU	0.3	0.3	TU	0.3
Chlorobenzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Chloroform	0.61	J	0.3	1.47	J	0.3	0.45	J	0.3	0.3	U	0.3	0.3	U	0.3	0.72	J	0.3
Ethylbenzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Methylene chloride	2.4	J	1.6	3.58	J	1.6	2.38	J	1.6	2.53	J	1.6	2.29	J	1.6	2.34	J	1.6
Tetrachloroethene	0.33	J	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Trichloroethene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Vinyl chloride	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Xylenes (total)	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Polycyclic Aromatic Hydrocarbons																		
Acenaphthene	0.612	U	0.612	0.612	U	0.612	0.286	U	0.286	0.3	U	0.3	0.286	U	0.286			
Acenaphthylene	0.612	U	0.612	0.612	U	0.612	0.286	U	0.286	0.3	U	0.3	0.286	U	0.286			
Anthracene	0.612	U	0.612	0.612	U	0.612	0.286	U	0.286	0.3	U	0.3	0.286	U	0.286			

Table 4-8. Groundwater Sample Results for Organics (July 2015)

Sample Number	B321L4			B321M6			B321M9			B321M0			B321K2			B321K8		
Well Name	199-N-3			199-N-19			199-N-56			199-N-96A			199-N-167			199-N-169		
	07/28/15			07/31/15			07/28/15			07/29/15			07/29/15			07/29/15		
Constituent	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
Polycyclic Aromatic Hydrocarbons																		
Benzo(a)anthracene	0.612	U	0.612	0.612	U	0.612	0.286	U	0.286	0.3	U	0.3	0.286	U	0.286			
Benzo(a)pyrene	0.612	U	0.612	0.612	U	0.612	0.286	U	0.286	0.3	U	0.3	0.286	U	0.286			
Benzo(b)fluoranthene	0.612	U	0.612	0.612	U	0.612	0.286	U	0.286	0.3	U	0.3	0.286	U	0.286			
Benzo(ghi)perylene	0.612	U	0.612	0.612	U	0.612	0.286	U	0.286	0.3	U	0.3	0.286	U	0.286			
Benzo(k)fluoranthene	0.612	U	0.612	0.612	U	0.612	0.286	U	0.286	0.3	U	0.3	0.286	U	0.286			
Chrysene	0.612	U	0.612	0.612	U	0.612	0.286	U	0.286	0.3	U	0.3	0.286	U	0.286			
Dibenz[a,h]anthracene	0.612	U	0.612	0.612	U	0.612	0.286	U	0.286	0.3	U	0.3	0.286	U	0.286			
Fluoranthene	0.612	U	0.612	0.612	U	0.612	0.286	U	0.286	0.3	U	0.3	0.286	U	0.286			
Fluorene	3.43		0.612	0.612	U	0.612	0.286	U	0.286	0.41	J	0.3	0.286	U	0.286			
Indeno(1,2,3-cd)pyrene	0.612	U	0.612	0.612	U	0.612	0.286	U	0.286	0.3	U	0.3	0.286	U	0.286			
Naphthalene	0.612	U	0.612	0.612	U	0.612	0.286	U	0.286	0.3	U	0.3	0.286	U	0.286			
Phenanthrene	0.612	U	0.612	0.612	U	0.612	0.286	U	0.286	0.3	U	0.3	0.286	U	0.286			
Pyrene	0.612	U	0.612	0.959	J	0.612	0.286	U	0.286	0.3	U	0.3	0.286	U	0.286			
Volatile Organic Compounds																		
1,1,1-Trichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3			
1,1,2-Trichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3			
1,1-Dichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3			
1,1-Dichloroethene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3			

Table 4-8. Groundwater Sample Results for Organics (July 2015)

Sample Number	B321L4			B321M6			B321M9			B321M0			B321K2			B321K8		
Well Name	199-N-3			199-N-19			199-N-56			199-N-96A			199-N-167			199-N-169		
	07/28/15			07/31/15			07/28/15			07/29/15			07/29/15			07/29/15		
Constituent	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
Volatile Organic Compounds																		
1,2-Dichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3			
2-Butanone	3	TU	3	3	TU	3	3	TU	3	3	TU	3	3	TU	3			
4-Methyl-2-pentanone	3	U	3	3	U	3	3	U	3	3	U	3	3	U	3			
Acetone	3	TU	3	3	TU	3	3	TU	3	3	TU	3	3	TU	3			
Benzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3			
Carbon disulfide	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6			
Carbon tetrachloride	0.3	TU	0.3	0.3	TU	0.3	0.3	TU	0.3	0.3	TU	0.3	0.3	TU	0.3			
Chlorobenzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3			
Chloroform	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.75	J	0.3			
Ethylbenzene	0.37	J	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3			
Methylene chloride	2.51	J	1.6	3.66	J	1.6	2.49	J	1.6	2.38	J	1.6	3.81	J	1.6			
Tetrachloroethene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3			
Trichloroethene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3			
Vinyl chloride	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3			
Xylenes (total)	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3			

Note: Blank cell means no laboratory qualifier.

- = not applicable
J = estimated value
PQL = practical quantitation limit
Q = laboratory qualifier
TPH = total petroleum hydrocarbon
U = undetected

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Table 4-9. Groundwater Sample Results for Organics (February 2016)

Sample Number	B33LY4			B33LY1			B33LY7			B33M00			B33LW3			B33LW6		
Well Name	199-N-3			199-N-19			199-N-56			199-N-96A			199-N-167			199-N-169		
	02/17/16			02/17/16			02/17/16			02/17/16			02/17/16			02/17/16		
Constituent	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
Polycyclic Aromatic Hydrocarbons																		
Acenaphthene	0.028	U	0.028	0.03	U	0.03	0.03	U	0.03	0.028	U	0.028	0.0283	U	0.0283	0.0283	U	0.0283
Acenaphthylene	0.028	U	0.028	0.03	U	0.03	0.03	U	0.03	0.028	U	0.028	0.0283	U	0.0283	0.0283	U	0.0283
Anthracene	0.028	U	0.028	0.03	U	0.03	0.03	U	0.03	0.028	U	0.028	0.0283	U	0.0283	0.0283	U	0.0283
Benzo(a)anthracene	0.028	U	0.028	0.03	U	0.03	0.03	U	0.03	0.028	U	0.028	0.0283	U	0.0283	0.0283	U	0.0283
Benzo(a)pyrene	0.028	U	0.028	0.03	U	0.03	0.03	U	0.03	0.028	U	0.028	0.0283	U	0.0283	0.0283	U	0.0283
Benzo(b)fluoranthene	0.028	U	0.028	0.03	U	0.03	0.03	U	0.03	0.028	U	0.028	0.0283	U	0.0283	0.0283	U	0.0283
Benzo(ghi)perylene	0.028	U	0.028	0.03	U	0.03	0.03	U	0.03	0.028	U	0.028	0.0283	U	0.0283	0.0283	U	0.0283
Benzo(k)fluoranthene	0.028	U	0.028	0.03	U	0.03	0.03	U	0.03	0.028	U	0.028	0.0283	U	0.0283	0.0283	U	0.0283
Chrysene	0.028	U	0.028	0.03	U	0.03	0.03	U	0.03	0.028	U	0.028	0.0283	U	0.0283	0.0283	U	0.0283
Dibenz[a,h]anthracene	0.028	U	0.028	0.03	U	0.03	0.03	U	0.03	0.028	U	0.028	0.0283	U	0.0283	0.0283	U	0.0283
Fluoranthene	0.028	U	0.028	0.03	U	0.03	0.03	U	0.03	0.028	U	0.028	0.0283	U	0.0283	0.0283	U	0.0283
Fluorene	0.028	U	0.028	0.03	U	0.03	0.03	U	0.03	0.028	U	0.028	0.0283	U	0.0283	0.0283	U	0.0283
Indeno(1,2,3-cd)pyrene	0.028	U	0.028	0.03	U	0.03	0.03	U	0.03	0.028	U	0.028	0.0283	U	0.0283	0.0283	U	0.0283
Naphthalene	0.028	U	0.028	0.03	J	0.03	0.03	U	0.03	0.028	U	0.028	0.0283	U	0.0283	0.0283	U	0.0283
Phenanthrene	0.028	U	0.028	0.03	U	0.03	0.03	U	0.03	0.028	U	0.028	0.0755	J	0.0283	0.0283	U	0.0283
Pyrene	0.028	U	0.028	0.03	U	0.03	0.03	U	0.03	0.028	U	0.028	0.0943	J	0.0283	0.0283	U	0.0283
Volatile Organic Compounds																		
1,1,1-Trichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,1,2-Trichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,1-Dichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,1-Dichloroethene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,2-Dichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
2-Butanone	3	TU	3	3	TU	3	3	TU	3	3	TU	3	3	TU	3	3	TU	3
4-Methyl-2-pentanone	3	U	3	3	U	3	3	U	3	3	U	3	3	U	3	3	U	3
Acetone	3	TU	3	3	TU	3	3	TU	3	3	TU	3	3	TU	3	3	TU	3
Benzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Carbon disulfide	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6

Table 4-9. Groundwater Sample Results for Organics (February 2016)

Sample Number	B33LY4			B33LY1			B33LY7			B33M00			B33LW3			B33LW6		
Well Name	199-N-3			199-N-19			199-N-56			199-N-96A			199-N-167			199-N-169		
	2/17/2016			2/17/2016			2/17/2016			2/17/2016			2/17/2016			2/17/2016		
Constituent	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
Volatile Organic Compounds																		
Carbon tetrachloride	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Chlorobenzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Chloroform	0.81	J	0.3	1.97	J	0.3	1.27	J	0.3	0.3	U	0.3	0.69	J	0.3	0.3	U	0.3
Ethylbenzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Methylene chloride	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6
Tetrachloroethene	0.39	J	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Trichloroethene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Vinyl chloride	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Xylenes (total)	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Sample Number	B33LW9			B33LX2			B33LX5			B33LX8			B33M03			B33M06		
Well Name	199-N-171			199-N-172			199-N-173			199-N-183			C6132			N116mArray-0A		
	2/17/2016			2/17/2016			2/17/2016			2/17/2016			2/17/2016			2/17/2016		
Constituent	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
Polycyclic Aromatic Hydrocarbons																		
Acenaphthene	0.0283	U	0.0283	0.0283	U	0.0283	0.0263	U	0.0263	0.03	U	0.03	0.028	U	0.028	0.028	U	0.028
Acenaphthylene	0.0283	U	0.0283	0.0283	U	0.0283	0.0263	U	0.0263	0.03	U	0.03	0.028	U	0.028	0.028	U	0.028
Anthracene	0.028	U	0.028	0.028	U	0.028	0.0263	U	0.0263	0.03	U	0.03	0.028	U	0.028	0.028	U	0.028
Benzo(a)anthracene	0.028	U	0.028	0.028	U	0.028	0.0263	U	0.0263	0.03	U	0.03	0.028	U	0.028	0.028	U	0.028
Benzo(a)pyrene	0.028	U	0.028	0.028	U	0.028	0.0263	U	0.0263	0.03	U	0.03	0.028	U	0.028	0.028	U	0.028
Benzo(b)fluoranthene	0.028	U	0.028	0.028	U	0.028	0.0263	U	0.0263	0.03	U	0.03	0.028	U	0.028	0.028	U	0.028
Benzo(ghi)perylene	0.028	U	0.028	0.028	U	0.028	0.0263	U	0.0263	0.03	U	0.03	0.028	U	0.028	0.028	U	0.028
Benzo(k)fluoranthene	0.028	U	0.028	0.028	U	0.028	0.0263	U	0.0263	0.03	U	0.03	0.028	U	0.028	0.028	U	0.028
Chrysene	0.028	U	0.028	0.028	U	0.028	0.0263	U	0.0263	0.03	U	0.03	0.028	U	0.028	0.028	U	0.028
Dibenz[a,h]anthracene	0.028	U	0.028	0.0472	J	0.0283	0.0526	J	0.0263	0.03	U	0.03	0.028	U	0.028	0.028	U	0.028
Fluoranthene	0.0755	J	0.0283	0.0283	U	0.0283	0.0263	U	0.0263	0.03	U	0.03	0.028	U	0.028	0.028	U	0.028
Fluorene	1.38	J	0.0283	0.0283	U	0.0283	0.0263	U	0.0263	0.33	J	0.03	0.028	U	0.028	0.028	U	0.028

Table 4-9. Groundwater Sample Results for Organics (February 2016)

Sample Number	B33LW9			B33LX2			B33LX5			B33LX8			B33M03			B33M06		
Well Name	199-N-171			199-N-172			199-N-173			199-N-183			C6132			N116mArray-0A		
	2/17/2016			2/17/2016			2/17/2016			2/17/2016			2/17/2016			2/17/2016		
Constituent	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
Polycyclic Aromatic Hydrocarbons																		
Indeno(1,2,3-cd)pyrene	0.028	U	0.028	0.0283	U	0.0283	0.0263	U	0.0263	0.03	U	0.03	0.028	U	0.028	0.028	U	0.028
Naphthalene	0.0283	U	0.0283	0.104	J	0.0283	0.0877	J	0.0263	0.03	U	0.03	0.028	U	0.028	0.028	U	0.028
Phenanthrene	0.0283	U	0.0283	0.0283	U	0.0283	0.0263	U	0.0263	0.03	U	0.03	0.028	U	0.028	0.028	U	0.028
Pyrene	0.142	J	0.0283	0.0283	U	0.0283	0.0263	U	0.0263	0.04	J	0.03	0.028	U	0.028	0.028	U	0.028
Volatile Organic Compounds																		
1,1,1-Trichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,1,2-Trichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,1-Dichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,1-Dichloroethene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,2-Dichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
2-Butanone	3	TU	3	3	TU	3	3	TU	3	3	TU	3	3	TU	3	3	TU	3
4-Methyl-2-pentanone	3	U	3	3	U	3	3	U	3	3	U	3	3	U	3	3	U	3
Acetone	3	TU	3	3.29	JT	3	3	TU	3	3	TU	3	3	TU	3	3	TU	3
Benzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Carbon disulfide	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6
Carbon tetrachloride	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Chlorobenzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Chloroform	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	1.81	J	0.3	0.3	U	0.3
Ethylbenzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Methylene chloride	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6
Tetrachloroethene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Trichloroethene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3

Table 4-9. Groundwater Sample Results for Organics (February 2016)

Sample Number	B33LW9			B33LX2			B33LX5			B33LX8			B33M03			B33M06		
Well Name	199-N-171			199-N-172			199-N-173			199-N-183			C6132			N116mArray-0A		
	2/17/2016			2/17/2016			2/17/2016			2/17/2016			2/17/2016			2/17/2016		
Constituent	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL	µg/L	Q	PQL
Polycyclic Aromatic Hydrocarbons																		
Vinyl chloride	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Xylenes (total)	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3

Note: Blank cell means no laboratory qualifier.

- = not applicable
J = estimated value
PQL = practical quantitation limit
Q = laboratory qualifier
T = spike and or spike duplicate sample recovery is outside of control limits
TPH = total petroleum hydrocarbon
U = undetected

.

Table 4-10. Groundwater Elevations during Sampling Events

Well Name	July 2015 Elevation (m)	February 2016 Elevation (m)	Delta (m/ft)
199-N-167	118.47	118.44	0.03/0.09
199-N-169	118.45	118.43	0.02/0.06
199-N-171	118.36	118.40	0.04/0.13
199-N-172	118.25	118.39	0.14/0.46
199-N-173	117.92	118.62	0.70/2.3
199-N-183	118.25	118.43	0.18/0.6
199-N-19	118.49	118.46	0.30/0.09
199-N-3	118.37	118.34	0.03/0.09
199-N-56	118.58	118.43	0.15/0.49
199-N-96A	117.84	118.62	0.78/2.56

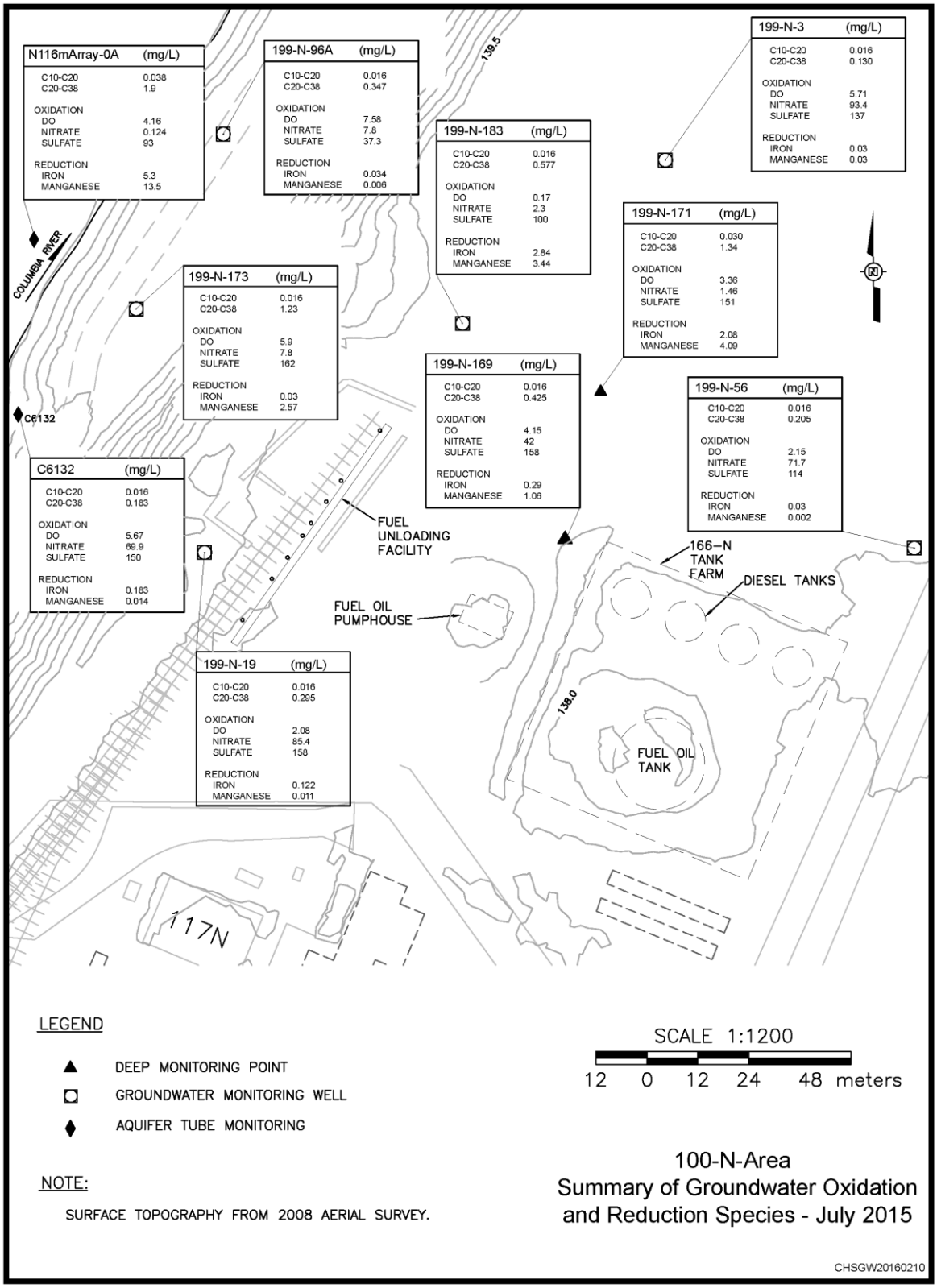

Figure 4-1. Summary of Groundwater Oxidation and Reduction Species, July 2015

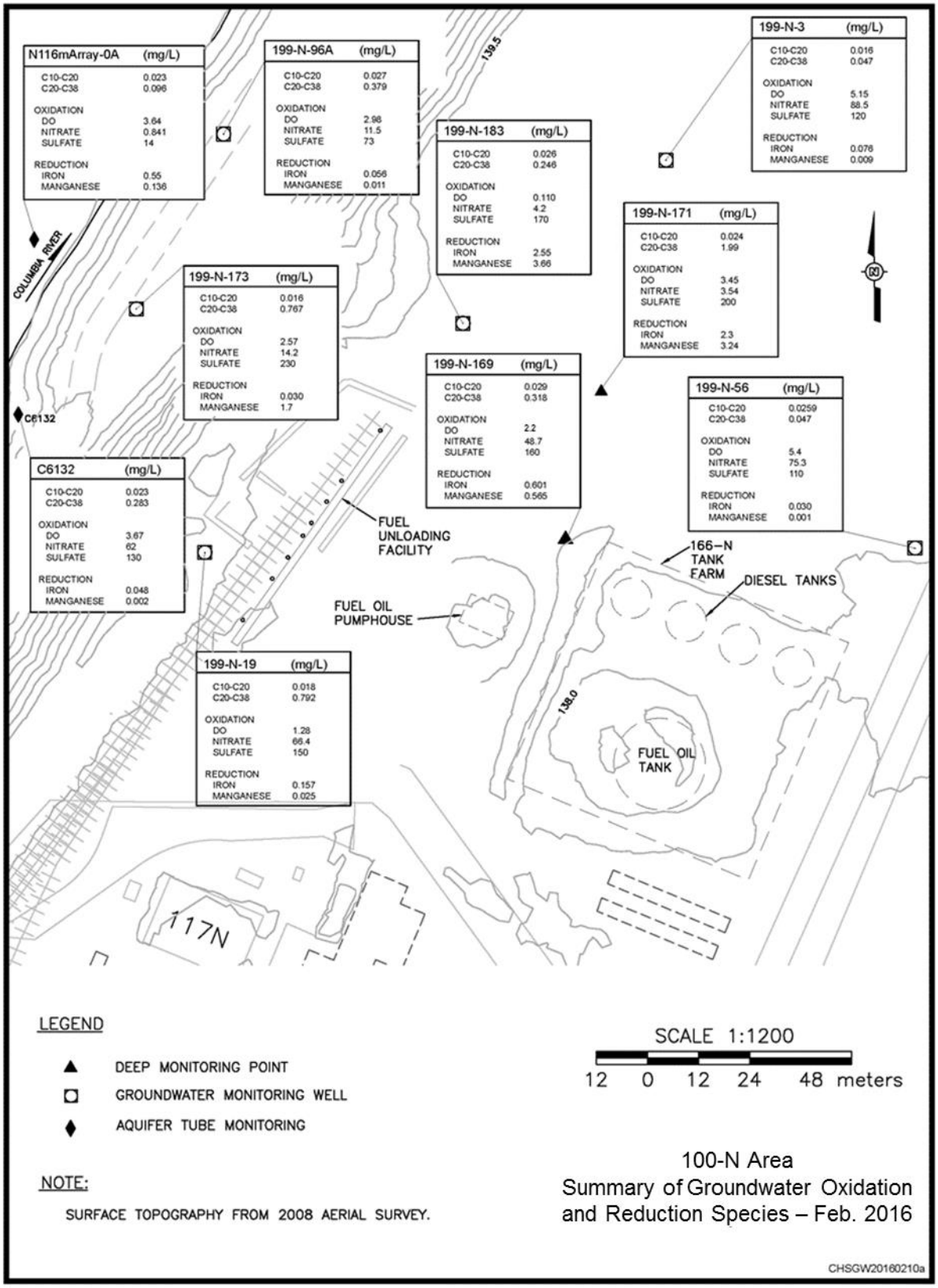

Figure 4-2. Summary of Groundwater Oxidation and Reduction Species, February 2016

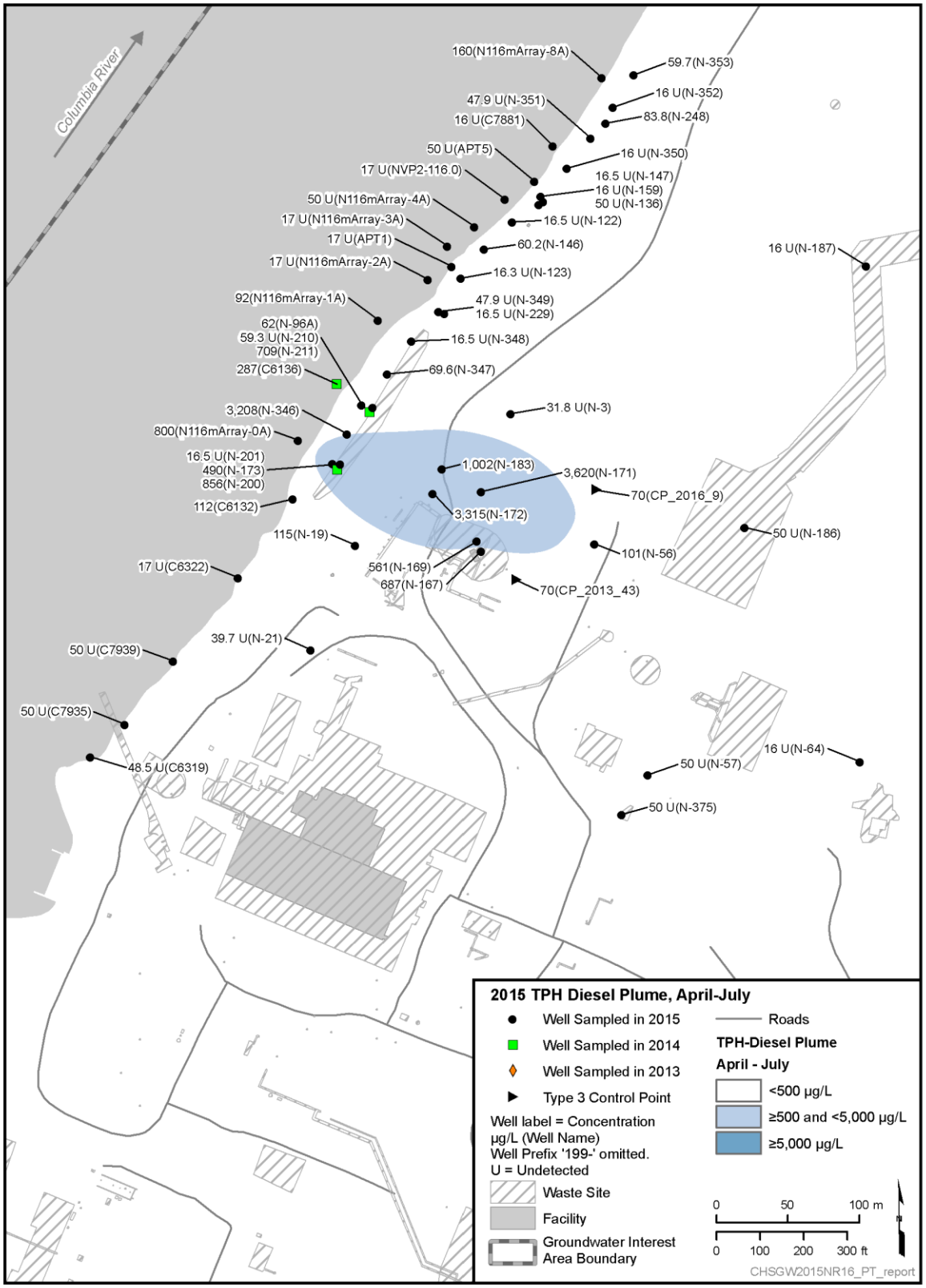

Figure 4-3. Petroleum Plume Distribution in Groundwater at the 100-NR-2 OU, July 2015

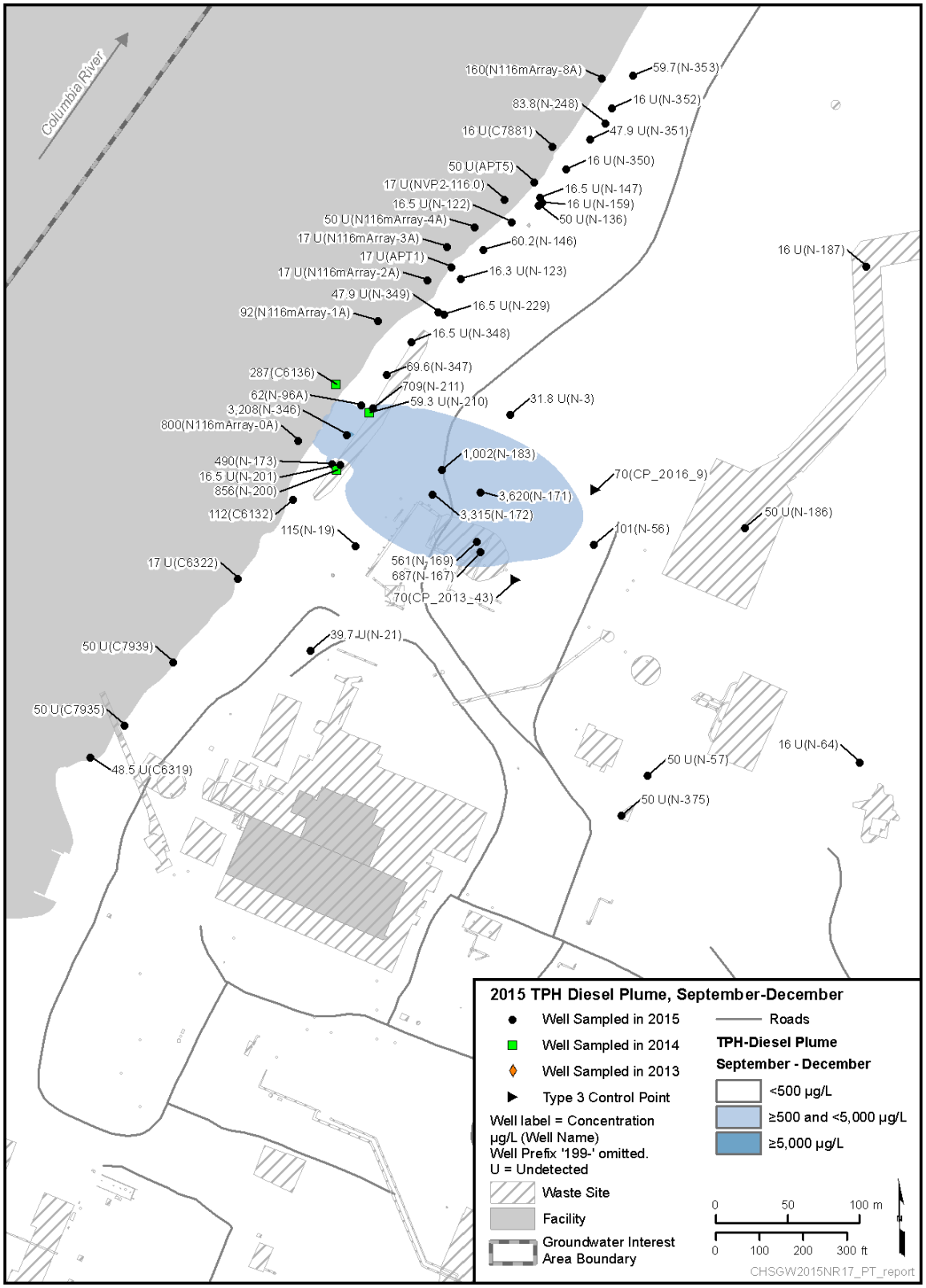

Figure 4-4. Petroleum Plume Distribution in Groundwater at the 100-NR-2 OU, December 2015

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5 Conclusions and Recommendations

The respirometry rates from the July 2015 and February 2016 testing events are generally below the literature values for recommending bioventing as a viable option. However, there is clear evidence that oxygen is a limiting factor for microbial degradation of petroleum hydrocarbons in the deep vadose zone and that bioventing will help maintain this degradation, albeit at a somewhat low rate. Since groundwater remains locally impacted at the site and appears to act as an ongoing hydrocarbon source in the smear zone, bioventing will continue to be beneficial as a remedial action approach, particularly during times of low river stage.

Based on results of the semiannual respirometry testing, the following recommendations are made regarding system operations and performance monitoring.

- Pulse the bioventing system on a predetermined schedule (e.g., 1 week on, 3 weeks off). This operational protocol is expected to be sufficient to maintain oxygen levels in the subsurface while substantially reducing costs for power consumption. This suggested "on/off" regimen could be adjusted to match other scheduled field events, thereby keeping site visits to a minimum.

- Continue semi-annual respirometry testing to evaluate remediation progress and the effect of seasonal variability and pulsing on the measured biodegradation rates. Coordinate semiannual respirometry testing during high and low groundwater periods. Because of the relatively low respirometry rates measured in the most recent tests, future testing should be conducted over a period of 4 to 6 weeks. Coordinate groundwater sampling in the area of the plume to measure petroleum hydrocarbon concentrations.

- Collect and evaluate soil samples at the site to determine progress toward achievement of cleanup criteria with respect to hydrocarbons in soil.

- Evaluate use of an additional treatment technology (e.g., sparging) to treat hydrocarbon-impacted groundwater and saturated zone soils in order to accelerate the overall cleanup time frame. Evaluation should consider converting the bioventing system to a combined bioventing/biosparging system or installing dedicated sparging wells. Converting existing bioventing wells to combined bioventing/biosparging is feasible and would be expected to maintain elevated oxygen concentrations in both the saturated and vadose zones. Pilot testing of such a system would be necessary to determine suitability of converting existing wells to combination bioventing and sparge wells and the radius of influence.

- Collect soil and groundwater samples to measure numbers of hydrocarbon-degrading bacteria prior to commencement of a biosparging pilot test. Other geochemical and nutrient parameters should also be measured in soil and groundwater.

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6 References

DOE/RL-95-111, 1997, *Corrective Measures Study for the 100-NR-1 and 100-NR-2 Operable Units*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D198056722.

DOE/RL-2005-93, 2013, *Remedial Design Report/Remedial Action Work Plan for the 100-N Area*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0086775.

DOE/RL-2015-20, 2015, Annual Operation and Monitoring Report for UPR-100-N-17: March 2014-February 2015, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0080062H

EPA/ROD/R10-99/112, 1999, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Region 10, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Seattle, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D9177845

WCH-370, 2009, *Bioremediation Well Borehole Soil Sampling and Data Analysis Summary Report for the 100-N Area Bioremediation Project (UPR-100-N-17)*, Rev. 0, Washington Closure Hanford, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0084017.

WCH-490, 2011, *UPR-100-N-17: Bioventing Pilot Plant Performance Report*, Rev. 0, Washington Closure Hanford, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0093690.

WCH-576, 2014, *Operation and Maintenance Manual, Phase II Testing – Bioremediation Design for Deep Zone Petroleum Contamination (UPR-100-N-17) at the 100-N Area*, Rev. 0, Washington Closure Hanford, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0085040.

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Appendix A

June - August 2015 Respirometry Testing

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Memorandum

To	Art Lee, CH2M HILL Plateau Remediation Company (CHPRC)	File no:	461m120342.03.01
From	Kylah Wyatt John Kuiper, PG Craig Weber, PE Amec Foster Wheeler Environment & Infrastructure, Inc.	c:	William Faught, CHPRC
Date	October 12, 2015		

Subject Summary of June to August 2015 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site

INTRODUCTION

Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler), has prepared this technical memorandum for CH2M HILL Plateau Remediation Company (CHPRC) to summarize the results of the June to August 2015 in-situ respiration test performed at the subsurface bioventing remediation system located at the 100-N Hanford DOE Site in Benton County, Washington. Since startup in November 2012, the bioventing system has been configured to supply air to the subsurface via two injection wells: 199-N-167 and 199-N-172. Approximately 250 cubic feet per minute (cfm) of air is routed to each well through a custom fitted wellhead. Based on previous studies, it is predicted that the radius of influence (ROI) for each injection well is at least 200 feet. The system was in continuous operation since startup through September 30, 2014, except for periodic short-term shutdowns for maintenance and respirometry test events. The operation and maintenance (O&M) of the system transitioned from Washington Closure Hanford (WCH) to CHPRC, and the system was shut down at the end of September 2014 while CHPRC developed their procedures for O&M. The system resumed operation on December 3, 2014. Testing was conducted in accordance with the procedures detailed in the Revised Subsurface Respirometry Test Plan (Test Plan) dated November 2014 with alterations as noted in the "Proposed Modifications to the 100-N Subsurface Respirometry Test Plan" memorandum, dated May 29, 2015.

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TESTING PROCEDURES

Respiration testing was initiated by turning off the bioventing system blower on June 22, 2015. Gas composition samples were then collected periodically, starting immediately after shut down and continuing through test completion on August 3, 2015. The samples were analyzed to evaluate soil gas concentrations of oxygen, carbon dioxide, methane, and total volatile hydrocarbons (TVH). Sampling was conducted by Amec Foster Wheeler and CHPRC field staff from the six wells in the monitoring program (shown on the attached figure):

- 199-N-167 (air injection well),
- 199-N-169 (monitoring well),
- 199-N-171 (monitoring well),
- 199-N-172 (air injection well),
- 199-N-183 (monitoring well), and
- 199-N-18 (monitoring well).

Prior to blower shutdown on June 22, 2015, baseline readings were collected from the four monitoring wells (199-N-169, 199-N-171, 199-N-183, and 199-N-18), while the air injection wells were still in operation. Respiration testing was initiated by turning off the bioventing system blowers on June 22, 2015 at 10:14 am.

A total of 11 samples were collected from three of the wells (199-N-167, 199-N-169, and 199-N-183,), and 10 samples were collected from the remaining three wells (199-N-171, 199-N-172, and 199-N-18). Samples were collected on a predetermined schedule over a period of approximately 1008 hours (6 weeks). Readings were collected frequently for the first two days (at approximately 0, 1.5 (except for 199-N-171 and 199-N-172, and 199-N-18), 5, 24, and 48 hours) and then every third day for the remainder of the first week (at approximately 72, and 168 hours). The bioventing system then remained off for five additional weeks during which four additional sampling events occurred at approximately 360, 504, 744, and 1008 hours.

Purge times for selected wells were extended relative to earlier test events, pursuant to the May 29, 2015, memo. The extended purge times were designed to evaluate if effects from recent air injections to the subsurface might result in a delayed response to oxygen utilization measured at well 199-N-169, and whether an extended purge time might mitigate such a delayed response. However, the extended purge times did not result in any apparent effect on the initial vapor measurements for the respirometry test.

Daily field reports and field measurements are included as Attachment 1, and instrument calibration sheets are included as Attachment 2.

BIODEGRADATION RATE RESULTS

The 2004 AFCEE guidance document[1] was followed for interpretation of results and calculating oxygen utilization and biodegradation rates. Oxygen utilization rates for each monitoring point were determined from the slope of the line obtained by plotting the measured oxygen concentration verses time for each monitoring point. Oxygen utilization rates are presented in Tables 1 and 2, and supporting data, calculations, and graphs of the data are included as Attachment 3.

Biodegradation rates were calculated using the following equation:

$$K_b = \frac{-k_o\ \theta_a\ \rho_{o2}\ \ C \times 0.01}{\rho_k}$$

Where (calculated or assumed values for the site follow each description):

- K_b: biodegradation rate calculated in mg hydrocarbon consumed per kg of soil per day
- k_o: oxygen utilization rate calculated for each monitoring point in $\%O_2$ consumed per day
- θ_a: gas-filled pore space (volumetric content at the vapor phase) = 0.19 cm^3 gas/cm^3 soil (based on measured value)
- ρ_{O2}: density of oxygen; assumed soil temp of 50F = 1,378 mg/L (AFCEE, 2004)
- C: mass ratio of hydrocarbons to oxygen required for mineralization (calculated assuming diesel as $C_{10}H_{20}$ and stoichiometric relationship of $C_{10}H_{20}$+ $15O_2$ => $10CO_2$ + $10H_2O$) = 0.29
- ρ_k: soil bulk density; measured value = 1.736 g/cm^3 (measured value)
- θ: total porosity (where $\theta = 1 - \rho_k/\rho_T$) = 0.22 cm^3/cm^3 (based on measured value)
- θ_w: water filled porosity (where $\theta_w = M^*\rho_k/\rho_T$) = 0.04 cm^3/cm^3 (based on measured value)
- ρ_T: soil mineral density; assumed value = 2.65 g/cm^3
- M: moisture content; 3.13% (measured value) = 0.0313 g moisture per g soil

The values for soil bulk density (1.736 g/cm^3) and moisture content (3.13%) are based on the average of two representative soil samples collected from well 199-N-183 at depth intervals of 53-55 feet and 63-65 feet below ground surface (bgs), as presented in Attachment 3 and described in detail in AMEC (2014) [2]. Calculations prior to January 2014 were made using the bulk density (2.063 g/cm^3) measured from a single soil sample collected from 58-60 feet bgs in 199-N-183. The updated soil bulk density value of 1.736 g/cm^3 is considered more representative

[1] Air Force Center for Environmental Excellence (AFCEE), 2004, Procedures for Conducting Bioventing Pilot Tests and Long-Term Monitoring of Bioventing Systems, May.

[2] AMEC Environment & Infrastructure, Inc., 2014, Technical Memorandum, Summary of January 2014 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site, February 7.

of the overall site lithology. The values for θ_a, θ, and θ_w from all of the monitoring events were adjusted using the updated bulk density value.

For the 6-week in-situ respirometry test initiated on June 22, 2015, calculated biodegradation rates and baseline measurements of oxygen are presented in Table 1. During the respiration test, methane and TVH were detected throughout the test at all the monitoring points at low level concentrations. The highest concentrations of both constituents, TVH at 29.7 parts per million (ppm) and methane at 50.6 ppm, were detected in 199-N-171; these results exhibit an increase in maximum values detected as compared to concentrations from the June 2014 and January 2015 tests.

Table 1: Soil Gas Monitoring Results, Oxygen Utilization and Biodegradation Rates Calculated from In-Situ Respiration Testing

Monitoring Point	Baseline Oxygen (%)	Oxygen Utilization (%/day)	Biodegradation Rate (mg/kg-day)
199-N-167	21.0	0.07	-0.05
199-N-169	21.0	0.16	-0.12
199-N-171	20.9	0.18	-0.14
199-N-172	20.6	0.05	-0.04
199-N-183	20.8	NA	NA
199-N-18	20.7	NA	NA
NA = Not applicable; oxygen depletion insignificant and biodegradation rate not calculated.			

Baseline or initial oxygen concentrations were near atmospheric levels in all six monitoring locations. Oxygen concentrations in monitoring wells 199-N-183 and 199-N-18 remained above 20% throughout the test and exhibited insignificant oxygen depletion; therefore, a biodegradation rate was not calculated for those wells. The results for these two wells are consistent with previously conducted respirometry test results as shown in Table 2 below and Attachment 3. Well construction information for 199-N-18 indicates that the eight-inch carbon steel casing has perforations from 12 to 78 feet deep, with a telescoping six-inch stainless steel 10-slot screen installed from 58.5 to 79. Since the well casing has perforations beginning at 12 feet deep, the gas composition samples collected from this well are likely heavily influenced by the shallow subsurface and not representative of deeper vadose zone activity

The oxygen consumption rates are relatively low at all six wells tested, with the highest utilization calculated for monitoring wells 199-N-169 and 199-N-171. The highest oxygen utilization values would be expected in soil zones with greater levels of hydrocarbon “food” that would tend to support a higher mass of microbes. Note that a hydrocarbon sheen was observed in wells 199-N-169 and 199-N-171 during groundwater sampling in June 2014. The presence of a sheen is evidence that this area could be affected by elevated concentrations of hydrocarbons in the smear zones above the groundwater surface. Comparing oxygen utilization rates in wells across the

affected area indicates that the most significant residual petroleum contamination is likely co-located with monitoring wells 199-N-169 and 199-N-171.

COMPARISON OF BIODEGRADATION RATES OVER TIME

Table 2 presents a comparison of the 2010 pilot test[3], December 2012[4], January 2014[5], June to July 2014[6], December 2014 to January 2015[7], and June to August 2015 respirometry testing data. Data from March 2010 and December 2012 were recalculated (March 23, 2015 memo) using a soil bulk density of 1.736 g/cm^3 and a moisture content of 3.13% for comparison to the most recent biodegradation rate calculations.

Table 2: Comparison of Biodegradation Rates over Time Calculated from In-Situ Respiration Testing

Monitoring Point	Biodegradation Rate (mg/kg-day)					
	Aug. 2015	Jan. 2015	Jul. 2014	Jan. 2014	Dec. 2012	Mar. 2010
199-N-167	-0.05	-0.05	-0.06	-0.01	-0.15	-0.99
199-N-169	-0.12	-0.23	-0.09	-0.07	-0.28	-0.97
199-N-171	-0.14	-0.23	-0.09	-0.05	-9.82	-0.37
199-N-172	-0.04	-0.05	-0.02	-0.01	-0.14	-0.54
199-N-183	NA	NA	NA	-0.09	not tested	not tested
199-N-18	NA	NA	NA	NA	not tested	not tested

NA = Not applicable; oxygen depletion insignificant and biodegradation rate not calculated.

The biodegradation rates exhibit a declining trend from the initial rates measured in 2010. A number of variables could be responsible for the decrease in biodegradation indicated, the most obvious being that the bio-available hydrocarbon food source in the treatment zone has been reduced to levels that no longer support significant biological activity. The concentration of hydrocarbons in vadose zone soils can most accurately be determined by direct soil sampling. Changes in subsurface conditions such as temperature, moisture, and/or nutrient availability may

[3] AMEC Geomatrix, 2010, Technical Memorandum, Results Summary of In-situ Respiration Testing at the N100 Bioremediation Pilot Test Site, March 22.

[4] AMEC Environment & Infrastructure, Inc., 2012, Technical Memorandum, Summary of Respiration Testing Results for the Startup of the Bioremediation System at the N100 Bioremediation Site, December 12.

[5] AMEC Environment & Infrastructure, Inc., 2014, Technical Memorandum, Summary of January 2014 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site, February 7.

[6] AMEC Environment & Infrastructure, Inc., 2014, Technical Memorandum, Summary of June to July 2014 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site, July 28.

[7] Amec Foster Wheeler Environment & Infrastructure, Inc., 2015, Technical Memorandum, Summary of December 2014 to January 2015 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site, March 3.

also have impacted the rates shown, though one would expect only minor fluctuations in temperature and moisture at these depths.

One goal of the recent respirometry tests is to evaluate the effect of seasonal variability on the degradation rates measured, specifically as they relate to the groundwater elevation and temperature at the site. An obvious difference is observed in the biodegradation rates from July 2014 as compared to August 2015, with higher degradation rates calculated for the August 2015 data (with the exception of 199-N-167, which showed no change in rate). The difference in calculated biodegradation rates over time may be partially attributed to changes in sampling methodology. Sampling events prior to July 2014 were conducted over an approximately one week period. The July 2014, January 2015, and August 2015 test events were carried out for significantly longer time periods (five weeks in 2014 and six weeks in 2015), providing more time for ambient conditions to become re-established. The longer test events provided a more robust trend of oxygen utilization, with the data generally exhibiting higher R-squared values, a measure of goodness-of-fit of linear regression.

There also is an obvious difference observed in the biodegradation rates from August 2015 compared with January 2015, with the higher degradation rate calculated for the January 2015 data. Groundwater sampling at the site indicates that elevations of impacted groundwater vary significantly over time, resulting in a smear zone that is likely to be several feet thick. Bioventing will be most effective when groundwater elevations are low and this smear zone is exposed. The summer (August 2015) respirometry test was completed during unseasonably low groundwater levels. Compared to the winter test, current biodegradation rates are almost half for wells 199-N-169, and 199-N-171. The comparison in biodegradation rates between winter and summer, as well as July 2014 (seasonable groundwater levels) and August 2015 (unseasonably low groundwater levels), correlate with the concept that bioventing will be most effective during low groundwater periods. Groundwater at the site has been recorded as 2 to 4 degrees Celsius colder in some winters than the summer months. Although the lower groundwater temperatures would be correlated to lower biodegradation rates, the higher biodegradation rates associated with the seasonally low water level likely outweigh the effects of lower temperatures.

ESTIMATING TIME-FRAME FOR SITE CLOSURE

Previous respirometry test reports (AMEC Environment & Infrastructure, Inc., 2012, Technical Memorandum, Summary of Respiration Testing Results for the Startup of the Bioremediation System at the N100 Bioremediation Site, December 12; AMEC Environment & Infrastructure, Inc., 2014, Technical Memorandum, Summary of January 2014 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site, February 7; AMEC Environment & Infrastructure, Inc., 2014, Technical Memorandum, Summary of June to July 2014 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site, July 28; Amec Foster Wheeler Environment & Infrastructure, Inc., 2015, Technical Memorandum, Summary of December 2014 to January 2015 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site, March 3.) estimated timeframes for site closure which relied on various assumptions regarding level of

contamination present, the cleanup goal, and the biodegradation rate to apply to the affected area. However, there is currently insufficient information available to reduce the uncertainty associated with the assumptions to be able to make a meaningful estimate as to a timeframe for site closure. If an estimate of cleanup timeframe is desired, then additional information regarding the following should be gathered/confirmed:

1) Confirmation of existing TPH concentrations in soil, both above and below the groundwater table. This could be accomplished by completing soil borings and collecting soil samples.
2) Confirmation that impacted soils do not exist outside of the radius of the two air injection wells, and that the radius of existing wells is homogenous (e.g. no channeling of air). This also could be addressed by collecting soil samples.
3) The fluctuating water table (with dissolved TPH and possibly free product) has an ongoing, but ill-defined impact on soil TPH levels within the smear zone where the bioventing system is operating.
4) A determination as to whether a 200 mg/Kg cleanup level will be the final remedial target for soil.
5) A determination as to whether some form of groundwater cleanup (i.e. sparging) will be employed.

SUMMARY AND RECOMMENDATIONS

The respirometry rates from the 2014 and 2015 testing events are generally below literature values for recommending bioventing as a viable remedial option. However, there is clear evidence that oxygen is a limiting factor for microbial degradation in the area of monitoring wells 199-N-169 and -171, and that bioventing will help maintain this biodegradation, even if the rate is somewhat low. The fact that groundwater remains locally impacted at the site and may act as an ongoing hydrocarbon source in the smear zone indicates bioventing will continue to be beneficial as a remedial approach. Amec Foster Wheeler is recommending the following actions at the site be performed over the next year:

- Conduct additional respirometry tests in the upcoming fall/winter (November, 2015 to February 2016) and spring/summer (April to July) time periods to continue to evaluate the effects of seasonal variability and groundwater elevations on the biodegradation rates measured, and to evaluate long-term remediation trends. This testing will be particularly important if a decision is made to proceed with pilot testing of an in-situ sparging system to treat contamination in the saturated zone. Testing events should be coordinated with groundwater sampling events (elevation measurements and sampling for petroleum hydrocarbon concentrations).
- Because of the relatively low respirometry rates measured in the most recent tests, it appears that the longer testing periods produce better (more reliable) results, and therefore future testing should continue to be conducted over a duration of four to six weeks.

- Because the extended purge times had no apparent effect on initially-measured respiration rates, it is recommended that the extended purge times should not be used during subsequent respirometry testing events.
- Consider pulsing the bioventing system on a predetermined schedule, such as one week on, three weeks off, or two weeks on two weeks off. This operational protocol is expected to be sufficient to maintain oxygen levels in the subsurface, while substantially reducing costs for power consumption. This suggested on/off regimen could be adjusted to match other scheduled field events, thereby keeping site visit costs to a minimum. Obviously, cost savings will be negated if the site needs to be visited frequently for other reasons, and so overall project objectives/constraints should be taken into account. Another potential benefit from the pulsing would be the ability to generate additional respiration data outside of major (bi-annual) testing events. If a two-week on and two-week off process is implemented, then the monthly vapor measurements could be scheduled to coincide with the latter part of the two-week shutdown period, providing the opportunity to more frequently monitor oxygen utilization.
- Consider the collection of soil samples at the site to verify achievement of cleanup criteria with respect to hydrocarbons in soil.
- Consider the collection of soil samples to the southwest of 199-N-167, 199-N-169, and 199-N-171 to evaluate whether significant petroleum mass is located along the fringe of system influence.
- Consider the use of an alternate treatment technology that is complementary to the existing treatment system (e.g. groundwater sparging) to treat the hydrocarbon-impacted groundwater and saturated zone soils, in order to accelerate the overall cleanup timeframe. Converting the bioventing system to a combined bioventing/biosparging system is feasible and would be expected to maintain elevated oxygen concentrations in both the saturated and vadose zones. Pilot testing of such a system would be necessary to determine how large the radius of influence would be within the saturated zone.

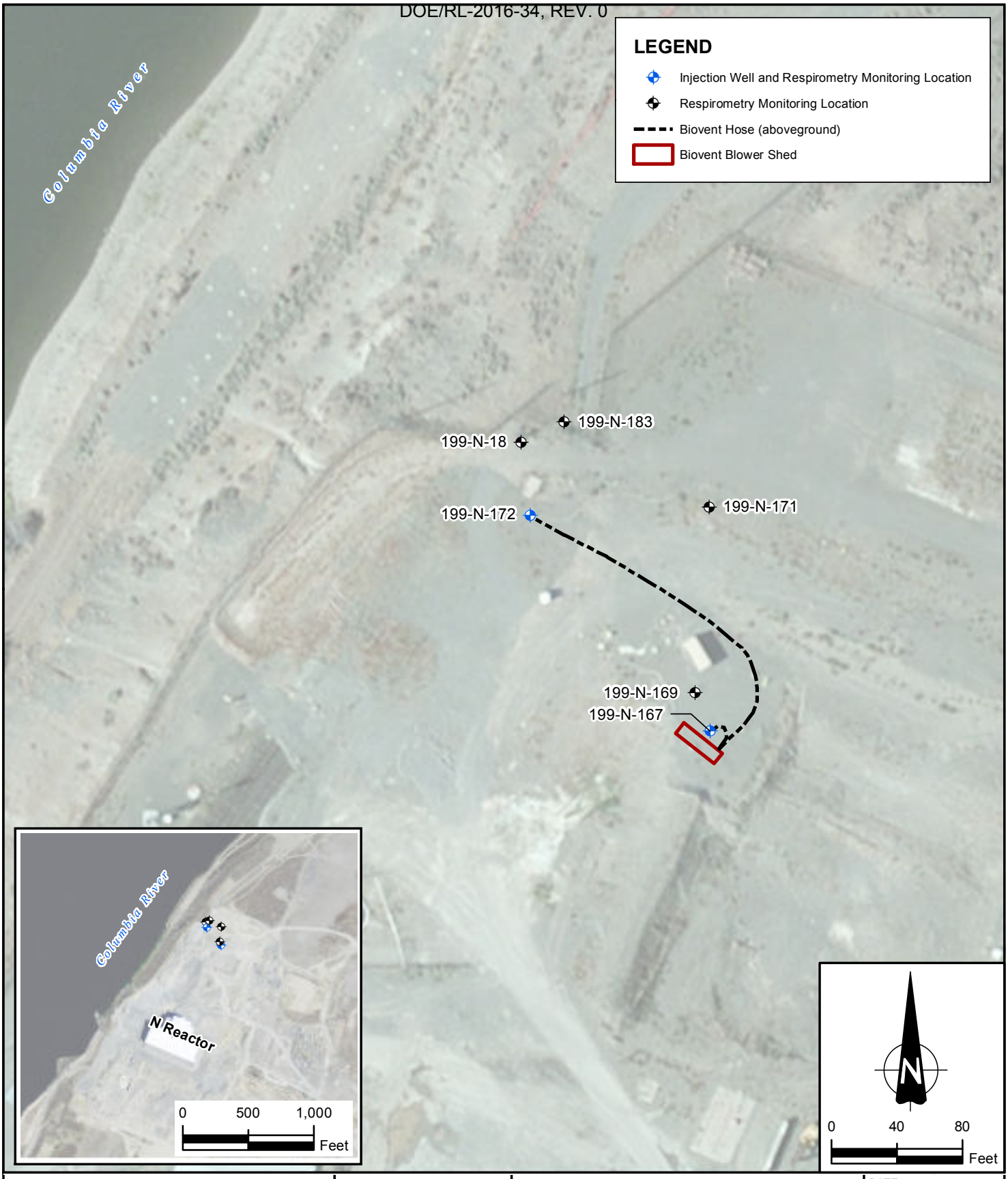
Figures:

Figure – Wells Utilized for Bioventing Respirometry Testing

Attachments:

Attachment 1 – Daily Field Reports and Field Measurements
Attachment 2 – Instrument Calibration Sheets
Attachment 3 – Design Worksheet for Oxygen Utilization and Biodegradation Rates

FIGURE



CHPRC	amec foster wheeler	100-N AREA BIOVENTING SYSTEM	DATE AUGUST 2015
			SCALE 1 " = 80 '
Amec Foster Wheeler Environment & Infrastructure, Inc. 7376 S.W. Durham Road Portland, OR 97224		WELLS UTILIZED FOR BIOVENT RESPIROMETRY TESTING	PROJECT NO. 461M1230342.03.1
			FIGURE 1

DRAWN BY: PM CHECKED BY: JKH

ATTACHMENT 1

Daily Field Reports and Field Measurements

DAILY FIELD REPORT

PROJECT NAME: HANFORD BIO VENT PROJECT

Project No: 461M120342.03.01	Date: 6/22/2015
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial) jg	AMEC Project Manager (Initials)
Weater Conditions	

amec foster wheeler
7376 SW Durham Road
Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

FIELD REPORT NOTES

Time:	Field Notes:

6/21/2015 Sunday calibration.

20:00 - Calibrated units.

6/22/2015 Monday test readings

06:10 - Load equipment and then mobe to site.
06:50 - On site and got equipment ready for days sampling.
08:00 - CH PRC Art Lee, and DOE samplers Barb and Frank on site with their supervisor Kyle. Performed tailgate meeting and did a job review. Did set up inside sampling trucks.
07:15 - Set up on well 169 and started purge for pre baseline with sparging system still on. We will run this collection event and the baseline event longer at wells 169, 167 and 172. For the remainder of the collection events they will be standard purge times. For this pre event no samples will be collected from 167 and 172 due to these being injection points.
8:30 - IH staff on site to clear wells 183 and 18 for access.
8:45 - IH has cleared wells and manifolds have been installed on each.
9:52 - Finished pre baseline sampling. Moved back to well 169. CH PRC staff on site to shut down system.
10:14 - Sparging system is off and began sample collection of the baseline event. Sampling order will be: 169, 167, 171, 183, 172 and then 18 for the rest of these collection events.
13:49 - Baseline event is complete. Moved back to 169.
14:14 - Began standard sampling round with normal purge times.
15:38 - Finished last event of the day. Picked up and mobed off site.

There was no difference between the extended purge sample collections and the standard one. They all appeared identical.

20:30 - Calibrated units.

Contractor's Rep. (Initials)	Continued

DAILY FIELD REPORT

PROJECT NAME: HANFORD BIO VENT PROJECT

Project No: 461M120342.03.01	Date: 6/24/2015
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial) jg	AMEC Project Manager (Initials)
Weater Conditions	

amec foster wheeler
7376 SW Durham Road
Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

FIELD REPORT NOTES

Time:	Field Notes:

6/23/2015 Tuesday Calibration

17:00 - Calibrated units for 6/24/15 sampling event.

6/24/2015 Wednesday sampling event.

07:00 - Load equipment and then mobe to site.
07:55 - On site and got equipment ready for days sampling.
08:00 - CH PRC Art Lee, and DOE samplers Chris and Frank with Kyle their supervisor on site. Did set up inside sampling truck.
08:09 - Set up on well 169 and started purge.
09:00 - Found a replacement valve for well 183 manifold. Gave it to Kyle so he can have maintenance switch it out bad one. Art noted that since vac has been significantly reduced now on 183 we can shorten purge times to 10 min.
09:18 - Finished sampling. Demobed equipment then off site.

11:00 - Calibrated units for 6/25/2015 sampling round.

Contractor's Rep. (Initials)	Continued

DAILY FIELD REPORT

PROJECT NAME: HANFORD BIO VENT PROJECT

Project No: 461M120342.03.01	Date: 6/25/2015
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial) jg	AMEC Project Manager (Initials)
Weater Conditions	

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Phone: 503-639-3400
Fax: 503-620-7892

FIELD REPORT NOTES

Time:	Field Notes:

6/24/2015 Tuesday Calibration

11:00 - Calibrated units for 6/24/15 sampling event.

6/25/2015 Thursday sampling event.

07:00 - Load equipment and then mobe to site.
07:55 - On site and got equipment ready for days sampling.
08:00 - Art Lee could not be on site today. DOE samplers Kevin and Frank with Kyle their supervisor on site. Did set up inside sampling truck.
08:17 - Set up on well 169 and started purge.
09:00 - Kevin pulled and worked on 183 valve. He determined that it was in good operational order when he finished and that we would not need to replace valve.
09:15 - Finished sampling round. Demobed equipment then off site.

10:00 - Demobed and checked equipment at hotel room and then reboxed for return to Portland.
12:00 - Return trip to Portland.

Contractor's Rep. (Initials)	Continued

DAILY FIELD REPORT

PROJECT NAME: HANFORD BIO VENT PROJECT

Project No: 461M120342.03.01	Date: 6/29/2015
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial) jg	AMEC Project Manager (Initials)
Weater Conditions	

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Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

FIELD REPORT NOTES

Time:	Field Notes:

6/28/2015 Sunday Calibration

10:30 - Calibrated units for 6/29/15 sampling event.

6/25/2015 Monday sampling event.

06:30 - Loaded equipment and then mobe to site.
07:10 - On site. Brush fires are burning near 100N. Art called and said area was being evacuated until threat level could be evaluated. Back off site to 200 area.
09:15 - Art Lee called and said site was now ok for work to continue. Returned to 100N
09:30 - On site with DOE samplers Frank and Barb. Set up on well 169 and started purge.
10:40 - Finished sampling round. Demobed equipment then off site.
11:20 - Demobed and checked equipment at hotel room and then reboxed for return to Portland.
12:00 - Return trip to Portland.

Contractor's Rep. (Initials)	Continued

DAILY FIELD REPORT

PROJECT NAME: HANFORD BIO VENT PROJECT

Project No: 461M120342.03.01	Date: 7/7/2015
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial) jg	AMEC Project Manager (Initials)
Weater Conditions	

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Fax: 503-620-7892

FIELD REPORT NOTES

Time:	Field Notes:

7/06/2015 Monday Calibration

10:00 - Calibrated units for 7/07/15 sampling event.

7/07/2015 Tuesday sampling event.

07:00 - Loaded equipment and then mobe to site.
07:55 - On site with DOE samplers Kevin and Frank and Art Lee.
08:08 - Set up on well 169 and started purge.
10:30 - Finished sampling round. Demobed equipment then off site.
11:10 - Demobed and checked equipment at hotel room and then reboxed for return to Portland.
11:50 - Return trip to Portland.

Contractor's Rep. (Initials) | Continued

DAILY FIELD REPORT

PROJECT NAME: HANFORD BIO VENT PROJECT

Project No: 461M120342.03.01	Date: 7/15/2015
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial) jg	AMEC Project Manager (Initials)
Weater Conditions	

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7376 SW Durham Road
Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

FIELD REPORT NOTES

Time:	Field Notes:

7/14/2015 Tuesday Calibration

10:00 - Calibrated units for 7/15/15 sampling event.

7/15/2015 Wednesday sampling event.

04:30 - Loaded equipment and then mobe to site.
07:35 - On site with DOE samplers Kevin and Barb. Art Lee will not be on site today.
08:08 - Set up on well 169 and started purge.
10:30 - Finished sampling round. Demobed equipment then off site.

Contractor's Rep. (Initials)	Continued

DAILY FIELD REPORT

PROJECT NAME: HANFORD BIO VENT PROJECT

Project No: 461M120342.03.01	Date: 7/27/2015
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial) jg	AMEC Project Manager (Initials)
Weather Conditions	

amec foster wheeler
7376 SW Durham Road
Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

FIELD REPORT NOTES

Time:	Field Notes:

7/26/2015 Tuesday Calibration

10:00 - Calibrated units for 7/26/15 sampling event.

7/27/2015 Wednesday sampling event.

03:00 - Loaded equipment and then mobe to site.
07:30 - On site. Set up for sampling.
08:30 - All hands meeting ran late for DOE sampling crew. Barb, Chris and Kyle on site. Set up on well 167 and started purge. Art Lee not on site for this round but his intern was here in his stead.
10:00 - Finished sampling round. Demobed equipment then off site.

Contractor's Rep. (Initials)	Continued

DAILY FIELD REPORT

PROJECT NAME: HANFORD BIO VENT PROJECT

Project No: 461M120342.03.01	Date: 8/3/2015
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial) jg	AMEC Project Manager (Initials)
Weather Conditions	

amec foster wheeler
7376 SW Durham Road
Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

FIELD REPORT NOTES

Time:	Field Notes:

8/2/2015 Sunday Calibration

9:00 - Calibrated units for 8/03/15 sampling event.

8/03/2015 Monday sampling event.

03:00 - Loaded equipment and then mobe to site.
07:30 - On site. Set up for sampling.
08:15 - All hands meeting ran late for DOE sampling crew. Frank and Eddie on site. Set up on well 169.
08:28 - Started purge.
09:14 - Art Lee on site.
09:34 - Finished sampling round. Demobed equipment.
10:05 - Took pictures of manifold changes inside the treatment box then off site.

Contractor's Rep. (Initials) | Continued

ATTACHMENT 2

Instrument Calibration Sheets

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Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.03.01

Date / Time: 6/21/2015 8:00:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	6/21/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	6/21/2015	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	6/21/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	6/21/2015	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	6/21/2015	30 min	zero air	0.19 ppm / 0.02 ppm	n/a	n/a
TVA 1000 (8810682)	6/21/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (8810682)	6/21/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	6/21/2015	30 min	zero air	0.06 ppm / -0.12 ppm	n/a	n/a
TVA 2020 (202001408040)	6/21/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 2020 (202001408040)	6/21/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100

Notes:

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Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.03.01

Date / Time: 6/22/2015 8:30:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	6/22/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	6/22/2015	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	6/22/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	6/22/2015	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	6/22/2015	30 min	zero air	0.31 ppm / -0.18 ppm	n/a	n/a
TVA 1000 (8810682)	6/22/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (8810682)	6/22/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	6/22/2015	30 min	zero air	0.21 ppm / -0.08 ppm	n/a	n/a
TVA 2020 (202001408040)	6/22/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 2020 (202001408040)	6/22/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100

Notes:

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.03.01

Date / Time: 6/23/2015 5:00:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	6/23/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	6/23/2015	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	6/23/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	6/23/2015	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	6/23/2015	30 min	zero air	-0.02 ppm / -0.10 ppm	n/a	n/a
TVA 1000 (8810682)	6/23/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (8810682)	6/23/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	6/23/2015	30 min	zero air	-0.13 ppm / 0.26 ppm	n/a	n/a
TVA 2020 (202001408040)	6/23/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 2020 (202001408040)	6/23/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100

Notes:
This calibration is for the 6/24/2015 sample round.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.03.01

Date / Time: 6/24/2015 11:00:00 AM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	6/24/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	6/24/2015	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	6/24/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	6/24/2015	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	6/24/2015	30 min	zero air	-0.11 ppm / 0.16 ppm	n/a	n/a
TVA 1000 (8810682)	6/24/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (8810682)	6/24/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	6/24/2015	30 min	zero air	-0.20 ppm / 0.18 ppm	n/a	n/a
TVA 2020 (202001408040)	6/24/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 2020 (202001408040)	6/24/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100

Notes:
This calibration is for the 6/25/2015 sample round.

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Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.03.01

Date / Time: 6/28/2015 10:30:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	6/28/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	6/28/2015	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	6/28/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	6/28/2015	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	6/28/2015	30 min	zero air	-0.19 ppm / 0.10 ppm	n/a	n/a
TVA 1000 (8810682)	6/28/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (8810682)	6/28/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	6/28/2015	30 min	zero air	0.36 ppm / 0.04 ppm	n/a	n/a
TVA 2020 (202001408040)	6/28/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 2020 (202001408040)	6/28/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100

Notes:
This calibration is for the 6/29/2015 sample round.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.03.01

Date / Time: 7/6/2015 10:00:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	7/6/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	7/6/2015	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	7/6/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	7/6/2015	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	7/6/2015	30 min	zero air	-0.10 ppm / 0.16 ppm	n/a	n/a
TVA 1000 (8810682)	7/6/2015	30 min	100 ppm Isob.	101 ppm (PID)	n/a	100 ppm
TVA 1000 (8810682)	7/6/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	7/6/2015	30 min	zero air	0.02 ppm / 0.09 ppm	n/a	n/a
TVA 2020 (202001408040)	7/6/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 2020 (202001408040)	7/6/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100

Notes:
This calibration is for the 7/7/2015 sample round.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.03.01

Date / Time: 7/14/2015 10:00:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	7/14/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	7/14/2015	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	7/14/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	7/14/2015	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	7/14/2015	30 min	zero air	0.03 ppm / 0.11 ppm	n/a	n/a
TVA 1000 (8810682)	7/14/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (8810682)	7/14/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	7/14/2015	30 min	zero air	0.18 ppm / 0.03 ppm	n/a	n/a
TVA 2020 (202001408040)	7/14/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 2020 (202001408040)	7/14/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100

Notes:
This calibration is for the 7/15/2015 sample round.

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Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.03.01

Date / Time: 7/26/2015 10:00:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	7/26/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	7/26/2015	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	7/26/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	7/26/2015	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	7/26/2015	30 min	zero air	0.00 ppm / 0.06 ppm	n/a	n/a
TVA 1000 (8810682)	7/26/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (8810682)	7/26/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	7/26/2015	30 min	zero air	0.26 ppm / 0.07 ppm	n/a	n/a
TVA 2020 (202001408040)	7/26/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 2020 (202001408040)	7/26/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100

Notes:
This calibration is for the 7/27/2015 sample round.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.03.01

Date / Time: 8/2/2015 9:00:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	8/2/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	8/2/2015	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	8/2/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	8/2/2015	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	8/2/2015	30 min	zero air	-0.2 ppm / -0.1 ppm	n/a	n/a
TVA 1000 (8810682)	8/2/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (8810682)	8/2/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	8/2/2015	30 min	zero air	0.1 ppm / -0.2 ppm	n/a	n/a
TVA 2020 (202001408040)	8/2/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 2020 (202001408040)	8/2/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100

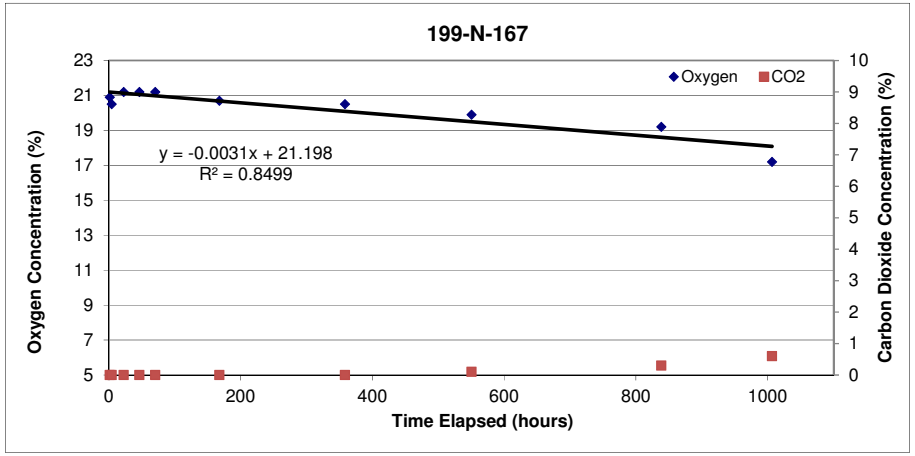
Notes:
This calibration is for the 8/3/2015 sample round.

ATTACHMENT 3

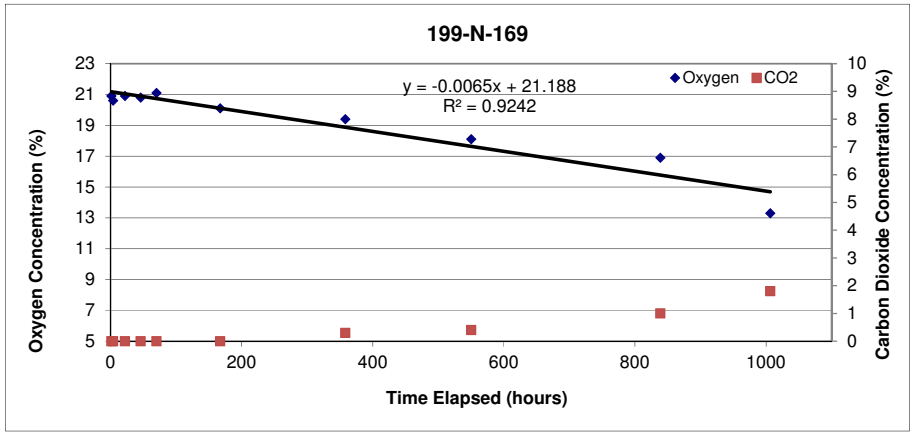
Design Worksheet for Oxygen Utilization and Biodegradation Rates

Oxygen Utilization Generation Plots
June to August 2015 Respirometry Test

199-N-167						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
6/22/2015	8:43		baseline reading	--	21	0
6/22/2015	10:14	6/22/2015 10:14	blower off	0	--	--
6/22/2015	11:36	6/22/2015 11:36	1:22:00	1.37	20.9	0
6/22/2015	14:26	6/22/2015 14:26	4:12:00	4.20	20.5	0
6/23/2015	8:31	6/23/2015 8:31	22:17:00	22.28	21.2	0
6/24/2015	8:29	6/24/2015 8:29	46:15:00	46.25	21.2	0
6/25/2015	8:33	6/25/2015 8:33	70:19:00	70.32	21.2	0
6/29/2015	9:53	6/29/2015 9:53	167:39:00	167.65	20.7	0
7/7/2015	8:28	7/7/2015 8:28	358:14:00	358.23	20.5	0
7/15/2015	8:31	7/15/2015 8:31	550:17:00	550.28	19.9	0.1
7/27/2015	8:44	7/27/2015 8:44	838:30:00	838.50	19.2	0.3
8/3/2015	8:44	8/3/2015 8:44	1006:30:00	1006.50	17.2	0.6



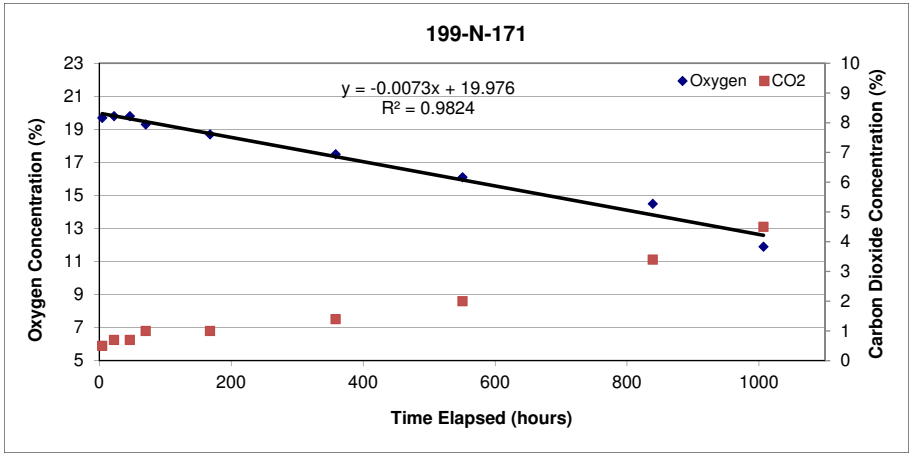
199-N-169						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
6/22/2015	8:43		before system restart	--	21	0
6/22/2015	10:14	6/22/2015 10:14	blower off	0	--	--
6/22/2015	11:29	6/22/2015 11:29	1:15:00	1.25	20.9	0
6/22/2015	14:18	6/22/2015 14:18	4:04:00	4.07	20.6	0
6/23/2015	8:20	6/23/2015 8:20	22:06:00	22.10	20.9	0
6/24/2015	8:15	6/24/2015 8:15	46:01:00	46.02	20.8	0
6/25/2015	8:23	6/25/2015 8:23	70:09:00	70.15	21.1	0
6/29/2015	9:35	6/29/2015 9:35	167:21:00	167.35	20.1	0
7/7/2015	8:17	7/7/2015 8:17	358:03:00	358.05	19.4	0.3
7/15/2015	8:21	7/15/2015 8:21	550:07:00	550.12	18.1	0.4
7/27/2015	8:58	7/27/2015 8:58	838:44:00	838.73	16.9	1
8/3/2015	8:34	8/3/2015 8:34	1006:20:00	1006.33	13.3	1.8



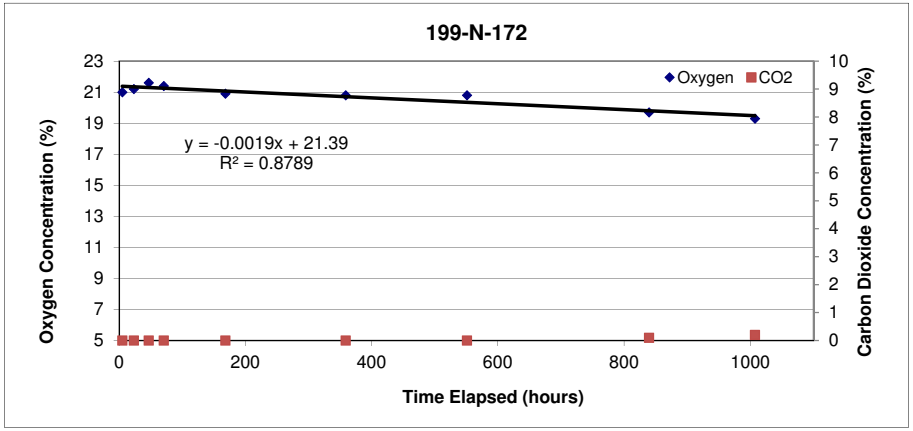
Sheet 1 of 3

Oxygen Utilization Generation Plots
June to August 2015 Respirometry Test

199-N-171						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
6/22/2015	9:00		before system restart	--	19.9	0.7
6/22/2015	10:14	6/22/2015 10:14	blower off	0	--	--
6/22/2015	12:22		initial reading	--	20.1	0.4
6/22/2015	14:38	6/22/2015 14:38	4:24:00	4.4	19.7	0.5
6/23/2015	8:43	6/23/2015 8:43	22:29:00	22.5	19.8	0.7
6/24/2015	8:43	6/24/2015 8:43	46:29:00	46.5	19.8	0.7
6/25/2015	8:42	6/25/2015 8:42	70:28:00	70.5	19.3	1
6/29/2015	10:06	6/29/2015 10:06	167:52:00	167.9	18.7	1
7/7/2015	8:34	7/7/2015 8:34	358:20:00	358.3	17.5	1.4
7/15/2015	8:45	7/15/2015 8:45	550:31:00	550.5	16.1	2
7/27/2015	9:10	7/27/2015 9:10	838:56:00	838.9	14.5	3.4
8/3/2015	8:57	8/3/2015 8:57	1006:43:00	1006.7	11.9	4.5

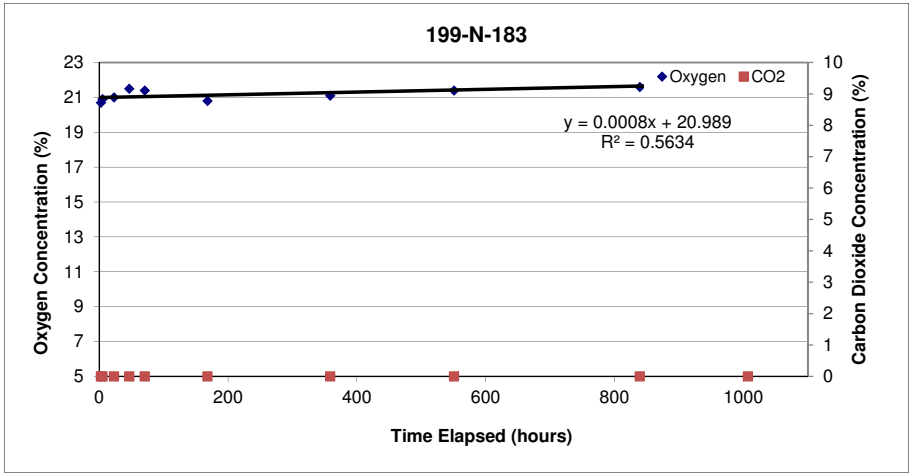


199-N-172						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
6/22/2015	10:14	6/22/2015 10:14	blower off	0	--	--
6/22/2015	12:59		initial reading	--	20.9	0
6/22/2015	15:22	6/22/2015 15:22	5:08:00	5.13	21	0
6/23/2015	9:27	6/23/2015 9:27	23:13:00	23.22	21.2	0
6/24/2015	9:04	6/24/2015 9:04	46:50:00	46.83	21.6	0
6/25/2015	9:01	6/25/2015 9:01	70:47:00	70.78	21.4	0
6/29/2015	10:25	6/29/2015 10:25	168:11:00	168.18	20.9	0
7/7/2015	9:10	7/7/2015 9:10	358:56:00	358.93	20.8	0
7/15/2015	9:17	7/15/2015 9:17	551:03:00	551.05	20.8	0
7/27/2015	9:46	7/27/2015 9:46	839:32:00	839.53	19.7	0.1
8/3/2015	9:34	8/3/2015 9:34	1007:20:00	1007.33	19.3	0.2

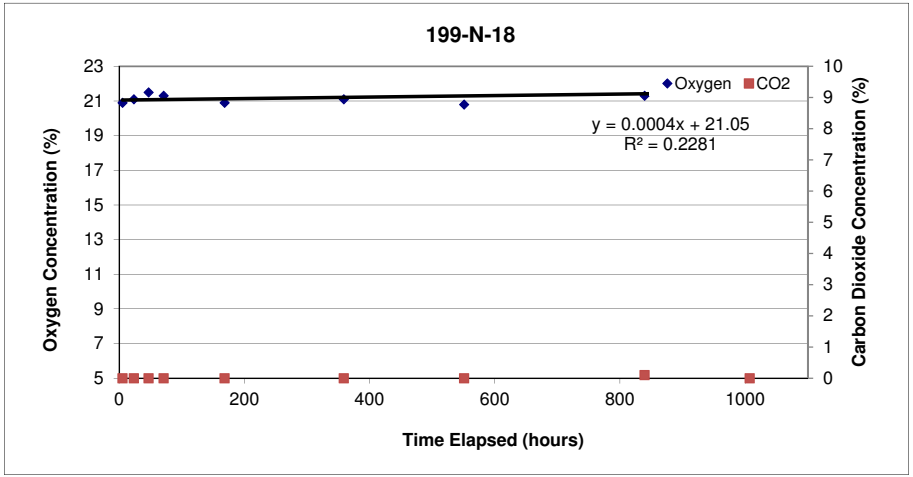


Oxygen Utilization Generation Plots
June to August 2015 Respirometry Test

199-N-183						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
6/22/2015	9:42		before system restart	--	21.2	0
6/22/2015	10:14	6/22/2015 10:14	blower off	0	--	--
6/22/2015	12:56	6/22/2015 12:56	2:42:00	2.70	20.7	0
6/22/2015	15:13	6/22/2015 15:13	4:59:00	4.98	20.9	0
6/23/2015	9:18	6/23/2015 9:18	23:04:00	23.07	21	0
6/24/2015	8:55	6/24/2015 8:55	46:41:00	46.68	21.5	0
6/25/2015	8:54	6/25/2015 8:54	70:40:00	70.67	21.4	0
6/29/2015	10:18	6/29/2015 10:18	168:04:00	168.07	20.8	0
7/7/2015	8:47	7/7/2015 8:47	358:33:00	358.55	21.1	0
7/15/2015	8:59	7/15/2015 8:59	550:45:00	550.75	21.4	0
7/27/2015	9:18	7/27/2015 9:18	839:04:00	839.07	21.6	0
8/3/2015	9:10	8/3/2015 9:10	1006:56:00	1006.93	21.9	0



199-N-18						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
6/22/2015	9:57		before system restart	--	21.2	0
6/22/2015	10:14	6/22/2015 10:14	blower off	0	--	--
6/22/2015	13:49		baseline reading	--	20.8	0
6/22/2015	15:38	6/22/2015 15:38	5:24:00	5.40	20.9	0
6/23/2015	9:40	6/23/2015 9:40	23:26:00	23.43	21.1	0
6/24/2015	9:18	6/24/2015 9:18	47:04:00	47.07	21.5	0
6/25/2015	9:15	6/25/2015 9:15	71:01:00	71.02	21.3	0
6/29/2015	10:40	6/29/2015 10:40	168:26:00	168.43	20.9	0
7/7/2015	9:01	7/7/2015 9:01	358:47:00	358.78	21.1	0
7/15/2015	9:14	7/15/2015 9:14	551:00:00	551.00	20.8	0
7/27/2015	9:31	7/27/2015 9:31	839:17:00	839.28	21.3	0.1
8/3/2015	9:26	8/3/2015 9:26	1007:12:00	1007.20	21.9	0



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Appendix B

January - February 2016 Respirometry Testing

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Memorandum

To	Art Lee, BTR William Faught, CAM CH2M HILL Plateau Remediation Company	Project No.:	661M120343.02.1
		cc	
From	Craig Weber John Kuiper, LG Melissa Roskamp Amec Foster Wheeler Environment & Infrastructure, Inc.		
Date	May 20, 2016		

Subject Summary of January to February 2016 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site

INTRODUCTION

Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler), has prepared this technical memorandum for CH2M HILL Plateau Remediation Company (CHPRC) to summarize the results of the January to February 2016 in-situ respiration test performed at the subsurface bioventing remediation system located at the 100-N Hanford DOE Site in Benton County, Washington. Testing was conducted in accordance with the procedures detailed in the Revised Subsurface Respirometry Test Plan (Test Plan) dated December 30, 2015, with exceptions as noted below.

Since startup in November 2012, the bioventing system has been configured to supply air to the subsurface via two injection wells: 199-N-167 and 199-N-172. Approximately 250 cubic feet per minute (cfm) of air is routed to each well through a custom fitted wellhead. Based on previous studies, it is predicted that the radius of influence (ROI) for each injection well is at least 200 feet.

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The system was in continuous operation since startup through September 30, 2014, except for periodic short-term shutdowns for maintenance and respirometry test events. The longest shutdown period was from September 30, 2014 to December 3, 2014 to replace the PVC air injection manifold with cast steel.

TESTING PROCEDURES

Respiration testing was initiated by turning off the bioventing system blower on January 11, 2016. Gas composition samples were then collected periodically, starting immediately after shut down and continuing through test completion on February 22, 2016. Sampling was conducted by Amec Foster Wheeler and CHPRC field staff from the six wells in the monitoring program (shown on Figure 1):

- 199-N-167 (air injection well),
- 199-N-169 (monitoring well),
- 199-N-171 (monitoring well),
- 199-N-172 (air injection well),
- 199-N-183 (monitoring well), and
- 199-N-18 (monitoring well).

The samples were collected and analyzed to evaluate soil gas concentrations of oxygen, carbon dioxide, methane, and total volatile hydrocarbons (TVH).

Prior to blower shutdown on January 11, 2016, baseline readings were collected from the four monitoring wells (199-N-169, 199-N-171, 199-N-183, and 199-N-18), while the air injection wells were still in operation. Respiration testing was initiated by turning off the bioventing system blowers on January 11, 2016 at 09:03am. Gas composition samples were then collected periodically, starting immediately after shut down and continuing through February 22, 2016. During the respiration testing, soil gas samples were collected and analyzed for oxygen, carbon dioxide, methane, and TVH from the four monitoring wells and two bioventing injection wells.

Twelve samples were collected from two monitoring locations (199-N-167 and 199-N-172) and thirteen samples were collected from four monitoring location (199-N-169, 199-N-171, 199-N-183, and 199-N-18). Samples were collected over a period of approximately 1,008 hours (6 weeks). Readings were collected frequently for the first two days (at approximately 0, 1, 2, 4, 24, 48 and 72 hours) and then at 168 hours (7 days). The bioventing system then remained off for five additional weeks during which four additional sampling events occurred at approximately 361, 552, 744, and 1,008 hours.

Purge times required to achieve the minimum of one casing volume of air extracted prior to monitoring were calculated in the field by the technician, using the pump curve for the purge pump to estimate the actual rate of purging. Sampling was performed according to the Test Plan and direct measurements were made (in-line sampling, no Tedlar bags) consistent with the June-August 2015 sampling event.

Daily field reports and field measurements are included as Attachment 1, and instrument calibration sheets are included as Attachment 2.

BIODEGRADATION RATE RESULTS

The 2004 Air Force Center for Environmental Excellence guidance document[1] was followed for interpretation of results and calculation of oxygen utilization and biodegradation rates. Oxygen utilization rates for each monitoring point were determined from the slope of the line obtained by plotting the measured oxygen concentration versus time for each monitoring point. Oxygen utilization rates are presented in Tables 1 and 2, and supporting data, calculations, and graphs of the data are included as Attachment 3.

Biodegradation rates were calculated using the following equation:

$$K_b = \frac{-k_o\ \theta_a\ \rho_{o2}\ C \times 0.01}{\rho_k}$$

Where (calculated or assumed values for the site follow each description):

- K_b: biodegradation rate calculated in mg hydrocarbon consumed per kg of soil per day
- k_o: oxygen utilization rate calculated for each monitoring point in $\%O_2$ consumed per day
- θ_a: gas-filled pore space (volumetric content at the vapor phase) = 0.19 cm^3 gas/cm^3 soil (based on measured value)
- ρ_{O2}: density of oxygen; assumed soil temp of 50ºF = 1,378 mg/L[1]
- C: mass ratio of hydrocarbons to oxygen required for mineralization (calculated assuming diesel as $C_{10}H_{20}$ and stoichiometric relationship of $C_{10}H_{20} + 15O_2 \Rightarrow 10CO_2 + 10H_2O$) = 0.29
- ρ_k: soil bulk density; measured value = 1.736 g/cm^3 (measured value)
- θ: total porosity (where $\theta = 1 - \rho_k/\rho_T$) = 0.22 cm^3/cm^3 (based on measured value)
- θ_w: water filled porosity (where $\theta_w = M^*\rho_k/\rho_T$) = 0.04 cm^3/cm^3 (based on measured value)

[1] Air Force Center for Environmental Excellence, 2004, Procedures for Conducting Bioventing Pilot Tests and Long-Term Monitoring of Bioventing Systems, May.

- ρ_T: soil mineral density; assumed value = 2.65 g/cm^3
- M: moisture content; 3.13% (measured value) = 0.0313 g moisture per g soil

Relevant Units: mg=milligram, kg= kilograms, %= percent, g= grams, cm= centimeter, mg/L=milligrams per liter, ºF= degrees Fahrenheit

The values for soil bulk density (1.736 g/cm^3) and moisture content (3.13%) are based on the average of two representative soil samples collected from well 199-N-183 at depth intervals of 53-55 feet and 63-65 feet below ground surface (bgs), as presented in Attachment 3 and described in detail in AMEC[2] (2014). Calculations prior to January 2014 were made using the bulk density (2.063 g/cm^3) measured from a single soil sample collected from 58-60 feet bgs in 199-N-183. The updated soil bulk density value of 1.736 g/cm^3 is considered more representative of the overall site lithology. The values for θ_a, θ, and θ_w from all of the monitoring events were adjusted using the updated bulk density value.

For the 6-week in-situ respirometry test initiated on January 11, 2016, calculated biodegradation rates and baseline measurements of oxygen are presented in Table 1. During the respiration test, methane and TVH were detected throughout the test at all the monitoring points, albeit mostly at low-level concentrations. The highest concentrations[3] of both constituents (TVH at 246 parts per million [ppm] and methane at 125 ppm) were detected in 199-N-171; these results exhibit an increase in maximum values detected as compared to concentrations from the June 2014 and both 2015 tests. It is noted that 199-N-171 is located within the upper-central portion of the groundwater plume and typically displays a product sheen on the groundwater. A groundwater sample collected from this well on February 17, 2016 during respirometry testing had the site's highest total petroleum hydrocarbons (TPH, diesel and motor oil range) concentrations of 13,800 micrograms per liter (ug/L) TPH. The groundwater result and corresponding respirometry TVH results are indicative of a residual source area. A characterization borehole installed in February 2015 to a depth of 10 m (located approximately 150 feet to the southwest of 199-N-171) encountered no petroleum contamination in excess of site soil and groundwater cleanup criteria in vadose zone soils, effectively ruling out the potential for an as-yet unidentified vadose zone source area within the area of influence of 199-N-171. The recent vapor and groundwater analyses, together with the absence of an identified remaining vadose zone source, are indicative of residual hydrocarbon

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[2] AMEC Environment & Infrastructure, Inc., 2014, Technical Memorandum, Summary of January 2014 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site, February 7.

[3] A TVH concentration of 6,414 ppm was measured at 199-N-171 at 9:09 AM on 1/12/2016, however this result is invalid because it was taken immediately after replacing a hose, which was then discovered to be contaminated with lubricating oil. Following this discovery, the hose was again replaced and all subsequent readings are considered valid.

contamination within a “smear” zone resulting from groundwater elevation fluctuations. These fluctuations cause hydrocarbon free-phase and dissolved constituents to be continually re-applied to soils located within the smear zone. Such zones are generally amenable to enhanced degradation through bioventing efforts during periods of low groundwater elevation – particularly if the soil lithology allows the pore spaces to effectively drain.

Table 1
Soil Gas Monitoring Results, Oxygen Utilization and Biodegradation Rates Calculated from In-Situ Respiration Testing, January and February 2016.

Monitoring Point	Initial Oxygen	Final Oxygen	Oxygen Utilization	Hydrocarbon Biodegradation Rate
	(%)	(%)	(%/day)	(mg/kg-day)
199-N-167	21.1	17.1	0.09	-0.07
199-N-169	21.0	13.3	0.16	-0.12
199-N-171	20.3	10.6	0.25	-0.19
199-N-172	21.2	18.7	0.05	-0.04
199-N-183	21.1	20.1	NA	NA
199-N-18	21.2	20.5	NA	NA

NA = Not applicable; oxygen depletion insignificant and biodegradation rate not calculated.

Baseline or initial oxygen concentrations were near atmospheric levels in all six monitoring locations. Oxygen concentrations in monitoring wells 199-N-183 and 199-N-18 remained above 20% throughout the test and exhibited insignificant oxygen depletion; therefore, a biodegradation rate was not calculated for those wells. The results for these two wells are consistent with previously conducted respirometry test results as shown in Table 2 below and Attachment 3. Well construction information for 199-N-18 indicates that the eight-inch carbon steel casing has perforations from 12 to 78 feet deep, with a telescoping six-inch stainless steel 10-slot screen installed from 58.5 to 79 feet. Since the well casing has perforations beginning at 12 feet deep, the gas composition samples collected from this well are likely heavily influenced by the shallow subsurface and not representative of deeper vadose zone activity. Both of these wells (199-N-18 and 199-N-183) are located within the middle portion of the groundwater plume (lower-concentration area), approximately 100 feet down-gradient of 199-N-171 (high concentration area).

Because significant respiration is not measured at 199-N-18 and 199-N-183, it is likely that some other factor is limiting bacterial activity such as a lack of organic matter (hydrocarbons) in the interval around the well screens. *[However, it is noted that site data indicate that petroleum-degrading bacteria are present within the groundwater plume, and that dissolved oxygen may be a limiting factor to cleanup within the groundwater plume and smear-zone soils. As measured in December 2013, dissolved oxygen concentrations decline significantly from up-gradient of the plume (4.77 mg/L in 199-N-56 and 4.95 mg/L in 199-N-3) to the upper plume (2.71 mg/L in 199-N-*

171), and decline even further in the middle plume (0.28 mg/L in 199-N-183)]. Dissolved oxygen at these locations show similar trends in February 2016 measurements with concentrations of 5.4 mg/L in 199-N-56, 5.14 mg/L in 199-N-3, 3.45 mg/L in 199-N-171, and 0.11 mg/L in 199-N-183.

The oxygen consumption rates are relatively low (compared to bioventing literature values) at all six wells tested, with the highest utilization calculated for monitoring wells 199-N-169 and 199-N-171. The highest oxygen utilization values would be expected in soil zones with greater levels of hydrocarbon "food" that would tend to support a higher mass of microbes. Note that a hydrocarbon sheen was observed in wells 199-N-169 and 199-N-171 during groundwater sampling in June 2014 and in a sample collected from well 199-N-171 in February 2016. The presence of a sheen is evidence that this area could be affected by elevated concentrations of hydrocarbons in the smear zone above the groundwater surface. Comparing oxygen utilization rates in wells across the affected area indicates that the most significant residual petroleum contamination is likely co-located with monitoring wells 199-N-169 and 199-N-171.

COMPARISON OF BIODEGRADATION RATES OVER TIME

Table 2 presents a comparison of the 2010 pilot test[4], December 2012[5], January 2014[6], June to July 2014[7], December 2014 to January 2015[8], June to August 2015[9], and January to February 2016 respirometry testing data. Data from March 2010 and December 2012 were recalculated using a soil bulk density of 1.736 g/cm^3 and a moisture content of 3.13% for comparison to the most recent biodegradation rate calculations.

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[4] AMEC Geomatrix, 2010, Technical Memorandum, Results Summary of In-situ Respiration Testing at the N100 Bioremediation Pilot Test Site, March 22.

[5] AMEC Environment & Infrastructure, Inc., 2012, Technical Memorandum, Summary of Respiration Testing Results for the Startup of the Bioremediation System at the N100 Bioremediation Site, December 12.

[6] AMEC Environment & Infrastructure, Inc., 2014, Technical Memorandum, Summary of January 2014 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site, February 7.

[7] AMEC Environment & Infrastructure, Inc., 2014, Technical Memorandum, Summary of June to July 2014 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site, July 28.

[8] Amec Foster Wheeler Environment & Infrastructure, Inc., 2015, Technical Memorandum, Summary of December 2014 to January 2015 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site, March 3.

[9] Amec Foster Wheeler Environment & Infrastructure, Inc., 2015, Technical Memorandum, Summary of June to August 2015 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site, Sept 1.

Table 2
Comparison of Biodegradation Rates over Time Calculated from In-Situ Respiration Testing

Monitoring Point	Biodegradation Rate (mg/kg-day)						
	Feb. 2016	Aug.2015	Jan. 2015	Jul. 2014	Jan. 2014	Dec. 2012	Mar. 2010
199-N-167	-0.07	-0.05	-0.05	-0.06	-0.01	-0.15	-0.99
199-N-169	-0.12	-0.12	-0.23	-0.09	-0.07	-0.28	-0.97
199-N-171	-0.19	-0.14	-0.23	-0.09	-0.05	-9.82	-0.37
199-N-172	-0.04	-0.04	-0.05	-0.02	-0.01	-0.14	-0.54
199-N-183	NA	NA	NA	NA	-0.09	not tested	not tested
199-N-18	NA	NA	NA	NA	NA	not tested	not tested

NA = Not applicable; oxygen depletion insignificant and biodegradation rate not calculated.

The biodegradation rates exhibit a declining trend from the initial rates measured in 2010, and have been relatively stable since January 2015. A number of variables could be responsible for the decrease in biodegradation indicated, the most obvious being that the bio-available hydrocarbon food source in the treatment zone has been reduced to levels that no longer support significant biological activity. The concentration of hydrocarbons in vadose zone soils can most accurately be determined by direct soil sampling. Changes in subsurface conditions such as temperature, moisture, and/or nutrient availability may also have impacted the rates shown, though one would expect only minor fluctuations in temperature and moisture at these depths.

One goal of the recent respirometry tests is to evaluate the effect of seasonal variability on the degradation rates measured, specifically as they relate to the groundwater elevation and temperature at the site. With the exception of a slight increase in the observed biodegradation rate at 199-N-167, the biodegradation rates observed in February 2016 are less than in January of 2015. There was an increase at 199-N-167 and 199-N-171 between August 2015 values and those observed in February 2016.

Groundwater sampling at the site indicates that elevations of impacted groundwater vary over time, resulting in a smear zone that is likely to be several feet thick. Bioventing will be most effective when groundwater elevations are low and this smear zone is exposed. The Columbia River water levels were unseasonably lower in 2015 with only about 1.5 meters of difference between low and high river stage compared to the typical 2-3 meter difference. While there was an increase to the respirometry rates from the August 2015 event to the February 2016 event, the increase is likely related to changes in the groundwater elevation. The decrease in the respirometry rate compared to January 2015 may be attributed in part to less smearing because of the smaller water elevation change in 2015.

Trend Charts 1 and 2 show the concentration trends for TPH-diesel measured in groundwater samples collected from the bioventing wells during the respirometry tests. Chart 1 shows the

TPH-diesel concentration trends for bioventing injection well 199-N-167 and its nearby monitoring well 199-N-169, TPH-diesel concentration trends for bioventing injection well 199-N-172 and its nearby monitoring well 199-N-171 are provided in Chart 2.

The TPH-diesel concentrations are lower in the 199-N-167/199-N-169 pair than in the 199-N-171/199-N-172 pair. Concentrations are also fairly constant in monitoring well 199-N-169 and decreasing in the injection well 199-N-167. This could be an indication that TPH contamination in the deep vadose zone at this location is cleaning up with minimal exchange between the soil and groundwater in the periodically rewetted zone (PRZ). At wells 199-N-171 and 199-N-172 the TPH-diesel concentrations are trending up; evidence that TPH contamination is still present in the deep vadose zone and exchange between soil and groundwater in the PRZ is occurring.

Chart 1
Wells 199-N-167 and 199-N-169 Groundwater TPH-Diesel Concentration

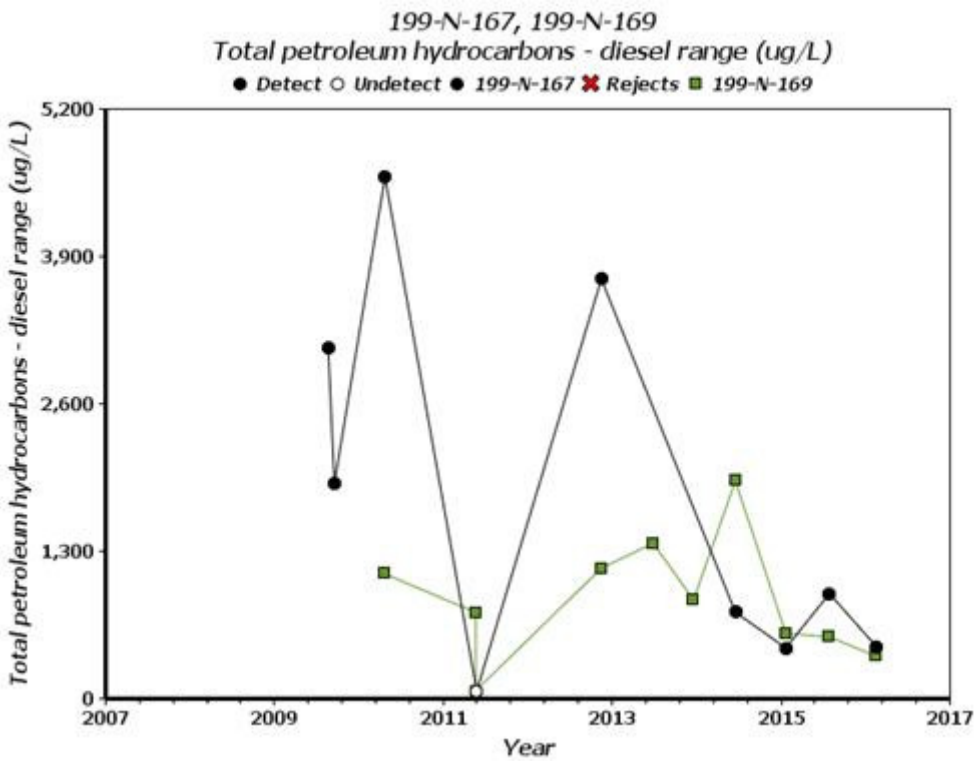
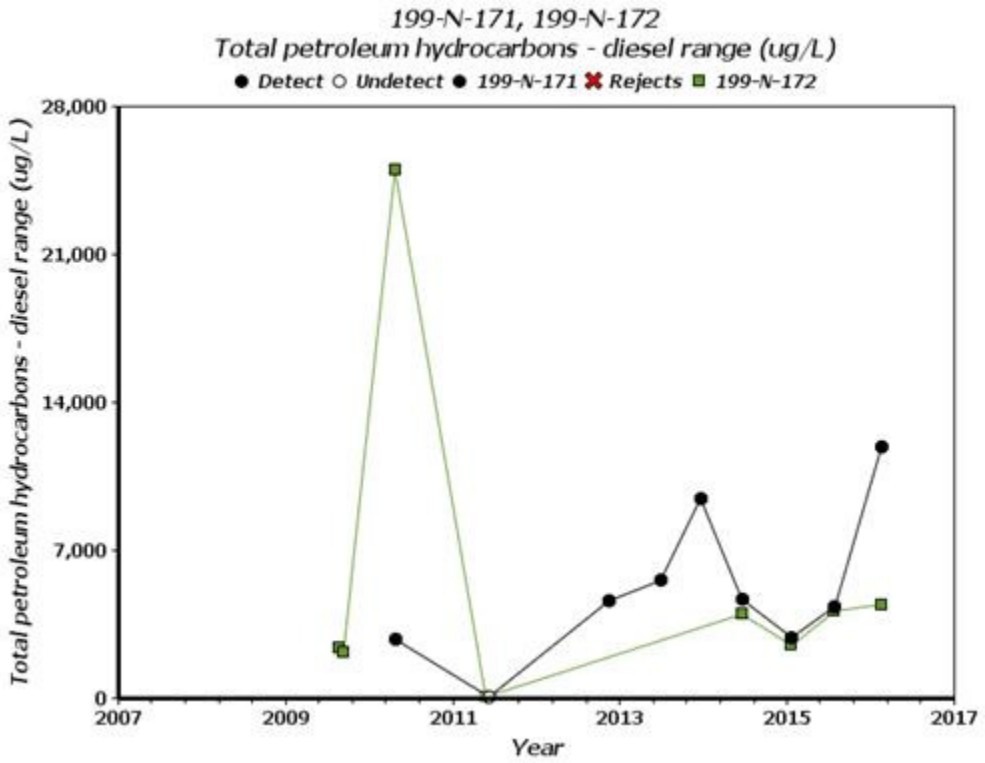


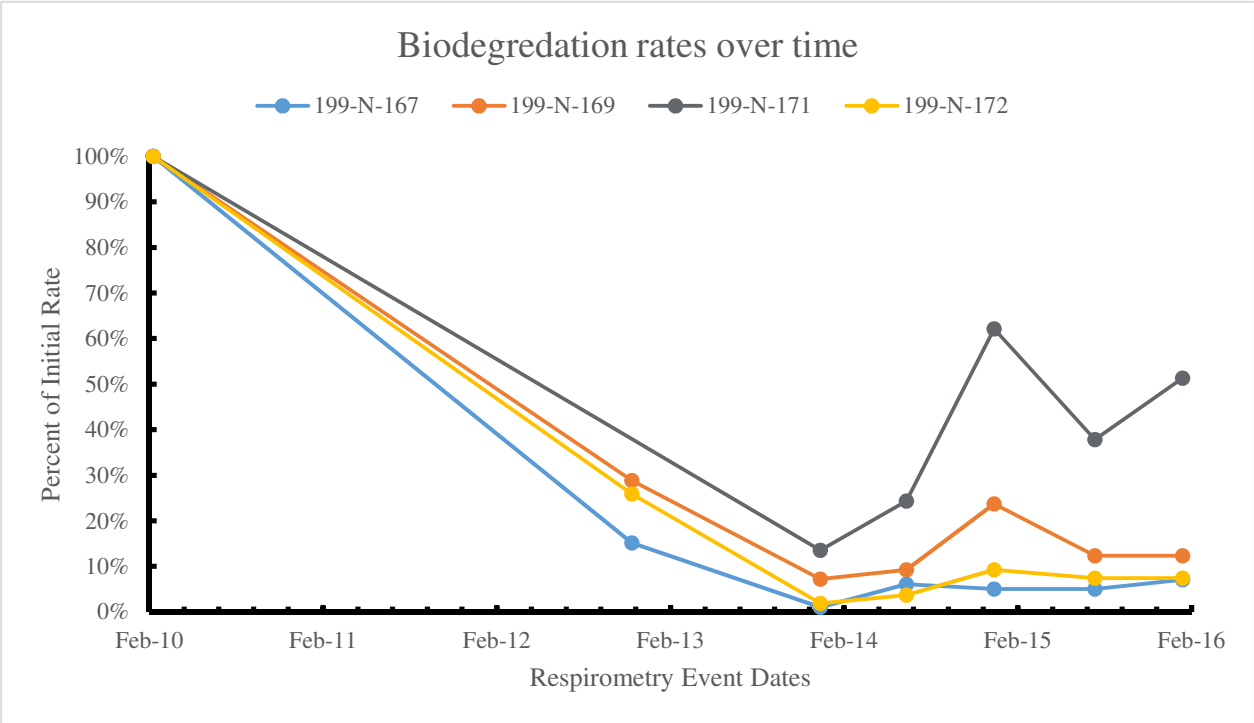
Chart 2
Wells 199-N-171 and 199-N-172 Groundwater TPH-Diesel Concentration



SUMMARY AND RECOMMENDATIONS

The respirometry rates from the February 2016 event remain generally below literature values for recommending bioventing as a cost effective remedial option. However, there is clear evidence that oxygen is a limiting factor for microbial degradation in the area of monitoring wells 199-N-169 and 199-N-171 and that bioventing will help maintain this biodegradation, even if the rate is somewhat low. As is frequently the case with remediation systems, cleanup rates may become asymptotic and efficiencies decrease as target contamination is removed. It appears that asymptotic levels have been achieved with respect to treatment within the unsaturated vadose zone at this site (Chart 3). While some treatment of the vadose zone likely continues, the majority of the biodegradation currently occurring appears to be associated with the smear zone. While bioventing will continue to be beneficial as a remedial action, particularly during times of low groundwater, cleanup of the site groundwater and smear zone will be difficult to treat with the current system. Amec Foster Wheeler therefore recommends the addition of groundwater biosparging (injection of air [oxygen] into groundwater) to increase biological degradation of hydrocarbons in soil and groundwater to achieve site cleanup goals.

Chart 3
Diminishing rates of hydrocarbon biodegradation



Note: December 2012 respirometry data for 199-N-171 was determined to be an outlier and has been removed from Chart 3.

The application of biosparging could complement the existing bioventing system and expedite the overall petroleum cleanup[10]. Biosparging also has been identified as a proposed remedy in the 100-NR-1 and 100-NR-2 Operable Units Proposed Plan[11].

Biosparging, or injection of atmospheric air into the shallow saturated zone, promotes bioremediation of both the shorter and longer-chain petroleum compounds, with the shorter chain compounds more easily degraded. Groundwater and soil analytical data collected during well installation indicates that lighter-end fractions of diesel (C12 and lighter) do not appear to be present in significant concentrations at the site. Biosparging would enhance the current treatment of site hydrocarbons, which consist primarily of the heavier fractions of diesel. If biosparging were to be employed at the site, it is expected to treat petroleum contamination within the smear zone,

[10] Amec Foster Wheeler, 2015. Summary of December 2014 to January 2015 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site, March 3.

[11] DOE/RL-2012-68, 2013. Proposed Plan for Remediation of the 100-NR-1 and 100-NR-2 Operable Units, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, WA.

saturated zone, and groundwater, and thereby complement the overlying vadose zone bioventing treatment. Biosparging would provide the oxygen needed to promote bioremediation processes below the fluctuating water table and move the site towards closure. Amec Foster Wheeler has previously submitted conceptual site plans and background information in the draft memorandum dated June 2, 2015 and titled “Evaluate Feasibility of Converting Existing Bioventing Wells to Combination Bioventing/Air Biosparging Wells at 100-N.”

Amec Foster Wheeler recommends conducting a pilot test to determine the suitability of converting existing wells to combination bioventing and sparge wells. Either 199-N-167 or 199-N-171 could be selected for conversion. Alternatively, it may prove to be more cost effective to install dedicated sparge wells which are specifically engineered for biosparging. In addition, two monitoring wells should be installed downgradient to monitor the effects of biosparging on the subsurface. The recommended operational testing conditions for the combined bioventing and air sparging are as follows:

- Air Biosparging– It is expected that if using the recommended equipment that the air flow rate would be approximately 10 cfm at a pressure of about 8 to 10 pounds per square inch (psi) (at the well head).
- Bioventing – Normal operating conditions with air flow approximately 250 to 300 standard cubic feet per minute (scfm) at a positive pressure of approximately 50 to 60 inches of water column.

The primary purpose of the pilot test would be to perform a qualitative evaluation of the achievable ROI, and attempt to determine how rapidly geochemical/biological changes propagate within the saturated zone relative to groundwater flow. This data would be used to determine the feasibility, costs, and potential timeline for achieving treatment goals.

In summary, Amec Foster Wheeler is recommending the following actions in 2016 at the site:

- Conduct on-going low-water and high-water (fall/spring) bioventing testing events to monitor for changes in overall biological activity, and provide updated biodegradation rates and cleanup timeframes for the site. Groundwater monitoring should be conducted concurrently with the respiration testing so that respirometry testing can be correlated against contaminant concentrations and the area of exposed smear zone soil.
- Use a pilot scale test to evaluate the effectiveness of adding a biosparging component to the existing bioventing system, thereby promoting further remediation of areas of contamination beneath the water table, and accelerating the overall cleanup timeframe. By converting the bioventing system to a combined bioventing/biosparging system, Amec Foster Wheeler expects to maintain elevated oxygen concentrations in both the saturated and vadose zones. Testing of such a system would be necessary to determine how large the ROI would be within the saturated zone and how quickly the system would reduce

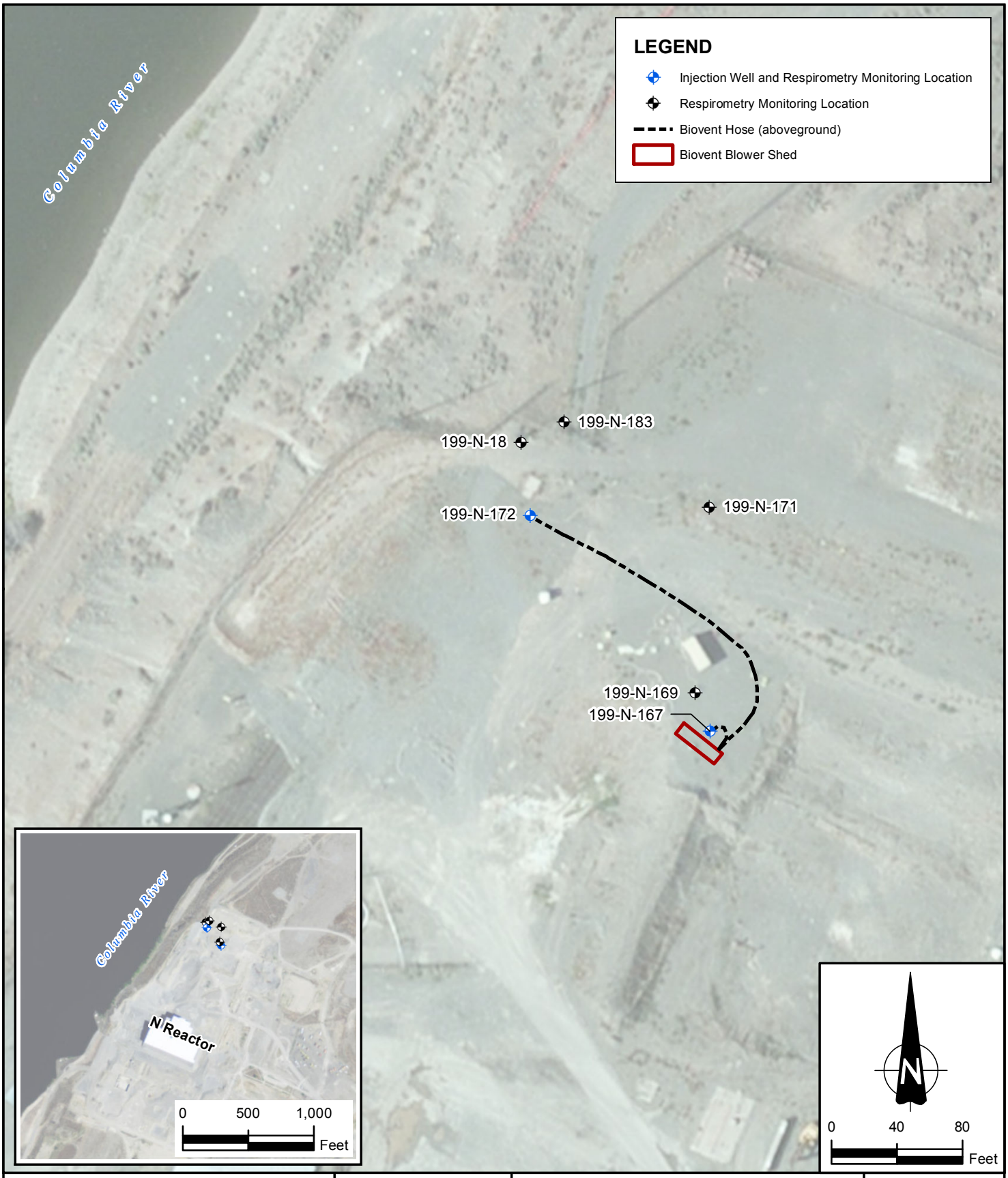
contaminant levels in groundwater and the smear zone to cleanup goals. The first step of this process will be to prepare the plans and design for the installation and monitoring of the pilot scale system. The plans and specifications should also identify the possible footprint of a full-scale system, should the results of the pilot test be successful and indicate an expansion is warranted.

- Consider the collection of soil samples within the cleanup area of the site to verify progress toward achievement of cleanup goals for soil. [Note: this sampling might be able to be combined *with the installation of new biosparging and monitoring wells].*
- Consider the collection of soil and groundwater samples to measure numbers of hydrocarbon-degrading bacteria prior to commencement of a combined bioventing/biosparging pilot test. Other geochemical and nutrient parameters should also be measured in soil and groundwater.
- Consider pulsing of the bioventing system (1 week on, 3 weeks off). If coordinated such that system down times are matched up with the regularly-scheduled monthly bioventing well measurements, then the carbon dioxide and methane test results could be used to provide additional respiration data for use in on-going evaluation of system performance.

Figures:
Figure – Wells Utilized for Biovent Respirometry Testing

Attachments:
Attachment 1 – Daily Field Reports and Field Measurements
Attachment 2 – Instrument Calibration Sheets
Attachment 3 – Design Worksheet for Oxygen Utilization and Biodegradation Rates

FIGURE



CHPRC	amec foster wheeler	100-N AREA BIOVENTING SYSTEM	DATE APRIL 2016
			SCALE 1 " = 80 '
Amec Foster Wheeler Environment & Infrastructure, Inc. 7376 S.W. Durham Road Portland, OR 97224		WELLS UTILIZED FOR BIOVENT RESPIROMETRY TESTING	PROJECT NO. 661M1230343.02.1
			FIGURE 1

DRAWN BY: PM CHECKED BY: JKH

ATTACHMENT 1

Daily Field Reports and Field Measurements

DAILY FIELD REPORT

PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 461M120342.12.01	Date: 1/11/2016
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial) jg	AMEC Project Manager (Initials)
Weather Conditions	

amec foster wheeler
7376 SW Durham Road
Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

FIELD REPORT NOTES

Time:	Field Notes:

1/10/2016 Sunday Calibration

9:00 - Calibrated units for 1/11/16 sampling event.

1/11/2016 Monday sampling event.

06:30 - Loaded equipment and then mobe to site.
07:15 - On site. Set up for sampling. Art on site shortly after as well as IH personnel.
07:30 - Kevin and Chris on site. Set up on well 171 for baseline pre shut down sampling. Baseline samples will be collected from wells: 169, 171, 183 and 18 (wells not on line with sparge system). After baseline is collected we will collect four rounds of sample data from all six wells after bio vent operation is shut down. This is one less then is in our procedures and is due to DOE crew needing to be back at their facility no later then 15:30. IH screened and cleared wells 183 and 18 then left site.
08:08 - Started purge on 171.
08:59 - Baseline sampling completed on all four non system wells, ending at 169.
09:03 - Bio vent operation shut down.
09:05 - Set up on system injection well 169 and started purge.
14:51 - Finished last sampling round, ending at 18. Demobed equipment.
15:15 - Off site.

Contractor's Rep. (Initials)

Continued

DAILY FIELD REPORT

PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 461M120342.12.01	Date: 1/12/2016
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial) jg	AMEC Project Manager (Initials)
Weather Conditions	

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Fax: 503-620-7892

FIELD REPORT NOTES

Time:	Field Notes:

1/11/2016 Monday Calibration

18:00 - Calibrated units for 1/12/16 sampling event.

1/12/2016 Tuesday sampling event.

08:00 - Loaded equipment and then mobe to site.
08:55 - On site with DOE operators Randy and Chris as well as Art and IH personnel. IH screened and okayed wells 183 and 18 then off site. Set up for sampling at well 171. Start time was set based on completion of baseline sampling.
09:09 - Started purge on 171. Well sampling progression will be 171, 183, 18, 173, 169 and then 167
10:20 - Finished last well . Demobed equipment.
10:30 - Off site.

Contractor's Rep. (Initials)	Continued

DAILY FIELD REPORT

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	461M120342.12.01	Date:	1/13/2016
Field Report No:		Page:	1
Arrival:		Departure:	
AMEC Field Rep. (Initial)	jg	AMEC Project Manager (Initials)	
Weather Conditions	Cloudy rain showers 33F 29.253 pressure trending down		

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Fax: 503-620-7892

FIELD REPORT NOTES

Time:	Field Notes:

1/12/2016 Tuesday Calibration

15:00 - Calibrated units for 1/13/16 sampling event.

1/13/2016 Wednesday sampling event.

07:45 - Loaded equipment and then mobe to site.
07:30 -
08:00 -DOE operators Randy and Chris as well IH personnel. IH screened and okayed wells 183 and 18 then off site. Set up for sampling at well 171 using TVA - 1000 s/n #1111734 and GEM 2000 s/n # 1116992.
09:09 - Started purge on 171. Well sampling progression will be 171, 183, 18, 173, 169 and then 167
10:20 - Finished last well . Demobed equipment.
10:30 - Off site.

Contractor's Rep. (Initials)

Continued

DAILY FIELD REPORT

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	461M120342.12.01	Date:	1/14/2016
Field Report No:		Page:	1
Arrival:		Departure:	
AMEC Field Rep. (Initial)	jg	AMEC Project Manager (Initials)	
Weather Conditions	Cloudy rain showers 33F 29.253 pressure trending down		

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FIELD REPORT NOTES

Time:	Field Notes:

1/13/2016 Tuesday Calibration

15:00 - Calibrated units for 1/14/16 sampling event.

1/14/2016 Wednesday sampling event.

07:45 - Loaded equipment and then mobe to site.
08:30 - On site with IH Tracey.
08:00 -DOE operators Randy , Frank and their supervisor Kyle as well as Art Lee on site. IH screened and okayed wells 183 and 18 then off site. Set up for sampling at well 171 using TVA - 1000 s/n #1111734 and GEM 2000 s/n # 1116992.
09:09 - Started purge on 171. Well sampling progression will be 171, 183, 18, 173, 169 and then 167
10:20 - Finished last well . Demobed equipment.
10:30 - Off site.

Contractor's Rep. (Initials) | Continued

DAILY FIELD REPORT

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	461M120342.12.01	Date:	1/18/2016
Field Report No:		Page:	1
Arrival:		Departure:	
AMEC Field Rep. (Initial)	jg	AMEC Project Manager (Initials)	
Weather Conditions	Partly cloudy 34 F		

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FIELD REPORT NOTES

Time:	Field Notes:

1/17/2016 Sunday Calibration

15:00 - Calibrated units for 1/18/16 sampling event.

1/18/2016 Monday sampling event.

03:45 - Loaded equipment and then mobe to site.
09:05 - On site with Art Lee, DOE crew of Frank, Chris and their supervisor Kyle and IH personal Tracey. IH screened and okayed wells 183 and 18 then off site. Set up for sampling at well 171 using TVA - 1000 s/n #1111734 and GEM 2000 s/n # 1116992.
09:10 - Started purge on 171. Well sampling progression will be 171, 183, 18, 173, 169 and then 167
10:18 - Finished last well . Demobed equipment.
10:30 - Off site.

Contractor's Rep. (Initials)

Continued

DAILY FIELD REPORT

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	461M120342.12.01	Date:	1/26/2016
Field Report No:		Page:	1
Arrival:	9:00	Departure:	11:05
AMEC Field Rep. (Initial)	TM	AMEC Project Manager (Initials)	JK
Weather Conditions	Mostly cloudy 33 F		

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FIELD REPORT NOTES

Time:	Field Notes:

1/25/2016 Monday Calibration

19:00 - Calibrated units for 1/26/16 sampling event.

1/26/2016 Tuesday sampling event.

07:45 - Loaded equipment and then mobe to site.
09:00 - On site with Art Lee
09:40 - DOE crew of Kevin, Randy, and their supervisor and IH personnel 'RS' arrived onsite. IH screened and okayed wells 183 and 18 then off site. Set up for sampling at well 171 using TVA - 1000 s/n #1111734 and GEM 2000 s/n # 1116992.
09:10 - Started purge on 171. Well sampling progression will be 171, 183, 18, 172, 167 and then 169
10:52 - Finished last well . Demobed equipment.
11:05 - Off site.

Contractor's Rep. (Initials)

Continued

DAILY FIELD REPORT

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	461M120342.12.01	Date:	1/26/2016
Field Report No:		Page:	1
Arrival:	9:00	Departure:	11:05
AMEC Field Rep. (Initial)	TM	AMEC Project Manager (Initials)	JK
Weather Conditions	Mostly cloudy 33 F		

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Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

FIELD REPORT NOTES

Time:	Field Notes:

1/25/2016 Monday Calibration

19:00 - Calibrated units for 1/26/16 sampling event.

1/26/2016 Tuesday sampling event.

07:45 - Loaded equipment and then mobe to site.
09:00 - On site with Art Lee
09:40 - DOE crew of Kevin, Randy, and their supervisor and IH personnel 'RS' arrived onsite. IH screened and okayed wells 183 and 18 then off site. Set up for sampling at well 171 using TVA - 1000 s/n #1111734 and GEM 2000 s/n # 1116992.
09:10 - Started purge on 171. Well sampling progression will be 171, 183, 18, 172, 167 and then 169
10:52 - Finished last well . Demobed equipment.
11:05 - Off site.

Contractor's Rep. (Initials)

Continued

DAILY FIELD REPORT

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	461M120342.12.01	Date:	2/11/2016
Field Report No:		Page:	1
Arrival:	8:45	Departure:	10:30
AMEC Field Rep. (Initial)	TM	AMEC Project Manager (Initials)	JK
Weather Conditions	Mostly cloudy 41 F		

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FIELD REPORT NOTES

Time:	Field Notes:

2/11/2016 Thursday Calibration and Sampling Event

01:00 - Calibrated units for 2/11/16 sampling event.

07:45 - Loaded equipment and then mobe to site.

08:45 - Arrived at the site.

09:05 - Art, Kevin, and Barbara arrived on site.

09:10 - Doug from IH cleared wells 183 and 18, then off site. Set up for sampling at well 171 using TVA - 1000 s/n #1111734 and GEM 2000 s/n # 1116992.

09:13 - Started purge on 171. Well sampling progression for the day will be 171, 183, 18, 172, 167, and then 169.

10:15 - Finished last well . Demobed equipment.

10:30 - Off site.

Contractor's Rep. (Initials)

Continued

DAILY FIELD REPORT

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	461M120342.12.01	Date:	2/22/2016
Field Report No:		Page:	1
Arrival:		Departure:	
AMEC Field Rep. (Initial)	jg	AMEC Project Manager (Initials)	
Weather Conditions	Partly cloudy 34 F		

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Portland, Oregon 97224
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FIELD REPORT NOTES

Time:	Field Notes:

2/21/2016 Sunday Calibration

15:00 - Calibrated units for 2/22/16 sampling event.

2/22/2016 Monday sampling event.

03:30 - Loaded equipment and then mobe to site.
07:30 - Picked up new badge from Hanford badging office.
08:20 - On site with Kyle Root. Kyle observed that MW-171 and MW-169 were still closed up and was on the line with operations in order to get someone out to take care of the issue.
09:00- -Art Lee, DOE crew of Frank, and Chris and IH personal Tracey on site . IH screened and okayed wells 183 and 18 then off site. Set up for sampling at well 183 using TVA - 1000 s/n #1111734 and GEM 2000 s/n # 1116992. Started on 183 while waiting for operations personnel to arrive at site.
09:09 - Started purge on 183. Well sampling progression will be 183, 18, 172, 171, 169 and then 167
10:07 - Finished last well . Demobed equipment.
10:30 - Off site.

Contractor's Rep. (Initials)

Continued

Field Measurements
January 2016 to February 2016 Respirometry Test
Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site

Monitoring Location	Date	Time	Vac During Extraction (inches H_2O)	Pre-Extraction Pressure/Vac	Purge Time	Oxygen (%)	Carbon Dioxide (%)	TVH (ppm)	Methane (ppm)	Notes
167	1/11/16	9:11	-259	0	6 min	21.1	0	3.1	12.6	Bio vent system off at 9:03. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	1/11/16	10:22	-260	0	6 min	21.2	0	4.07	19.71	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	1/11/16	12:07	-260	0	6 min	20.8	0	6	27.15	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	1/11/16	14:06	-265	0	6 min	21	0	4.51	20.73	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	1/12/16	10:14	-249	0	6 min	21	0.1	4.14	21.3	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	1/13/16	10:02	-247	0	6 min	20.9	0.1	4	13.07	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	1/14/16	10:14	-253	0	6 min	21.2	0	3.39	14.9	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	1/18/16	4:19	-243	0	6 min	20.9	0	1.9	8.9	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	2/22/16	10:07	-259	0	6 min	17.1	0.3	3.05	4.62	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	1/26/16	10:38	-252	0	6 min	20.6	0.1	1.37	6.71	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	2/3/16	9:58	-249	0	6 min	19.9	0.1	1.56	8.53	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	2/11/16	10:05	-255	0	6 min	18.3	0.4	1.4	8.25	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	2/22/16	10:07	-259	0	6 min	17.1	0.3	3.05	4.62	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

cu ft/sec = cubic feet per second
ppm = parts per million
TVH = total volatile hydrocarbons

Field Measurements
January 2016 to February 2016 Respirometry Test
Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site

Monitoring Location	Date	Time	Vac During Extraction (inches H_2O)	Pre-Extraction Pressure/Vac	Purge Time	Oxygen (%)	Carbon Dioxide (%)	TVH (ppm)	Methane (ppm)	Notes
169	1/11/16	8:54	-235	0	5 min	20.9	0	4.05	18.2	Baseline sampling prior to system shut down. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	1/11/16	9:05	-235	0	5 min	21	0	3.63	21.58	Bio vent system off at 9:03. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	1/11/16	10:10	-235	0	5 min	21.2	0	5.28	32.19	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	1/11/16	12:00	-239	0	5 min	20.7	0	4.45	24.09	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	1/11/16	14:00	-242	0	5 min	20.7	0	3.24	19.44	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	1/12/16	10:08	-225	0	5 min	20.9	0	5.02	26.32	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	1/13/16	9:55	-226	0	5 min	20.7	0	4.31	16.12	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	1/14/16	10:05	-224	0	5 min	20.8	0.1	4.34	19.57	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	1/18/16	10:06	-227	0	5 min	20.3	0.1	1.85	13.5	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	2/22/16	10:00	-241	0	5min	13.3	1.5	4.64	8.21	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	1/26/16	10:45	-231	0	5min	19.4	0.3	1.76	9.07	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	2/3/16	9:52	-227	0	5min	17.6	0.5	1.55	13.04	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	2/11/16	9:59	-233	0	5min	18.4	0.4	1.58	13.44	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	2/22/16	10:00	-241	0	5min	13.3	1.5	4.64	8.21	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

cu ft/sec = cubic feet per second
ppm = parts per million
TVH = total volatile hydrocarbons

Field Measurements
January 2016 to February 2016 Respirometry Test
Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site

Monitoring Location	Date	Time	Vac During Extraction (inches H_2O)	Pre-Extraction Pressure/Vac	Purge Time	Oxygen (%)	Carbon Dioxide (%)	TVH (ppm)	Methane (ppm)	Notes
171	1/11/16	8:08	-285	0	5 min	20.6	0.1	39	116	Baseline sampling prior to system shut down. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	1/11/16	9:22	-280	0	5 min	20.3	0.6	23.18	122	Bio vent system off at 9:03. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	1/11/16	10:33	-289	0	5 min	20.3	0.7	22.55	116	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	1/11/16	12:18	-283	0	5 min	20	0.7	23.27	116	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	1/11/16	14:17	-281	0	5 min	20.1	0.7	23.65	125	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	1/12/16	9:09	-284	0	5 min	19.8	0.8	6414 [1]	87.9	[1] New hose was run out to well and was determined to be contaminated. It most likely had been used as air line on an oil lubed compressor. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	1/12/16	9:35	-294	0	5 min	19.9	0.8	45	102	Resampled well for 24 hr collection event. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	1/13/16	9:15	-268	0	5 min	18.7	1	246	102	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	1/14/16	9:05	-262	0	5 min	19.3	0.9	175	87	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	1/18/16	9:16	-281	0	10 min	18.3	1.4	20.86 [2]	77.45 [2]	[2] Meter took awhile to stabilize hence the longer purge time. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	1/26/16	9:54	-272	0	4 min	16.5	2.2	15.56	51.61	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	2/3/16	9:05	-269	0	4 min	13	3.7	17.48	50.94	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	2/11/16	9:13	-274	0	4 min	11.5	4.6	20.1	36	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	2/22/16	9:50	-272	0	4 min	10.6	5.3	15.6 [3]	18.56	3 Purge air contains too little O2 to keep flame lit on FID. Sample collected is diluted. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

cu ft/sec = cubic feet per second
ppm = parts per million
TVH = total volatile hydrocarbons

Field Measurements
January 2016 to February 2016 Respirometry Test
Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site

Monitoring Location	Date	Time	Vac During Extraction (inches H_2O)	Pre-Extraction Pressure/Vac	Purge Time	Oxygen (%)	Carbon Dioxide (%)	TVH (ppm)	Methane (ppm)	Notes
172	1/11/16	9:58	-249	0	6 min	21.2	0	6.65	37.12	Bio vent system off at 9:03. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	1/11/16	11:10	-243	0	6 min	21.2	0	7.07	41.05	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	1/11/16	12:55	-242	0	6 min	21	0	7.24	42.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	1/11/16	14:52	-249	0	6 min	21.1	0	5.61	33.9	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	1/12/16	9:57	-244	0	6 min	21.1	0.1	4.82	27.67	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	1/13/16	9:44	-240	0	6 min	20.9	0.1	4.02	15.63	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	1/14/16	9:55	-234	0	6 min	21	0.1	6.5	19.7	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	1/18/16	9:56	-241	0	6 min	20.7	0.1	2.03	15.5	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	1/26/16	10:27	-240	0	6 min	20.8	0.1	1.6	7.69	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	2/3/16	9:11	-247	0	6 min	20.3	0.1	2.46	11.94	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	2/11/16	9:48	-243	0	6 min	19.6	0.1	1.25	7.04	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	2/22/16	9:42	-253	0	6 min	18.7	0.2	1.3	6.4	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

cu ft/sec = cubic feet per second
ppm = parts per million
TVH = total volatile hydrocarbons

Field Measurements
January 2016 to February 2016 Respirometry Test
Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site

Monitoring Location	Date	Time	Vac During Extraction (inches H_2O)	Pre-Extraction Pressure/Vac	Purge Time	Oxygen (%)	Carbon Dioxide (%)	TVH (ppm)	Methane (ppm)	Notes
183	1/11/16	8:14	-200	0	10 min	20.5	0	14.41	70.9	Baseline sampling prior to system shut down. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	1/11/16	9:29	-207	0	10 min	21.1	0	10.95	61	Bio vent system off at 9:03. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	1/11/16	10:40	-204	0	10 min	21.2	0	9.53	55.12	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	1/11/16	12:25	-201	0	10 min	21	0	11.69	70.9	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	1/11/16	14:24	-200	0	10 min	21.1	0	10.05	64.51	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	1/12/16	9:23	-201	0	10 min	20.9	0.1	9.76	43.14	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	1/13/16	9:17	-205	0	10 min	20.7	0.1	9.11	47.9	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	1/14/16	9:12	-199	0	10 min	20.9	0.1	8.34	42.07	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	1/18/16	9:27	-195	0	10 min	20.5	0	4.23	31.63	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	1/26/16	9:59	-206	0	10 min	21	0.1	3.29	17.8	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	2/3/16	9:18	-199	0	10 min	21.1	0.1	2.39	17.76	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	2/11/16	9:19	-257	0	10 min	20.3	0.3	2.85	11.27	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	2/22/16	9:18	-208	0	10 min	20.1	0.4	1	2.16	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

cu ft/sec = cubic feet per second
ppm = parts per million
TVH = total volatile hydrocarbons

Field Measurements
January 2016 to February 2016 Respirometry Test
Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site

Monitoring Location	Date	Time	Vac During Extraction (inches H_2O)	Pre-Extraction Pressure/Vac	Purge Time	Oxygen (%)	Carbon Dioxide (%)	TVH (ppm)	Methane (ppm)	Notes
18	1/11/16	8:30	-211	0	15 min	20.7	0.1	6.66	30.4	Baseline sampling prior to system shut down. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	1/11/16	9:41	-213	0	15 min	21.2	0	8.22	50.5	Bio vent system off at 9:03. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	1/11/16	10:52	-212	0	15 min	21.2	0	8.88	51.9	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	1/11/16	12:37	-211	0	15 min	20.9	0	7.3	42.3	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	1/11/16	14:36	-211	0	15 min	20.9	0	6.92	49.35	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	1/12/16	9:41	-224	0	15 min	21	0.1	9.55	35.24	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	1/13/16	9:28	-207	0	15 min	20.8	0.1	7.47	24.63	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	1/14/16	9:28	-203	0	27 min [1]	20.9	0.1	3.64	17.6	[1] Had a problem keeping flame lit on FID. Replaced gas cartridge and lowered air line flow to meter and solved issue. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	1/18/16	9:39	-206	0	15 min	20.7	0.1	2.34	15.42	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	1/26/16	10:11	-208	0	15 min	21	0.1	1.67	6.9	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	2/3/16	9:30	-205	0	15 min	21	0.1	1	5.73	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	2/11/16	9:31	-207	0	15 min	20.7	0.1	1.14	6.21	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	2/22/16	9:35	-219	0	15 min	20.5	0.1	1.02	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

cu ft/sec = cubic feet per second
ppm = parts per million
TVH = total volatile hydrocarbons
NA = Not applicable

ATTACHMENT 2

Instrument Calibration Sheets

amec foster wheeler

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120342.12.01

Date / Time: 1/10/2016 9:00:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM 2000 #1116992	1/10/2016	30 min	zero air	n/a	0.00%	0.00%
GEM 2000 #1116992	1/10/2016	30 min	15% CO2	n/a	15%	15%
GEM 2000 #1109736	1/10/2016	30 min	zero air	n/a	0.00%	0.00%
GEM 2000 #1109736	1/10/2016	30 min	15% CO2	n/a	15%	15%
TVA 1000 (0011882)	1/10/2016	30 min	zero air	0.9 ppm / 0.2 ppm	n/a	n/a
TVA 1000 (0011882)	1/10/2016	30 min	100 ppm Isob.	103 ppm (PID)	n/a	100 ppm
TVA 1000 (0011882)	1/10/2016	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 1000 (1111734)	1/10/2016	30 min	zero air	0.2 ppm / -0.3 ppm	n/a	n/a
TVA 1000 (1111734)	1/10/2016	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (1111734)	1/10/2016	30 min	100 ppm Methane	99.4 ppm (FID)	n/a	100

Notes:
This calibration is for the 1/11/2016 sample round.

amec foster wheeler

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120342.12.01

Date / Time: 1/11/2016 6:00:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM 2000 #1116992	1/11/2016	30 min	zero air	n/a	0.00%	0.00%
GEM 2000 #1116992	1/11/2016	30 min	15% CO2	n/a	15%	15%
GEM 2000 #1109736	1/11/2016	30 min	zero air	n/a	0.00%	0.00%
GEM 2000 #1109736	1/11/2016	30 min	15% CO2	n/a	15%	15%
TVA 1000 (0011882)	1/11/2016	30 min	zero air	0.7 ppm / 0.2 ppm	n/a	n/a
TVA 1000 (0011882)	1/11/2016	30 min	100 ppm Isob.	100 ppm (PID)	n/a	101 ppm
TVA 1000 (0011882)	1/11/2016	30 min	100 ppm Methane	99.7 ppm (FID)	n/a	100 ppm
TVA 1000 (1111734)	1/11/2016	30 min	zero air	0.1 ppm / 0.2 ppm	n/a	n/a
TVA 1000 (1111734)	1/11/2016	30 min	100 ppm Isob.	105 ppm (PID)	n/a	100 ppm
TVA 1000 (1111734)	1/11/2016	30 min	100 ppm Methane	101 ppm (FID)	n/a	100 ppm

Notes:
This calibration is for the 1/12/2016 sample round.

amec foster wheeler

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120342.12.01

Date / Time: 1/12/2016 3:00:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM 2000 #1116992	1/12/2016	30 min	zero air	n/a	0.00%	0.00%
GEM 2000 #1116992	1/12/2016	30 min	15% CO2	n/a	15%	15%
GEM 2000 #1109736	1/12/2016	30 min	zero air	n/a	0.00%	0.00%
GEM 2000 #1109736	1/12/2016	30 min	15% CO2	n/a	15%	15%
TVA 1000 (0011882)	1/12/2016	30 min	zero air	0.8 ppm / 0.3 ppm	n/a	n/a
TVA 1000 (0011882)	1/12/2016	30 min	100 ppm Isob.	104 ppm (PID)	n/a	100 ppm
TVA 1000 (0011882)	1/12/2016	30 min	100 ppm Methane	101 ppm (FID)	n/a	100 ppm
TVA 1000 (1111734)	1/12/2016	30 min	zero air	-0.1 ppm / -0.4 ppm	n/a	n/a
TVA 1000 (1111734)	1/12/2016	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (1111734)	1/12/2016	30 min	100 ppm Methane	97.9 ppm (FID)	n/a	101 ppm

Notes:
This calibration is for the 1/13/2016 sample round.

amec foster wheeler

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120342.12.01

Date / Time: 1/13/2016 3:00:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM 2000 #1116992	1/13/2016	30 min	zero air	n/a	0.00%	0.00%
GEM 2000 #1116992	1/13/2016	30 min	15% CO2	n/a	15%	15%
GEM 2000 #1109736	1/13/2016	30 min	zero air	n/a	0.00%	0.00%
GEM 2000 #1109736	1/13/2016	30 min	15% CO2	n/a	15%	15%
TVA 1000 (0011882)	1/13/2016	30 min	zero air	-0.1 ppm / 0.5 ppm	n/a	n/a
TVA 1000 (0011882)	1/13/2016	30 min	100 ppm Isob.	102 ppm (PID)	n/a	100 ppm
TVA 1000 (0011882)	1/13/2016	30 min	100 ppm Methane	98.7 ppm (FID)	n/a	100 ppm
TVA 1000 (1111734)	1/13/2016	30 min	zero air	0.0 ppm / -0.1 ppm	n/a	n/a
TVA 1000 (1111734)	1/13/2016	30 min	100 ppm Isob.	103 ppm (PID)	n/a	100 ppm
TVA 1000 (1111734)	1/13/2016	30 min	100 ppm Methane	101 ppm (FID)	n/a	99.3 ppm

Notes:
This calibration is for the 1/14/2016 sample round.

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Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120342.12.01

Date / Time: 1/17/2016 3:00:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM 2000 #1116992	1/17/2016	30 min	zero air	n/a	0.00%	0.00%
GEM 2000 #1116992	1/17/2016	30 min	15% CO2	n/a	15%	15%
GEM 2000 #1109736	1/17/2016	30 min	zero air	n/a	0.00%	0.00%
GEM 2000 #1109736	1/17/2016	30 min	15% CO2	n/a	15%	15%
TVA 1000 (0011882)	1/17/2016	30 min	zero air	-0.2 ppm / 0.2 ppm	n/a	n/a
TVA 1000 (0011882)	1/17/2016	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (0011882)	1/17/2016	30 min	100 ppm Methane	99.8 ppm (FID)	n/a	100 ppm
TVA 1000 (1111734)	1/17/2016	30 min	zero air	0.3 ppm / 0.1 ppm	n/a	n/a
TVA 1000 (1111734)	1/17/2016	30 min	100 ppm Isob.	101 ppm (PID)	n/a	100 ppm
TVA 1000 (1111734)	1/17/2016	30 min	100 ppm Methane	100 ppm (FID)	n/a	99.8 ppm

Notes:
This calibration is for the 1/18/2016 sample round.

amec foster wheeler

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120342.12.01

Date / Time: 1/25/2016 7:00:00 PM Completed By: Tyler Marley

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM 2000 #1116992	1/25/2016	30 min	zero air	n/a	0.00%	0.00%
GEM 2000 #1116992	1/25/2016	30 min	15% CO2	n/a	15%	15%
GEM 2000 #1109736	1/25/2016	30 min	zero air	n/a	0.00%	0.00%
GEM 2000 #1109736	1/25/2016	30 min	15% CO2	n/a	15%	15%
TVA 1000 (0011882)	1/25/2016	30 min	zero air	-0.02 ppm / 0.0 ppm	n/a	n/a
TVA 1000 (0011882)	1/25/2016	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (0011882)	1/25/2016	30 min	100 ppm Methane	99.7 ppm (FID)	n/a	100 ppm
TVA 1000 (1111734)	1/25/2016	30 min	zero air	0.1 ppm / 0.0 ppm	n/a	n/a
TVA 1000 (1111734)	1/25/2016	30 min	100 ppm Isob.	101 ppm (PID)	n/a	100 ppm
TVA 1000 (1111734)	1/25/2016	30 min	100 ppm Methane	100 ppm (FID)	n/a	99.6 ppm

Notes:
This calibration is for the 1/26/2016 sample round.

amec foster wheeler

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120342.12.01

Date / Time: 2/2/2016 7:00:00 PM Completed By: Tyler Marley

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM 2000 #1116992	2/2/2016	30 min	zero air	n/a	0.00%	0.00%
GEM 2000 #1116992	2/2/2016	30 min	15% CO2	n/a	15%	15%
GEM 2000 #1109736	2/2/2016	30 min	zero air	n/a	0.00%	0.00%
GEM 2000 #1109736	2/2/2016	30 min	15% CO2	n/a	15%	15%
TVA 1000 (0011882)	2/2/2016	30 min	zero air	0.02 ppm / 0.0 ppm	n/a	n/a
TVA 1000 (0011882)	2/2/2016	30 min	100 ppm Isob.	100 ppm (PID)	n/a	99.4 ppm
TVA 1000 (0011882)	2/2/2016	30 min	100 ppm Methane	100 ppm (FID)	n/a	99.2 ppm
TVA 1000 (1111734)	2/2/2016	30 min	zero air	-.08 ppm / 0.0 ppm	n/a	n/a
TVA 1000 (1111734)	2/2/2016	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (1111734)	2/2/2016	30 min	100 ppm Methane	100 ppm (FID)	n/a	99.1 ppm

Notes:
This calibration is for the 2/3/2016 sample round.

amec foster wheeler

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120342.12.01

Date / Time: 2/11/2016 1:00:00 AM Completed By: Tyler Marley

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM 2000 #1116992	2/11/2016	30 min	zero air	n/a	0.00%	0.00%
GEM 2000 #1116992	2/11/2016	30 min	15% CO2	n/a	15%	15%
GEM 2000 #1109736	2/11/2016	30 min	zero air	n/a	0.00%	0.00%
GEM 2000 #1109736	2/11/2016	30 min	15% CO2	n/a	15%	15%
TVA 1000 (0011882)	2/11/2016	30 min	zero air	0.03 ppm / 0.0 ppm	n/a	n/a
TVA 1000 (0011882)	2/11/2016	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (0011882)	2/11/2016	30 min	100 ppm Methane	100 ppm (FID)	n/a	101 ppm
TVA 1000 (1111734)	2/11/2016	30 min	zero air	0.27 ppm / 0.0 ppm	n/a	n/a
TVA 1000 (1111734)	2/11/2016	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (1111734)	2/11/2016	30 min	100 ppm Methane	100 ppm (FID)	n/a	99.6 ppm

Notes:
This calibration is for the 2/11/2016 sample round.

amec foster wheeler

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120342.12.01

Date / Time: 2/21/2016 3:00:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM 2000 #1116992	1/17/2016	30 min	zero air	n/a	0.00%	0.00%
GEM 2000 #1116992	1/17/2016	30 min	15% CO2	n/a	15%	15%
GEM 2000 #1109736	1/17/2016	30 min	zero air	n/a	0.00%	0.00%
GEM 2000 #1109736	1/17/2016	30 min	15% CO2	n/a	15%	15%
TVA 1000 (0011882)	1/17/2016	30 min	zero air	0.0 ppm / 0.5 ppm	n/a	n/a
TVA 1000 (0011882)	1/17/2016	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (0011882)	1/17/2016	30 min	100 ppm Methane	99.9 ppm (FID)	n/a	100 ppm
TVA 1000 (1111734)	1/17/2016	30 min	zero air	0.1 ppm / 0.1 ppm	n/a	n/a
TVA 1000 (1111734)	1/17/2016	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (1111734)	1/17/2016	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm

Notes:
This calibration is for the 2/22/2016 sample round.

ATTACHMENT 3

Design Worksheet for Oxygen Utilization and Biodegradation Rates

DESIGN WORKSHEET

Client:	CHPRC	Date:	12-Apr-16
Project:	Hanford 100-N Biovent	Project Number:	461M120342.03.01
Data For:	Jan to Feb 2016 Respiration Test	Prepared by:	M. Roskamp
		Reviewed by:	C. Weber

An in-situ respiration test was conducted at the Hanford Site 100-N from January 2016 to February 2016. Data collected from the field test is used to calculate oxygen utilization (k_o) and biodegradation rates (K_b). Calculations and results are presented below.

OXYGEN UTILIZATION RATE CALCULATION

Oxygen utilization rates (%/hour) are derived from the slope of the linear portion of the line when percent oxygen (y-axis) measured in the soil is plotted against time in hours (x-axis). See attached for data plots.

Location	O_2 Utilization (%/hour)	k_o O_2 Utilization (%/day)	R^2 value for linear curve fit
199-N-167	0.0037	0.09	0.894
199-N-169	0.0068	0.16	0.911
199-N-171	0.0104	0.25	0.970
199-N-172	0.0021	0.05	0.929
199-N-183	--	--	--
199-N-18	--	--	--

Oxygen readings between 19 and 22% represent essentially atmospheric conditions and amount to insignificant oxygen depletion. Biodegradation rates are only calculated for wells with significant oxygen depletion (below 19%); others are marked as --.

BIODEGRADATION RATE CALCULATION

Biodegradation rates (K_b) are calculated for each of the monitoring points.

The Kb values below are calculated using updated site-specific soil bulk density and moisture content soil parameters, based on measured values from samples collected in the screen interval of 199-N-183. The biodegradation calculations for the 2010 and 2012 respiration test data have also been updated with these site-specific soil parameters.

Equation for biodegradation rate calculation:

$$K_b = \frac{-k_o \, \theta_a \, \rho_{o2} \, C \times 0.01}{\rho_k}$$

Parameters using site-specific measured values from 199-N-183 soil samples

θ_a =	0.32	cm^3 gas/cm^3 soil	Gas-filled pore space (volumetric content at the vapor phase); where $\theta_a = \theta - \theta_w$
ρ_{O2} =	1,378	mg/L	Density of oxygen; assuming 10°C (50°F) soil temperature reference value from AFCEE, 2004
C =	0.29	---	Mass ratio of hydrocarbons to oxygen required for mineralization; calculated assuming diesel as $C_{10}H_{20}$ and stoichiometric relationship of $C_{10}H_{20}$+ $15O_2$ => $10CO_2$ + $10H_2O$
ρ_k =	1.736	g/cm^3	Soil bulk density; measured value from 199-N-183, average of bulk densities from samples 212 and 215
θ =	0.34	cm^3/cm^3	Total porosity; where $\theta = 1 - \rho_k/\rho_T$
θ_w =	0.02	cm^3/cm^3	Water filled porosity; where $\theta_w = M^*\rho_k/\rho_T$
ρ_T =	2.65	g/cm^3	Soil mineral density; assumed value
M =	0.0313	g moisture /g soil	3.13% moisture content; measured value from 199-N-183, average of percent moisture from samples 212, 214, and 215

Note: Subsurface soil temperature is assumed to be constant year-round and temperature adjustments of oxygen utilization rates were not conducted. If temperatures are warmer in the summer months then oxygen utilization rates are expected to increase. Temperature changes are extremely unlikely for the deep well locations.

DESIGN WORKSHEET

Client: CHPRC
Project: Hanford 100-N Biovent
Data For: Jan to Feb 2016 Respiration Test

Date: 12-Apr-16
Project Number: 461M120342.03.01
Prepared by: M. Roskamp
Reviewed by: C. Weber

Location	Parameter	Apr-16	Aug-15	Jan-15	Jul-14	Jan-14	Mar-10	Units	Notes
199-N-167	K_o =	0.09	0.07	0.07	0.08	0.01	1.32	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.07**	**-0.05**	**-0.05**	**-0.06**	**-0.01**	**-0.99**	mg/Kg-	Biodegradation rate; calculated value
199-N-169	K_o =	0.16	0.16	0.3	0.12	0.09	1.29	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.12**	**-0.12**	**-0.23**	**-0.09**	**-0.07**	**-0.97**	mg/Kg-	Biodegradation rate; calculated value
199-N-171	K_o =	0.25	0.18	0.3	0.12	0.07	0.49	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.19**	**-0.14**	**-0.23**	**-0.09**	**-0.05**	**-0.37**	mg/Kg-	Biodegradation rate; calculated value
199-N-172	K_o =	0.05	0.05	0.07	0.03	0.02	0.71	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.04**	**-0.04**	**-0.05**	**-0.02**	**-0.01**	**-0.54**	mg/Kg-	Biodegradation rate; calculated value
199-N-183	K_o =	--	--	--	--*	0.12	not tested	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**--**	**--**	**--**	**--***	**-0.09**	not tested	mg/Kg-	Biodegradation rate; calculated value
199-N-18	K_o =	--	--	--	--*	--*	not tested	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**--**	**--**	**--**	**--***	**--***	not tested	mg/Kg-	Biodegradation rate; calculated value

* Biodegradation rates were previously calculated based on respirometry data, but upon further review, insignificant oxygen depletion was recorded in the wells and biodegradation should have been reported as insignificant.

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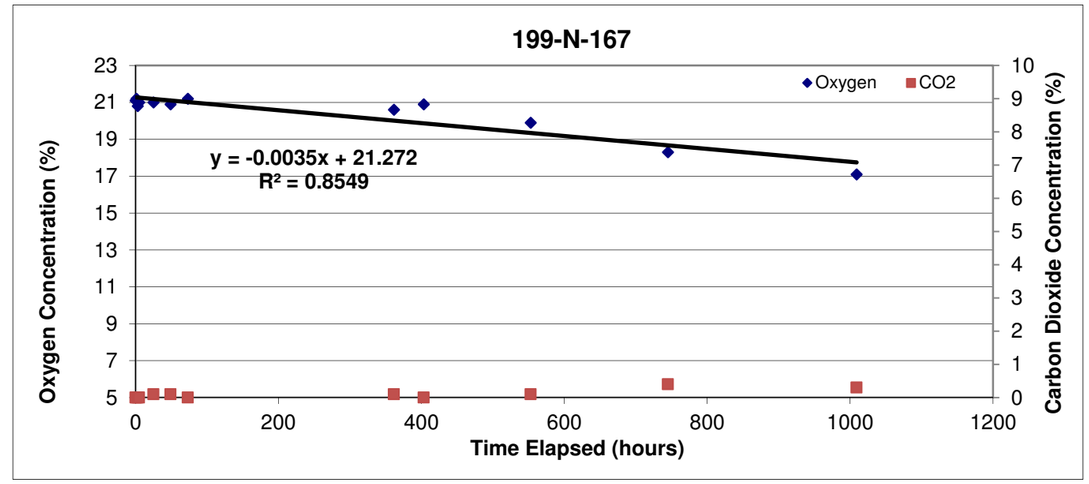
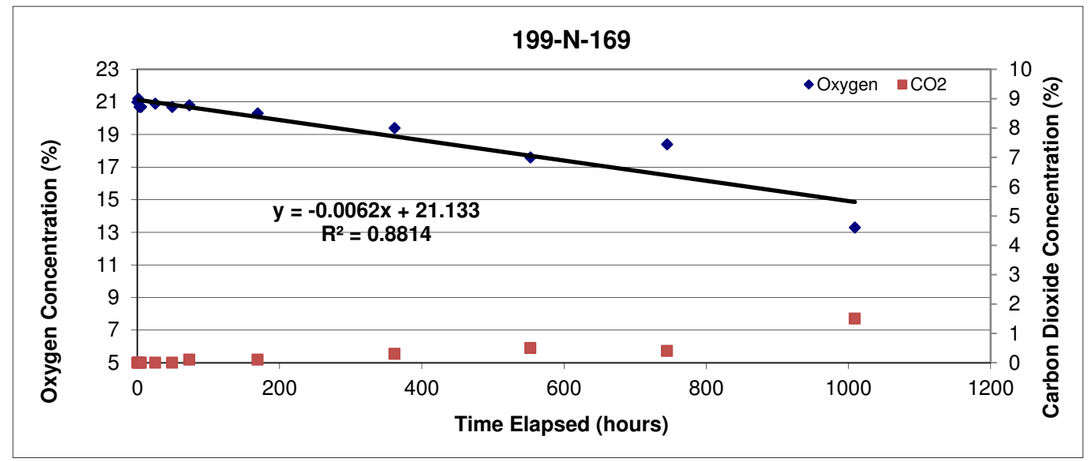
Oxygen Utilization Generation Plots
January to February 2016 Respirometry Test

199-N-167						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
1/11/2016	9:03	1/11/2016 9:03	blower off	0	--	--
1/11/2016	9:11	1/11/2016 9:11	Initial reading	0.00	21.1	0
1/11/2016	10:22	1/11/2016 10:22	1:19:00	1.32	21.2	0
1/11/2016	12:07	1/11/2016 12:07	3:04:00	3.07	20.8	0
1/11/2016	14:06	1/11/2016 14:06	5:03:00	5.05	21	0
1/12/2016	10:14	1/12/2016 10:14	25:11:00	25.18	21	0.1
1/13/2016	10:02	1/13/2016 10:02	48:59:00	48.98	20.9	0.1
1/14/2016	10:14	1/14/2016 10:14	73:11:00	73.18	21.2	0
1/18/2016	4:19	1/28/2016 4:19	403:16:12	403.27	20.9	0
1/26/2016	10:38	1/26/2016 10:38	361:35:00	361.58	20.6	0.1
2/3/2016	9:58	2/3/2016 9:58	552:55:00	552.92	19.9	0.1
2/11/2016	10:05	2/11/2016 10:05	745:02:00	745.03	18.3	0.4
2/22/2016	10:07	2/22/2016 10:07	1009:04:00	1009.07	17.1	0.3
					12	

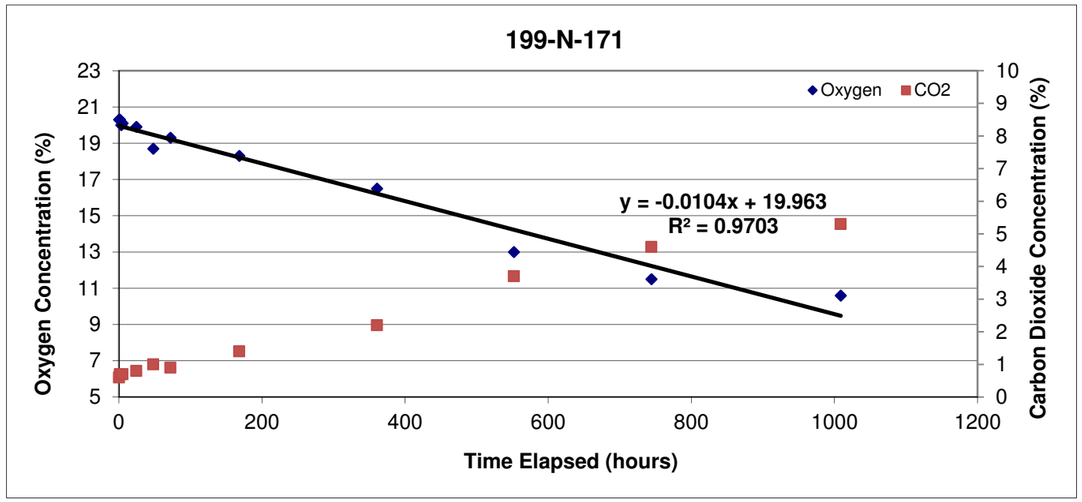


199-N-169						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
1/11/2016	8:54	1/11/2016 8:54	Baseline	--	20.9	0
1/11/2016	9:03	1/11/2016 9:03	Blower off	0	--	--
1/11/2016	9:05	1/11/2016 9:05	Initial reading	0.03	21	0
1/11/2016	10:10	1/11/2016 10:10	1:07:00	1.1	21.2	0
1/11/2016	12:00	1/11/2016 12:00	2:57:00	3.0	20.7	0
1/11/2016	14:00	1/11/2016 14:00	4:57:00	5.0	20.7	0
1/12/2016	10:08	1/12/2016 10:08	25:05:00	25.1	20.9	0
1/13/2016	9:55	1/13/2016 9:55	48:52:00	48.9	20.7	0
1/14/2016	10:05	1/14/2016 10:05	73:02:00	73.0	20.8	0.1
1/18/2016	10:06	1/18/2016 10:06	169:03:00	169.0	20.3	0.1
1/26/2016	10:45	1/26/2016 10:45	361:42:00	361.7	19.4	0.3
2/3/2016	9:52	2/3/2016 9:52	552:49:00	552.8	17.6	0.5
2/11/2016	9:59	2/11/2016 9:59	744:56:00	744.9	18.4	0.4
2/22/2016	10:00	2/22/2016 10:00	1008:57:00	1008.9	13.3	1.5
					13	

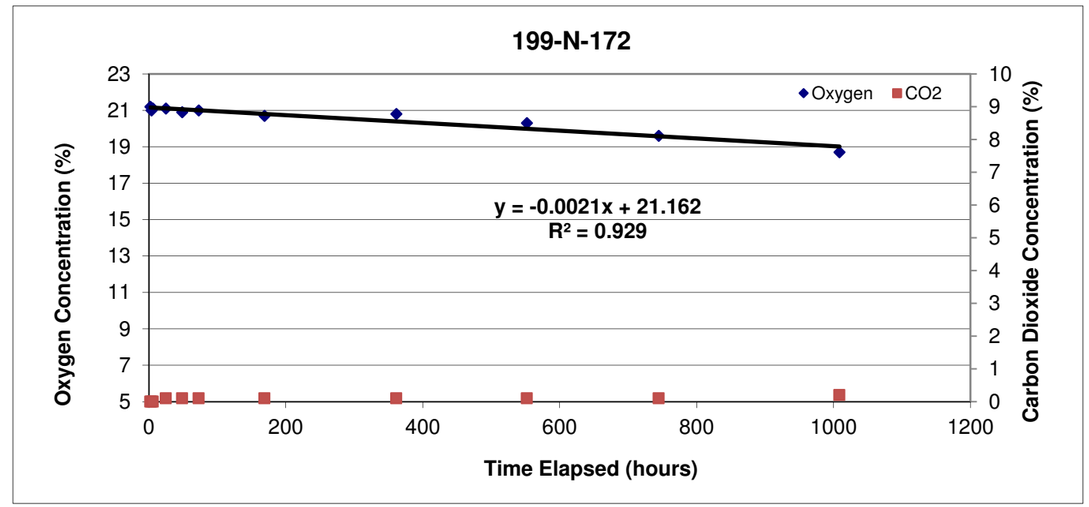


Oxygen Utilization Generation Plots
January to February 2016 Respirometry Test

199-N-171						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
1/11/2016	8:08	1/11/2016 8:08	Baseline	--	20.6	0.1
1/11/2016	9:03	1/11/2016 9:03	Blower off	0	--	--
1/11/2016	9:22	1/11/2016 9:22	Initial reading	0.32	20.3	0.6
1/11/2016	10:33	1/11/2016 10:33	1:30:00	1.5	20.3	0.7
1/11/2016	12:18	1/11/2016 12:18	3:15:00	3.2	20	0.7
1/11/2016	14:17	1/11/2016 14:17	5:14:00	5.2	20.1	0.7
1/12/2016	9:35	1/12/2016 9:35	24:32:00	24.5	19.9	0.8
1/13/2016	9:15	1/13/2016 9:15	48:12:00	48.2	18.7	1
1/14/2016	9:05	1/14/2016 9:05	72:02:00	72.0	19.3	0.9
1/18/2016	9:16	1/18/2016 9:16	168:13:00	168.2	18.3	1.4
1/26/2016	9:54	1/26/2016 9:54	360:51:00	360.8	16.5	2.2
2/3/2016	9:05	2/3/2016 9:05	552:02:00	552.0	13	3.7
2/11/2016	9:13	2/11/2016 9:13	744:10:00	744.2	11.5	4.6
2/22/2016	9:50	2/22/2016 9:50	1008:47:00	1008.8	10.6	5.3
					13	

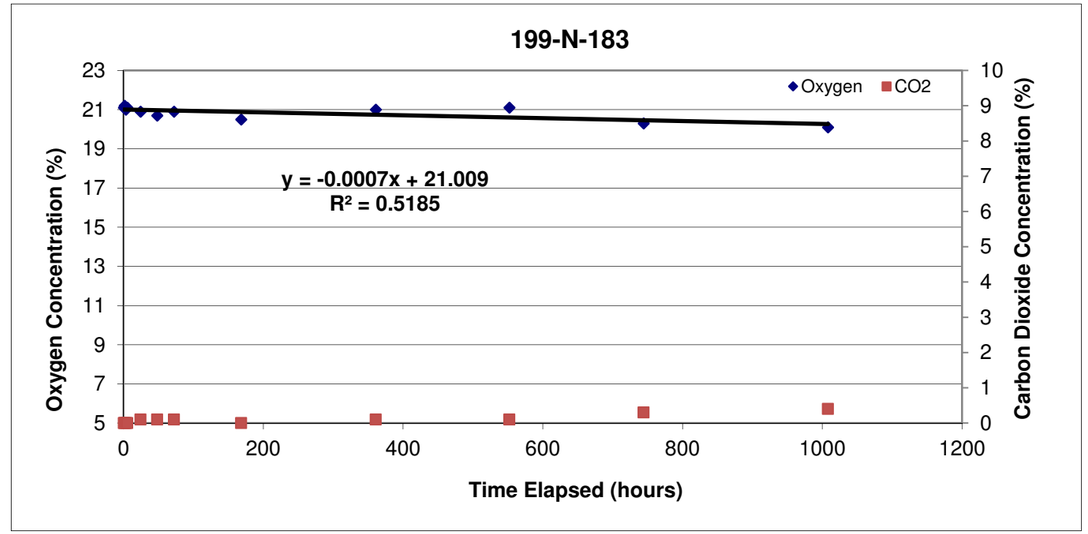


199-N-172						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
1/11/2016	9:03	1/11/2016 9:03	Blower off	0	--	--
1/11/2016	9:58	1/11/2016 9:58	Initial reading	0.92	21.2	0
1/11/2016	11:10	1/11/2016 11:10	2:07:00	2.12	21.2	0
1/11/2016	12:55	1/11/2016 12:55	3:52:00	3.87	21	0
1/11/2016	14:52	1/11/2016 14:52	5:49:00	5.82	21.1	0
1/12/2016	9:57	1/12/2016 9:57	24:54:00	24.90	21.1	0.1
1/13/2016	9:44	1/13/2016 9:44	48:41:00	48.68	20.9	0.1
1/14/2016	9:55	1/14/2016 9:55	72:52:00	72.87	21	0.1
1/18/2016	9:56	1/18/2016 9:56	168:53:00	168.88	20.7	0.1
1/26/2016	10:27	1/26/2016 10:27	361:24:00	361.40	20.8	0.1
2/3/2016	9:11	2/3/2016 9:11	552:08:00	552.13	20.3	0.1
2/11/2016	9:48	2/11/2016 9:48	744:45:00	744.75	19.6	0.1
2/22/2016	9:42	2/22/2016 9:42	1008:39:00	1008.65	18.7	0.2
					12	

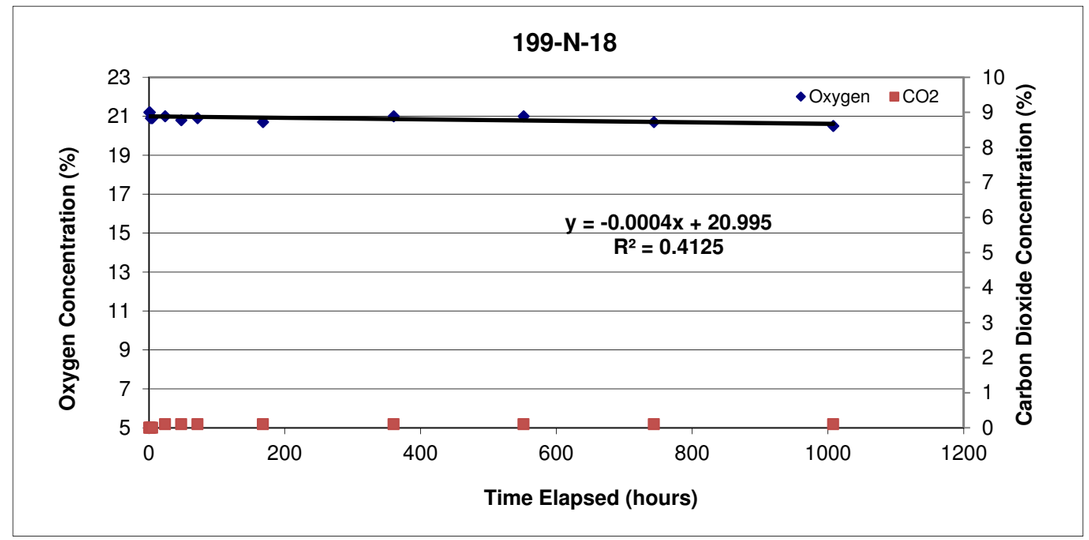


Oxygen Utilization Generation Plots
January to February 2016 Respirometry Test

199-N-183						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
1/11/2016	8:14	1/11/2016 8:14	Baseline	--	20.5	0
1/11/2016	9:03	1/11/2016 9:03	Blower off	0	--	--
1/11/2016	9:29	1/11/2016 9:29	Initial reading	0.43	21.1	0
1/11/2016	10:40	1/11/2016 10:40	1:37:00	1.62	21.2	0
1/11/2016	12:25	1/11/2016 12:25	3:22:00	3.37	21	0
1/11/2016	14:24	1/11/2016 14:24	5:21:00	5.35	21.1	0
1/12/2016	9:23	1/12/2016 9:23	24:20:00	24.33	20.9	0.1
1/13/2016	9:17	1/13/2016 9:17	48:14:00	48.23	20.7	0.1
1/14/2016	9:12	1/14/2016 9:12	72:09:00	72.15	20.9	0.1
1/18/2016	9:27	1/18/2016 9:27	168:24:00	168.40	20.5	0
1/26/2016	9:59	1/26/2016 9:59	360:56:00	360.93	21	0.1
2/3/2016	9:18	2/3/2016 9:18	552:15:00	552.25	21.1	0.1
2/11/2016	9:19	2/11/2016 9:19	744:16:00	744.27	20.3	0.3
2/22/2016	9:18	2/22/2016 9:18	1008:15:00	1008.25	20.1	0.4
					13	



199-N-18						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
1/11/2016	8:30	1/11/2016 8:30	Baseline	--	20.7	0.1
1/11/2016	9:03	1/11/2016 9:03	Blower off	0	--	--
1/11/2016	9:41	1/11/2016 9:41	Initial reading	0.63	21.2	0
1/11/2016	10:52	1/11/2016 10:52	1:11:00	1.18	21.2	0
1/11/2016	12:37	1/11/2016 12:37	2:56:00	2.93	20.9	0
1/11/2016	14:36	1/11/2016 14:36	4:55:00	4.92	20.9	0
1/12/2016	9:41	1/12/2016 9:41	24:00:00	24.00	21	0.1
1/13/2016	9:28	1/13/2016 9:28	47:47:00	47.78	20.8	0.1
1/14/2016	9:28	1/14/2016 9:28	71:47:00	71.78	20.9	0.1
1/18/2016	9:39	1/18/2016 9:39	167:58:00	167.97	20.7	0.1
1/26/2016	10:11	1/26/2016 10:11	360:30:00	360.50	21	0.1
2/3/2016	9:30	2/3/2016 9:30	551:49:00	551.82	21	0.1
2/11/2016	9:31	2/11/2016 9:31	743:50:00	743.83	20.7	0.1
2/22/2016	9:35	2/22/2016 9:35	1007:54:00	1007.90	20.5	0.1
					13	



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