CHPRC-03726
Revision 0

Summary of Calendar Year 2017 Bioremediation at the UPR-100-N-17 Waste Site

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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TECHNICAL MEMORANDUM

Summary of Calendar Year 2017 Bioremediation at the UPR-100-N-17 Waste Site

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1 Introduction

This technical memorandum provides a summary of bioremediation and monitoring activities performed at the UPR-100-N-17 waste site in 2017. Results of the two respirometry tests conducted in 2017 for high and low river stage periods are included in Appendices A and B.

2 Background

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," DOE is operating a bioventing system to cleanup petroleum-contaminated soil within the deep vadose zone (waste site UPR-100-N-17) associated with an unplanned release of diesel oil that occurred between August 1965 and September 1966 in the 166-N Tank Farm (Figure 1). The bioremediation system consists of a blower system housed within a CONEX container that can operate 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, *Operation and Maintenance Manual, Phase II Testing – Bioremediation Design for Deep Zone Petroleum Contamination (UPR-100-N-17) at the 100-N Area*.

3 Performance Monitoring

In 2017, monthly vapor sampling was conducted at the two deep vadose zone monitoring wells 199-N-169 and 199-N-171. Two respirometry tests were conducted in 2017 during high and low river period during June-July and October-November, respectively. Groundwater samples were also collected from the bioremediation monitoring wells during the respirometry tests.

3.1 Monthly Soil Gas Measurements

Table 1 presents the monthly soil gas measurements of the deep vadose zone that were collected throughout 2017 from monitoring wells 199-N-169 and 199-N-171 (Figure 1) to provide indictors of biodegradation. Monthly samples of soil gas are collected from these wells when the bioventing system is operating (i.e., injecting air) to measure oxygen, carbon dioxide, methane, volatile organic concentration, and other parameters such as temperature and barometric pressure. As a general rule, decreasing oxygen levels and increasing CO_2 levels are indicators of biodegradation.

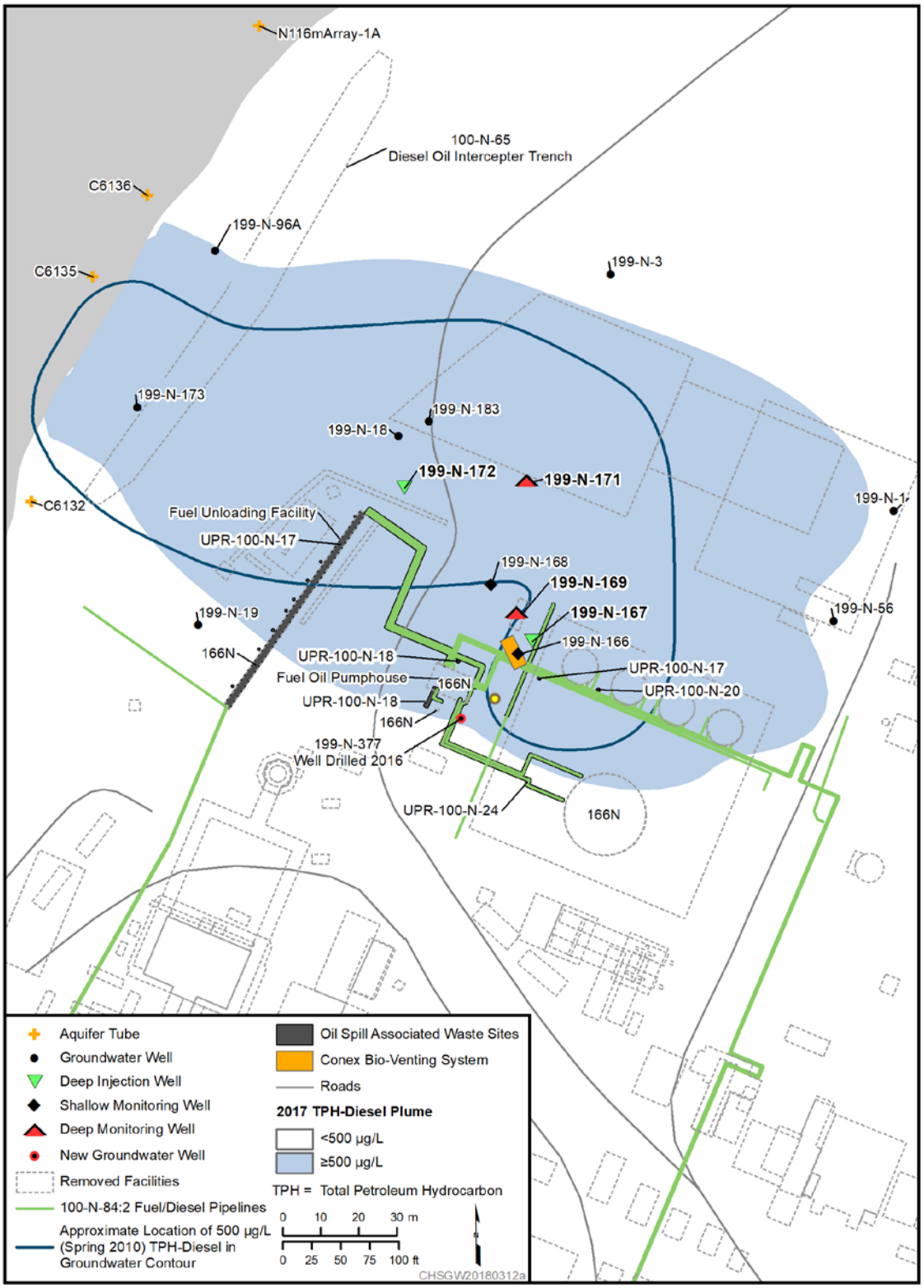

Figure 1. Bioventing System Location and Total Petroleum Hydrocarbon–Diesel Plume Map

Table 1. Monthly Vapor Monitoring

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								
1/30/17	0903	29.91	29.4	20.9	390	0.0	0.0	-273
2/28/17	0831	29.43	29.9	20.9	320	0.0	0.0	-271
3/28/17	0821	29.79	42	20.9	290	0.0	0.0	-208
4/26/17	0828	29.28	46	20.9	320	0.0	0.0	-258
5/31/17	0824	29.30	56.7	20.9	450	0.0	0.0	285.5
7/31/17	1156	30.1	86.6	20	8550	0.2	0.0	-265
8/31/17	0838	20.9	64	20.9	620	0.1	0.0	-256
11/30/17	0853	29.72	32.6	20.9	640	0.1	0.0	268
*1/2/18	1116	30.7	30.9	20.9	590	0.6	0.0	-273
Average				**20.8**	**1,352**	**0.1**	**0.0**	**-**
Monitoring Well 199-N-171								
1/30/17	0921	29.91	29.4	19.33	10,700	17.1	4.0	-266
2/28/17	0855	29.43	29.9	19.6	9860	11.8	0.0	-324
3/28/17	0838	29.75	42	19.7	8480	15.3	0.0	-263
4/26/17	0847	29.28	46	19.8	6630	10.8	0.0	-257
5/31/17	0845	29.30	56.7	20.1	5780	2.5	0.0	252.1
7/31/17	1214	30.1	86.6	6.1	>50,000 (over range)	6.8	0.0	-252
8/31/17	0904	29.52	64	18.4	20,200	14.5	0.0	-249
11/30/17	0853	29.72	32.6	13.0	40,900	8.4	0.0	265
*1/2/18	1133	30.7	30.9	17.8	21,500	8.7	0.0	-265
Average				**17.08**	**19,339**	**10.6**	**.44**	**-**

*Scheduled December sampling was conducted on January 2, 2018.

LEL = lower explosive limit

ppm = parts per million

ppmv = parts per million vapor

VOC = volatile organic compound

Data collected from well 199-N-169 indicate that very little biodegradation is occurring compared to well 199-N-171. With the exception of the July sampling events, oxygen levels were constant (~20.9%) throughout the year, while CO_2 levels typically ranged from 290 to 640 ppm. Indicators of biodegradation increased in July, as oxygen levels decreased to 20% and CO_2 levels increased to 8,550 ppm. The July vapor sampling was performed following completion of the high river respirometry test. The high CO_2

measurements reflect equilibration of the subsurface system after respirometry testing since the vapor samples were collected only one day after restart of air injection by the bioventing system. During the second half of the year, CO_2 and volatile organic concentration were higher compared to the first part of the year. Volatile organic concentrations were <0.7 ppmv throughout the year.

Changes in oxygen and CO_2 levels were much greater in well 199-N-171 compared to well 199-N-169. Oxygen levels ranged from 6.1% to 20.1%, while CO_2 levels range from 5,780 to >50,000 ppm. The consistently higher CO_2 and lower oxygen levels in well 199-N-171 are indicators of greater biodegradation and microbial activity in the vicinity of well 199-N-171. The higher levels of volatile organics detected (2.5 to 17.1 ppmv) is a likely indicator of greater vadose zone contamination near well 199-N-171.

3.2 Respirometry Testing

Two in situ respirometry tests were performed (June 5 to July 10, 2017, and October 2 to November 6, 2017) to measure microbial respiration rates and estimate biodegradation rates. Each test was initiated after the system was shut off. Field measurements of oxygen, carbon dioxide, total vapor hydrocarbons, and methane were collected from six monitoring wells:

- 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 June to July 2017 and October to November 2017 respirometry test results, including field measurements, are provided in Appendices A and B, respectively.

The calculated biodegradation rates at wells 199-N-167, 199-N-169, 199-N-171, and 199-N-172 were greater in November 2017 than in July 2017. This is expected given the overall decline in the elevation of the water table in November and the corresponding increase in the thickness of the smear zone available for oxygen delivery. The rates of biodegradation calculated (Table 2) for the respirometry test are consistent with the monthly vapor monitoring data (Table 1). The combined 2017 data set suggests that greater biodegradation occurred during the last 6 months of the year during lower river stage.

The biodegradation rates in Table 2 exhibit a declining trend from the initial rates measured in 2010. This may indicate a 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, or nutrient availability may also have affected the rates shown, although only minor fluctuations are expected in temperature and moisture at depth above the water table. Table 2 presents a comparison of the biodegradation rates for the respirometry tests conducted in 2010 (pilot test), to the last three years (2015, 2016, and 2017). It appears that asymptotic levels have been achieved with respect to treatment within the unsaturated vadose zone near wells 199-N-167, 199-N-169, and 199-N-172. Current respirometry rates are generally below literature values for bioventing as a cost-effective remedial alternative with biodegradation rates typically above 1 mg/kg-day, although rates less than 1 mg/kg-day have been demonstrated to be effective. The rates of biodegradation in wells relative to initial rate is shown in Chart 5 of Appendix B.

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

Monitoring Point	Biodegradation Rate (mg/kg-day)							
	Nov. 2017	Jul. 2017	Dec. 2016	Aug. 2016	Feb. 2016	Aug. 2015	Jan. 2015	Mar. 2010
199-N-167	-0.14	-0.08	-0.06	-0.06	-0.07	-0.05	-0.05	-0.99
199-N-169	-0.19	-0.11	-0.14	-0.07	-0.12	-0.12	-0.23	-0.97
199-N-171	-0.11	-0.07	-0.22	-0.08	-0.19	-0.14	-0.23	-0.37
199-N-172	-0.07	-0.08	-0.03	-0.02	-0.04	-0.04	-0.05	-0.54

NA = not applicable: oxygen depletion insignificant and biodegradation rate not calculated

3.3 Groundwater Monitoring

Table 3 presents the total petroleum hydrocarbon-diesel (TPH-D) concentrations measured in groundwater samples collected from the bioremediation monitoring wells during the 2017 high and low river respirometry tests. The groundwater data were used to interpret the 2017 TPH-D plume distribution shown in Figure 1. The two highest concentrations in 2017 were detected in wells 199-N-18 and 199-N-167 (16,600 and 13,000 µg/L, respectively). Additional information on TPH-D groundwater contamination at 100-N is available in DOE/RL-2017-66, *Hanford Site Groundwater Monitoring Report for 2017*, and DOE/RL-2017-67, *Calendar Year 2017 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump and Treat Operations, and 100-NR-2 Groundwater Remediation*.

Table 3. TPH-D Concentrations (in µg/L) for Bioventing Performance Monitoring Wells and Aquifer Tubes

Type	Well Name	High River Sampling (July 2017)	Low River Sampling (November 2017)
Bioventing Air Injection Well	199-N-167	7,730 (DT)	13,000 (B)
	199-N-172	7,550 (DT)	28,600[c] (D)
Bioventing Monitoring Well	199-N-3	47.2 (U)	48.1 (TU)
	199-N-19	67.1 (JT)	97.6 (JT)
	199-N-96A	77.2 (JT)	1,800[d] (B)
	199-N-169	10,000 (DT)	7,300[d] (B)
	199-N-171	7,280 (DT)	5,900 (D)
	199-N-173	1,690 (T)	11,000[d] (B)
	199-N-183	1,980 (T)	7,300[d] (B)
	199-N-377[a]	1,400 (B)	48 (U)
	199-N-56	50 (TU)	71.5 (B)
	188-N-18	7,255 (DT)	16,600 (D)

Table 3. TPH-D Concentrations (in µg/L) for Bioventing Performance Monitoring Wells and Aquifer Tubes

Type	Well Name	High River Sampling (July 2017)	Low River Sampling (November 2017)
Aquifer Tube	C6132	50 (TU)	102 (J)
	N116mArray-0A	—[b]	1,010
	C6135	140 (U)	4,430 (D)

a. New well installed in August 2016.

b. Unable to sample N116mArray-0A in July because aquifer tube needed repairs.

c. Unable to sample in November with other wells because of low water level in the well. Sampled on January 8, 2018, when water level increased.

d. Results were flagged as "B" to indicate that TPH-D was also detected in the associated quality control blank. Values are high and out of trend, but most of the bioremediation monitoring wells had higher values due to higher than normal water levels in the summer.

TPH-D = total petroleum hydrocarbons-diesel

Data flags:

B = analyte was detected in both the associated quality control blank and in the sample

D = analyte was identified in an analysis at a secondary dilution factor

J = estimated

T = spike and/or spike duplicate sample recovery is outside control limits

U = analyzed for but not detected above reporting limit

4 Summary and Conclusions

The respirometry rates from the 2017 event remain generally below literature values for recommending bioventing as a cost-effective remedial option. However, there is evidence that oxygen in the vadose zone 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 near wells 199-N-167, 199-N-169, and 199-N-172 (Chart 5 of Appendix B). The biodegradation rate in the vicinity of well 199-N-171 fluctuates semiannually, and continuation of bioventing may continue to provide petroleum mass removal. Because the recent respirometry tests have shown consistent and predictable results, the frequency of respirometry testing is being reduced to a biennial basis as identified in TPA-CN-0815, *Tri-Party Agreement Change Notice Form: DOE/RL-2005-93, Remedial Design Report/Remedial Action Work Plan for the 100-N Area, Rev. 1*. Currently, the next respirometry testing event is planned for fall 2019.

While hydrocarbon reduction in vadose zone is likely continuing in a slow manner, the smear zone has better potential for increased biodegradation rates (petroleum removal) if more oxygen can be delivered to that zone. During high river stage periods, the system is prevented from delivering significant oxygen to the smear zone because the higher soil pore water saturation percentage creates a barrier to air flow. The air (oxygen) currently being delivered to the subsurface preferentially enters the drier, shallower vadose zone. While bioventing will continue to be beneficial as a remedial action for the unsaturated deep vadose zone, the system is not designed to effectively treat site groundwater or the smear zone.

5 Recommendations

- Reduce semiannual frequency of bioventing tests, but continue to conduct periodic high and low river bioventing testing events to monitor for changes in overall biological activity to provide updates to biodegradation rates for the site. Groundwater monitoring should be conducted concurrently with the respiration testing so that results can be correlated against dissolved contaminant concentrations and the area of exposed smear zone soil (groundwater elevations).
- Consider groundwater biosparging (injection of air [oxygen] into groundwater) to increase biological degradation of hydrocarbons in the smear zone, capillary fringe, and groundwater. If biosparging is planned, conduct a pilot-scale test to evaluate the effectiveness of the system.
- Collect soil samples to determine the concentrations of hydrocarbons, population of hydrocarbon degrading bacteria, nutrients, and other geochemical properties.

6 References

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Appendix A

June-July 2017 Respirometry Testing

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Memorandum

To Art Lee, BTR
William Faught, CAM
CH2M HILL Plateau Remediation Company

Project No.:
661M120343.02.1

From John Kuiper, LG
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Melissa Roskamp, PE (OR)

Amec Foster Wheeler
Environment & Infrastructure, Inc.

Date November 6, 2017

Subject Summary of June through July 2017 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 July 2017 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 May 30, 2017 (Amec Foster Wheeler Environment and Infrastructure, Inc., 2017a), with exceptions as noted below.

Since startup in November 2012, the bioventing system has been configured to supply air to an area of the subsurface impacted by petroleum hydrocarbons (diesel) via two injection wells: 199-N-167 and 199-N-172 (Figure 1). These wells are screened from 53 to 78 feet below ground surface (bgs) and 57 to 77 feet bgs, respectively. Both wells are screened exclusively within the Ringold Formation (Unit E), which consists of layers (slightly weathered and consolidated) of silty, sandy gravel (msG), sandy gravel (sG), sand (S), and gravelly sand (gS). The contact with the overlying Hanford Formation (unconsolidated msG and sG) ranges from approximately 45 to 51 feet bgs. Approximately 250 cubic feet per minute (cfm) of air is routed to each injection well

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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 has been in continuous operation since startup in late 2012, 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 June 5, 2017. Gas composition samples were then collected periodically, starting immediately after shut down and continuing through test completion on July 10, 2017. 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, carbon monoxide, and total volatile hydrocarbons (TVH).

Prior to blower shutdown on June 5, 2017, 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 at 9:05 am on June 5 when the blower was switched off.

Eleven samples were collected from two monitoring locations (199-N-167 and 199-N-172) and twelve samples were collected from four monitoring locations (199-N-169, 199-N-171, 199-N-183, and 199-N-18). Samples were collected over a period of approximately 840 hours (5 weeks). Readings were collected frequently for the first three days (at approximately 0, 1, 2, 4, 5, 24, 48 and 72 hours) and then at 168 hours (7 days). The bioventing system then remained off for four additional weeks during which four additional sampling events occurred at approximately 334, 502, 720, and 840 hours at all six locations.

A minimum of one casing volume of air was extracted prior to monitoring using a purge pump. Sampling was performed according to the Test Plan and direct measurements were made (in-line sampling, no Tedlar bags) consistent with the prior November-December 2016 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 (Air Force Center for Environmental Excellence, 2004) 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 and calculations are included as Attachment 3.

Biodegradation rates were calculated using the following equation:

$$K_b = \frac{Z k_o \theta_a \rho_{O2} C}{\rho_k} \times 0.01$$

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] (AFCEE 2004)
- C: mass ratio of hydrocarbons to oxygen required for mineralization (calculated assuming diesel as $C_{10}H_{20}$ and stoichiometric relationship of $C_{10}H_{20} + 15O_2 \Rightarrow 10CO_2 + 10H_2O$ = 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)
- 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 bgs, as presented in Attachment 3 and described in detail in the January 2014 respirometry test results summary (AMEC Environment and Infrastructure, Inc., 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 five-week in-situ respirometry test initiated on June 5, 2017, calculated biodegradation rates and baseline measurements of oxygen are presented in Table 1. Throughout the respiration test, TVH was detected in soil gas at most of the monitoring points at low concentrations (Attachment 1). The highest detected concentrations of TVH (3.2 parts per million volume [ppmv]) was at 199-N-171. Overall, TVH concentrations measured in all wells from June and July 2017 were lower than in prior 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 July 11, 2017 immediately following respirometry testing had one of the site's highest total petroleum hydrocarbons (TPH) concentrations (diesel range) of 7,280 micrograms per liter (µg/L). During July 2017 sampling, water elevations in site wells, except those immediately adjacent to the Columbia River, were generally higher than water levels measured in December 2016 (Charts 1 through 4 on following pages). An increase in TPH diesel-range concentrations was observed in up-gradient wells which also exhibited the higher water level measurements, compared to December 2016; 199-N-169 (10,000 µg/L), and 199-N-167 (7,730 µg/L). An increase in water levels was also observed in downgradient wells, but they exhibited a decrease in TPH diesel-range concentrations (7,550 µg/L at 199-N-172 and 1,980 µg/L 199-N-183).

In February 2015, a characterization borehole (199-N-375) was installed in an area where shallow petroleum-impacted soil previously had been removed. The boring was completed to a depth of about 35 feet bgs, and was located approximately 150 feet southwest of 199-N-171 (slightly southwest of the former tank farm). Soil and groundwater samples were collected and no petroleum contamination in excess of site soil and groundwater cleanup criteria was identified in this boring (vadose zone soils of the Hanford Formation). Boring 199-N-375 was not completed as a monitoring well. In August 2016, a borehole was completed for the installation of monitoring well 199-N-377, completed to a depth of about 120 feet bgs, and located closer to the treatment area (about 80 feet southwest of 199-N-167 and at the western edge of the former tank farm). TPH-impacted soil was encountered in this boring at depths ranging from 18 to 45 feet bgs, with the top of the Ringold Formation potentially having acted as a barrier to further downward migration. No evidence of TPH impact was identified below 45 feet bgs, and no sheen was apparent on the groundwater. Specifically, laboratory results indicate TPH diesel range concentrations exceed soil cleanup levels in the shallow soils. Soil concentrations exceeded 2,000 mg/kg TPH-diesel at a depth of 18 feet bgs. From 24 feet to 45 feet bgs, TPH-diesel concentrations were above 200 mg/kg and were less than 200 mg/kg from 45 feet bgs to the water table.

It is noteworthy that 199-N-167 is a bioventing air-injection well that is screened entirely within the Ringold Formation whereas the TPH impacted soils at 199-N-377 are located within the shallower Hanford Formation. Therefore, it is unlikely that the bioventing system, as currently configured, will have much effect on the shallower impacted soil identified at 199-N-377. Well 199-N-377 was constructed with screen at the water table for groundwater monitoring and a screen section in the shallow vadose zone region to enable air injection to target the shallow (Hanford Formation) soils if future decisions include bioremediation of the contaminated soil.

The groundwater and soil gas TPH results, and respirometry testing results, are suggestive of: 1) a potential residual source area remaining up-gradient of the main area of groundwater contamination, possibly in the vicinity of the former 166-N tank farm; and 2) residual hydrocarbon contamination within a "smear" zone resulting from groundwater elevation fluctuations. Hydrocarbons (dissolved and free-phase) associated with the fluctuating groundwater are likely creating a smear zone that continually re-contaminates soils within this zone. The result is that while the existing bioventing system continues to treat the smear zone (primarily during periods of low water table), the process is slow, and unless the system is upgraded (i.e. biosparging), it is expected to become progressively less efficient.

Table 1

Soil Gas Monitoring Results, Oxygen Utilization and Biodegradation Rates Calculated from In-Situ Respiration Testing, June through July 2017.

Monitoring Point	Initial Oxygen (%)	Final Oxygen (%)	Oxygen Utilization (%/day)	Hydrocarbon Biodegradation Rate (mg/kg-day)
199-N-167	20.9	16.6	0.11	-0.08
199-N-169	20.9	15.5	0.14	-0.11
199-N-171	20.4	15.8	0.09	-0.07
199-N-172	20.9	17.3	0.10	-0.08
199-N-183	20.9	19.5	0.02	-0.02
199-N-18	20.9	20.9	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 well 199-N-18 remained above 20% throughout the test and exhibited insignificant oxygen depletion; therefore, a biodegradation rate was not calculated for this well. The results for this well are consistent with previously conducted respirometry test results as shown in 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 bgs, the gas composition samples collected from this well are likely heavily influenced by the shallow subsurface and not representative of deeper vadose zone conditions.

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-167. 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.

As mentioned above, significant respiration is not measured at 199-N-18, and while this may be due to the influence of shallow vadose-zone air dominating the sample, it is also possible that some other factor may be limiting bacterial activity in this area of the plume (e.g. lack of hydrocarbons within the vadose zone soils and contamination constrained to the saturated soils).

Because groundwater in 199-N-18 typically displays some of the highest dissolved TPH concentrations of the test wells (indicating sufficient food source for bacteria), it is likely that dissolved oxygen is a limiting factor to cleanup within the groundwater plume and smear-zone soils. This assessment is supported by the fact that groundwater dissolved oxygen concentrations are much lower within the petroleum plume than outside of the plume. Table 2 presents a summary of dissolved oxygen concentrations measured in the vicinity of the petroleum plume from March 2010 to July 2017.

Table 2

Dissolved Oxygen Concentrations in Groundwater from 3/10 to 7/17 (results in mg/L)

Location Area Relative to Plume	Well # / Range / Average	Overall Average
Up-gradient or Cross-Gradient	199-N-56 / 2.10 – 5.95 / 4.06	4.52
	199-N-3 / 2.15 - 6.47 / 5.05	
Upper Margin	199-N-167 / 0.02– 4.86 / 2.63	2.43
	199-N-169 / 0.03 – 4.62 / 2.27	
Lateral Margin (mid-portion)	199-N-183 / 0.00 – 11.86 / 2.12	2.55
	199-N-19 / 0.53 – 7.38 / 3.08	
Upper Main	199-N-171 / 0.00 – 4.08 / 1.75	1.75
Middle Main	199-N-18 / 0.00 – 2.43 / 1.11	1.31
	199-N-172 / 0.06 – 4.64 / 1.45	
Lower Main	199-N-173 / 0.04 – 5.9 / 2.37	2.37
Lateral Margin (lower portion)	199-N-96A / 0.81 – 10.0 / 5.23	5.90
	C6132 / 3.67 – 9.34 / 6.46	

COMPARISON OF BIODEGRADATION RATES OVER TIME

Table 3 presents a comparison of biodegradation rates over time. Dates of the measurements begin with the 2010 pilot test (Amec Geomatrix, 2010) and include subsequent respirometry testing at roughly six-month intervals: June to July 2014 (AMEC Environment and Infrastructure, Inc., 2014), December 2014 to January 2015 (Amec Foster Wheeler, 2015a), June to August 2015 (Amec Foster Wheeler, 2015b), January to February 2016 (Amec Foster Wheeler, 2016a), June to August 2016 (Amec Foster Wheeler, 2016b), and November to December 2016 (Amec Foster Wheeler, 2017b).

Table 3

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

Monitoring Point	Biodegradation Rate (mg/kg-day)							
	Jul. 2017	**Dec. 2016**	**Aug. 2016**	**Feb. 2016**	**Aug. 2015**	**Jan. 2015**	**Jul. 2014**	**Mar. 2010**
199-N-167	-0.09	-0.06	-0.06	-0.07	-0.05	-0.05	-0.06	-0.99
199-N-169	-0.11	-0.14	-0.07	-0.12	-0.12	-0.23	-0.09	-0.97
199-N-171	-0.08	-0.22	-0.08	-0.19	-0.14	-0.23	-0.09	-0.37
199-N-172	-0.08	-0.03	-0.02	-0.04	-0.04	-0.05	-0.02	-0.54
199-N-183	-0.02	NA	NA	NA	NA	NA	NA	not tested
199-N-18	NA	NA	NA	NA	NA	NA	NA	not tested

NA = Not applicable; oxygen depletion insignificant and biodegradation rate not calculated.
Focus of table is to compare relatively recent data with the earliest data; therefore, some older data (December 2012, January 2014) has been omitted due to space limitations.

The biodegradation rates exhibit an overall declining trend from the initial rates measured in 2010, with the rates being relatively stable since July 2014. 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 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 elevations at the site. The observed biodegradation rates at 199-N-167 and 199-N-172 were slightly higher in July 2017 than in December 2016. An increase in TPH concentrations were observed in 199-N-167 and 199-N-172 has had some of the highest TPH concentrations measured at the site. At 199-N-169 and 199-N-171 the biodegradation rates observed in July 2017 are less than in December 2016. A low biodegradation rate was observed in 199-N-183 for the first time, however no changes in oxygen concentration were measured until 840 hours after shutdown. In addition to the decrease in oxygen, a significant increase in carbon dioxide was also observed (Attachment 3). Water levels measured at 199-N-183 were the highest observed since August of 2012, however the increased water levels do not correspond with an increased TPH concentration in groundwater.

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. Groundwater elevations in July 2017 were higher than in the prior corresponding seasonal sampling event (July 2016) by approximately 2.0 to 3.0 ft. The reduced ability to deliver oxygen to the smear zone in July versus

July 2016 may be responsible (in whole or in part) for the apparent reduction in year-over-year bioremediation activity in certain wells.

Charts 1, 2, 3, and 4 (below) show dissolved diesel concentration trends in groundwater, relative to groundwater elevations, for bioventing test wells 199-N-167, 199-N-169, 199-N-171, and 199-N-172, respectively. The charts span an approximately seven-year period from 2010 to 2017. Together, these four wells provide coverage of the main portion of the contaminant plume (Figure 2). Following the July 2017 sampling event, 199-N-167 (Chart 1) and 199-N-169 (Chart 2) no longer display declining trends in groundwater diesel concentrations, but instead indicate diesel has recently rebounded to the highest levels in at least the past seven years. Concentrations in 199-N-171 and 199-N-172 (Charts 3 and 4) also indicate significant fluctuation (upward for 199-N-171 and downward for 199-N-172, albeit well within the recent historical ranges. The higher concentrations of dissolved diesel in several of the wells seem to correlate with the higher groundwater table, and therefore it is likely that the increase in concentrations is partially or wholly the result of the elevated water table re-contacting contaminated soils in the upper portion of the smear zone (or periodically rewetted zone [PRZ]) that may not have been contacted for some time. This also may be an indication that significant TPH contamination remains in the deep vadose zone, and TPH exchange between soil and groundwater in the PRZ is occurring.

Chart 1

Well 199-N-167 Groundwater TPH-Diesel Concentrations and Groundwater Elevations

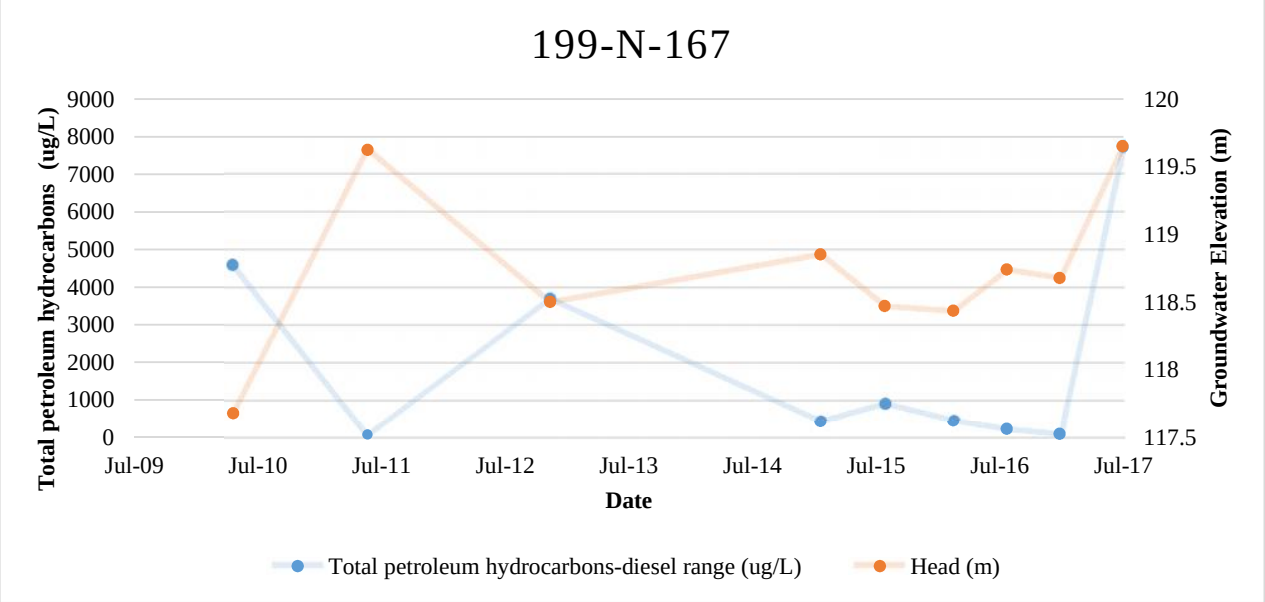


Chart 2

Well 199-N-169 Groundwater TPH-Diesel Concentrations and Groundwater Elevations

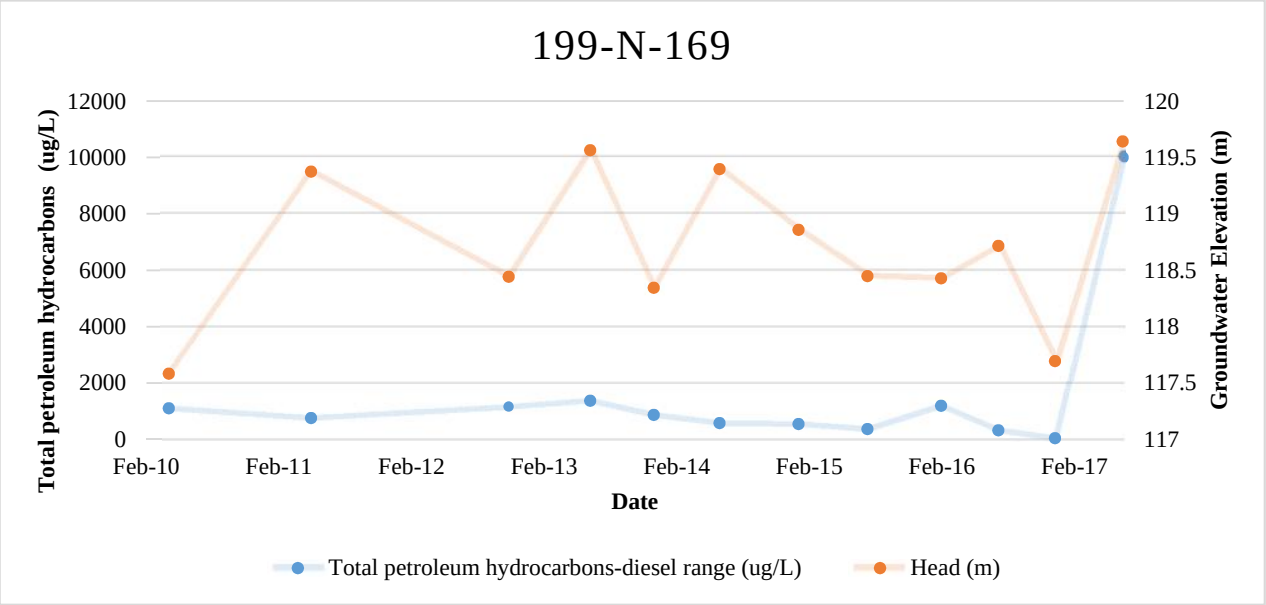


Chart 3

Wells 199-N-171 Groundwater TPH-Diesel Concentrations and Groundwater Elevations

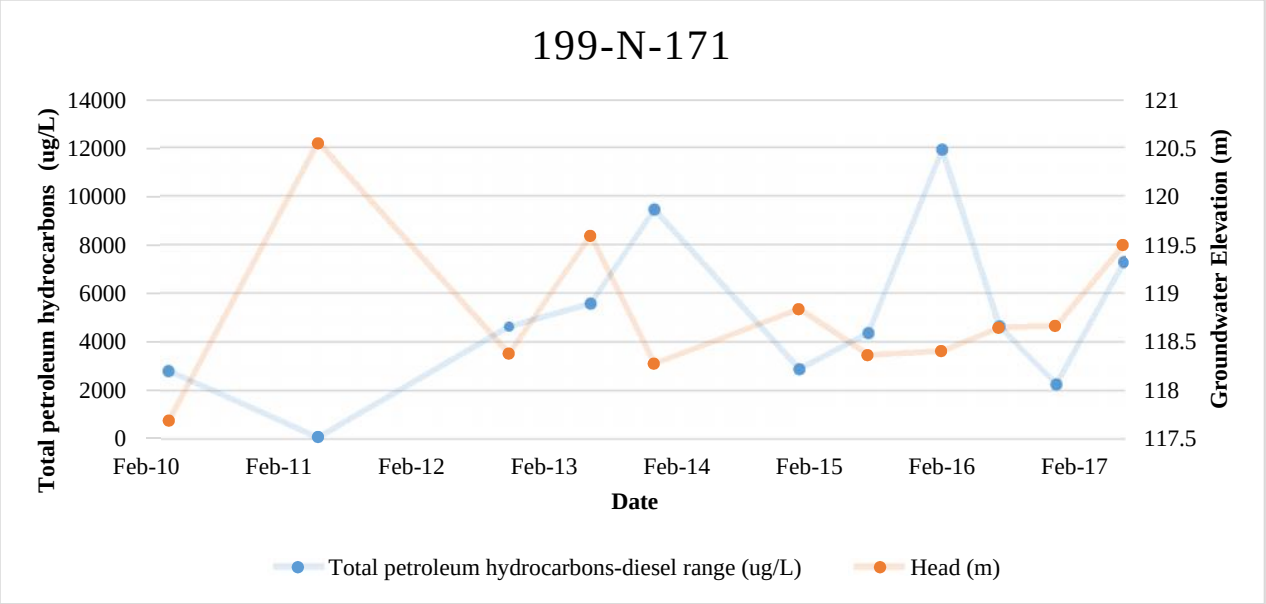
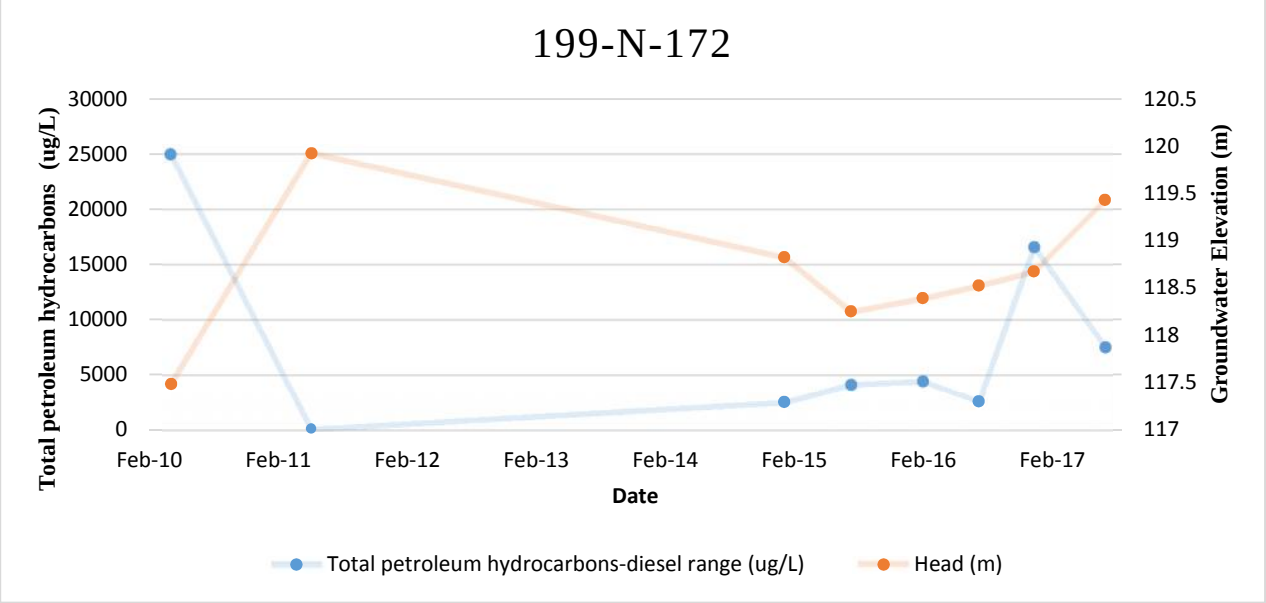


Chart 4

Wells 199-N-172 Groundwater TPH-Diesel Concentrations and Groundwater Elevations

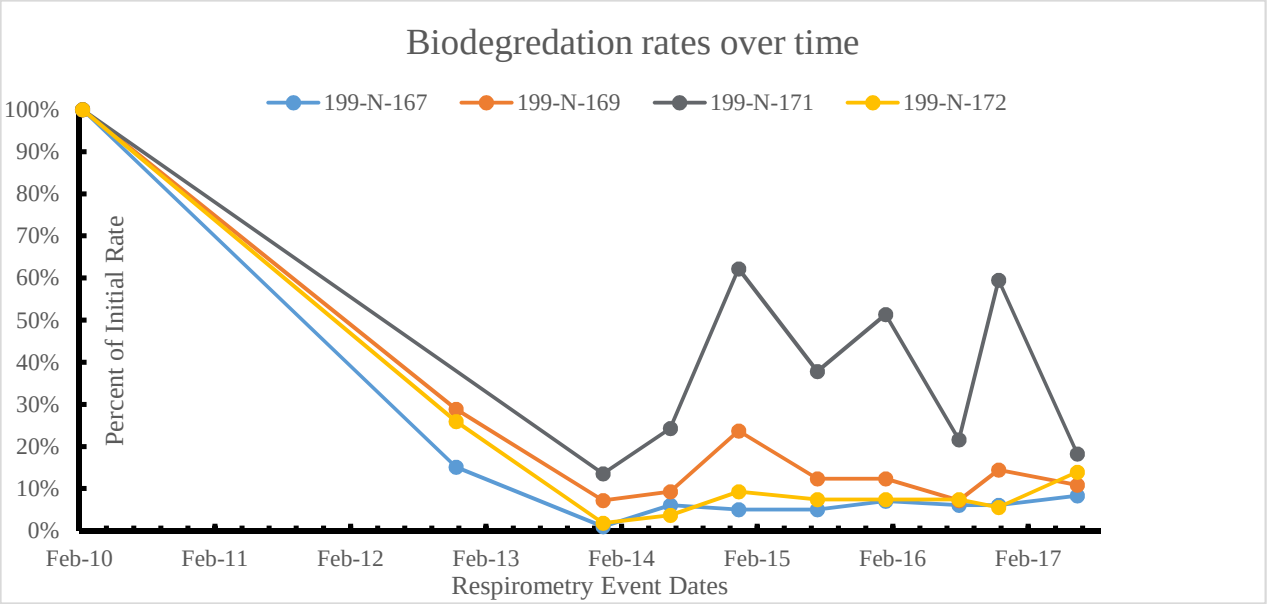


SUMMARY AND RECOMMENDATIONS

The respirometry rates from the July 2017 event remain generally below literature values for recommending bioventing as a cost effective remedial option. However, there is evidence that oxygen in the vadose zone 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 near wells 199-N-167, 199-N-169 and 199-N-172 (Chart 5). The biodegradation in the vicinity of well 199-N-171 fluctuates semi-annually, and continuation of bioventing may continue to provide petroleum mass removal at 199-N-171.

Chart 5

Rates of hydrocarbon biodegradation relative to initial rate



Note: December 2012 respirometry data for 199-N-171 was determined to be an outlier and has been removed from Chart 5.

While some treatment of the vadose zone likely continues, the smear zone has better potential for increased biodegradation rates if more oxygen could be delivered to that zone. Currently the system is prevented from delivering significant oxygen to the smear zone because the higher soil pore water saturation percentage creates a barrier to air flow. The air (oxygen) currently being delivered to the subsurface therefore preferentially enters the drier, shallower vadose zone. While bioventing will continue to be beneficial as a remedial action, particularly during times of low groundwater, site groundwater and the 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 the smear zone, capillary fringe, and groundwater to progress towards site cleanup goals. The application of biosparging could complement the existing bioventing system and expedite the overall petroleum cleanup (Amec Foster Wheeler, 2015b). Biosparging also has been identified as a proposed remedy in the 100-NR-1 and 100-NR-2 Operable Units Proposed Plan (DOE/RL-2012-68, 2013).

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,

saturated zone, and groundwater, and thereby complement the overlying vadose zone bioventing treatment. Biosparging would provide the oxygen needed to increase microbiological activity below the fluctuating water table and move the site towards closure.

Amec Foster Wheeler recommends conducting a biosparging pilot test, and has submitted conceptual site plans and background information in the "Design Basis for Biosparging Pilot System in Diesel Plume near 166-N Tank Farm Facility at Hanford Site" (Amec Foster Wheeler, 2016b). Amec Foster Wheeler also has prepared a draft pilot study test design (60% design) entitled: "Groundwater Biosparging Treatability Test Plan and 60% Engineering Design for Diesel Plume near 166-N Tank Farm Facility at Hanford Site" (Amec Foster Wheeler, 2017c).

In summary, Amec Foster Wheeler is recommending the following actions be completed at the site (several of which have already been proposed as part of the biosparging design and treatability test plan documents):

- 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 for the site. Groundwater monitoring should be conducted concurrently with the respiration testing so that respirometry testing results can be correlated against dissolved contaminant concentrations and the area of exposed smear zone soil (groundwater elevations).
- Collection of groundwater samples should be conducted after respirometry sampling has been completed so as to minimize external disturbances.
- Evaluate converting 199-N-377 to a combined groundwater monitoring and bioventing well, with air injection targeting TPH-diesel contamination in the shallow (Hanford Formation) soils.
- Use a pilot scale test to evaluate the effectiveness of adding a biosparging component to the existing bioventing system, thereby promoting further remediation of zones 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, preparation of the plans and design for the installation and monitoring of the pilot scale system, is currently at the 60% design stage.
- 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 test results could be used to provide additional respiration data for use in on-going evaluation of system performance.

FIGURE:

Figure 1 – Wells Utilized for Biovent Respirometry Testing

ATTACHMENTS:

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

REFERENCES

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

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

AMEC, 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. (Amec Foster Wheeler), 2015a. 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.

Amec Foster Wheeler, 2015b. 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.

Amec Foster Wheeler, 2016a. Technical Memorandum, Summary of January to February 2016 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site, May 20.

Amec Foster Wheeler, 2016b. Design Basis for Biosparging Pilot System in Diesel Plume near 166-N Tank Farm Facility at Hanford Site, August 29.

Amec Foster Wheeler, 2016c. Technical Memorandum, Summary of June to August 2015 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site, October 24.

Amec Foster Wheeler, 2016d. Groundwater Biosparge Treatability Study Test Plan for Diesel Plume near 166-N Tank Farm Facility at Hanford Site, December 23.

Amec Foster Wheeler, 2017a. Technical Memorandum, Summary of November to December 2016 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site, April 5.

Amec Foster Wheeler, 2017b. Subsurface Respirometry Test Plan, 100-N Area, Hanford Site, May 30.

Amec Foster Wheeler, 2017c. Groundwater Biosparging Treatability Test Plan and 60% Engineering Design for Diesel Plume near 166-N Tank Farm Facility at Hanford Site, August 31.

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

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.

FIGURES

CHPRC		100-N AREA BIOVENTING SYSTEM	DATE: JANUARY 2017
			SCALE: 1 " = 100 '
Amec Foster Wheeler Environment & Infrastructure, Inc. 7376 S.W. Durham Road Portland, OR 97224	amec foster wheeler	WELLS UTILIZED FOR BIOVENT RESPIROMETRY TESTING	PROJECT NO. 661M1230343.02.1
			FIGURE 1

DRAWN BY: PM CHECKED BY: JKH

K:\12000\12000\12034\120342 - CH2MHill\DWG\1 - Wells Utilized for Biovent Respirometry Testing.mxd - patrick.mccarthy - 1/9/2017 - 10:19:15 AM

ATTACHMENT 1

Daily Field Reports and Field Measurements

DAILY FIELD REPORT

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

PROJECT NAME: HANFORD BIO VENT PROJECT

Project No: 661M120343.02.1	Date: 6/5/2017
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial) JVG	AMEC Project Manager (Initials) JK
Weather Conditions	

FIELD REPORT NOTES

Time:	Field Notes:

6/04/2017 Sunday Calibration

21:00 - Calibrated units for 6/05/17 sampling event.

6/05/2017 Monday sampling event.

06:10 - Loaded equipment and then mobe to site.
06:45 - On site. Set up for sampling. For this event we are no longer monitoring for Methane and so will not be using a FID. We will using a MultiRae multi gas meter that measure O2, CO2, CO and H2S. as well as a MiniRae 2000 for VOC concentrations. Performed cal check on units.
07:40 - Art Lee on site.
08:02 - Kevin and Roger on site. Set up on well 169 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.
08:05 - Kyle and IH on site. IH screened and cleared wells.
08:14 - Started purge on 169.
08:54 - Baseline sampling completed on all four non system wells, ending at 171.
09:05 - Bio vent operation shut down.
09:20 - Set up on system injection well 169 and started purge.

Purge rounds started and ended at 8:14 and 8:54 (baseline), 9:20 and 10:14 (round 1), 11:20 and 12:17 (round 2), 13:21 and14:20 (round 3), 14:25 and 15:19 (round 4).
15:19 - Finished last sampling round, ending at 171. Demobed equipment.
15:40 - Off site.

20:00 - Calibrated meters for tomorrows event.

Contractor's Rep. (Initials) | Continued

DAILY FIELD REPORT

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

PROJECT NAME: HANFORD BIO VENT PROJECT

Project No:	661M120343.02.1	Date:	6/6/2017
Field Report No:		Page:	1
Arrival:		Departure:	
AMECFW Field Rep.	Jason Gardner	AMECFW Project Manager	John Kuiper
Weather Conditions			

FIELD REPORT NOTES

Time:	Field Notes:

06/06/2017 Tuesday sampling event.

07:00 - On site. Performed cal check.
07:15 -DOE operators Kevin and Malcomb on site.
07:40 - IH on site and screening wells. Started sampling on 169.
08:40 - Finished sampling on 171.
09:00 - Off site.

14:00 - Calibrated instruments tomorrows event.

Contractor's Rep. (Initials)

Continued

DAILY FIELD REPORT

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	661M120343.02.1	Date:	6/7/2017
Field Report No:		Page:	1
Arrival:		Departure:	
AMECFW Field Rep.	Jason Gardner	AMECFW Project Manager	John Kuiper
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:

06/07/2017 Tuesday sampling event.

07:00 - On site. Performed cal check.
07:30 -DOE operators Kevin and Malcomb on site. IH personnel on site and clearing wells.
07:40 - Started sampling on 169.
08:40 - Finished sampling on 171.
09:00 - Off site.

14:40 - Calibrated instruments tomorrows event.

Contractor's Rep. (Initials)

Continued

DAILY FIELD REPORT

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

PROJECT NAME: HANFORD BIO VENT PROJECT

Project No:	661M120343.02.1	Date:	6/8/2017
Field Report No:		Page:	1
Arrival:		Departure:	
AMECFW Field Rep.	Jason Gardner	AMECFW Project Manager	John Kuiper
Weather Conditions			

FIELD REPORT NOTES

Time:	Field Notes:

06/08/2017 Thursday sampling event.

07:00 - On site. Performed cal check.
07:00 -DOE operators Kevin and Malcomb on site.
07:55 - IH on site. Cleared wells for todays event.
08:04 - Started sampling on 169.
08:57 - Finished sampling on 171.
09:30 - Off site.

Contractor's Rep. (Initials)

Continued

DAILY FIELD REPORT

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

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	661M120343.02.1	Date:	6/12/2017
Field Report No:		Page:	1
Arrival:		Departure:	
AMECFW Field Rep.	Jason Gardner	AMECFW Project Manager	John Kuiper
Weather Conditions			

FIELD REPORT NOTES

Time:	Field Notes:

06/11/2017 Calibration

13:00 - Calibrated instruments for use on Mondays event.

06/12/2017 Mondays sampling event.

07:00 - On site. Performed cal check.
07:00 -DOE operators Kevin and Malcomb on site.
08:00 - IH on site. Cleared wells for todays event.
08:01 - Started sampling on 169.
08:57 - Finished sampling on 171.
09:30 - Off site.

Contractor's Rep. (Initials)

Continued

DAILY FIELD REPORT

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

PROJECT NAME: HANFORD BIO VENT PROJECT

Project No:	661M120343.02.1	Date:	6/19/2017
Field Report No:		Page:	1
Arrival:		Departure:	
AMECFW Field Rep.	Jason Gardner	AMECFW Project Manager	John Kuiper
Weather Conditions			

FIELD REPORT NOTES

Time:	Field Notes:

06/18/2017 Calibration

17:00 - Calibrated instruments for use on Mondays event.

06/19/2017 Mondays sampling event.

07:00 - On site. Performed cal check.
07:40 -DOE operators Kevin and Malcomb on site.
08:10 - IH on site. Cleared wells for todays event.
08:15 - Started sampling on 169.
09:10 - Finished sampling on 171.
09:30 - Off site.

Contractor's Rep. (Initials)

Continued

DAILY FIELD REPORT

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

PROJECT NAME: HANFORD BIO VENT PROJECT

Project No:	661M120343.02.1	Date:	6/26/2017
Field Report No:		Page:	1
Arrival:		Departure:	
AMECFW Field Rep.	Bill McFarland	AMECFW Project Manager	John Kuiper
Weather Conditions			

FIELD REPORT NOTES

Time:	Field Notes:

06/25/2017 Travel and Calibration

06/26/2017 Monday's sampling event.

07:30 - On site. .
08:00 -IH on Site.
08:15 - Sampling crew on site. IH clears wells prior to sampling. Set up on MW 167
09:25 - Sampling complete.
09:10 - Finished sampling on 171.
09:30 - Off site.

Contractor's Rep. (Initials)

Continued

DAILY FIELD REPORT

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

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	661M120343.02.1	Date:	7/5/2017
Field Report No:		Page:	1
Arrival:		Departure:	
AMECFW Field Rep.	Jason Gardner	AMECFW Project Manager	John Kuiper
Weather Conditions			

FIELD REPORT NOTES

Time:	Field Notes:

07/04/2017 Calibration

19:30 - Calibrated instruments for use on Mondays event.

07/05/2017 Wednesday sampling event.

07:30 - On site. Performed cal check.
08:00 -DOE operators Chris and two trainees on site. Art, Kyle and IH also on site.
08:05 - IH on site. Cleared wells for todays event.
08:14 - Started sampling on 167.
09:10 - Finished sampling on 171.
09:30 - Wrote up report.
10:30 - Off site.

Contractor's Rep. (Initials) | Continued

DAILY FIELD REPORT

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

PROJECT NAME: HANFORD BIO VENT PROJECT

Project No: 661M120343.02.1	Date: 7/10/2017
Field Report No:	Page: 1
Arrival: 7:30	Departure: 10:15
AMEC Field Rep. (Initial) WJM	AMEC Project Manager (Initials) JK
Weather Conditions Sunny, warm	

FIELD REPORT NOTES

Time:	Field Notes:

07/09/2017 - Sunday night calibration.

7/10/2017 Mondaysampling event.

06:45 - Loaded equipment and then mobe to site.

07:30 - On site. Set up for sampling.
07:45 - IH arrived, Kyle with DOE team. IH screened and cleared wells prior to sampling and left site.
- Sampling Team on site. Set up at Well 169.
08:00 - IH Team off site.
-Sampling Team does not have a vacuum meter. One is in route
08:55 - Vacuum meter arrives.
09:00 - Begin sampling

10:03 - Finished last well, pack up equipment.

10:25 - Off site.

Contractor's Rep. (Initials) | Continued

Field Measurements
November 2016 to July 2017 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 (ppm)	Carbon Monoxide (ppm)	TVH (ppm)	Notes
167	6/5/2017	NA	NA	0	NA	NA	NA	NA	NA	Baseline sampling prior to system shut down. Active line so not sampled.
167	6/5/2017	9:32	-272	0	4 min	20.9	500	0	1.4	Biovent system off at 9:05. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	6/5/2017	11:29	-272	0	4 min	20.9	800	0	1.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	6/5/2017	13:30	-271	0	4 min	20.9	700	0	1.5	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	6/5/2017	14:35	-268	0	4 min	20.9	600	0	1.5	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	6/6/2017	7:49	-270	0	4 min	20.9	700	6	0.6	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling. CO reading is likely due to thermal breakdown of contaminate attributed to heat from system.
167	6/7/2017	7:51	-263	0	4 min	20.9	900	10	0.4	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling. CO reading is likely due to thermal breakdown of contaminate attributed to heat from system.
167	6/8/2017	8:13	-265	0	4 min	20.9	900	6	0.4	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling. CO reading is likely due to thermal breakdown of contaminate attributed to heat from system.
167	6/12/2017	8:10	-268	0	4 min	20.9	1,500	12	0.4	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling. CO reading is likely due to thermal breakdown of contaminate attributed to heat from system.
167	6/19/2017	8:25	-269	0	4 min	20.4	1,400	11	0.6	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling. CO reading is likely due to thermal breakdown of contaminate attributed to heat from system.
167	6/26/2017	8:33	-268	0	4min	19.7	2,900	11	0.3	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling. CO reading is likely due to thermal breakdown of contaminate attributed to heat from system.
167	7/5/2017	8:18	-271	0	4 min	17.6	6,800	8	0.6	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling. CO reading is likely due to thermal breakdown of contaminate attributed to heat from system.
167	7/10/2017	9:09	-265	0	4 min	16.6	9,300	15	0.3	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling. CO reading is likely due to thermal breakdown of contaminate attributed to heat from system.

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

Field Measurements
November 2016 to July 2017 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 (ppm)	Carbon Monoxide (ppm)	TVH (ppm)	Notes
171	6/5/2017	8:47	-275	0	4 min	20.4	4,800	0	2	Baseline sampling prior to system shut down. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	6/5/2017	10:14	-257	0	4 min	20.5	3,700	0	1.4	Biovent system off at 9:05. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	6/5/2017	12:17	-261	0	4 min	20.5	3,800	0	2.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	6/5/2017	14:20	-260	0	4 min	20.9	4,000	0	3.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	6/5/2017	15:19	-267	0	4 min	20.9	4,000	0	1.3	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	6/6/2017	8:39	-257	0	4 min	20.3	4,700	0	0.3	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	6/7/2017	8:38	-250	0	4 min	20	5,800	0	0.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	6/8/2017	8:56	-251	0	4 min	20	5,600	0	0.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	6/12/2017	8:57	-255	0	4 min	19.2	8,700	0	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	6/19/2017	9:10	-258	0	4 min	18.9	10,300	0	0.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	6/26/2017	9:25	-246	0	4min	19.5	6,700	0	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	7/5/2017	9:14	-247	0	4 min	19.3	8,100	0	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	7/10/2017	9:57	-249	0	4 min	15.8	10,200	0	1.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

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

Field Measurements
November 2016 to July 2017 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 (ppm)	Carbon Monoxide (ppm)	TVH (ppm)	Notes
169	6/5/2017	8:18	-264	0	4 min	20.9	300	6	0	Baseline sampling prior to system shut down. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling. CO reading is likely due to thermal breakdown of contaminate attributed to heat from system.
169	6/5/2017	9:24	-258	0	4 min	20.9	300	0	0.9	Biovent system off at 9:05. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	6/5/2017	11:24	-264	0	4 min	20.9	300	0	0.8	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	6/5/2017	13:25	-262	0	4 min	20.9	300	0	1.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	6/5/2017	14:29	-260	0	4 min	20.9	400	0	0.4	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	6/6/2017	7:47	-262	0	4 min	20.9	400	0	0.4	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	6/7/2017	7:49	-260	0	4 min	20.9	500	0	0.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	6/8/2017	8:05	-261	0	4 min	20.9	400	0	0.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	6/12/2017	8:05	-267	0	4 min	20.3	700	0	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	6/19/2017	8:19	-263	0	4 min	19.5	1,400	0	0.5	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	6/26/2017	8:40	-258	0	4min	18.7	3,000	4	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	7/5/2017	8:24	-253	0	4 min	16.9	6,200	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	7/10/2017	9:00	-256	0	4 min	15.5	9,700	4	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

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

Field Measurements
November 2016 to July 2017 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 (ppm)	Carbon Monoxide (ppm)	TVH (ppm)	Notes
172	6/5/2017	NA	NA	0	NA	NA	NA	NA	NA	Baseline sampling prior to system shut down. Active line so not sampled.
172	6/5/2017	9:40	-275	0	4 min	20.9	500	0	1.0	Biovent system off at 9:05. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	6/5/2017	11:39	-276	0	4 min	20.9	600	0	0.9	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	6/5/2017	13:38	-274	0	4 min	20.9	600	0	1.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	6/5/2017	14:42	-272	0	4 min	20.9	500	0	1.3	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	6/6/2017	8:01	-270	0	4 min	20.9	500	0	0.6	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	6/7/2017	8:03	-265	0	4 min	20.9	500	0	0.4	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	6/8/2017	8:21	-265	0	4 min	20.9	400	0	0.4	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	6/12/2017	8:17	-268	0	4 min	20.9	600	0	0.3	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	6/19/2017	8:34	-275	0	4 min	20.3	900	0	0.5	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	6/26/2017	8:51	-263	0	4min	19.4	2800	0	0.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	7/5/2017	8:34	-265	0	4 min	18.1	5,800	0	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	7/10/2017	9:18	-265	0	4 min	17.3	8,000	0	0.4	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

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

Field Measurements
November 2016 to July 2017 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 (ppm)	Carbon Monoxide (ppm)	TVH (ppm)	Notes
183	6/5/2017	8:54	-258	0	15 min	20.9	300	0	0.6	Baseline sampling prior to system shut down. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling. CO reading is likely due to thermal breakdown of contaminate attributed to heat from system.
183	6/5/2017	10:11	-267	0	15 min	20.9	300	0	0.7	Biovent system off at 9:05. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	6/5/2017	12:10	-274	0	15 min	20.9	300	0	1.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	6/5/2017	14:18	-270	0	15 min	20.9	300	0	1.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	6/5/2017	15:12	-277	0	15 min	20.9	300	0	1.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	6/6/2017	8:31	-268	0	15 min	20.9	300	0	0.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	6/7/2017	8:31	-262	0	15 min	20.9	300	0	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	6/8/2017	8:50	-261	0	15 min	20.9	200	0	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	6/12/2017	8:51	-266	0	15 min	20.9	200	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	6/19/2017	9:03	-269	0	15 min	20.9	200	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	6/26/2017	9:08	-255	0	15min	20.9	500	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	7/5/2017	9:07	-258	0	15 min	20.9	500	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	7/10/2017	9:37	-259	0	15 min	19.5	7,100	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

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

Field Measurements
November 2016 to July 2017 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 (ppm)	Carbon Monoxide (ppm)	TVH (ppm)	Notes
18	6/5/2017	8:38	-260	0	10 min	20.9	400	0	0	Baseline sampling prior to system shut down. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling. CO reading is likely due to thermal breakdown of contaminate attributed to heat from system.
18	6/5/2017	9:52	-259	0	10 min	20.9	400	0	0.4	Biovent system off at 9:05. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	6/5/2017	11:52	-265	0	10 min	20.9	400	0	0.9	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	6/5/2017	13:50	-260	0	10 min	20.9	400	0	0.8	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	6/5/2017	14:55	-268	0	10 min	20.9	500	0	1.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	6/6/2017	8:14	254	0	10 min	20.9	500	0	0.3	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	6/7/2017	8:14	-254	0	10 min	20.9	500	0	0.3	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	6/8/2017	8:32	-246	0	10 min	20.9	300	0	0.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	6/12/2017	8:28	-259	0	10 min	20.9	400	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	6/19/2017	8:46	-262	0	10 min	20.9	400	0	0.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	6/26/2017	8:56	-253	0	10min	20.9	500	0	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	7/5/2017	8:49	-253	0	10 min	20.9	500	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	7/10/2017	9:23	-250	0	10 min	20.9	500	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

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

ATTACHMENT 2

Instrument Calibration Sheets

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 661M120343.02.1

Date / Time: 6/4/2017 9:00:00 PM Completed By: Jason Gardner

Instrument name(s) Multi Rae 435-1054 and Mini Rae 2000

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	PID readings	Span Readings	Final readings
Multi Rae- 435-1054 s/n 1135277	6/4/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 1135277	6/4/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 1135277	6/4/2017	30 min	5000 ppm CO2	n/a	5000	5000
Multi Rae- 435-1054 s/n 0008605	6/4/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0008605	6/4/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0008605	6/4/2017	30 min	5000 ppm CO2	n/a	5000	5000
Mini Rae 2000 s/n 110 003625	6/4/2017	30 min	100 ppm Isob.	100 ppm (PID)	100	100
Mini Rae 2000 back up	6/4/2017	30 min	100 ppm Isob.	100 ppm (PID)	100	100

Notes:
This calibration is for the 6/5/2017 sample event.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 661M120343.02.1

Date / Time: 6/5/2017 8:00:00 PM Completed By: Jason Gardner

Instrument name(s): Multi Rae 435-1054 and Mini Rae 2000

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	PID readings	Span Readings	Final readings
Multi Rae- 435-1054 s/n 1135277	6/5/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 1135277	6/5/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 1135277	6/5/2017	30 min	5000 ppm CO2	n/a	5000	5000
Multi Rae- 435-1054 s/n 0008605	6/5/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0008605	6/5/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0008605	6/5/2017	30 min	5000 ppm CO2	n/a	5000	5000
Mini Rae 2000 s/n 110 003625	6/5/2017	30 min	100 ppm Isob.	100 ppm (PID)	100	100
Mini Rae 2000 back up	6/5/2017	30 min	100 ppm Isob.	100 ppm (PID)	100	100

Notes:
This calibration is for the 6/6/2017 sample event.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 661M120343.02.1

Date / Time: 6/6/2017 14:00:00 PM Completed By: Jason Gardner

Instrument name(s): Multi Rae 435-1054 and Mini Rae 2000

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	PID readings	Span Readings	Final readings
Multi Rae- 435-1054 s/n 1135277	6/6/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 1135277	6/6/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 1135277	6/6/2017	30 min	5000 ppm CO2	n/a	5000	5000
Multi Rae- 435-1054 s/n 0008605	6/6/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0008605	6/6/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0008605	6/6/2017	30 min	5000 ppm CO2	n/a	5000	5000
Mini Rae 2000 s/n 110 003625	6/6/2017	30 min	100 ppm Isob.	100 ppm (PID)	100	100
Mini Rae 2000 back up	6/6/2017	30 min	100 ppm Isob.	100 ppm (PID)	100	100

Notes:
This calibration is for the 6/7/2017 sample event.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 661M120343.02.1

Date / Time: 6/7/2017 14:40:00 PM Completed By: Jason Gardner

Instrument name(s): Multi Rae 435-1054 and Mini Rae 2000

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	PID readings	Span Readings	Final readings
Multi Rae- 435-1054 s/n 1135277	6/7/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 1135277	6/7/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 1135277	6/7/2017	30 min	5000 ppm CO2	n/a	5000	5000
Multi Rae- 435-1054 s/n 0008605	6/7/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0008605	6/7/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0008605	6/7/2017	30 min	5000 ppm CO2	n/a	5000	5000
Mini Rae 2000 s/n 110 003625	6/7/2017	30 min	100 ppm Isob.	100 ppm (PID)	100	100
Mini Rae 2000 back up	6/7/2017	30 min	100 ppm Isob.	100 ppm (PID)	100	100

Notes:
This calibration is for the 6/8/2017 sample event.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 661M120343.02.1

Date / Time: 6/11/2017 1:00:00 PM Completed By: Jason Gardner

Instrument name(s) Multi Rae 435-1054 and Mini Rae 2000

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	PID readings	Span Readings	Final readings
Multi Rae- 435-1054 s/n 1135277	6/11/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 1135277	6/11/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 1135277	6/11/2017	30 min	5000 ppm CO2	n/a	5000	5000
Multi Rae- 435-1054 s/n 0008605	6/11/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0008605	6/11/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0008605	6/11/2017	30 min	5000 ppm CO2	n/a	5000	5000
Mini Rae 2000 s/n 110 003625	6/11/2017	30 min	100 ppm Isob.	100 ppm (PID)	100	100
Mini Rae 2000 back up	6/11/2017	30 min	100 ppm Isob.	100 ppm (PID)	100	100

Notes:
This calibration is for the 6/12/2017 sample event.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 661M120343.02.1

Date / Time: 6/18/2017 5:00:00 PM Completed By: Jason Gardner

Instrument name(s) Multi Rae 435-1054 and Mini Rae 2000

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	PID readings	Span Readings	Final readings
Multi Rae- 435-1054 s/n 1135277	6/18/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 1135277	6/18/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 1135277	6/18/2017	30 min	5000 ppm CO2	n/a	5000	5000
Multi Rae- 435-1054 s/n 0008605	6/18/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0008605	6/18/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0008605	6/18/2017	30 min	5000 ppm CO2	n/a	5000	5000
Mini Rae 2000 s/n 110 003625	6/18/2017	30 min	100 ppm Isob.	100 ppm (PID)	100	100
Mini Rae 2000 back up	6/18/2017	30 min	100 ppm Isob.	100 ppm (PID)	100	100

Notes:
This calibration is for the 6/19/2017 sample event.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 661M120343.02.1

Date / Time: 6/25/2017 7:00:00 PM Completed By: Bill McFarland

Instrument name(s) Multi Rae 435-1054 and Mini Rae 2000

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	PID readings	Span Readings	Final readings
Multi Rae- 435-1054 s/n 1135277	6/25/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 1135277	6/25/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 1135277	6/25/2017	30 min	5000 ppm CO2	n/a	5000	5000
Multi Rae- 435-1054 s/n 0008605	6/25/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0008605	6/25/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0008605	6/25/2017	30 min	5000 ppm CO2	n/a	5000	5000
Mini Rae 2000 s/n 110 003625	6/25/2017	30 min	100 ppm Isob.	100 ppm (PID)	100	100
Mini Rae 2000 back up	6/25/2017	30 min	100 ppm Isob.	100 ppm (PID)	100	100

Notes:
This calibration is for the 6/26/2017 sample event.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 661M120343.02.1

Date / Time: 7/4/2017 7:30:00 PM Completed By: Jason Gardner

Instrument name(s) Multi Rae 435-1054 and Mini Rae 2000

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	PID readings	Span Readings	Final readings
Multi Rae- 435-1054 s/n 1135277	7/4/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 1135277	7/4/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 1135277	7/4/2017	30 min	5000 ppm CO2	n/a	5000	5000
Multi Rae- 435-1054 s/n 0008605	7/4/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0008605	7/4/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0008605	7/4/2017	30 min	5000 ppm CO2	n/a	5000	5000
Mini Rae 2000 s/n 110 003625	7/4/2017	30 min	100 ppm Isob.	100 ppm (PID)	100	100
Mini Rae 2000 back up	7/4/2017	30 min	100 ppm Isob.	100 ppm (PID)	100	100

Notes:
This calibration is for the 7/05/2017 sample event.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 661M120343.02.1

Date / Time: 7/9/2017 7:30:00 PM Completed By: Bill McFarland

Instrument name(s) Multi Rae 435-1054 and Mini Rae 2000

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	PID readings	Span Readings	Final readings
Multi Rae- 435-1054 s/n 1135277	7/9/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 1135277	7/9/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 1135277	7/9/2017	30 min	5000 ppm CO2	n/a	5000	5000
Multi Rae- 435-1054 s/n 0008605	7/9/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0008605	7/9/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0008605	7/9/2017	30 min	5000 ppm CO2	n/a	5000	5000
Mini Rae 2000 s/n 110 003625	7/9/2017	30 min	100 ppm Isob.	100 ppm (PID)	100	100
Mini Rae 2000 back up	7/9/2017	30 min	100 ppm Isob.	100 ppm (PID)	100	100

Notes:
This calibration is for the 7/10/2017 sample event.

ATTACHMENT 3

Design Worksheet for Oxygen Utilization and Biodegradation Rates

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DESIGN WORKSHEET

Date: 2-Aug-17

Client: CHPRC

Project Number: 661M120343.02.01

Project: Hanford 100-N Biovent

Prepared by: J. Malone

Data For: Jun to Jul 2017 Respiration Test

Reviewed by: C. Weber

An in-situ respiration test was conducted at the Hanford Site 100-N from June 2017 to July 2017. 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	0.0046	0.11	0.899
199-N-169	0.006	0.14	0.970
199-N-171	0.0038	0.09	0.689
199-N-172	0.0041	0.10	0.945
199-N-183	0.0009	0.02	0.407
199-N-18	--	--	--

Oxygen readings between 19.5 and 22% represent essentially atmospheric conditions and generally amount to insignificant oxygen depletion. Biodegradation rates are only calculated for wells with significant oxygen depletion (>1% change during testing); others with insignificant biodegradation rates 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

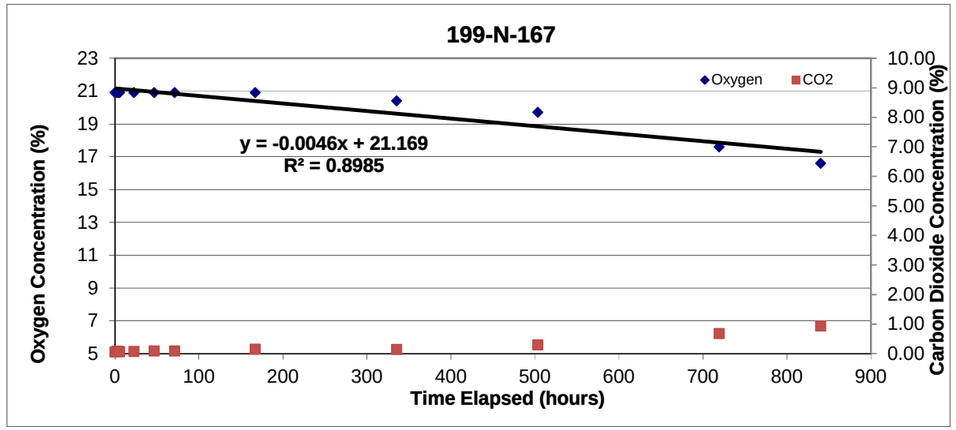
Client: CHPRC
Project: Hanford 100-N Biovent
Data For: Jun to Jul 2017 Respiration Test

Date: 2-Aug-17
Project Number: 661M120343.02.01
Prepared by: J. Malone
Reviewed by: C. Weber

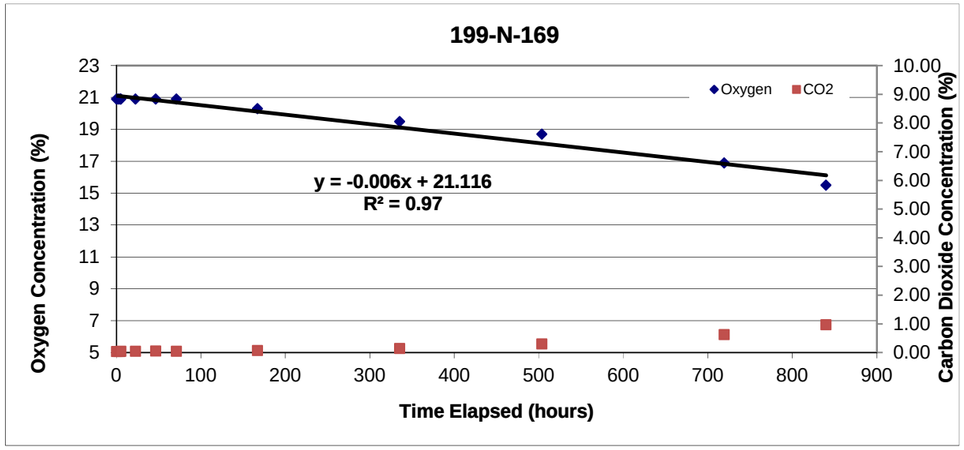
Location	Parameter	Jul-17	Dec-16	Aug-16	Feb-16	Aug-15	Jan-15	Mar-10	Units	Notes
199-N-167	K_o =	0.11	0.08	0.09	0.09	0.07	0.07	1.32	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.08**	**-0.06**	**-0.06**	**-0.07**	**-0.05**	**-0.05**	**-0.99**	mg/Kg-day	Biodegradation rate; calculated value
199-N-169	K_o =	0.14	0.18	0.09	0.16	0.16	0.3	1.29	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.11**	**-0.14**	**-0.07**	**-0.12**	**-0.12**	**-0.23**	**-0.97**	mg/Kg-day	Biodegradation rate; calculated value
199-N-171	K_o =	0.09	0.29	0.11	0.25	0.18	0.3	0.49	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.07**	**-0.22**	**-0.08**	**-0.19**	**-0.14**	**-0.23**	**-0.37**	mg/Kg-day	Biodegradation rate; calculated value
199-N-172	K_o =	0.10	0.04	0.03	0.05	0.05	0.07	0.71	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.08**	**-0.03**	**-0.02**	**-0.04**	**-0.04**	**-0.05**	**-0.54**	mg/Kg-day	Biodegradation rate; calculated value
199-N-183	K_o =	0.02	--	--	--	--	--	not tested	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.02**	**--**	**--**	**--**	**--**	**--**	not tested	mg/Kg-day	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-day	Biodegradation rate; calculated value

Oxygen Utilization Generation Plots
June to July 2017 Respirometry Test

199-N-167						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
6/5/2017	9:05	6/5/2017 9:05	blower off	0	--	--
6/5/2017	9:32	6/5/2017 9:32	Initial reading	0.00	20.9	0.05
6/5/2017	11:29	6/5/2017 11:29	2:24:00	2.40	20.9	0.08
6/5/2017	13:30	6/5/2017 13:30	4:25:00	4.42	20.9	0.07
6/5/2017	14:35	6/5/2017 14:35	5:30:00	5.50	20.9	0.06
6/6/2017	7:49	6/6/2017 7:49	22:44:00	22.73	20.9	0.07
6/7/2017	7:51	6/7/2017 7:51	46:46:00	46.77	20.9	0.09
6/8/2017	8:13	6/8/2017 8:13	71:08:00	71.13	20.9	0.09
6/12/2017	8:10	6/12/2017 8:10	167:05:00	167.08	20.9	0.15
6/19/2017	8:25	6/19/2017 8:25	335:20:00	335.33	20.4	0.14
6/26/2017	8:33	6/26/2017 8:33	503:28:00	503.47	19.7	0.29
7/5/2017	8:18	7/5/2017 8:18	719:13:00	719.22	17.6	0.68
7/10/2017	9:09	7/10/2017 9:09	840:04:00	840.07	16.6	0.93

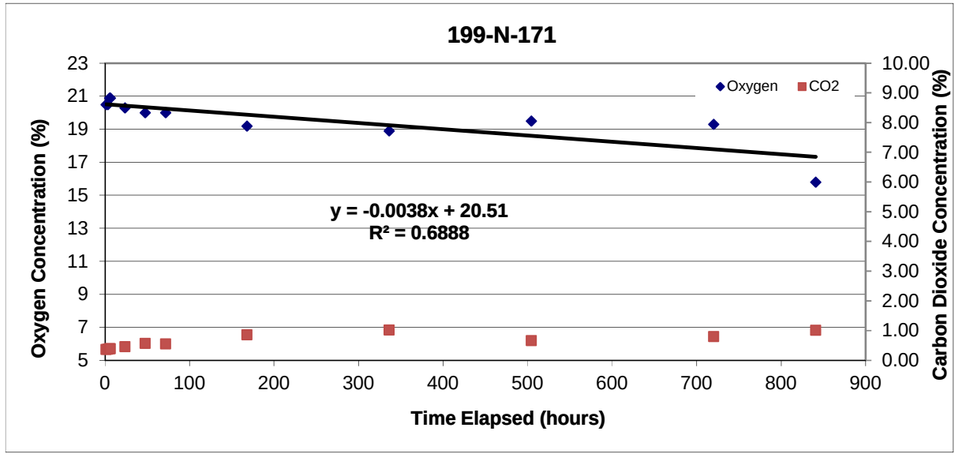


199-N-169						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
6/5/2017	8:18	6/5/2017 8:18	Baseline	--	20.9	0.03
6/5/2017	9:05	6/5/2017 9:05	Blower off	0	--	--
6/5/2017	9:24	6/5/2017 9:24	Initial reading	0.32	20.9	0.03
6/5/2017	11:24	6/5/2017 11:24	2:19:00	2.3	20.9	0.03
6/5/2017	13:25	6/5/2017 13:25	4:20:00	4.3	20.9	0.03
6/5/2017	14:29	6/5/2017 14:29	5:24:00	5.4	20.9	0.04
6/6/2017	7:47	6/6/2017 7:47	22:42:00	22.7	20.9	0.04
6/7/2017	7:49	6/7/2017 7:49	46:44:00	46.7	20.9	0.05
6/8/2017	8:05	6/8/2017 8:05	71:00:00	71.0	20.9	0.04
6/12/2017	8:05	6/12/2017 8:05	167:00:00	167.0	20.3	0.07
6/19/2017	8:19	6/19/2017 8:19	335:14:00	335.2	19.5	0.14
6/26/2017	8:40	6/26/2017 8:40	503:35:00	503.6	18.7	0.30
7/5/2017	8:24	7/5/2017 8:24	719:19:00	719.3	16.9	0.62
7/10/2017	9:00	7/10/2017 9:00	839:55:00	839.9	15.5	0.97

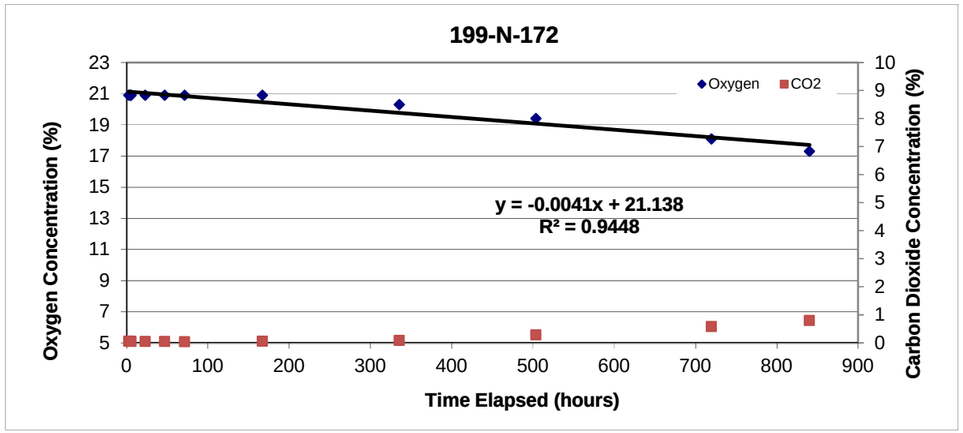


Oxygen Utilization Generation Plots
June to July 2017 Respirometry Test

199-N-171						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
6/5/2017	8:47	6/5/2017 8:47	Baseline	--	20.4	0.48
6/5/2017	9:05	6/5/2017 9:05	Blower off	0	--	--
6/5/2017	10:14	6/5/2017 10:14	Initial reading	1.15	20.5	0.37
6/5/2017	12:17	6/5/2017 12:17	3:12:00	3.2	20.5	0.38
6/5/2017	14:20	6/5/2017 14:20	5:15:00	5.3	20.9	0.40
6/5/2017	15:19	6/5/2017 15:19	6:14:00	6.2	20.9	0.40
6/6/2017	8:39	6/6/2017 8:39	23:34:00	23.6	20.3	0.47
6/7/2017	8:38	6/7/2017 8:38	47:33:00	47.6	20	0.58
6/8/2017	8:56	6/8/2017 8:56	71:51:00	71.9	20	0.56
6/12/2017	8:57	6/12/2017 8:57	167:52:00	167.9	19.2	0.87
6/19/2017	9:10	6/19/2017 9:10	336:05:00	336.1	18.9	1.03
6/26/2017	9:25	6/26/2017 9:25	504:20:00	504.3	19.5	0.67
7/5/2017	9:14	7/5/2017 9:14	720:09:00	720.2	19.3	0.81
7/10/2017	9:57	7/10/2017 9:57	840:52:00	840.9	15.8	1.02

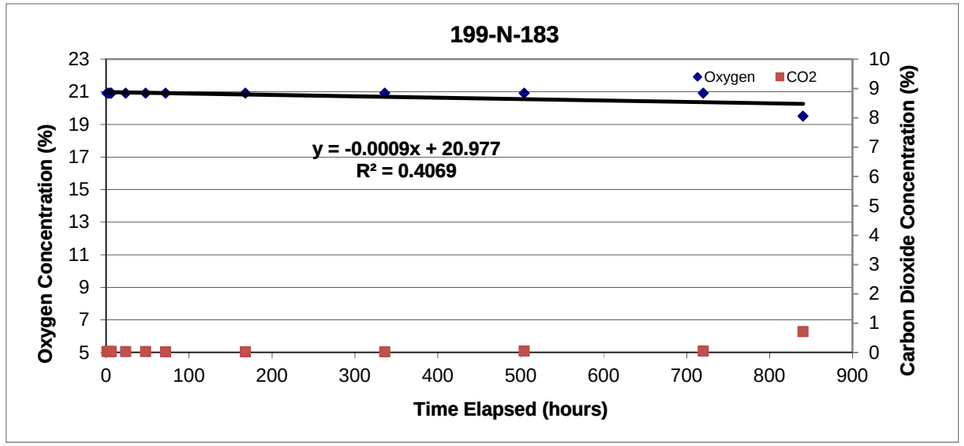


199-N-172						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
6/5/2017	9:05	6/5/2017 9:05	Blower off	0.00	--	--
6/5/2017	9:40	6/5/2017 9:40	Initial reading	0.58	20.9	0.05
6/5/2017	11:39	6/5/2017 11:39	2:34:00	2.57	20.9	0.06
6/5/2017	13:38	6/5/2017 13:38	4:33:00	4.55	20.9	0.06
6/5/2017	14:42	6/5/2017 14:42	5:37:00	5.62	20.9	0.05
6/6/2017	8:01	6/6/2017 8:01	22:56:00	22.93	20.9	0.05
6/7/2017	8:03	6/7/2017 8:03	46:58:00	46.97	20.9	0.05
6/8/2017	8:21	6/8/2017 8:21	71:16:00	71.27	20.9	0.04
6/12/2017	8:17	6/12/2017 8:17	167:12:00	167.20	20.9	0.06
6/19/2017	8:34	6/19/2017 8:34	335:29:00	335.48	20.3	0.09
6/26/2017	8:51	6/26/2017 8:51	503:46:00	503.77	19.4	0.28
7/5/2017	8:34	7/5/2017 8:34	719:29:00	719.48	18.1	0.58
7/10/2017	9:18	7/10/2017 9:18	840:13:00	840.22	17.3	0.8

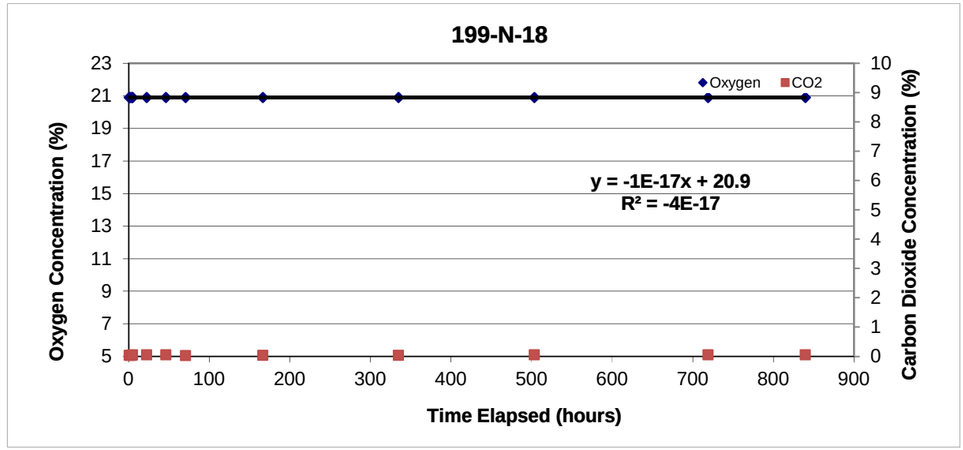


Oxygen Utilization Generation Plots
June to July 2017 Respirometry Test

199-N-183						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
6/5/2017	8:54	6/5/2017 8:54	Baseline	--	20.9	0.03
6/5/2017	9:05	6/5/2017 9:05	Blower off	0	--	--
6/5/2017	10:11	6/5/2017 10:11	Initial reading	1.10	20.9	0.03
6/5/2017	12:10	6/5/2017 12:10	3:05:00	3.08	20.9	0.03
6/5/2017	14:18	6/5/2017 14:18	5:13:00	5.22	20.9	0.03
6/5/2017	15:12	6/5/2017 15:12	6:07:00	6.12	20.9	0.03
6/6/2017	8:31	6/6/2017 8:31	23:26:00	23.43	20.9	0.03
6/7/2017	8:31	6/7/2017 8:31	47:26:00	47.43	20.9	0.03
6/8/2017	8:50	6/8/2017 8:50	71:45:00	71.75	20.9	0.02
6/12/2017	8:51	6/12/2017 8:51	167:46:00	167.77	20.9	0.02
6/19/2017	9:03	6/19/2017 9:03	335:58:00	335.97	20.9	0.02
6/26/2017	9:08	6/26/2017 9:08	504:03:00	504.05	20.9	0.05
7/5/2017	9:07	7/5/2017 9:07	720:02:00	720.03	20.9	0.05
7/10/2017	9:37	7/10/2017 9:37	840:32:00	840.53	19.5	0.71



199-N-18						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
6/5/2017	8:38	6/5/2017 8:38	Baseline	--	20.9	0.04
6/5/2017	9:05	6/5/2017 9:05	Blower off	0	--	--
6/5/2017	9:52	6/5/2017 9:52	Initial reading	0.78	20.9	0.04
6/5/2017	11:52	6/5/2017 11:52	2:00:00	2.00	20.9	0.04
6/5/2017	13:50	6/5/2017 13:50	3:58:00	3.97	20.9	0.04
6/5/2017	14:55	6/5/2017 14:55	5:03:00	5.05	20.9	0.05
6/6/2017	8:14	6/6/2017 8:14	22:22:00	22.37	20.9	0.05
6/7/2017	8:14	6/7/2017 8:14	46:22:00	46.37	20.9	0.05
6/8/2017	8:32	6/8/2017 8:32	70:40:00	70.67	20.9	0.03
6/12/2017	8:28	6/12/2017 8:28	166:36:00	166.60	20.9	0.04
6/19/2017	8:46	6/19/2017 8:46	334:54:00	334.90	20.9	0.04
6/26/2017	9:08	6/26/2017 9:08	503:16:00	503.27	20.9	0.05
7/5/2017	8:49	7/5/2017 8:49	718:57:00	718.95	20.9	0.05
7/10/2017	9:23	7/10/2017 9:23	839:31:00	839.52	20.9	0.05



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Appendix B

October-November Respirometry Testing

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Memorandum

To Art Lee, BTR
William Faught, CAM
CH2M HILL Plateau Remediation Company

Project No.: 6-61M-120343.02.1

From John Kuiper, LG, Project Manager
Craig Weber, PE (CO)
Melissa Roskamp, PE
Jessica Malone, LG

Amec Foster Wheeler
Environment & Infrastructure, Inc.

Date January 31, 2018

Subject: Summary of October through November 2017 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 October to November 2017 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 Subsurface Respirometry Test Plan (Test Plan) dated September 22, 2017 (Amec Foster Wheeler Environment and Infrastructure, Inc., 2017d), with exceptions as noted below.

Since startup in November 2012, the bioventing system has been configured to supply air to an area of the subsurface impacted by petroleum hydrocarbons (diesel) via two injection wells: 199-N-167 and 199-N-172 (Figure 1). These wells are screened from 53 to 78 feet below ground surface (bgs) and 57 to 77 feet bgs, respectively. Both wells are screened exclusively within the Ringold Formation (Unit E), which consists of layers (slightly weathered and consolidated) of silty, sandy gravel (msG), sandy gravel (sG), sand (S), and gravelly sand (gS). The contact with the overlying Hanford Formation (unconsolidated msG and sG) ranges from approximately 45 to 51 feet bgs. Approximately 250 cubic feet per minute (cfm) of air is routed to each injection well through a custom fitted wellhead. Based on previous studies, it is predicted that the radius of

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influence (ROI) for each injection well is at least 200 feet. The system has been in continuous operation since startup in late 2012, 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 October 2, 2017. Gas composition samples were then collected periodically, starting immediately after shut down and continuing through test completion on November 6, 2017. 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, carbon monoxide, and total volatile hydrocarbons (TVH).

Prior to blower shutdown on October 2, 2017, 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 at 9:05 am on October 2 when the blower was switched off.

Thirteen samples were collected from two monitoring locations (199-N-167 and 199-N-172) and fourteen samples were collected from four monitoring locations (199-N-169, 199-N-171, 199-N-183, and 199-N-18). Samples were collected over a period of approximately 840 hours (5 weeks). Readings were collected frequently for the first three days (at approximately 0, 1, 2, 4, 5, 24, 48 and 72 hours) and then at 168 hours (7 days). The bioventing system then remained off for four additional weeks during which four additional sampling events occurred at approximately 334, 502, 672, and 840 hours at all six locations.

A minimum of one casing volume of air was extracted prior to monitoring using a purge pump. Sampling was performed according to the Test Plan and direct measurements were made (in-line sampling, no Tedlar bags) consistent with the prior June-July 2017 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 (Air Force Center for Environmental Excellence, 2004) 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 and calculations 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] (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

[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 bgs, as presented in Attachment 3 and described in detail in the January 2014 respirometry test results summary (AMEC Environment and Infrastructure, Inc., 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 five-week in-situ respirometry test initiated on October 2, 2017, calculated biodegradation rates and baseline measurements of oxygen are presented in Table 1. Throughout the respiration test, TVH was detected in soil gas at most of the monitoring points at low concentrations (Attachment 1). The highest detected concentrations of TVH (18.6 parts per million volume [ppmv]) was at 199-N-171. TVH concentrations measured in wells 199-N-169, 199-N-167, 199-N-172 and 199-N-18 from October to November 2017 were lower than in prior tests. TVH concentrations measured in wells 199-N-171 and 199-N-183 were slightly higher than those from the previous sampling event in June and July of 2017, but lower than most other previous 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 November 8, 2017 immediately following respirometry testing had one of the site's highest total petroleum hydrocarbons (TPH) concentrations (diesel range) of 5,900 micrograms per liter (µg/L). During the June to July 2017 sampling event, water elevations in site wells, except those immediately adjacent to the Columbia River, were generally higher than water levels measured in December 2016 (Charts 1 through 4 on following pages). At that time, an increase in TPH diesel-range concentrations was observed in up-gradient wells which also exhibited the higher water level measurements, compared to December 2016. Water levels measured at all wells in November 2017, with the exception of 199-N-172 which was dry, were 2.2 to 5.6 ft lower than those measured in July 2017, with TPH diesel-range concentrations declining at all inland wells with the exception of 199-N-167 (13,000 µg/L). The water levels measured in November 2017 are among the lowest recorded at these wells throughout the bioventing program. Although the water levels in the downgradient wells declined compared to July 2017, the wells closest to the river exhibited an increase in TPH diesel-range concentrations, which may be due to the migration of mobilized TPH toward the river as a result of receding water levels (11,000 µg/L at 199-N-173, 7,300 µg/L at 199-N-183, and 1,800 µg/L at 199-N-96A).

In February 2015, a characterization borehole (199-N-375) was installed in an area where shallow petroleum-impacted soil previously had been removed. The boring was completed to a depth of about 35 feet bgs, and was located approximately 150 feet southwest of 199-N-171 (slightly southwest of the former tank farm). Soil and groundwater samples were collected and no petroleum contamination in excess of site soil and groundwater cleanup criteria was identified in this boring (vadose zone soils of the Hanford Formation). Boring 199-N-375 was not completed as a monitoring well. In August 2016, a borehole was completed for the installation of monitoring well 199-N-377, completed to a depth of about 120 feet bgs, and located closer to the treatment area (about 80 feet southwest of 199-N-167 and at the western edge of the former tank farm). TPH-impacted soil was encountered in this boring at depths ranging from 18 to 45 feet bgs, with the top of the Ringold Formation potentially having acted as a barrier to further downward migration. No evidence of TPH impact was identified below 45 feet bgs, and no sheen was apparent on the groundwater. Specifically, laboratory results indicate TPH diesel range concentrations exceed soil cleanup levels in the shallow soils. Soil concentrations exceeded 2,000 mg/kg TPH-diesel at a depth of 18 feet bgs. From 24 feet to 45 feet bgs, TPH-diesel concentrations were above 200 mg/kg and were less than 200 mg/kg from 45 feet bgs to the water table.

It is noteworthy that 199-N-167 is a bioventing air-injection well that is screened entirely within the Ringold Formation whereas the TPH impacted soils at 199-N-377 are located within the shallower Hanford Formation. Therefore, it is unlikely that the bioventing system, as currently configured, will have much effect on the shallower impacted soil identified at 199-N-377. Well 199-N-377 was constructed with screen at the water table for groundwater monitoring and a screen section in the shallow vadose zone region to enable air injection to target the shallow (Hanford Formation) soils if future decisions include bioremediation of the contaminated soil.

The groundwater and soil gas TPH results, and respirometry testing results, are suggestive of: 1) a potential residual source area remaining up-gradient of the main area of groundwater contamination, possibly in the vicinity of the former 166-N tank farm; and 2) residual hydrocarbon contamination within a “smear” zone resulting from groundwater elevation fluctuations. Hydrocarbons (dissolved and free-phase) associated with the fluctuating groundwater are likely creating a smear zone that continually re-contaminates soils within this zone. The result is that while the existing bioventing system continues to treat the smear zone (primarily during periods of low water table), the process is slow, and unless the system is upgraded (i.e. biosparging), it is expected to become progressively less efficient.

Table 1

Soil Gas Monitoring Results, Oxygen Utilization and Biodegradation Rates Calculated from In-Situ Respiration Testing, October through November 2017.

Monitoring Point	Initial Oxygen (%)	Final Oxygen (%)	Oxygen Utilization (%/day)	Hydrocarbon Biodegradation Rate (mg/kg-day)
199-N-167	20.9	14.0	0.18	-0.14
199-N-169	20.9	12.5	0.25	-0.19
199-N-171	18.4	15.1	0.20	-0.15
199-N-172	20.9	18.3	0.09	-0.07
199-N-183	20.9	18.1	0.08	-0.06
199-N-18	20.9	20.9	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 well 199-N-18 remained above 20% throughout the test and exhibited insignificant oxygen depletion; therefore, a biodegradation rate was not calculated for this well. The results for this well are consistent with previously conducted respirometry test results as shown in 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 bgs, the gas composition samples collected from this

well are likely heavily influenced by the shallow subsurface and not representative of deeper vadose zone conditions.

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-167. 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.

During the final sampling event on November 6, 2017 at 199-N-171, an increased oxygen level was observed (Attachment 3). It is not clear why the oxygen content increased during the final week of the test. The calculated oxygen consumption rate for 199-N-171, 0.09%/day, includes the final elevated oxygen value. If this final value were excluded, the calculated oxygen consumption rate would be approximately doubled (0.20%/day) and the resultant calculated biodegradation rate also would be approximately doubled (-0.15 mg/kg-day).

As mentioned above, significant respiration is not measured at 199-N-18, and while this may be due to the influence of shallow vadose-zone air dominating the sample, it is also possible that some other factor may be limiting bacterial activity in this area of the plume (e.g. lack of hydrocarbons within the vadose zone soils and contamination constrained to the saturated soils).

Because groundwater in 199-N-18 typically displays some of the highest dissolved TPH concentrations of the test wells (indicating sufficient food source for bacteria), it is likely that dissolved oxygen is a limiting factor to cleanup within the groundwater plume and smear-zone soils. This assessment is supported by the fact that groundwater dissolved oxygen concentrations are much lower within the petroleum plume than outside of the plume. Table 2 presents a summary of dissolved oxygen concentrations measured in the vicinity of the petroleum plume from March 2010 to November 2017.

Table 2

Dissolved Oxygen Concentrations in Groundwater from 3/10 to 11/17 (results in mg/L)

Location Area Relative to Plume	Well # / Range / Average	Overall Average
Up-gradient or Cross-Gradient	199-N-56 / 2.10 – 6.84 / 4.23	4.71
	199-N-3 / 2.15 - 6.71 / 5.14	
Upper Margin	199-N-167 / 0.02– 4.86 / 2.38	2.23
	199-N-169 / 0.03 – 4.62 / 2.11	
Lateral Margin (mid-portion)	199-N-183 / 0.00 – 11.86 / 2.02	2.50
	199-N-19 / 0.53 – 7.38 / 3.09	
Upper Main	199-N-171 / 0.00 – 4.08 / 1.75	1.62
Middle Main	199-N-18 / 0.00 – 2.43 / 1.45	1.26
	199-N-172 / 0.06 – 4.64 / 1.00	

Location Area Relative to Plume	Well # / Range / Average	Overall Average
Lower Main	199-N-173 / 0.04 – 5.9 / 2.37	2.30
Lateral Margin (lower portion)	199-N-96A / 0.22 – 10.0 / 5.06	5.80
	C6132 / 3.67 – 9.34 / 6.40	

COMPARISON OF BIODEGRADATION RATES OVER TIME

Table 3 presents a comparison of biodegradation rates over time. Dates of the measurements began with the 2010 pilot test (Amec Geomatrix, 2010), and then occurred roughly every six months from the end of 2012 through 2017. Due to space constraints only the initial 2010 data and the more recent data are presented in Table 3.

Table 3

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

Monitoring Point	Biodegradation Rate (mg/kg-day)							
	Nov. 2017	Jul. 2017	Dec. 2016	Aug. 2016	Feb. 2016	Aug. 2015	Jan. 2015	Mar. 2010
199-N-167	-0.14	-0.08	-0.06	-0.06	-0.07	-0.05	-0.05	-0.99
199-N-169	-0.19	-0.11	-0.14	-0.07	-0.12	-0.12	-0.23	-0.97
199-N-171	-0.11	-0.07	-0.22	-0.08	-0.19	-0.14	-0.23	-0.37
199-N-172	-0.07	-0.08	-0.03	-0.02	-0.04	-0.04	-0.05	-0.54
199-N-183	-0.06	-0.02	NA	NA	NA	NA	NA	not tested
199-N-18	NA	NA	NA	NA	NA	NA	NA	not tested

1) NA = Not applicable: oxygen depletion insignificant and biodegradation rate not calculated.
2) Focus of table is to compare initial data with more recent data. Results for all prior events have been provided previously: March 2010 (AMEC Geomatrix, 2010), December 2012 (AMEC Environment & Infrastructure, Inc., 2012), January 2014 (AMEC Environment & Infrastructure, Inc., 2014a), July 2014 (AMEC Environment & Infrastructure, Inc., 2014b), December 2014 to January 2015 (Amec Foster Wheeler, 2015a), June to August 2015 (Amec Foster Wheeler, 2015b), January to February 2016 (Amec Foster Wheeler, 2016a), June to August 2016 (Amec Foster Wheeler, 2016b), November to December 2016 (Amec Foster Wheeler, 2017b), and June to July 2017 (Amec Foster Wheeler, 2017e).

The biodegradation rates exhibit an overall declining trend from the initial rates measured in 2010, with the rates being relatively stable since July 2014. 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 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 it relates to the groundwater elevations at the site. The observed biodegradation rates at 199-N-167, 199-N-169, 199-N-171, and 199-N-183 were greater in November 2017 than in July 2017, which is to be expected given the overall drop in groundwater elevations (approximately 2.4 to 3.9 feet) and corresponding increase in smear zone available for the air-injection system to deliver oxygen to. At 199-N-172 the biodegradation rate observed in November 2017 was slightly less than in July 2017. No changes in oxygen concentration in 199-N-18 were observed during the test.

Charts 1, 2, 3, and 4 (below) show dissolved diesel concentration trends in groundwater relative to groundwater elevations, for bioventing test wells 199-N-167, 199-N-169, 199-N-171, and 199-N-172, respectively. The charts span an approximately seven-year period from 2010 to 2017. Together, these four wells provide coverage of the main portion of the contaminant plume. Beginning in 2017, 199-N-167 (Chart 1) and 199-N-169 (Chart 2) no longer display declining trends in groundwater diesel concentrations, but instead indicate diesel has rebounded to some of the highest levels in at least the past seven years. Concentrations in 199-N-171 (Chart 3) also indicate significant fluctuation, albeit well within the recent historical range. No groundwater sample or water level measurement was collected from 199-N-172 in November 2017 because the well was dry (Chart 4). The elevated concentrations of dissolved diesel observed in several of the wells in July 2017, and attributed to higher than average groundwater table levels, have declined in the November samples, except at 199-N-167. The wells closer to the river (199-N-183, 199-N-173, and 199-N-96A) showed an increase in dissolved diesel concentrations the November samples which may be from migration of mobilized TPH towards the river with receding water levels.

Chart 1

Well 199-N-167 Groundwater TPH-Diesel Concentrations and Groundwater Elevations

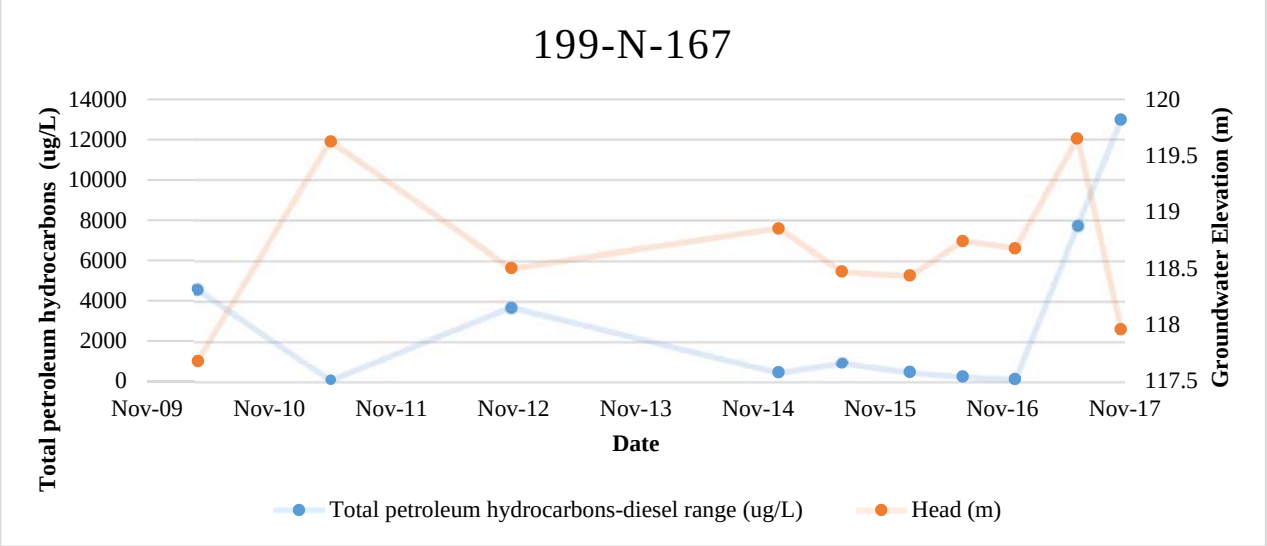


Chart 2

Well 199-N-169 Groundwater TPH-Diesel Concentrations and Groundwater Elevations

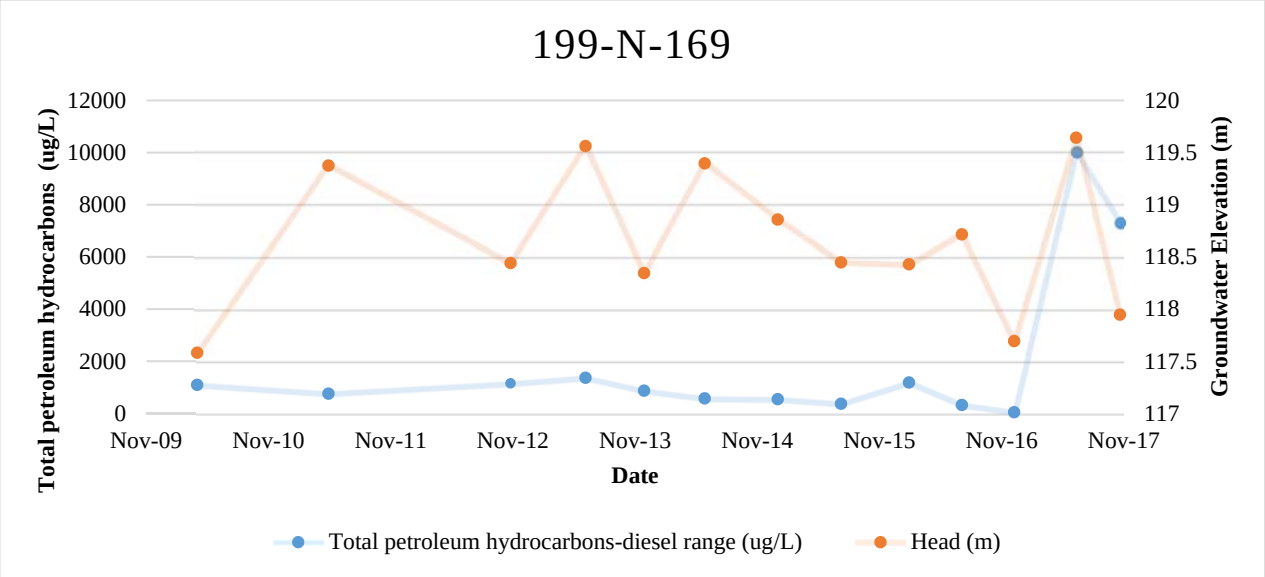


Chart 3

Wells 199-N-171 Groundwater TPH-Diesel Concentrations and Groundwater Elevations

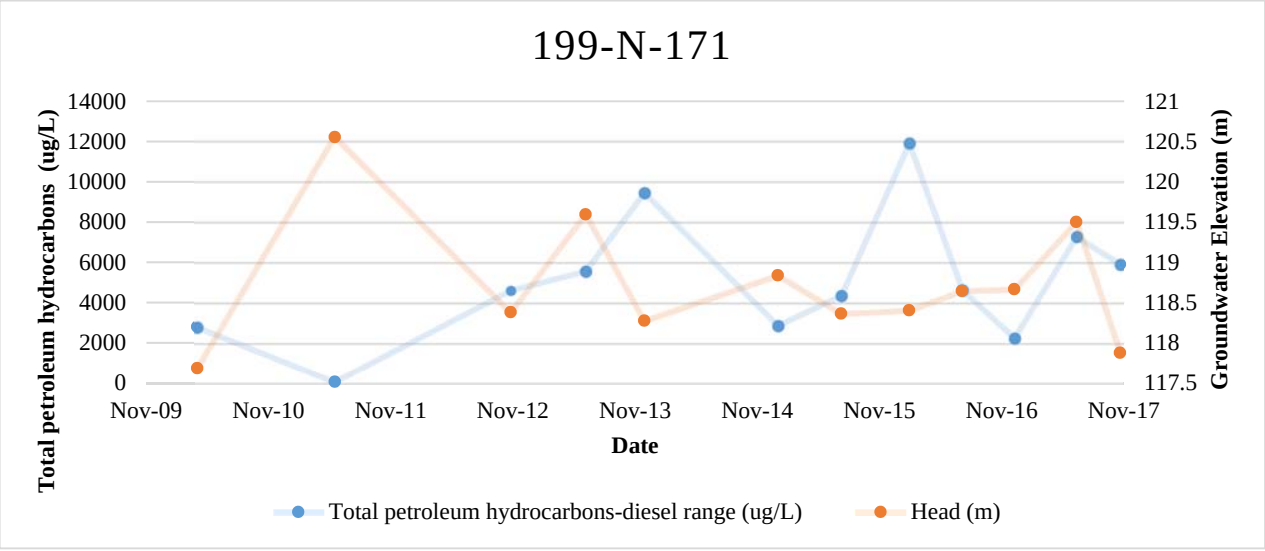
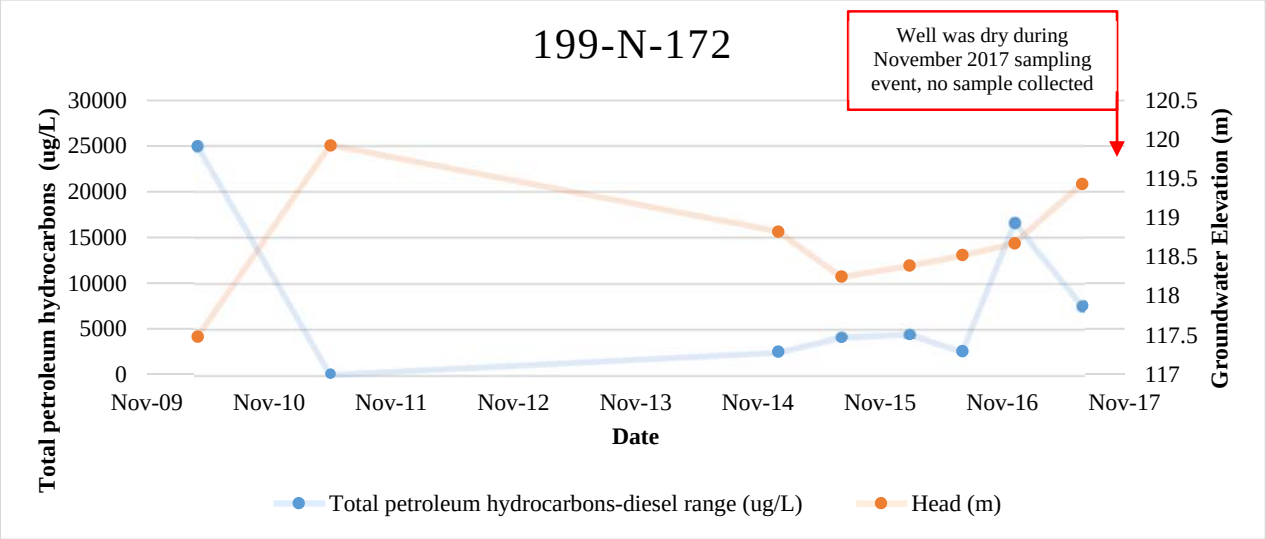


Chart 4

Wells 199-N-172 Groundwater TPH-Diesel Concentrations and Groundwater Elevations

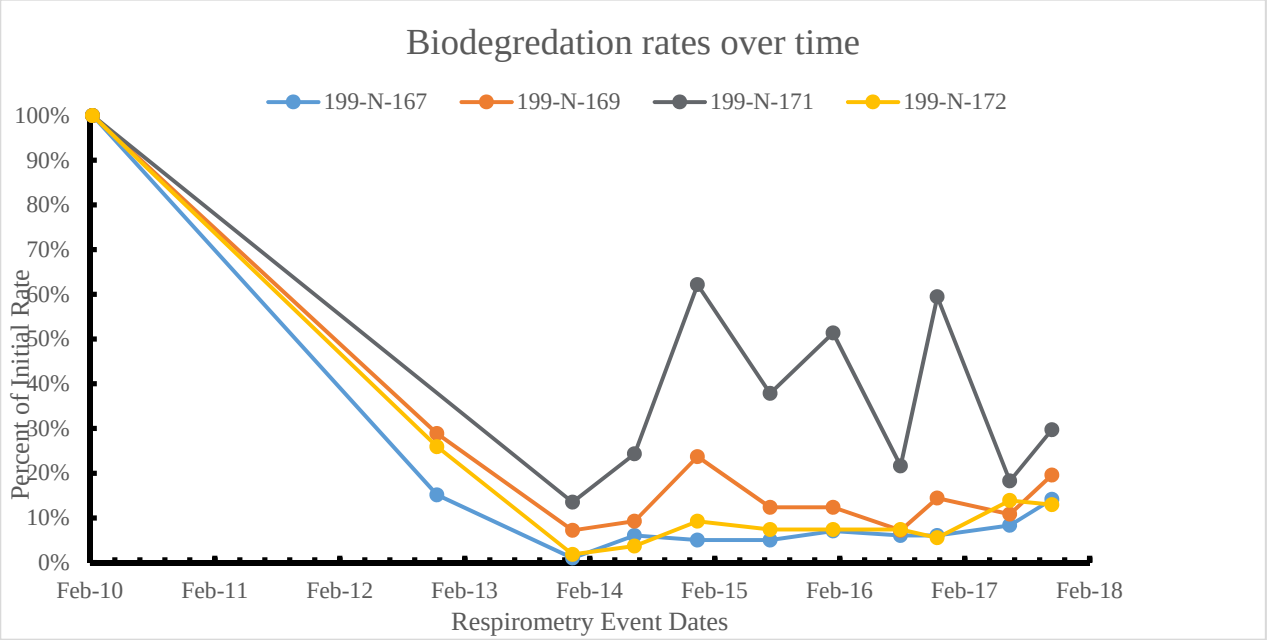


SUMMARY AND RECOMMENDATIONS

The respirometry rates from the November 2017 event remain generally below literature values for recommending bioventing as a cost effective remedial option. However, there is evidence that oxygen in the vadose zone 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 near wells 199-N-167, 199-N-169, and 199-N-172 (Chart 5). The biodegradation rate in the vicinity of well 199-N-171 fluctuates semi-annually, and continuation of bioventing may continue to provide petroleum mass removal at 199-N-171. Because the recent respirometry tests have shown consistent and predictable results, the frequency of respirometry testing is being reduced to a biennial basis. Currently the next respirometry testing event is planned for fall 2019.

Chart 5

Rates of hydrocarbon biodegradation relative to initial rate



Note: December 2012 respirometry data for 199-N-171 was determined to be an outlier and has been removed from Chart 5.

While hydrocarbon reduction in vadose zone is likely continuing in a slow manner, the smear zone has better potential for increased biodegradation rates (petroleum removal) if more oxygen can be delivered to that zone. Currently the system is prevented from delivering significant oxygen to the smear zone because the higher soil pore water saturation percentage creates a barrier to air flow. The air (oxygen) currently being delivered to the subsurface therefore preferentially enters the drier, shallower vadose zone. While bioventing will continue to be beneficial as a remedial action, particularly during times of low groundwater, site groundwater and the 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 the smear zone, capillary fringe, and groundwater to progress towards site cleanup goals. The application of biosparging could complement the existing bioventing system and expedite the overall petroleum cleanup (Amec Foster Wheeler, 2015b). Biosparging also has been identified as a proposed remedy in the 100-NR-1 and 100-NR-2 Operable Units Proposed Plan (DOE/RL-2012-68, 2013).

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, saturated zone, and groundwater, and thereby complement the overlying vadose zone bioventing treatment. Biosparging would provide the oxygen needed to increase microbiological activity below the fluctuating water table and move the site towards closure.

Amec Foster Wheeler recommends conducting a biosparging pilot test, and has submitted conceptual site plans and background information in the "Design Basis for Biosparging Pilot System in Diesel Plume near 166-N Tank Farm Facility at Hanford Site" (Amec Foster Wheeler, 2016b). Amec Foster Wheeler also has prepared a draft pilot study test design (60% design) entitled: "Groundwater Biosparging Treatability Test Plan and 60% Engineering Design for Diesel Plume near 166-N Tank Farm Facility at Hanford Site" (Amec Foster Wheeler, 2017c).

In summary, Amec Foster Wheeler is recommending the following actions be completed at the site (several of which have already been proposed as part of the biosparging design and treatability test plan documents):

- Reduce semi-annual frequency of bioventing tests, but continue to conduct periodic high and low river bioventing testing events to monitor for changes in overall biological activity to provide updates to biodegradation rates for the site. Groundwater monitoring should be conducted concurrently with the respiration testing so that respirometry testing results can be correlated against dissolved contaminant concentrations and the area of exposed smear zone soil (groundwater elevations).
- Collection of groundwater samples should be conducted after respirometry sampling has been completed so as to minimize external disturbances.
- Evaluate converting 199-N-377 to a combined groundwater monitoring and bioventing well, with air injection targeting TPH-diesel contamination in the shallow (Hanford Formation) soils.
- Use a pilot scale test to evaluate the effectiveness of adding a biosparging component to the existing bioventing system, thereby promoting further remediation of zones 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, preparation of the plans and design for the installation and monitoring of the pilot scale system, is currently at the 60% design stage.
- 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 test results could be used to provide additional respiration data for use in on-going evaluation of system performance.

FIGURE:

Figure 1 – Wells Utilized for Biovent Respirometry Testing

ATTACHMENTS:

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

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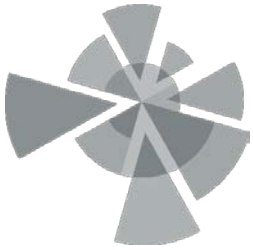
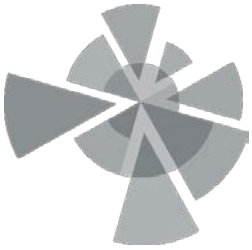


FIGURE

CHPRC		100-N AREA BIOVENTING SYSTEM	DATE: FEBRUARY 2017
			SCALE: 1 " = 100 '
Amec Foster Wheeler Environment & Infrastructure, Inc. 7376 S.W. Durham Road Portland, OR 97224	amec foster wheeler	WELLS UTILIZED FOR BIOVENT RESPIROMETRY TESTING	PROJECT NO. 661M120343.02.1
			FIGURE 1

DRAWN BY: PM CHECKED BY: JKH

K:\12000\12000\12034\120343 - CHPRC - 2016\dwg_Ave_DO_WaterLevels\1 - Wells Utilized for Biovent Respirometry Testing.mxd - patrick.mccarthy - 2/20/2017 - 11:24:38 AM



ATTACHMENT 1

Daily Field Reports and Field Measurements

DAILY FIELD REPORT

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

PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 661M120343.01.1	Date: 10/2/2017
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial) JVG	AMEC Project Manager (Initials) JK
Weather Conditions	

FIELD REPORT NOTES

Time:	Field Notes:

10/01/2017 Sunday Calibration

20:00 - Calibrated units for 10/02/17 sampling event.

10/02/2017 Monday sampling event.

06:10 - Loaded equipment and then mobe to site.
07:00 - On site. Set up for sampling. For this event we are no longer monitoring for Methane and so will not be using a FID. We will using a MultiRae multi gas meter that measure O2, CO2, CO and H2S. as well as a MiniRae 2000 for VOC concentrations. Performed cal check on units.
07:40 - Art Lee and IH on site.
08:00 - Malcomb and Katheryn on site. Set up on well 169 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 five rounds of sample data from all six wells after bio vent operation is shut down.
08:05 - Kyle on site. IH screened and cleared wells.
08:19 - Started purge on 169.
09:01 - Baseline sampling completed on all four non system wells, ending at 171.
09:05 - Bio vent operation shut down.
09:16 - Set up on system injection well 169 and started purge.

Purge rounds started and ended at 8:19 and 9:01 (baseline), 9:16 and 10:02 (round 1), 10:12 and 11:00 (round 2), 11:09 and12:10 (round 3), 13:12 and 13:58 (round 4), 14:39 and 15:23 (round 5)
15:23 - Finished last sampling round, ending at 171. Demobed equipment.
15:40 - Off site.

21:00 - Calibrated meters for tomorrow's event.

Contractor's Rep. (Initials)	Continued

DAILY FIELD REPORT

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

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	661M120343.01.1	Date:	10/3/2017
Field Report No:		Page:	1
Arrival:		Departure:	
AMECFW Field Rep.	Jason Gardner	AMECFW Project Manager	John Kuiper
Weather Conditions			

FIELD REPORT NOTES

Time:	Field Notes:

10/03/2017 Wednesday sampling event.

07:30 - On site. Performed cal check.
07:55 -DOE operators Katheryn and Malcomb on site.
08:00 - IH on site and screening wells. Started sampling on 169.
08:55 - Finished sampling on 171.
09:15 - Off site.

15:00 - Calibrated instruments tomorrow's event.

Contractor's Rep. (Initials) | Continued

DAILY FIELD REPORT

PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 661M120343.01.1	Date: 10/4/2017
Field Report No:	Page: 1
Arrival:	Departure:
AMECFW Field Rep. Jason Gardner	AMECFW Project Manager John Kuiper
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:

10/04/2017 Wednesday sampling event.

07:30 - On site. Performed cal check.
08:00 -DOE operators Katheryn and Malcomb on site.
08:00 - IH on site and screening wells. Started sampling on 169.
09:05 - Finished sampling on 171.
09:15 - Off site.

15:45 - Calibrated instruments tomorrow's event.

Contractor's Rep. (Initials) | Continued

DAILY FIELD REPORT

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

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	661M120343.01.1	Date:	10/5/2017
Field Report No:		Page:	1
Arrival:		Departure:	
AMECFW Field Rep.	Jason Gardner	AMECFW Project Manager	John Kuiper
Weather Conditions			

FIELD REPORT NOTES

Time:	Field Notes:

10/05/2017 Wednesday sampling event.

07:30 - On site. Performed cal check.
08:00 -DOE operators Katheryn and Malcomb on site.
08:00 - IH on site and screening wells. Started sampling on 169.
08:58 - Finished sampling on 171.
09:15 - Off site.

Contractor's Rep. (Initials) | Continued

DAILY FIELD REPORT

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

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	661M120343.01.1	Date:	10/9/2017
Field Report No:		Page:	1
Arrival:		Departure:	
AMECFW Field Rep.	WJM	AMECFW Project Manager	John Kuiper
Weather Conditions			

FIELD REPORT NOTES

Time:	Field Notes:

10-08-17 Travel and calibration

10-09-17
07:30 On site
07:45 IH On site.
08:10 Sampling crew on site. IH clears wells prior to sampling. Set up on MW 167
09:15 Sampling complete
09:30 Off site

Contractor's Rep. (Initials)	Continued

DAILY FIELD REPORT

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

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	661M120343.01.1	Date:	10/16/2017
Field Report No:		Page:	1
Arrival:		Departure:	
AMECFW Field Rep.	WJM	AMECFW Project Manager	John Kuiper
Weather Conditions			

FIELD REPORT NOTES

Time:	Field Notes:

10-15-17 Travel and calibration

10-16-17
07:40 On site
08:00 IH On site.
08:25 Sampling crew on site. IH clears wells prior to sampling. Set up on MW 167
09:30 Sampling complete
09:45 Off site

Contractor's Rep. (Initials)	Continued

DAILY FIELD REPORT

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

PROJECT NAME: HANFORD BIO VENT PROJECT

Project No:	661M120343.01.1	Date:	10/23/2017
Field Report No:		Page:	1
Arrival:		Departure:	
AMECFW Field Rep.	Jason Gardner	AMECFW Project Manager	John Kuiper
Weather Conditions			

FIELD REPORT NOTES

Time:	Field Notes:

10/22/2017 Sunday calibration

14:00 - Calibrated instruments for Monday's event.

10/23/2017 Monday sampling event

07:30 -On site. Performed cal check.
08:30 -DOE operators Kevin and frank on site. IH on site and screening wells.
08:41 - Started sampling on 167.
09:45 - Finished sampling on 171.
10:15 - Off site.

Contractor's Rep. (Initials) | Continued

DAILY FIELD REPORT

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

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	661M120343.01.1	Date:	10/30/2017
Field Report No:		Page:	1
Arrival:		Departure:	
AMECFW Field Rep.	Jason Gardner	AMECFW Project Manager	John Kuiper
Weather Conditions			

FIELD REPORT NOTES

Time:	Field Notes:

10/29/2017 Sunday calibration

14:00 - Calibrated instruments for Monday's event.

10/30/2017 Monday sampling event

07:15 - On site. Performed cal check.
07:55 -DOE operators Kevin and Mike on site. IH on site and screening wells.
08:15 - Started sampling on 167.
09:24 - Finished sampling on 171.
09:45 - Off site.

Contractor's Rep. (Initials) | Continued

DAILY FIELD REPORT

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

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	661M120343.01.1	Date:	11/6/2017
Field Report No:		Page:	1
Arrival:		Departure:	
AMECFW Field Rep.	Jason Gardner	AMECFW Project Manager	John Kuiper
Weather Conditions			

FIELD REPORT NOTES

Time:	Field Notes:

11/05/2017 Sunday calibration

15:30 - Calibrated instruments for Monday's event.

11/06/2017 Monday sampling event

07:15 - On site. Performed cal check.
07:45 -. IH on site (Douglas) and screening wells.
08:08 - DOE operators Kevin and Mike on site.
08:28 - Started sampling on 167.
09:39 - Finished sampling on 171.
10:00 - Off site.

Contractor's Rep. (Initials) | Continued

Field Measurements
November 2016 to December 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 (ppm)	Carbon Monoxide (ppm)	TVH (ppm)	Notes
167	10/2/2017	9:15	-272	0	4 min	20.9	200	0	0.0	No Base line sample on this well due to on-going injection. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	10/2/2017	10:12	-280	0	4 min	20.9	200	0	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	10/2/2017	11:08	-269	0	4 min	20.9	200	0	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	10/2/2017	13:11	-275	0	4 min	20.9	200	0	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	10/2/2017	14:34	-273	0	4 min	20.9	200	0	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	10/3/2017	8:05	-286	0	5 min	20.9	400	0	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling. Ran for 5 min due to high vac at start.
167	10/4/2017	8:09	-280	0	4 min	20.9	400	5	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	10/5/2017	8:08	-281	0	4 min	20.9	400	7	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	10/9/2017	8:19	-285	0	4 min	20.4	500	9	0.4	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	10/16/2017	8:37	-275	0	4 min	19.3	1,500	9	0.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	10/23/2017	8:46	-281	0	5 min	18.1	3,000	7	0.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	10/30/2017	8:19	-271	0	4 min	16.1	7,200	6	0.3	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	11/6/2017	8:33	-290	0	5 min	14	11,300	7	0.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

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

Field Measurements
November 2016 to December 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 (ppm)	Carbon Monoxide (ppm)	TVH (ppm)	Notes
171	10/2/2017	9:05	-258	0	4 min	18.4	21,900	0	0	Baseline sampling prior to system shut down. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling. CO reading is likely due to thermal breakdown of contaminate attributed to heat from system.
171	10/2/2017	10:02	-257	0	4 min	19	15,900	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	10/2/2017	11:00	-257	0	4 min	18.9	17,000	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	10/2/2017	12:10	-257	0	4 min	19	16,500	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	10/2/2017	13:58	-257	0	4 min	18.8	17,900	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	10/2/2017	15:23	-256	0	4 min	18.8	18,000	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	10/3/2017	8:55	-264	0	4 min	19.5	9,500	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	10/4/2017	9:02	-263	0	4 min	18	19,300	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	10/5/2017	8:58	-262	0	4 min	17.4	25,100	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	10/9/2017	9:15	-266	0	4 min	16	32,000	0	6.6	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	10/16/2017	9:30	-253	0	4 min	14.1	37,300	4	9.9	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	10/23/2017	9:45	-263	0	4 min	18.5	15,100	0	9.4	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	10/30/2017	9:20	-250	0	4 min	11.5	49,900	0	18.6	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	11/6/2017	9:39	-262	0	4 min	15.1	34,300	0	9.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

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

Field Measurements
November 2016 to December 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 (ppm)	Carbon Monoxide (ppm)	TVH (ppm)	Notes
169	10/2/2017	8:23	-266	0	4 min	20.9	400	0	0	Baseline sampling prior to system shut down. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling. CO reading is likely due to thermal breakdown of contaminate attributed to heat from system.
169	10/2/2017	9:20	-258	0	4 min	20.9	400	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	10/2/2017	10:16	-255	0	4 min	20.9	400	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	10/2/2017	11:13	-255	0	4 min	20.9	400	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	10/2/2017	13:16	-266	0	4 min	20.9	400	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	10/2/2017	14:39	-258	0	4 min	20.9	500	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	10/3/2017	8:10	-271	0	4 min	20.9	900	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	10/4/2017	8:13	-264	0	4 min	20.6	1,200	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	10/5/2017	8:14	-265	0	4 min	20.4	1,400	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	10/9/2017	8:25	-272	0	4 min	19.7	2,700	0	0.3	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	10/16/2017	8:43	-261	0	4 min	18	5,800	0	0.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	10/23/2017	9:52	-264	0	4 min	16.5	8,900	0	0.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	10/30/2017	8:26	-256	0	4 min	12.9	19,900	0	0.5	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	11/6/2017	8:39	-264/-339	0	4 min	12.5	22,700	0	0.6	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

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

Field Measurements
November 2016 to December 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 (ppm)	Carbon Monoxide (ppm)	TVH (ppm)	Notes
172	10/2/2017	9:28	-273	0	4 min	20.9	200	0	0	No Base line sample on this well due to on-going injection. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	10/2/2017	10:23	-271	0	4 min	20.9	200	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	10/2/2017	11:33	-269	0	15 min	20.9	400	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	10/2/2017	13:24	-275	0	4 min	20.9	200	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	10/2/2017	14:47	-272	0	4 min	20.9	200	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	10/3/2017	8:19	-276	0	4 min	20.9	300	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	10/4/2017	8:24	-270	0	4 min	20.9	300	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	10/5/2017	8:21	-278	0	4 min	20.9	400	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	10/9/2017	8:34	-282	0	4 min	20.4	600	0	0.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	10/16/2017	8:52	-273	0	4 min	19.3	2,300	0	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	10/23/2017	9:05	-277	0	4 min	18.3	4,800	0	0.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	10/30/2017	8:39	-270	0	4 min	18.3	4,800	0	0.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	11/6/2017	9:10	-269	0	4 min	18.3	4,800	0	0.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

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

Field Measurements
November 2016 to December 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 (ppm)	Carbon Monoxide (ppm)	TVH (ppm)	Notes
183	10/2/2017	8:58	-269	0	15 min	20.9	1,600	0	0	
183	10/2/2017	9:56	-269	0	15 min	20.9	700	0	0	
183	10/2/2017	10:54	-267	0	15 min	20.9	700	0	0	
183	10/2/2017	12:03	-266	0	15 min	20.9	700	0	0	
183	10/2/2017	13:52	-269	0	15 min	20.9	800	0	0	
183	10/2/2017	15:16	-268	0	15 min	20.9	800	0	0	
183	10/3/2017	8:49	-276	0	15 min	20.5	1,800	0	0	
183	10/4/2017	8:53	-274	0	15 min	20.3	2,700	0	0	
183	10/5/2017	8:50	-273	0	15 min	20.1	3,500	0	0	
183	10/9/2017	9:03	-273	0	15 min	19.9	4,900	0	1.1	
183	10/16/2017	9:22	-269	0	15 min	19.3	7,300	11	1.0	
183	10/23/2017	9:35	-272	0	15 min	20.2	3,400	0	0.8	
183	10/30/2017	9:16	-260	0	17 min	17.6	16,900	0	1.7	
183	11/6/2017	9:31	-271	0	18 min	18.1	15,900	0	0.4	

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

Field Measurements
November 2016 to December 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 (ppm)	Carbon Monoxide (ppm)	TVH (ppm)	Notes
18	10/2/2017	8:38	-264	0	10 min	20.9	500	0	0	Baseline sampling prior to system shut down. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling. CO reading is likely due to thermal breakdown of contaminate attributed to heat from system.
18	10/2/2017	9:39	-260	0	10 min	20.9	500	0	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	10/2/2017	10:35	-260	0	10 min	20.9	500	0	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	10/2/2017	11:45	-260	0	10 min	20.9	500	0	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	10/2/2017	13:36	-264	0	10 min	20.9	500	0	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	10/2/2017	14:58	-259	0	10 min	20.9	500	0	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	10/3/2017	8:30	-269	0	10 min	20.9	600	0	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	10/4/2017	8:35	-267	0	10 min	20.9	700	0	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	10/5/2017	8:32	-267	0	10 min	20.9	600	0	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	10/9/2017	8:46	-269	0	10 min	20.9	600	0	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	10/16/2017	9:04	-259	0	10 min	20.9	700	6	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	10/23/2017	9:17	-265	0	10 min	20.9	600	0	0.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	10/30/2017	8:53	-254	0	10 min	20.9	600	0	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	11/6/2017	9:01	-266	0	10 min	20.9	600	0	0.0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

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

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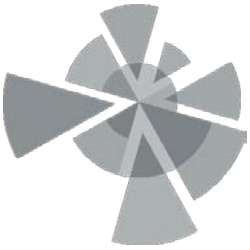


ATTACHMENT 2

Instrument Calibration Sheets

GAS METERS	MODEL AND SERIAL NUMBERS	DATES USED
Pimary O2/CO2 meter	Multi Rae- 435-1054 s/n 0009374	Oct 2 thru Nov 6, 2017
Back up O2/CO2 meter	Multi Rae- 435-1054 s/n 0009372	not used to date.
Primary VOC meter	Mini Rae- 2000 s/n 110	Oct 2 thru Nov 6, 2017
Back up VOC meter	Mini Rae- 2000	not used to date.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 661M120343.02.1

Date / Time: 10/1/2017 8:00:00 PM Completed By: Jason Gardner

Instrument name(s) Multi Rae 435-1054 and Mini Rae 2000

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	PID readings	Span Readings	Final readings
Multi Rae- 435-1054 s/n 0009374	10/1/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0009374	10/1/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0009374	10/1/2017	30 min	5000 ppm CO2	n/a	5000	5000
Multi Rae- 435-1054 s/n 0009372	10/1/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0009372	10/1/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0009372	n/a	n/a	n/a	n/a	n/a	n/a
Mini Rae 2000 s/n 110	n/a	n/a	n/a	n/a	n/a	n/a
Mini Rae 2000 back up	n/a	n/a	n/a	n/a	n/a	n/a

Notes:
This calibration is for the 10/2/2017 sample event.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 661M120343.02.1

Date / Time: 10/2/2017 9:00:00 PM Completed By: Jason Gardner

Instrument name(s) Multi Rae 435-1054 and Mini Rae 2000

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	PID readings	Span Readings	Final readings
Multi Rae- 435-1054 s/n 0009374	10/2/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0009374	10/2/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0009374	10/2/2017	30 min	5000 ppm CO2	n/a	5000	5000
Multi Rae- 435-1054 s/n 0009372	10/2/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0009372	10/2/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0009372	n/a	n/a	n/a	n/a	n/a	n/a
Mini Rae 2000 s/n 110	n/a	n/a	n/a	n/a	n/a	n/a
Mini Rae 2000 back up	n/a	n/a	n/a	n/a	n/a	n/a

Notes:
This calibration is for the 10/3/2017 sample event.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 661M120343.02.1

Date / Time: 10/3/2017 3:00:00 PM Completed By: Jason Gardner

Instrument name(s) Multi Rae 435-1054 and Mini Rae 2000

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	PID readings	Span Readings	Final readings
Multi Rae- 435-1054 s/n 0009374	10/3/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0009374	10/3/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0009374	10/3/2017	30 min	5000 ppm CO2	n/a	5000	5000
Multi Rae- 435-1054 s/n 0009372	10/3/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0009372	10/3/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0009372	n/a	n/a	n/a	n/a	n/a	n/a
Mini Rae 2000 s/n 110	n/a	n/a	n/a	n/a	n/a	n/a
Mini Rae 2000 back up	n/a	n/a	n/a	n/a	n/a	n/a

Notes:
This calibration is for the 10/4/2017 sample event.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 661M120343.02.1

Date / Time: 10/4/2017 3:45:00 PM Completed By: Jason Gardner

Instrument name(s) Multi Rae 435-1054 and Mini Rae 2000

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	PID readings	Span Readings	Final readings
Multi Rae- 435-1054 s/n 0009374	10/4/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0009374	10/4/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0009374	10/4/2017	30 min	5000 ppm CO2	n/a	5000	5000
Multi Rae- 435-1054 s/n 0009372	10/4/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0009372	10/4/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0009372	n/a	n/a	n/a	n/a	n/a	n/a
Mini Rae 2000 s/n 110	n/a	n/a	n/a	n/a	n/a	n/a
Mini Rae 2000 back up	n/a	n/a	n/a	n/a	n/a	n/a

Notes:
This calibration is for the 10/5/2017 sample event.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 661M120343.02.1

Date / Time: 10/8/2017 7:45PM Completed By: WJM

Instrument name(s) Multi Rae 435-1054 and Mini Rae 2000

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	PID readings	Span Readings	Final readings
Multi Rae- 435-1054 s/n 0009374	10/8/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0009374	10/8/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0009374	10/8/2017	30 min	5000 ppm CO2	n/a	5000	5000
Multi Rae- 435-1054 s/n 0009372	10/8/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0009372	10/8/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0009372	10/8/2017	30 min	5000 ppm CO2	n/a	4999	5000
Mini Rae 2000 s/n 110-003625	10/8/2017	30 min	100 ppm Isob.	100 ppm (PID)	98.7	100
Mini Rae 2000 back up	10/8/2017	30 min	100 ppm Isob.	100 ppm (PID)	96.6	100

Notes:
This calibration is for the 10/09/2017 sample event.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 661M120343.02.1

Date / Time: 10/15/2017 7:50PM Completed By: WJM

Instrument name(s) Multi Rae 435-1054 and Mini Rae 2000

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	PID readings	Span Readings	Final readings
Multi Rae- 435-1054 s/n 0009374	10/15/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0009374	10/15/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0009374	10/15/2017	30 min	5000 ppm CO2	n/a	5000	5000
Multi Rae- 435-1054 s/n 0009372	10/15/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0009372	10/15/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0009372	10/15/2017	30 min	5000 ppm CO2	n/a	5000	5000
Mini Rae 2000 s/n 110-003625	10/15/2017	30 min	100 ppm Isob.	100 ppm (PID)	100	100
Mini Rae 2000 back up	10/15/2017	30 min	100 ppm Isob.	100 ppm (PID)	100	100

Notes:
This calibration is for the 10/16/2017 sample event.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 661M120343.02.1

Date / Time: 10/22/2017 2:00:00 PM Completed By: Jason Gardner

Instrument name(s) Multi Rae 435-1054 and Mini Rae 2000

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	PID readings	Span Readings	Final readings
Multi Rae- 435-1054 s/n 0009374	10/22/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0009374	10/22/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0009374	10/22/2017	30 min	5000 ppm CO2	n/a	5000	5000
Multi Rae- 435-1054 s/n 0009372	10/22/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0009372	10/22/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0009372	10/22/2017	30 min	5000 ppm CO2	n/a	n/a	n/a
Mini Rae 2000 s/n 110	10/22/2017	30 min	100 ppm IsoB	n/a	n/a	n/a
Mini Rae 2000 back up	n/a	n/a	n/a	n/a	n/a	n/a

Notes:
This calibration is for the 10/23/2017 sample event.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 661M120343.02.1

Date / Time: 10/29/2017 2:00:00 PM Completed By: Jason Gardner

Instrument name(s) Multi Rae 435-1054 and Mini Rae 2000

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	PID readings	Span Readings	Final readings
Multi Rae- 435-1054 s/n 0009374	10/29/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0009374	10/29/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0009374	10/29/2017	30 min	5000 ppm CO2	n/a	5000	5000
Multi Rae- 435-1054 s/n 0009372	10/29/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0009372	10/29/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0009372	10/29/2017	30 min	5000 ppm CO2	n/a	n/a	n/a
Mini Rae 2000 s/n 110	10/29/2017	30 min	100 ppm IsoB	n/a	n/a	n/a
Mini Rae 2000 back up	n/a	n/a	n/a	n/a	n/a	n/a

Notes:
This calibration is for the 10/30/2017 sample event.

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 661M120343.02.1

Date / Time: 11/5/2017 3:30:00 PM Completed By: Jason Gardner

Instrument name(s) Multi Rae 435-1054 and Mini Rae 2000

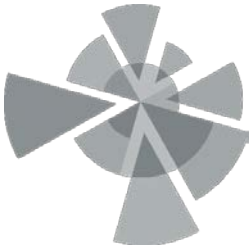
Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	PID readings	Span Readings	Final readings
Multi Rae- 435-1054 s/n 0009374	11/5/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0009374	11/5/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0009374	11/5/2017	30 min	5000 ppm CO2	n/a	5000	5000
Multi Rae- 435-1054 s/n 0009372	11/5/2017	30 min	zero air	n/a	20.9%	20.9%
Multi Rae- 435-1054 s/n 0009372	11/5/2017	30 min	100 ppm CO	n/a	100	100
Multi Rae- 435-1054 s/n 0009372	11/5/2017	30 min	5000 ppm CO2	n/a	n/a	n/a
Mini Rae 2000 s/n 110	11/5/2017	30 min	100 ppm IsoB	n/a	n/a	n/a
Mini Rae 2000 back up	n/a	n/a	n/a	n/a	n/a	n/a

Notes:
This calibration is for the 11/06/2017 sample event.



ATTACHMENT 3

Design Worksheet for Oxygen Utilization and Biodegradation Rates

DESIGN WORKSHEET

Date: 18-Dec-17

Client: CHPRC

Project Number: 661M120343.02.01

Project: Hanford 100-N Biovent

Prepared by: J. Malone

Data For: Oct to Nov 2017 Respiration Test

Reviewed by: M. Roskamp

An in-situ respiration test was conducted at the Hanford Site 100-N from June 2017 to July 2017. 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	0.0076	0.18	0.962
199-N-169	0.0105	0.25	0.980
199-N-171	0.0062	0.15	0.554
199-N-172	0.0038	0.09	0.932
199-N-183	0.0034	0.08	0.809
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

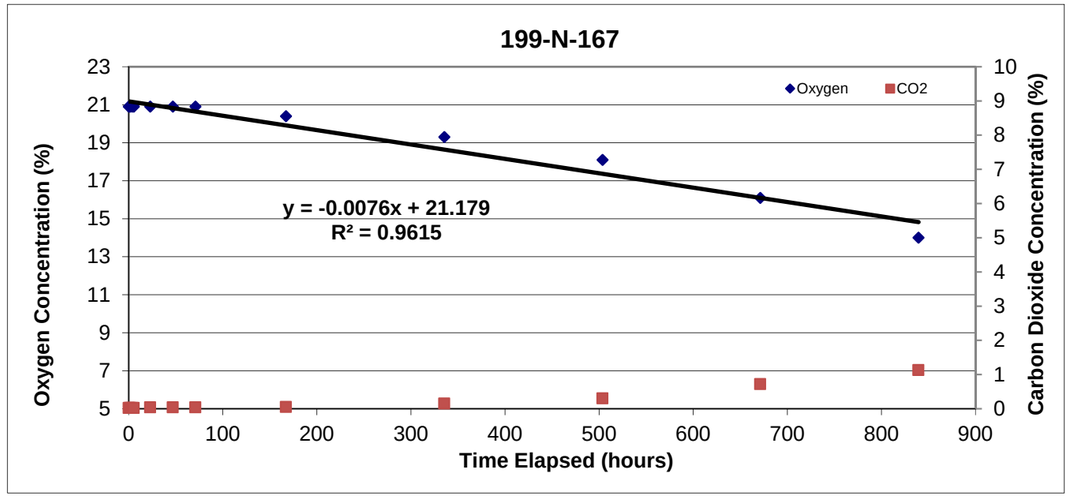
Client: CHPRC
Project: Hanford 100-N Biovent
Data For: Oct to Nov 2017 Respiration Test

Date: 18-Dec-17
Project Number: 661M120343.02.01
Prepared by: J. Malone
Reviewed by: M. Roskamp

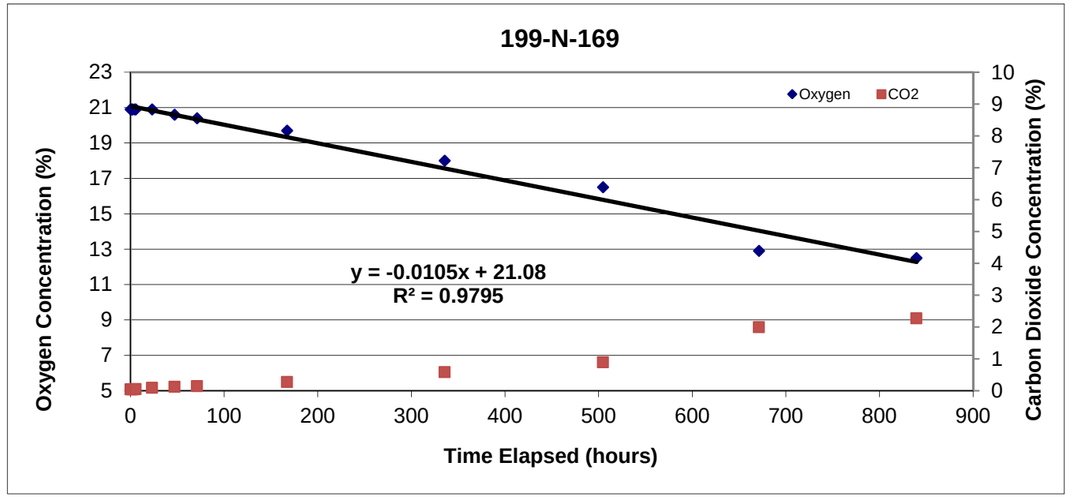
Location	Parameter	Nov-17	Jul-17	Dec-16	Aug-16	Feb-16	Jan-15	Units	Notes
199-N-167	K_o =	0.18	0.11	0.08	0.09	0.09	0.07	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.14**	**-0.08**	**-0.06**	**-0.06**	**-0.07**	**-0.05**	mg/Kg-day	Biodegradation rate; calculated value
199-N-169	K_o =	0.25	0.14	0.18	0.09	0.16	0.3	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.19**	**-0.11**	**-0.14**	**-0.07**	**-0.12**	**-0.23**	mg/Kg-day	Biodegradation rate; calculated value
199-N-171	K_o =	0.15	0.09	0.29	0.11	0.25	0.3	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.11**	**-0.07**	**-0.22**	**-0.08**	**-0.19**	**-0.23**	mg/Kg-day	Biodegradation rate; calculated value
199-N-172	K_o =	0.09	0.10	0.04	0.03	0.05	0.07	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.07**	**-0.08**	**-0.03**	**-0.02**	**-0.04**	**-0.05**	mg/Kg-day	Biodegradation rate; calculated value
199-N-183	K_o =	0.08	0.02	--	--	--	--	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.06**	**-0.02**	**--**	**--**	**--**	**--**	mg/Kg-day	Biodegradation rate; calculated value
199-N-18	K_o =	--	--	--	--	--	--	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**--**	**--**	**--**	**--**	**--**	**--**	mg/Kg-day	Biodegradation rate; calculated value

Oxygen Utilization Generation Plots
October to December 2017 Respirometry Test

199-N-167						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
10/2/2017	9:05	10/2/2017 9:05	Blower off	0	--	--
10/2/2017	9:15	10/2/2017 9:15	0:10:00	0.17	20.9	0.02
10/2/2017	10:12	10/2/2017 10:12	1:07:00	1.12	20.9	0.02
10/2/2017	11:08	10/2/2017 11:08	2:03:00	2.05	20.9	0.02
10/2/2017	13:11	10/2/2017 13:11	4:06:00	4.10	20.9	0.02
10/2/2017	14:34	10/2/2017 14:34	5:29:00	5.48	20.9	0.02
10/3/2017	8:05	10/3/2017 8:05	23:00:00	23.00	20.9	0.04
10/4/2017	8:09	10/4/2017 8:09	47:04:00	47.07	20.9	0.04
10/5/2017	8:08	10/5/2017 8:08	71:03:00	71.05	20.9	0.04
10/9/2017	8:19	10/9/2017 8:19	167:14:00	167.23	20.4	0.05
10/16/2017	8:37	10/16/2017 8:37	335:32:00	335.53	19.3	0.15
10/23/2017	8:46	10/23/2017 8:46	503:41:00	503.68	18.1	0.30
10/30/2017	8:19	10/30/2017 8:19	671:14:00	671.23	16.1	0.72
11/6/2017	8:33	11/6/2017 8:33	839:28:00	839.47	14.0	1.13

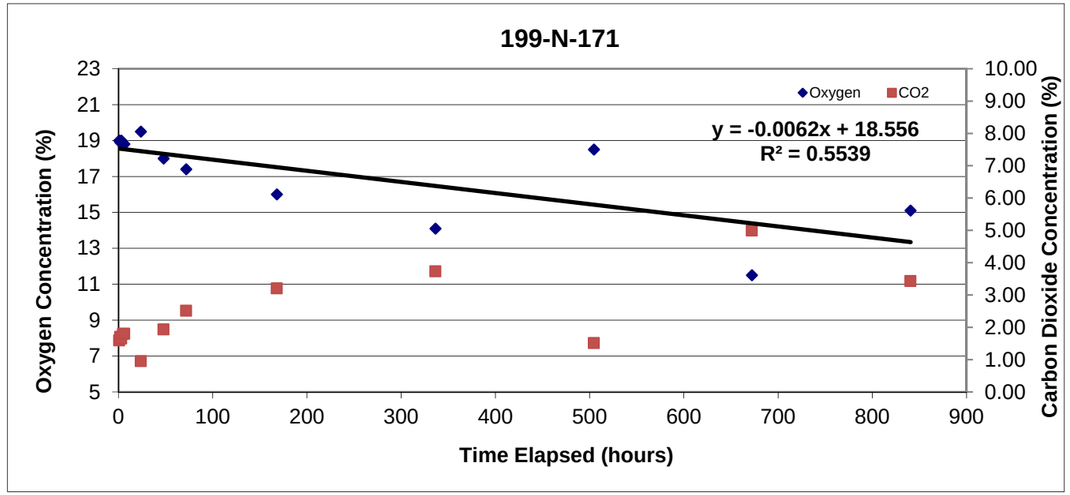


199-N-169						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
10/2/2017	8:23	10/2/2017 8:23	Baseline	--	20.9	0.04
10/2/2017	9:05	10/2/2017 9:05	Blower off	0	--	--
10/2/2017	9:20	10/2/2017 9:20	Initial reading	0.25	20.9	0.04
10/2/2017	10:16	10/2/2017 10:16	1:11:00	1.2	20.9	0.04
10/2/2017	11:13	10/2/2017 11:13	2:08:00	2.1	20.9	0.04
10/2/2017	13:16	10/2/2017 13:16	4:11:00	4.2	20.9	0.04
10/2/2017	14:39	10/2/2017 14:39	5:34:00	5.6	20.9	0.05
10/3/2017	8:10	10/3/2017 8:10	23:05:00	23.1	20.9	0.09
10/4/2017	8:13	10/4/2017 8:13	47:08:00	47.1	20.6	0.12
10/5/2017	8:14	10/5/2017 8:14	71:09:00	71.2	20.4	0.14
10/9/2017	8:25	10/9/2017 8:25	167:20:00	167.3	19.7	0.27
10/16/2017	8:43	10/16/2017 8:43	335:38:00	335.6	18.0	0.58
10/23/2017	9:52	10/23/2017 9:52	504:47:00	504.8	16.5	0.89
10/30/2017	8:26	10/30/2017 8:26	671:21:00	671.4	12.9	1.99
11/6/2017	8:39	11/6/2017 8:39	839:34:00	839.6	12.5	2.27

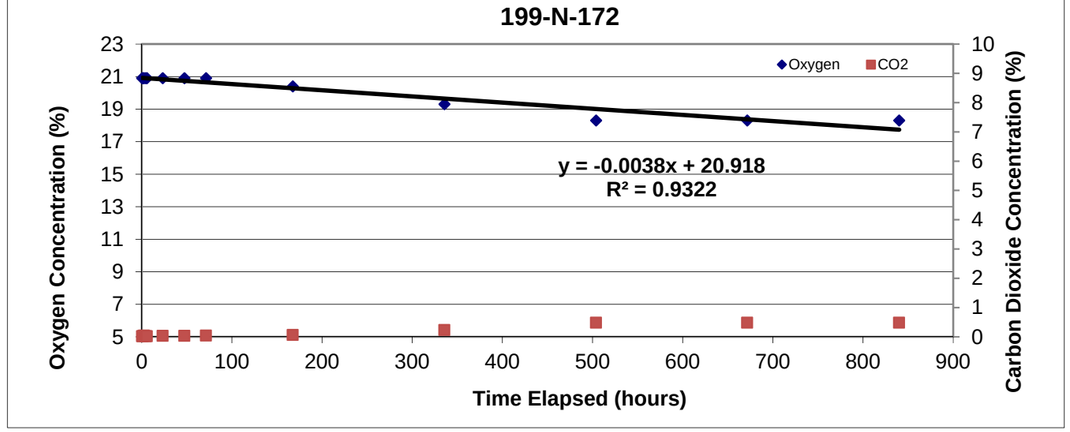


Oxygen Utilization Generation Plots
October to December 2017 Respirometry Test

199-N-171						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
10/2/2017	9:05	10/2/2017 9:05	Baseline	--	18.4	2.19
10/2/2017	9:05	10/2/2017 9:05	Blower off	0	--	--
10/2/2017	10:02	10/2/2017 10:02	Initial reading	0.95	19	1.59
10/2/2017	11:00	10/2/2017 11:00	1:55:00	1.9	18.9	1.70
10/2/2017	12:10	10/2/2017 12:10	3:05:00	3.1	19	1.65
10/2/2017	13:58	10/2/2017 13:58	4:53:00	4.9	18.8	1.79
10/2/2017	15:23	10/2/2017 15:23	6:18:00	6.3	18.8	1.80
10/3/2017	8:55	10/3/2017 8:55	23:50:00	23.8	19.5	0.95
10/4/2017	9:02	10/4/2017 9:02	47:57:00	48.0	18	1.93
10/5/2017	8:58	10/5/2017 8:58	71:53:00	71.9	17.4	2.51
10/9/2017	9:15	10/9/2017 9:15	168:10:00	168.2	16	3.20
10/16/2017	9:30	10/16/2017 9:30	336:25:00	336.4	14.1	3.73
10/23/2017	9:45	10/23/2017 9:45	504:40:00	504.7	18.5	1.51
10/30/2017	9:20	10/30/2017 9:20	672:15:00	672.3	11.5	4.99
11/6/2017	9:39	11/6/2017 9:39	840:34:00	840.6	15.1	3.43

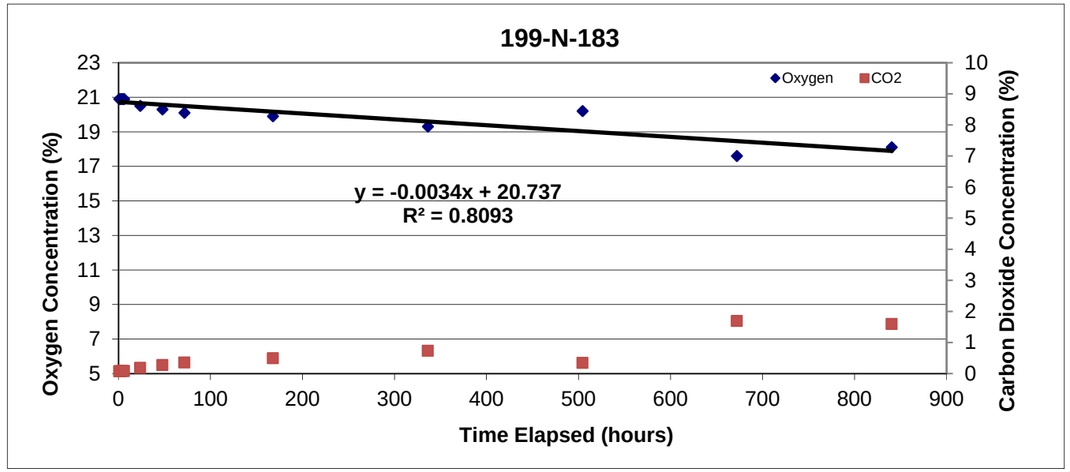


199-N-172						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
10/2/2017	9:05	10/2/2017 9:05	Blower off	0	--	--
10/2/2017	9:28	10/2/2017 9:28	Initial reading	0.38	20.9	0.02
10/2/2017	10:23	10/2/2017 10:23	1:18:00	1.30	20.9	0.02
10/2/2017	11:33	10/2/2017 11:33	2:28:00	2.47	20.9	0.04
10/2/2017	13:24	10/2/2017 13:24	4:19:00	4.32	20.9	0.02
10/2/2017	14:47	10/2/2017 14:47	5:42:00	5.70	20.9	0.02
10/3/2017	8:19	10/3/2017 8:19	23:14:00	23.23	20.9	0.03
10/4/2017	8:24	10/4/2017 8:24	47:19:00	47.32	20.9	0.03
10/5/2017	8:21	10/5/2017 8:21	71:16:00	71.27	20.9	0.04
10/9/2017	8:34	10/9/2017 8:34	167:29:00	167.48	20.4	0.06
10/16/2017	8:52	10/16/2017 8:52	335:47:00	335.78	19.3	0.23
10/23/2017	9:05	10/23/2017 9:05	504:00:00	504.00	18.3	0.48
10/30/2017	8:39	10/30/2017 8:39	671:34:00	671.57	18.3	0.48
11/6/2017	9:10	11/6/2017 9:10	840:05:00	840.08	18.3	0.48

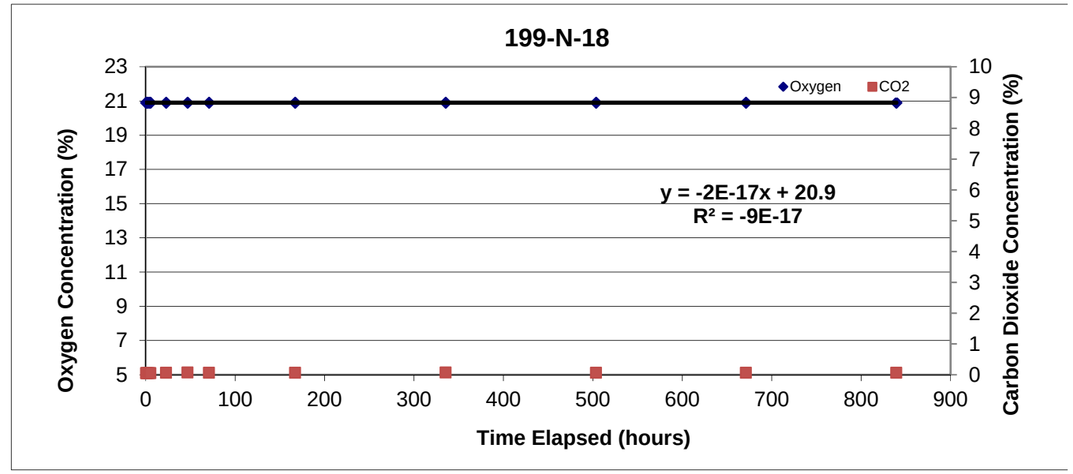


Oxygen Utilization Generation Plots
October to December 2017 Respirometry Test

199-N-183						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
10/2/2017	8:58	10/2/2017 8:58	Baseline	--	20.9	0.16
10/2/2017	9:05	10/2/2017 9:05	Blower off	0	--	--
10/2/2017	9:56	10/2/2017 9:56	Initial reading	0.85	20.9	0.07
10/2/2017	10:54	10/2/2017 10:54	1:49:00	1.82	20.9	0.07
10/2/2017	12:03	10/2/2017 12:03	2:58:00	2.97	20.9	0.07
10/2/2017	13:52	10/2/2017 13:52	4:47:00	4.78	20.9	0.08
10/2/2017	15:16	10/2/2017 15:16	6:11:00	6.18	20.9	0.08
10/3/2017	8:49	10/3/2017 8:49	23:44:00	23.73	20.5	0.18
10/4/2017	8:53	10/4/2017 8:53	47:48:00	47.80	20.3	0.27
10/5/2017	8:50	10/5/2017 8:50	71:45:00	71.75	20.1	0.35
10/9/2017	9:03	10/9/2017 9:03	167:58:00	167.97	19.9	0.49
10/16/2017	9:22	10/16/2017 9:22	336:17:00	336.28	19.3	0.73
10/23/2017	9:35	10/23/2017 9:35	504:30:00	504.50	20.2	0.34
10/30/2017	9:16	10/30/2017 9:16	672:11:00	672.18	17.6	1.69
11/6/2017	9:31	11/6/2017 9:31	840:26:00	840.43	18.1	1.59



199-N-18						
Date	Time		Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
10/2/2017	8:38	10/2/2017 8:38	Baseline	--	20.9	0.05
10/2/2017	9:05	10/2/2017 9:05	Blower off	0	--	--
10/2/2017	9:39	10/2/2017 9:39	Initial reading	0.57	20.9	0.05
10/2/2017	10:35	10/2/2017 10:35	0:56:00	0.93	20.9	0.05
10/2/2017	11:45	10/2/2017 11:45	2:06:00	2.10	20.9	0.05
10/2/2017	13:36	10/2/2017 13:36	3:57:00	3.95	20.9	0.05
10/2/2017	14:58	10/2/2017 14:58	5:19:00	5.32	20.9	0.05
10/3/2017	8:30	10/3/2017 8:30	22:51:00	22.85	20.9	0.06
10/4/2017	8:35	10/4/2017 8:35	46:56:00	46.93	20.9	0.07
10/5/2017	8:32	10/5/2017 8:32	70:53:00	70.88	20.9	0.06
10/9/2017	8:46	10/9/2017 8:46	167:07:00	167.12	20.9	0.06
10/16/2017	9:04	10/16/2017 9:04	335:25:00	335.42	20.9	0.07
10/23/2017	9:17	10/23/2017 9:17	503:38:00	503.63	20.9	0.06
10/30/2017	8:53	10/30/2017 8:53	671:14:00	671.23	20.9	0.06
11/6/2017	9:01	11/6/2017 9:01	839:22:00	839.37	20.9	0.06



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