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Rev. 0

River Corridor
Closure Contract

UPR-100-N-17: Bioventing Pilot Plant Performance Report

June 2011

For Public Release

Washington Closure Hanford

Prepared for the U.S. Department of Energy, Richland Operations Office
Office of Assistant Manager for River Corridor

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EXECUTIVE SUMMARY

The purpose of this report is to summarize the 6-month bioventing pilot plant operational test results at the UPR-100-N-17 166-N Diesel Oil Supply Line Leak waste site located at the 100-N Area in the U.S. Department of Energy's Hanford Site in Benton County, Washington. The UPR-100-N-17 waste site is impacted by historical releases of petroleum hydrocarbons, primarily No. 2 fuel oil and No. 6 fuel oil. In-situ bioremediation (ISB) using bioventing was chosen as the remedial technology for addressing petroleum contamination in selected subsurface areas at 100-N Area.

Drilling and construction of seven bioremediation wells was completed between January and March 2009. Analytical results indicate that total petroleum hydrocarbons, oil, and grease were present in all of the bioremediation well boreholes at concentrations above the cleanup level of 200 milligrams per kilogram (mg/kg). Generally, higher concentrations were encountered at depths of 17 m (55 ft) below ground surface (bgs) or greater. Groundwater was encountered at depths from 21 to 23 m (70 to 75 ft) bgs.

Pilot testing began in February 2010 and continued through May 2011. The pilot testing included collection of baseline measurements at the seven bioremediation wells, a respirometry test, an air injection (radius of influence [ROI]) test, and a 6-month operational test period. Results from the pilot testing indicate that deep-vadose-zone hydrocarbon-impacted soils are amenable to bioventing enhanced ISB.

The following conclusions are made from the pilot test results:

- Overall microbial degradation of hydrocarbons is significantly enhanced through bioventing in the vadose zone, though oxygen utilization rates were found to vary between monitoring wells.

- The ROI for deep injection well DIW-1 is at least 61 m (200 ft) under the testing conditions. Similar ROIs are expected for the other deep bioremediation wells at this site when air is injected at approximately 250 cubic feet per minute (cfm) or higher.

- Microbial degradation in the shallow wells (SIW-1 and SMP-1) is not measureable using the protocols established for this testing. Baseline soil vapor levels for oxygen and carbon dioxide are at atmospheric concentrations. Thus, it was not possible to determine an oxygen utilization rate, and oxygen is not a rate limiting factor.

- Bioventing appears to be an effective and efficient method of promoting ISB in the deep soils at this site. Depressed baseline oxygen levels are clearly a key rate-limiting factor. Even at moderate air flow rates, bioventing has been shown to affect a large area around injection wells, suggesting the soils are relatively permeable to air flow.

Based on the results of the pilot study, bioventing provides a method for enhancing ISB of deep soils impacted with hydrocarbons at the UPR-100-N-17 waste site.

The data from the pilot test will support the design of full-scale bioventing systems for this and similar waste sites.

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ACRONYMS

asl	above sea level
bgs	below ground surface
DIW	deep injection well
DMP	deep monitoring point
ISB	in-situ bioremediation
ppmv	parts per million by volume
PRZ	periodically rewetted zone
QAPP	quality assurance project plan
RCCS	RC Construction Services, Inc.
ROI	radius of influence
SIW	shallow injection well
SMP	shallow monitoring point
TPH	total petroleum hydrocarbons
TVH	total volatile hydrocarbons
WCH	Washington Closure Hanford

METRIC CONVERSION CHART

Into Metric Units			Out of Metric Units		
If You Know	*Multiply By*	*To Get*	*If You Know*	*Multiply By*	*To Get*
Length			**Length**		
inches	25.4	millimeters	millimeters	0.039	inches
inches	2.54	centimeters	centimeters	0.394	inches
feet	0.305	meters	meters	3.281	feet
yards	0.914	meters	meters	1.094	yards
miles	1.609	kilometers	kilometers	0.621	miles
Area			**Area**		
sq. inches	6.452	sq. centimeters	sq. centimeters	0.155	sq. inches
sq. feet	0.093	sq. meters	sq. meters	10.76	sq. feet
sq. yards	0.836	sq. meters	sq. meters	1.196	sq. yards
sq. miles	2.6	sq. kilometers	sq. kilometers	0.4	sq. miles
acres	0.405	hectares	hectares	2.47	acres
Mass (weight)			**Mass (weight)**		
ounces	28.35	grams	grams	0.035	ounces
pounds	0.454	kilograms	kilograms	2.205	pounds
ton	0.907	metric ton	metric ton	1.102	ton
Volume			**Volume**		
teaspoons	5	milliliters	milliliters	0.033	fluid ounces
tablespoons	15	milliliters	liters	2.1	pints
fluid ounces	30	milliliters	liters	1.057	quarts
cups	0.24	liters	liters	0.264	gallons
pints	0.47	liters	cubic meters	35.315	cubic feet
quarts	0.95	liters	cubic meters	1.308	cubic yards
gallons	3.8	liters			
cubic feet	0.028	cubic meters			
cubic yards	0.765	cubic meters			
Temperature			**Temperature**		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius	Celsius	multiply by 9/5, then add 32	Fahrenheit
Radioactivity			**Radioactivity**		
picocuries	37	millibecquerel	millibecquerels	0.027	picocuries

1.0 INTRODUCTION

This report summarizes the results of testing conducted at the UPR-100-N-17 166-N Diesel Oil Supply Line Leak waste site in the 100-N Area of the U.S. Department of Energy's Hanford Site in Benton County, Washington. The report describes the testing protocols and results from the testing, and makes recommendations for future full-scale application as appropriate. Figure 1 shows the location of the 100-N Bioremediation Pilot Study Site.

Figure 1. Location of 100-N Bioremediation Pilot Study Site.

2.0 PURPOSE AND OBJECTIVES

As stated in *Bioremediation Well Borehole Soil Sampling and Data Analysis Summary Report for the 100-N Area Bioremediation Project (UPR-100-N-17)* (WCH 2009), bioventing was chosen as the remedial technology for addressing petroleum contamination in selected subsurface areas at the 100-N Area UPR-100-N-17 waste site by the U.S. Environmental Protection Agency and the Washington State Department of Ecology. This report consolidates the data and information in the *Bioventing Pilot Study Summary Report Deep Zone Petroleum Contamination* report (AMEC 2010) and completion of the six month operation test results with follow-up well sampling results.

One of the objectives of the testing program was to establish whether bioventing is capable of significantly enhancing microbial degradation of petroleum hydrocarbons in the deep subsurface at the UPR-100-N-17 waste site by providing excess oxygen as the terminal electron acceptor. Besides oxygen, aerobic organisms also require an environment with appropriate moisture, pH, temperature, and nutrient levels. Data was not collected during this test program to determine if these other factors were adequate or rate-limiting. Secondary objectives included collecting design information that can be used for a full-scale long-term application of bioventing, such as air injection rates and associated radius of influence (ROI) for bioremediation wells.

3.0 SITE DESCRIPTION

The following site information was extracted from *Bioremediation Well Borehole Soil Sampling and Data Analysis Summary Report for the 100-N Area Bioremediation Project (UPR-100-N-17)* (WCH 2009). Further site background information can be obtained from that report.

3.1 SITE BACKGROUND

The UPR-100-N-17 waste site vadose zone is impacted by historical releases of petroleum hydrocarbons, primarily No. 2 fuel oil and No. 6 fuel oil, from storage tanks and associated equipment. In August 1966 an estimated 302,833 kL (80,000 gal) of diesel oil leaked from an oil transfer valve. Previous site borings indicate the impacts extend from the surface to the groundwater at a depth of about 24 m (80 ft) below ground surface (bgs). Bioremediation was selected as a possible technology for remediation of the vadose zone soils. In-situ bioremediation (ISB) consists of adding air (oxygen) to the vadose zone through the use of injection wells to enhance microbial degradation of hydrocarbons in soils. Drilling and construction of seven bioremediation wells was conducted between January and March 2009 (WCH 2009). Pilot testing began in February 2010 and continued through May 2011.

3.2 SITE GEOLOGY

Based on information previously published (WCH 2009), the two major hydrogeologic units that make up the shallow vadose zone and the unconfined aquifer, in descending order, are the Hanford Formation and the Upper Ringold Formation. Borehole logs completed in 2009 during the drilling of the seven bioremediation wells identify sand, sandy gravel, and gravel as the predominant soil types, with lesser amounts of intermixed silt and clay.

A summary of pertinent lithologic properties for the site includes:

- The lithology in the drilling area was dominated by silty sandy gravels in the upper vadose zone and sandy gravels, silty sandy gravels, and sand in the lower portion of the vadose zone. Some borehole intervals contain silts and clays mixed with the gravels.

- The periodic presence of minor amounts of clay and silt in the drill cuttings indicate that interbedded silt and clay layers may be present.

- Zones of cementation were randomly encountered in the boreholes at depth intervals ranging from 13.7 to 23.8 m (45 to 78 ft) below ground surface (bgs).

- A 1.5- to 2.1-m (5- to 7-ft)-thick bed of fine- to coarse-grained sand was noted in the borehole logs between 18.3 to 21.3 m (60 and 70 ft) bgs.

3.3 SITE HYDROGEOLOGY

The UPR-100-N-17 waste site is located approximately 122 to 152 m (400 to 500 ft) from the edge of the Columbia River. The flow rate and stage of the river are regulated by the Priest Rapids Dam located upstream of the Hanford Site. River-level fluctuations are reflective of a number of cyclical factors including daily, weekly, seasonal, and annual cycles. Normally, late winter-, early spring-, and summer-runoff releases from Priest Rapids Dam increase river flow and stage, and have been documented to affect groundwater levels in wells located up to 305 m (1,000 ft) inland. Daily stage fluctuations affected groundwater levels up to 229 m (750 ft) inland. Groundwater levels were observed to fluctuate as much as 3 m (10 ft) in monitor well 199-N-8S, which is located 24 m (80 ft) inland from the river.

Depth to groundwater encountered during the drilling period from January to early March 2009 ranged from 21.9 to 23 m (71.9 to 75.5 ft) bgs (elevation of 118.6 to 117.9 m [389.2 to 386.9 ft] above sea level [asl]). The periodically rewetted zone (PRZ) consists of a zone of soil that is periodically saturated with groundwater when groundwater levels are high and unsaturated at times when the groundwater levels are low. The PRZ defines the top of the water table. The top of the PRZ is located at 0.6 m (2 ft) above the highest groundwater elevation measured during drilling. The top of the PRZ is located at 119.22 m (391.15 ft) asl.

3.4 NATURE AND EXTENT OF SOIL CONTAMINANTS

The full nature and extent of subsurface hydrocarbon impacts in the UPR-100-N-17 waste site has not been determined and is beyond the scope of this pilot test activity. This study focused the feasibility of using bioventing to remediate vadose-zone soils known to be impacted by diesel-range hydrocarbons. Soil samples were collected from each of the seven bioremediation well boreholes drilled as part of this study. Soil samples were analyzed for diesel- and gasoline-range total petroleum hydrocarbons (TPH), and oil and grease (WCH 2009).

Analytical results indicate that diesel-range TPH was present at concentrations ranging from 3,000 to 4,000 mg/kg in the deep boreholes (DIW-1, DMP-1 through DMP-4), with increasing levels from 17 m (55 ft) bgs and deeper. Oil and grease were detected in shallow well SIW-1 at depths less than 4.6 m (15 ft) bgs and at concentrations of approximately 1,000 mg/kg. In general, the shallower soils showed lower levels of hydrocarbon impacts, possibly due to the availability of oxygen in shallow soils as well as other weathering effects.

Groundwater was encountered at depths from 21 to 23 m (70 to 75 ft) bgs. Evaluation of hydrocarbon impacts to groundwater was not part of this study; however, the groundwater plume map shows an irregular-shaped dissolved hydrocarbon plume bounded by the 166-N Tank Farm to the east, the Columbia River to the west, well 199-N-19 and the 166-N Tank Farm to the south, and wells 199-N-96A and 199-N-3 to the north.

4.0 PILOT TEST DESCRIPTION

The pilot testing included the collection of baseline measurements, a respirometry test, an air injection ROI test, and a 6-month “long-term” operating test of the pilot system.

Equipment and facilities required for all phases of the pilot testing included seven bioremediation wells, a 20-horsepower regenerative blower (Figure 2), a flow-control manifold (Figure 3), ancillary hoses, valves and fittings, and electrical supply and controls for the blower. The electrical controls, flow-control manifold, and blower are housed in a transportable steel container (skid) (Figure 4) and the bioremediation wells were connected to the manifold using flexible hoses and quick-disconnect couplers. Initially, power was provided by a portable diesel generator. Following the respirometry test program, a fixed power line was routed to the bioventing skid and used for the remainder of the test program.

The bioremediation wells (Figures 5 and 6) were assigned pilot testing designations and also unique Hanford ID numbers (Figure 7). Construction details for each well are provided in Table 1.

Figure 2. Blower Package Inside Container

Figure 3. Air Distribution Manifold.

Figure 4. Pilot Test Skid Ready for Shipment to Hanford.

Figure 5. Test Well DMP-1.

Figure 6. Test Well Monitoring Setup.

Figure 7. Bioremediation Well Location Map.

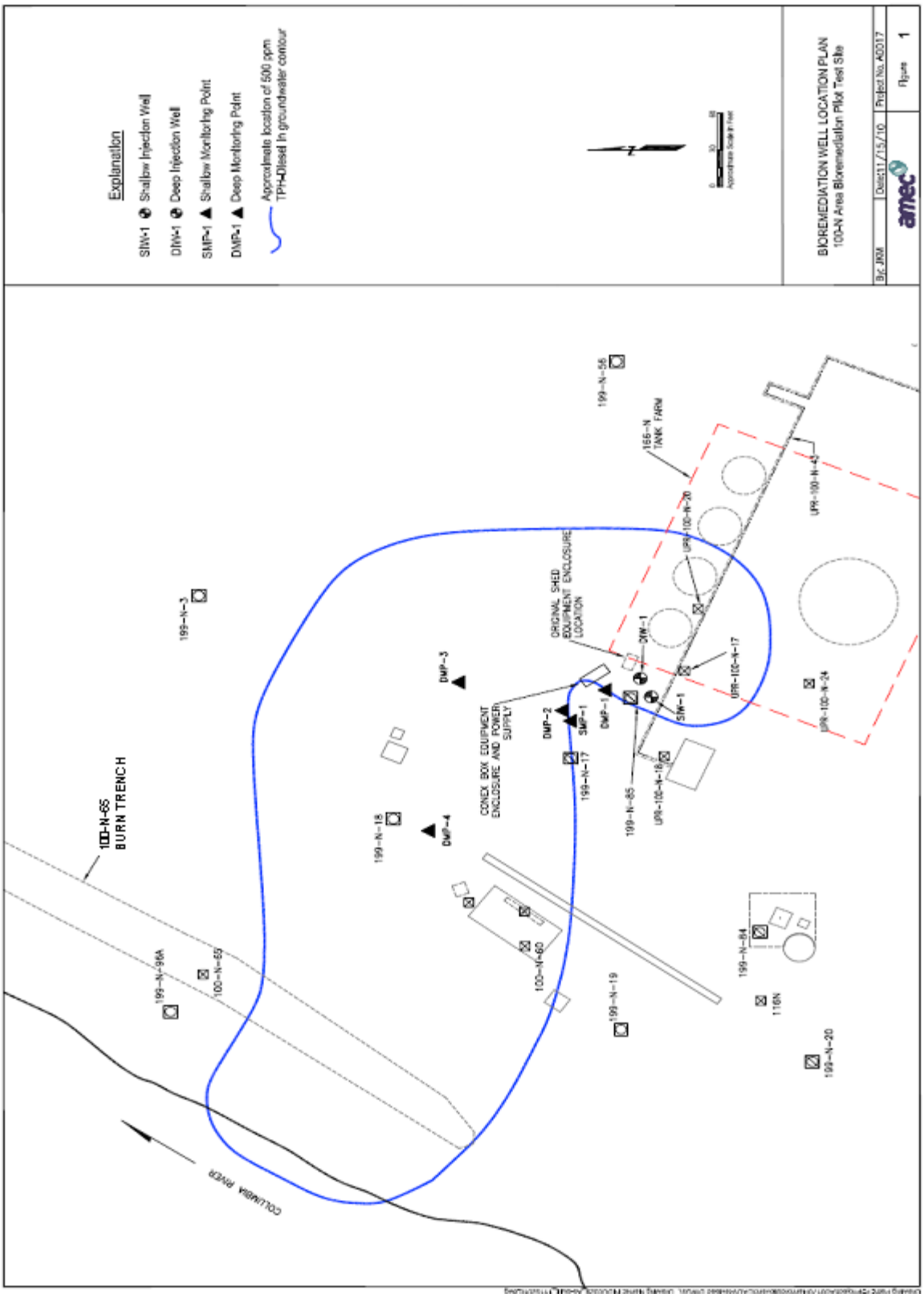

Table 1. Bioremediation Well Construction Summary.

Pilot Test Designation (Well Number)	Total Depth (ft bgs)	Top of Screen (ft bgs)	Bottom Screen (ft bgs)	Screen Interval (ft)	Top of Well Casing Elevation (ft asl)	Groundwater Elevation (ft asl) [a]	Depth to Groundwater (ft bgs)
SIW-1 (199-N-166)	33	10	30	20	461.69	NA	NA
DIW-1 (199-N-167)	83	53	78	25	461.33	388.17	73.16
SMP-1 (199-N-168)	33	10	30	20	462.02	NA	NA
DMP-1 (199-N-169)	83	53	78	25	461.48	387.88	73.60
DMP-2 (199-N-170)	83.5	54	79	25	461.66	387.56	74.10
DMP-3 (199-N-171)	82.4	55	80	25	462.35	386.85	75.50
DMP-4 (199-N-172)	82	57	77	20	461.05	389.15	71.90

[a] Groundwater elevations represent conditions for the construction dates and are not assumed to be static through time. Data from the *Bioremediation Well Borehole Soil Sampling and Data Analysis Summary Report for the 100-N Area Bioremediation Project (UPR-100-N-17)* (WCH 2009).

asl = above sea level
bgs = below ground surface
DIW = deep injection well
DMP = deep monitoring point
NA = not applicable – well did not intersect groundwater surface
SIW = shallow injection well
SMP = shallow monitoring point

4.1 RESPIROMETRY TESTING

The in-situ respiration test was initiated on February 24, 2010. The objective of this test was to determine an oxygen utilization rate and associated microbial respiration efficiency in the zone surrounding each well. The subsurface was thoroughly aerated by blowing atmospheric air into each of the seven test wells (Figure 8). After aerating the subsurface for a period of 41 hours, the blower was shut off and the oxygen and carbon dioxide levels in each well were measured over time. The rate of oxygen decrease is related to the level of microbial activity (respiration) in the subsurface as organic matter is consumed. The rate of oxygen depletion is calculated and used to evaluate the effectiveness of bioremediation as a means of degrading the petroleum hydrocarbon contamination. Aerating the subsurface for a period of approximately 48 hours prior to these measurements mitigates the potential for oxygen decreases due to concentration gradient induced diffusion.

Figure 8. Air Distribution Hose to Test Wells.

Prior to the respiration test startup, initial baseline soil gas monitoring was conducted on January 7, 2010. After purging each well casing, soil-gas samples were collected from the seven bioremediation wells and analyzed for oxygen, carbon dioxide, methane, and total volatile hydrocarbons (TVH). Each sample was collected into a Tedlar® bag and then analyzed using direct-read field instruments. Table 2 shows the baseline concentrations for each of these parameters.

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Table 2. Baseline Concentrations in Bioremediation Wells.

Monitoring Point	Baseline Oxygen (%)	Baseline CO_2 (%)	Baseline TVH (ppmv)	Baseline Methane (%)
DIW-1	4.1	13.3	60.63	0.2
DMP-1	1.6	14.9	3.93	0.0
DMP-2	1.5	14.9	92.34	0.2
DMP-3	2.3	13.8	109	0.2
DMP-4	1.3	15.6	16.34	0.0
SIW-1	20.2	1.3	84.32	0.1
SMP-1	20.3	0.8	117	0.2

CO_2 = carbon dioxide
DIW = deep injection well
DMP = deep monitoring point
ppmv = parts per million by volume
SIW = shallow injection well
SMP = shallow monitoring point
TVH = total volatile hydrocarbons.

Aeration of the subsurface was performed by connecting the bioremediation wells to the blower manifold and operating the blower for a period of two days. Valves on the control manifold were used to regulate the air flow to each well at approximately 15 cubic feet per minute (cfm). Samples were collected on a predetermined schedule starting on February 26, 2010, immediately following shutoff of the blower, and continuing through test completion on March 10, 2010. The sampling interval and sampling methods are described in the quality assurance project plan (QAPP) prepared for this phase of work (RCCS 2009). In total, twenty-seven samples were collected from each of the bioremediation wells over a period of approximately 292 hours (12 days).

Results of the respirometry testing, including baseline and post-testing samples, are summarized in Section 5.1, with additional details provided in Appendix A.

4.2 AIR INJECTION RADIUS OF INFLUENCE TESTING

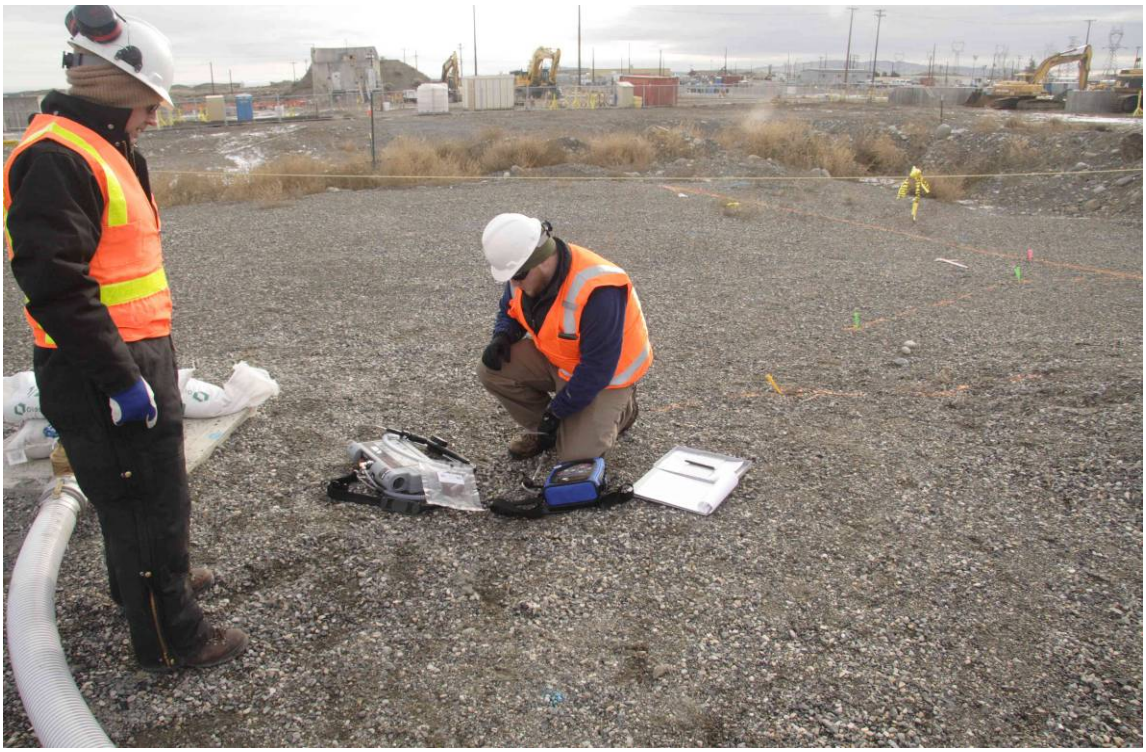
Air-injection testing was conducted to evaluate the ROI of the test wells. ROI is a critical design parameter for bioventing applications, as it helps establish the number of injection wells needed and the spacing between wells. For the purposes of this pilot test, two air-injection tests were completed – a deep injection test and a shallow injection test. For each test, air was injected into one bioremediation well and the soil gas in the remaining six wells was monitored for pressure, oxygen, carbon dioxide, methane, and TVH over time. The sampling intervals and sampling methods are described in the QAPP (RCCS 2009).

The deep-injection ROI test was conducted in September 2010, whereby air was continuously injected into well DIW-1 at a flow rate of 350 cfm. Soil gas monitoring at the other bioremediation wells was performed throughout the injection period, starting with baseline sampling on September 20, 2010, and continuing through test completion on September 27, 2010. Thirteen rounds of measurements for pressure, carbon dioxide, oxygen, methane, and

TVH were made at each of the six monitoring points over a period of approximately 165 hours (about 7 days).

Figure 9 shows workers collecting samples for testing.

Figure 9. Sample Collection and Testing.



The second (shallow) injection ROI test was conducted in October 2010, similar to the deep-injection test except air was injected into well SIW-1 at a flow rate of 350 cfm. The other six bioremediation wells were monitored on a predetermined schedule beginning on October 4, 2010. The shallow test was terminated on October 18, 2010. Eighteen rounds of vapor measurements were made at each of the six monitoring points over a period of approximately 334 hours (about 14 days).

Results of the air injection ROI testing are summarized in Section 5.2, with additional details provided in Appendix B.

4.3 6-MONTH LONG-TERM OPERATION TEST

The six-month operation test was completed to verify that elevated oxygen concentrations can be sustained in the deep vadose zone, and to evaluate the mechanical reliability of the blower and associated equipment. This test was intended to verify the suitability of the selected blower package and identify long-term operations and maintenance needs of the system, including operations during both warm and cold weather conditions.

The 6-month operation test was initiated on October 18, 2010 when the shallow-well ROI pilot test was completed and baseline samples for the 6-month operation test were collected. The bioventing system was operational from October 21, 2010 to May 14, 2011. The 6-month operation test concluded on May 18, 2011 when the final monitoring event was conducted. Throughout the testing, air was injected into DIW-1 and DMP-4 at a rate of 250 cfm per well. A Bioremediation Well Location Map is provided as Figure 7. A sampling event was conducted two weeks after system startup (2-week monitoring event) to determine if the injection rates and locations were adequate to enhance oxygen concentrations throughout the pilot study deep injection zone. The injection rates and locations were adequately selected for the purposes of the 6-month operation test and no changes were made to the testing program. Monitoring was then conducted monthly as planned for the duration of the test.

Three deep monitoring wells (DMP-1, DMP-2, and DMP-3) were used to evaluate changes in the soil gas composition. The wells were monitored for oxygen, carbon dioxide, methane, TVH using a Mini-Rae 4-gas meter, and pressure at the wellhead. The shallow bioremediation wells were not monitored during the 6-month operation test because oxygen concentrations in these wells have been consistently near oxygen saturation throughout the previous pilot study testing. Results of the monitoring are provided in Section 5.3.

5.0 PILOT TEST RESULTS

The results are summarized in the subsections that follow with supporting data located in Appendices A, B, and C.

5.1 RESPIROMETRY TESTING

An in-situ respiration test was conducted in February and March 2010 to determine the feasibility of bioventing. Biodegradation efficiency is related to the oxygen-utilization rate, and is 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) = 0.27 cm^3 gas/cm^3 soil
- ρ_{O2} = density of oxygen; assumed soil temp of 50 °F = 1,378 mg/L (Parsons 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; assumed value from assumed site soil characterized as mixed grain sand, dense = 1.86 g/cm^3 (Parsons 2004)

θ: = total porosity (where $\theta = 1 - \rho_k/\rho_T$) = 0.30 cm^3/cm^3

θ_w = water filled porosity (where $\theta_w = M*\rho_k/\rho_T$) = 0.03 cm^3/cm^3

ρ_T = soil mineral density; assumed value = 2.65 g/cm^3

M = moisture content; 4.63% reported site average (WCH 2009) = 0.0463 g moisture per g soil.

Baseline measurements of oxygen and carbon dioxide and subsequent calculated biodegradation rates are presented in Tables 3 and 4. Plots showing oxygen utilization and carbon dioxide generation are provided in Attachment A. During the respiration test methane was detected infrequently at 0.1%. The highest levels of TVH, up to 130 ppmv, were detected on the first day of sampling. TVH levels generally decreased over the duration of the test.

Table 3. Respirometry Test – Initial Bioremediation Well Measurements.

Monitoring Point	Baseline O_2 (%)	Baseline CO_2 (%)	O_2 after 41-hr aeration (%)	CO_2 after 41-hr aeration (%)
DIW-1	4.1	13.3	20.8	0.0
DMP-1	1.6	14.9	20.8	0.1
DMP-2	1.5	14.9	21.0	0.0
DMP-3	2.3	13.8	21.1	0.0
DMP-4	1.3	15.6	21.1	0.1
SIW-1	20.2	1.3	21.0	0.1
SMP-1	20.3	0.8	21.0	0.0

CO_2 = carbon dioxide
DIW = deep injection well
DMP = deep monitoring point
O_2 = oxygen
SIW = shallow injection well
SMP = shallow monitoring point

Table 4. Respiration Rate Calculations. (2 Pages)

Monitoring Point	O_2 Utilization (%/day)	Biodegradation Rate (mg/kg-day)
DIW-1	1.32	-0.76
DMP-1	1.29	-0.74
DMP-2	0.96	-0.55
DMP-3	0.49	-0.28
DMP-4	0.71	-0.41

Table 4. Respiration Rate Calculations. (2 Pages)

Monitoring Point	O_2 Utilization (%/day)	Biodegradation Rate (mg/kg-day)
SIW-1	0.20	-0.11
SMP-1	0.18	-0.11

DIW = deep injection well
DMP = deep monitoring point
O_2 = oxygen
SIW = shallow injection well
SMP = shallow monitoring point

In general, oxygen utilization rates of 1% per day or greater indicate treatment by bioventing to enhance microbial activity is feasible. Lower oxygen utilization rates in areas with significant hydrocarbon content indicate that other factors may be limiting biodegradation such as insufficient nutrients or moisture, low temperature, or contaminant toxicity. Results from wells DIW-1, DMP-1, and DMP-2 indicate remediation by bioventing is feasible. Results from the shallow wells (SIW-1 and SMP-1) indicate either a lack of significant hydrocarbon mass, inhibition of biodegradation, or that these locations have significant air exchange with the atmosphere, such that oxygen depletion is not occurring due to respiration.

The results from DMP-3 and DMP-4 indicate that biodegradation of hydrocarbons is occurring; however, the relatively low oxygen utilization rate indicates a lower efficiency compared to the other areas. It is possible that the environment in the vicinity of these wells is limiting microbial activity due to some other factor such as moisture or nutrient deficiency. Another possibility is that the initial population of microbes capable of aerobically degrading the hydrocarbons was lower in these areas, and so there was a lower apparent response time to the introduction of oxygen.

In this analysis, several of the parameter values used to calculate the degradation rate were estimated. For example, a simple sensitivity analysis of soil bulk density over the range of probable values had a significant impact, up to 64% difference from the initially calculated rate. Therefore, determination of an appropriate bulk density is important in biodegradation rate calculations. If the soil is suspected of being highly heterogeneous, the collection of soil samples from each bioremediation well for physical testing would be recommended. Supporting data and calculations are provided as Appendix A.

5.2 RADIUS OF INFLUENCE TESTING

A deep injection ROI test was completed in September 2010. Air was continuously injected into DIW-1 at a rate of 350 cfm. All of the six monitoring points exhibited an increase in oxygen concentrations and a decrease in carbon dioxide concentrations as a result of the air injection at DIW-1. Well DMP-4 is the farthest well from DIW-1 at approximately 200 ft away. Measurable changes in oxygen and carbon dioxide were observed in DMP-4 within 50 hours of injection. The testing indicates that an effective ROI for DIW-1 is at least 61 m (200 ft) under the testing conditions. Plots showing the monitoring results for oxygen, carbon dioxide, and methane are provided in Attachment B.

It is important to note that ROI calculations are a function of several parameters, and that the test conditions should be stated for any ROI claim. For the testing described herein, the deep well ROI of 61 m (200 ft) was obtained at an airflow of 350 cfm into a bioremediation well with a 7.6 m (25 ft) screen installed from 16 to 24 m (53 to 78 ft) in a sandy, relatively dry, and homogenous environment. The stated ROI may or may not be reproducible at other sites with different test conditions. It should also be noted that the ROI was based primarily on the observed change in soil gas composition (oxygen increase) at distant monitoring points, not on an observed subsurface pressure gradient. While pressure differences were noted in monitoring points relatively close to the injection location, measurable changes in pressure decrease rapidly as the distance from the injection well increases. Changes in soil gas composition are a more reliable measure of bioventing influence at distant monitoring points.

A shallow injection ROI test was conducted in October 2010 using SIW-1 as the injection well. Results indicate that the shallow air injections did not have an appreciable effect on shallow or deep subsurface conditions and are not likely to significantly enhance microbial activity. In general, the oxygen and carbon dioxide concentrations hovered near the baseline conditions observed in each well prior to starting the shallow ROI injection test, even after more than 300 hours of air injection. Because the baseline oxygen concentration is near atmospheric levels in the shallow wells, oxygen is not a rate limiting factor for biodegradation in shallow soils. Plots showing the monitoring results for oxygen, carbon dioxide, and methane are provided in Appendix B.

5.3 6-MONTH OPERATION TEST RESULTS

The 6-month pilot test was conducted between October 25, 2010 and May 18, 2011. Deep monitoring points DMP-1, DMP-2, and DMP-3 exhibited oxygen concentrations that increased significantly over the baseline conditions and were near oxygen saturation throughout the pilot study. Carbon dioxide concentrations also dropped significantly in these wells. Each well exhibited a measurable increase in pressure, indicating air flow from DIW-1 and DMP-4 was adequate to influence the entire study area. In DMP-2 and DMP-3 the TVH concentrations measured at the wellhead peaked at around day 100 (2,400 hours) of the test and then declined. All three deep monitoring points exhibited a small peak in TVH near the end of the testing at around day 187 (4,500 hours). Methane was detected only one time; the detected methane concentration was 0.1% in well DMP-2 during the baseline monitoring. Monitoring results for each of the three deep monitoring wells are shown below in Tables 5 through 7.

Table 5. DMP-1 6-month Test Monitoring Results. (2 Pages)

Time Elapsed (hr:min:sec)	O_2 (%)	CO_2 (%)	TVH (ppmv)	Pressure (in. H_2O)
0:00:00	9.7	4.4	19.1	0.02
433:50:00	20.9	0.014	21.2	2.9
1465:16:00	21.1	0.073	24.5	2.5
2350:29:00	20.9	0.025	20.9	2.4
2975:09:00	21.3	0.037	14.3	2.5
3611:56:00	20.9	0.044	25.7	2.2

Table 5. DMP-1 6-month Test Monitoring Results. (2 Pages)

Time Elapsed (hr:min:sec)	O_2 (%)	CO_2 (%)	TVH (ppmv)	Pressure (in. H_2O)
4485:46:00	20.9	0.043	50.2	1.8
5003:56:00*	19.6	0.206	9.7	0

* The last monitoring event was conducted approximately 4 days after system shutdown.

CO_2 = carbon dioxide
H_2O = water
O_2 = oxygen
ppmv = parts per million by volume
TVH = total volatile hydrocarbons.

Table 6. DMP-2 6-month Test Monitoring Results.

Time Elapsed (hr:min:sec)	O_2 (%)	CO_2 (%)	TVH (ppmv)	Pressure (in. H_2O)
0:00:00	13	2.7	36	0.02
434:00:00	21	0.24	188	1.1
770:44:00	19.2	0.39	241	2.2
1465:33:00	20.9	0.405	405	1.1
2350:46:00	20.9	0.209	417	0.98
2975:17:00	20.9	0.226	395	1
3611:56:00	20.5	0.25	194	1
4486:06:00	20.6	0.24	222	0.8
5003:56:00*	18	0.742	47	0

* The last monitoring event was conducted approximately 4 days after system shutdown.

CO_2 = carbon dioxide
H_2O = water
O_2 = oxygen
ppmv = parts per million by volume
TVH = total volatile hydrocarbons.

Table 7. DMP-3 6-month Test Monitoring Results. (2 Pages)

Time Elapsed (hr:min:sec)	O_2 (%)	CO_2 (%)	TVH (ppmv)	Pressure (in. H_2O)
0:00:00	12	4.6	16.3	0
434:15:00	20.2	0.86	101	0.65
770:54:00	18.7	1.32	116	0.57
1465:49:00	20.1	1.15	286	0.56
2350:59:00	20.2	0.605	374	0.57
2975:33:00	20.9	0.486	152	0.52
3611:56:00	20.1	0.507	101	0.52

Table 7. DMP-3 6-month Test Monitoring Results. (2 Pages)

Time Elapsed (hr:min:sec)	O_2 (%)	CO_2 (%)	TVH (ppmv)	Pressure (in. H_2O)
4486:21:00	20.3	0.459	104	0.9
5003:56:00*	19.4	0.728	26.3	0

* The last monitoring event was conducted approximately 4 days after system shutdown.

CO_2 = carbon dioxide
H_2O = water
O_2 = oxygen
ppmv = parts per million by volume
TVH = total volatile hydrocarbons.

Of note is the final monitoring event which was conducted after the bioventing system was shut down. The system shut down due to a power failure on May 14, 2011, after approximately 205 days (4,920 hours) of operation. This shutdown coincided with the conclusion of the 6-month operation test and the system was not restarted. The final monitoring event was conducted on May 18, 2011, approximately 4 days after system shutdown. The final monitoring event shows a slight decrease in oxygen concentrations and a corresponding rise in carbon dioxide concentrations. TVH concentrations also dropped significantly. Although it is difficult to assess the effectiveness of the pilot system without collecting soil samples, these observations indicate that oxygen and hydrocarbons are being consumed to produce carbon dioxide; therefore, long-term bioventing is likely to be effective at enhancing microbial degradation of deep vadose zone hydrocarbons. Supporting data for 6-month operational testing final sampling is provided in Appendix C.

6.0 CONCLUSIONS

Bioventing appears to be an effective and efficient method of promoting ISB in the deep vadose soils at this site. The well spacing and flow rates used during the 6-month operation test are capable of significantly increasing and sustaining deep vadose zone oxygen concentrations over a large area. The two 6-month test injection wells, DIW-1 and DMP-4, are approximately 61 m (200 ft) apart, and the zone between them reached near atmospheric levels of oxygen shortly after the air injection was initiated (250 cfm each). This suggests that the effective radius of influence of these deep wells was at least 61 m (200 ft).

The 6-month operation test demonstrates the suitability and reliability of the equipment used and will provide useful information for full-scale expansion of the technology. In addition, soil samples will be collected during installation of new wells.

The results of the 6-month operation test provide strong support for continued bioventing to reduce hydrocarbon concentrations in the deep vadose zone.

The following conclusions can be made from the pilot test results:

- Overall microbial degradation of hydrocarbons is significantly enhanced through bioventing in the vadose zone of this test area. Some variation in oxygen utilization rates were noted

between monitoring wells. Factors besides the presence of oxygen that may be affecting the efficiency of degradation in some areas include soil moisture, nutrient availability, and/or contaminant mass presence.

- The equation used to calculate degradation rate is sensitive to assumptions made about physical soil parameters such as bulk density. Future bioventing tests should include the collection of soil samples for contaminant analyses, geotechnical parameter testing, nutrients, and moisture evaluation.

- The ROI for DIW-1 is at least 61 m (200 ft) under the specific test conditions employed. Similar ROIs are expected for the other deep bioremediation wells, since the lithology at depth is relatively homogenous across the test area.

- Microbial degradation in the shallow wells (SIW-1 and SMP-1) is not measureable using the protocols established for this testing. Baseline soil vapor levels for oxygen and carbon dioxide are at atmospheric concentrations. Oxygen is not rate limiting with respect to bioremediation in the shallow vadose zone. Bioventing in the shallow soils of this test area will have a negligible effect on microbial degradation rates.

- Bioventing appears to be an effective and efficient method of promoting ISB in the deep soils at this site. Depressed baseline oxygen levels are clearly a key rate-limiting factor. Even at moderate air flow rates, bioventing has been shown to affect a large area around injection wells, suggesting the soils are relatively permeable to air flow.

- After two weeks of injection, it appeared that two injection wells (DIW-1 and DMP-4) were adequate to significantly increase deep vadose zone oxygen concentrations throughout the entire pilot study area when operated at a flow rate of 250 cfm each.

- Soil vapor samples collected after 4 days of system shutdown showed a clear decrease in subsurface oxygen levels that can be assumed to indicate that microbial degradation continues at measurable rates.

7.0 RECOMMENDATIONS

Based on the results of the pilot study, bioventing will be a cost-effective method for remediating deep soils impacted with hydrocarbons at the 100-N Area.

It is difficult to verify the success of bioventing without collecting soil samples for laboratory analysis. Baseline soil concentration data is available as a result of samples collected during the installation of the bioremediation wells, and a cleanup level of 200 mg/kg is assumed. Additional sampling will be necessary in the future to validate the success of ISB at the site.

The data from the pilot test is adequate for designing a full-scale bioventing system for the site.

The existing blower is expected to have more than sufficient capacity to supply air to the subsurface. ROI data along with maps of the expected contaminant distribution would be used to lay out a bioremediation well field.

8.0 REFERENCES

AMEC, 2010, *Bioventing Pilot Study Summary Report Deep Zone Petroleum Contamination*, AMEC Earth and Environmental, Inc., Denver, Colorado.

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

RCCS, 2009, *Quality Assurance Project Plan for the Phase 1 Bioremediation Pilot Test for Deep Zone Petroleum Contamination at 100N Area, DOE Hanford Reservation, Washington,* RC Construction Services, Inc., Richland, Washington.

WCH, 2009, *Bioremediation Well Borehole Soil Sampling and Data Analysis Summary Report for the 100-N Area Bioremediation Project (UPR-100-N-17),* WCH-370, Rev. 0, Washington Closure Hanford, Richland, Washington.

APPENDIX A

SUPPORTING DATA FOR RESPIROMETRY TESTING

APPENDIX A

SUPPORTING DATA FOR RESPIROMETRY TESTING

AMEC Geomatrix, Inc (AMEC) has prepared this technical memorandum for Washington Closure Hanford (WCH) to summarize the results of the in-situ respiration test performed at the 100N Bioremediation Pilot Test Site (Site). Initial baseline soil gas monitoring was conducted on January 7, 2010, and the in-situ respiration test was initiated on February 24, 2010. Samples were collected periodically, starting on February 26, 2010 and continuing through test completion on March 10, 2010.

Respiration testing was conducted by using a blower to deliver air to the subsurface for a period of 2 days via seven injection points identified as: DIW-1; SIW-1; DMP-1; DMP-2; DMP-3; DMP-4, and SMP-1. Air was provided to each point at a rate of approximately 15 cubic feet per minute (cfm). After the air injection ceased, soil gas samples were collected and analyzed for oxygen, carbon dioxide, methane, and total volatile hydrocarbons (TVH). Twenty-seven samples were collected from each of the injection points on a predetermined schedule over a period of approximately 12 days (292 hours).

The AFCEE Bioventing Design (2004) guidance document was followed for interpretation of results and calculating oxygen utilization and biodegradation rates. Oxygen utilization rates for each monitoring point were determined from the slope of the line obtained by plotting the measured oxygen concentration verses time for each monitoring point. Oxygen utilization rates are presented in Table 1, and the graphs of the data are included as an attachment to this memorandum.

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) = 0.27 cm^3 gas/cm^3 soil
- ρ_{O2} = density of oxygen; assumed soil temp of 50F = 1,378 mg/L (Parsons 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; assumed value from assumed site soil characterized as mixed grain sand, dense = 1.86 g/cm^3 (Parsons 2004)

θ = total porosity (where $\theta = 1 - \rho_k/\rho_T$) = 0.30 cm^3/cm^3

θ_w = water filled porosity (where $\theta_w = M^*\rho_k/\rho_T$) = 0.03 cm^3/cm^3

ρ_T = soil mineral density; assumed value = 2.65 g/cm^3

M = moisture content; 4.63% reported Site average (WCH 2009) = 0.0463 g moisture per g soil.

Calculated biodegradation rates and baseline measurements of oxygen and carbon dioxide are presented in Table A-1. During the respiration test methane was detected infrequently at 0.1% and the highest levels of TVH, up to 130 parts per million by volume (ppmv), were detected on the first day of sampling. TVH levels generally decreased over the duration of the test.

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

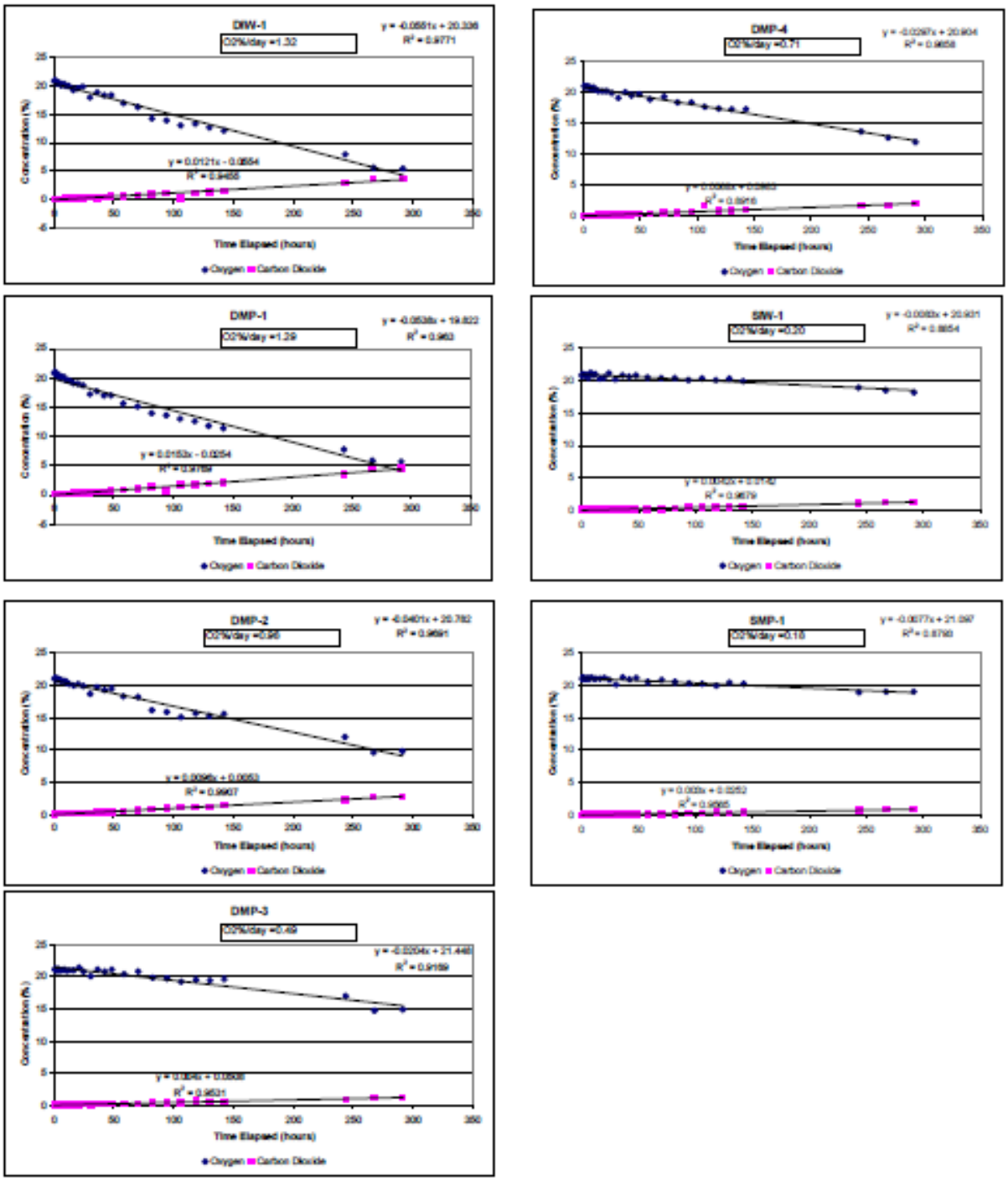
Monitoring Point	Baseline Oxygen (%)	Baseline Carbon Dioxide (%)	Oxygen Utilization (%/day)	Biodegradation Rate (mg/kg-day)
DIW-1	4.1	13.3	1.32	-0.76
DMP-1	1.6	14.9	1.29	-0.74
DMP-2	1.5	14.9	0.96	-0.55
DMP-3	2.3	13.8	0.49	-0.28
DMP-4	1.3	15.6	0.71	-0.41
SIW-1	20.2	1.3	0.20	-0.11
SMP-1	20.3	0.8	0.18	-0.11

In general, oxygen utilization rates of 1% per day or greater indicate treatment by bioventing is feasible. Lower oxygen utilization rates in areas with significant hydrocarbon content indicate that another factor may be limiting biodegradation such as insufficient nutrients or moisture, low temperature or toxicity. Results from wells DIW-1, DMP-1, and DMP-2 indicate remediation by bioventing is feasible. Results from the shallow wells (SIW-1 and SMP-1) indicate that either significant hydrocarbon mass is not present, biodegradation is inhibited, or that these locations have significant air exchange with the surface. The results from DMP-3 and DMP-4 indicate that biodegradation of hydrocarbons is occurring; however, the relatively low oxygen utilization rate indicates that some other factor is limiting microbial activity (lower hydrocarbon mass, toxicity, nutrient deficit, channelization/poor distribution of air, etc.).

Biodegradation rates can be used to help estimate the design life of the treatment system. In this analysis two parameter values used to calculate the degradation rate have the least confidence, (1) oxygen density, and (2) soil bulk density. In order to determine their impact on the calculated rate a simple sensitivity analysis was preformed with the probable range of values for these two parameters. The range of oxygen density had minimal impact on the calculated rate. However, the range of probable values of soil bulk density had a significant impact, up to 64% difference from the initially calculated rate, indicating that selection of the appropriate bulk density is integral

to accurate biodegradation rate calculations. Supporting data and calculations are provided as an attachment to this memorandum.

Figure A-1. In-Situ Respiration Test: Oxygen Utilization Carbon Dioxide Generation Plots and Design Worksheet. (4 Pages)



DESIGN WORKSHEET
Client: WCH
Project: Hanford Biovent
Data For: In-Situ Respiration Test

Date: 3/22/2010
Project Number: A000170
Prepared by: J.Jenkins
Reviewed by: C.Weber

An in-situ respiration test was conducted at the Hanford Site 100N. Data collected from the field test is used to calculate (1) oxygen utilization and (2) biodegradation rates. Calculations and results are presented below. Seven wells were monitored during the field test.

1) Oxygen utilization rates 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 (x-axis).
See attached for data plots

Location	O2 Utilization (%/hour)	O2 Utilization (%/day)	R^2 value for linear curve fit
a) DIW-1	0.0551	1.32	0.977
b) DMP-1	0.0538	1.29	0.963
c) DMP-2	0.0401	0.96	0.969
d) DMP-3	0.0204	0.49	0.917
e) DMP-4	0.0297	0.71	0.986
f) SIW-1	0.0083	0.20	0.885
g) SMP-1	0.0077	0.18	0.879

2) Biodegradation rates are calculated for each of the seven monitoring points.

Equation for biodegradation rate calculation:

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

θ_a =	0.27	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 $C_{10}H_{20} + 15O_2 \Rightarrow 10CO_2 + 10H_2O$
ρ_k =	1.86	g/cm^3	Soil bulk density; assumed value from assumed site soil characterized as mixed grain sand, dense
θ =	0.30	cm^3/cm^3	Total porosity; where $\theta = 1 - \rho_k/\rho_T$
θ_w =	0.03	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 =	0.0463	g moisture /g soil	4.63% moisture content reported Site average (WCH370, 2009)

Sheet 1 of 3

DESIGN WORKSHEET
Client: WCH
Project: Hanford Biovent
Data For: In-Situ Respiration Test

Date: 3/22/2010
Project Number: A000170
Prepared by: J.Jenkins
Reviewed by: C.Weber

Calculated biodegradation rate for each of the seven wells are listed below:
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 and may or may not occur in portions of the shallow wells' influence.

a) DIW-1

K_o =	1.32	%/day	Oxygen utilization rate; calculated value from respiration test
K_b =	**-0.76**	mg/Kg-day	Biodegradation rate (mg hydrocarbon per Kg soil per day; calculated value

b) DMP-1

K_o =	1.29	%/day	Oxygen utilization rate; calculated value from respiration test
K_b =	**-0.74**	mg/Kg-day	Biodegradation rate (mg hydrocarbon per Kg soil per day; calculated value

c) DMP-2

K_o =	0.96	%/day	Oxygen utilization rate; calculated value from respiration test
K_b =	**-0.55**	mg/Kg-day	Biodegradation rate (mg hydrocarbon per Kg soil per day; calculated value

d) DMP-3

K_o =	0.49	%/day	Oxygen utilization rate; calculated value from respiration test
K_b =	**-0.28**	mg/Kg-day	Biodegradation rate (mg hydrocarbon per Kg soil per day; calculated value

e) DMP-4

K_o =	0.71	%/day	Oxygen utilization rate; calculated value from respiration test
K_b =	**-0.41**	mg/Kg-day	Biodegradation rate (mg hydrocarbon per Kg soil per day; calculated value

f) SIW-1

K_o =	0.20	%/day	Oxygen utilization rate; calculated value from respiration test
K_b =	**-0.11**	mg/Kg-day	Biodegradation rate (mg hydrocarbon per Kg soil per day; calculated value

g) SMP-1

K_o =	0.18	%/day	Oxygen utilization rate; calculated value from respiration test
K_b =	**-0.11**	mg/Kg-day	Biodegradation rate (mg hydrocarbon per Kg soil per day; calculated value

DESIGN WORKSHEET
Client: WCH
Project: Hanford Biovent
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3) Sensitivity Analysis

Two parameter values required in the biodegradation rate calculation were selected based on assumed Site conditions 1) Density of Oxygen (ρ_{O2}) and 2) Soil Bulk Density (ρ_b).
Density of oxygen was based on an assumed soil temperature of 10°C (50°F) and soil bulk density was based on an assumed soil type of densely mixed-grain sand.
A sensitivity analysis was performed to determine the impact of these assumptions on the calculated biodegradation rate.

Density of Oxygen feasible range:
Min temp of 5C = mg/L 1,403
Max temp of 20C = mg/L 1,331

Soil Bulk Density feasible range:
Minimum = 1.59
Maximum= 2.12

K_b Calculated above	Calculated K_b with min parameter value	Calculated K_b with max parameter value	% difference with Min parameter value	% difference with Max parameter value
Density of Oxygen				
-0.76	-0.77	-0.73	1.8%	-3.4%
Soil Bulk Density				
-0.76	-1.24	-0.32	63.9%	-57.9%

In summary, the selected density of oxygen value (based on an assumed Site soil temperature) has only minor influence on the calculated biodegradation rate, while the impact of the selected soil bulk density value has a more significant impact on the calculated biodegradation rate.

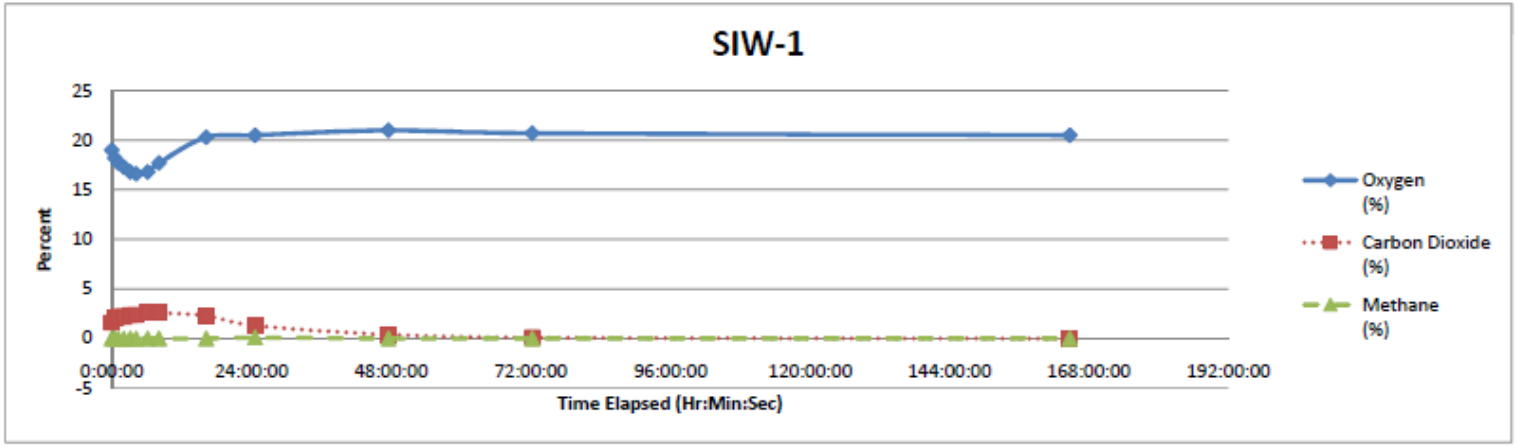
Sheet 3 of 3

APPENDIX B

SUPPORTING DATA FOR RADIUS OF INFLUENCE TESTING

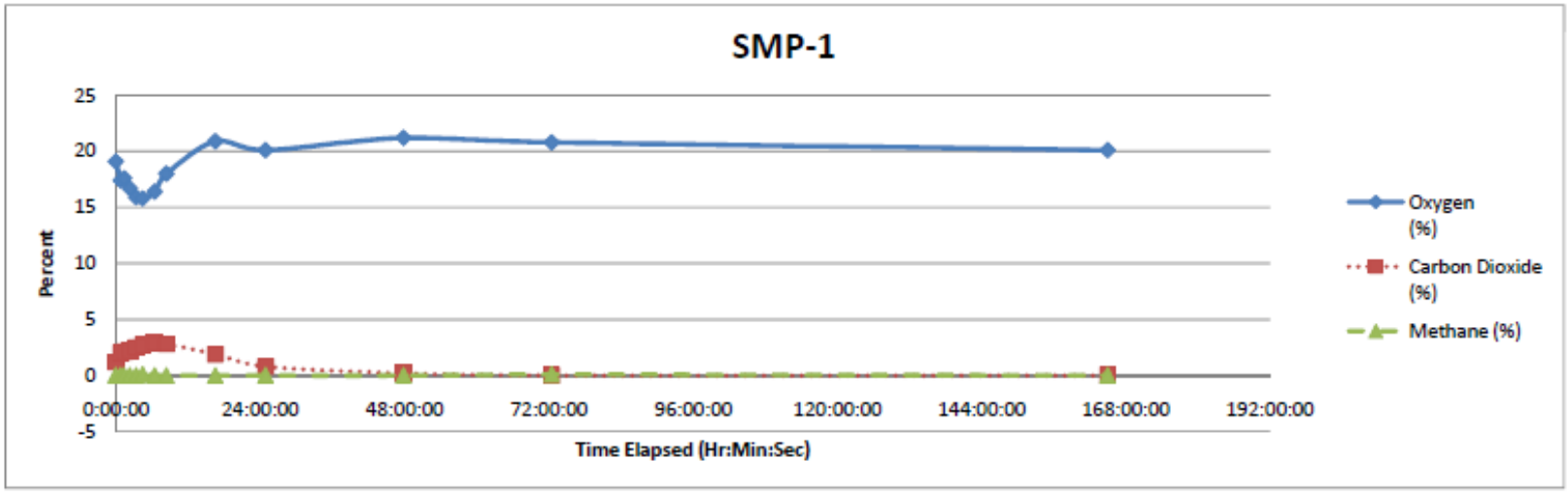
Deep Well ROI Testing Results

Date	Well	Time	Time Elapsed (Hr:Min:Sec)	Oxygen (%)	Carbon Dioxide (%)	Methane (%)	TVH (ppmv)	Pressure (inches H_2O)	Notes
9/20/10	SIW-1	8:40	0:00:00	19	1.6	0	1.9	0.3	Baseline Monitoring
9/20/10	SIW-1	10:29	0:34:00	18.2	2.1	0	2	0.05	
9/20/10	SIW-1	11:04	1:09:00	17.7	2.2	0	5.2	0.06	
9/20/10	SIW-1	12:01	2:06:00	17.3	2.2	0	8.4	0.05	
9/20/10	SIW-1	13:07	3:12:00	16.8	2.4	0	6.5	0.05	
9/20/10	SIW-1	14:08	4:13:00	16.6	2.4	0	28.4	0.02	
9/20/10	SIW-1	16:07	6:12:00	16.8	2.7	0	7	0.05	
9/20/10	SIW-1	18:03	8:08:00	17.7	2.6	0	8.1	0.03	
9/21/10	SIW-1	2:10	16:15:00	20.3	2.3	0.1	2.7	0.63	
9/21/10	SIW-1	10:35	24:40:00	20.5	1.3	0	8.6	0.03	
9/22/10	SIW-1	9:30	47:35:00	21	0.4	0	5.5	0.01	
9/23/10	SIW-1	10:13	72:18:00	20.7	0.1	0	3.2	0.01	
9/27/10	SIW-1	10:50	164:42:00	20.5	0	0	2.3	0.02	



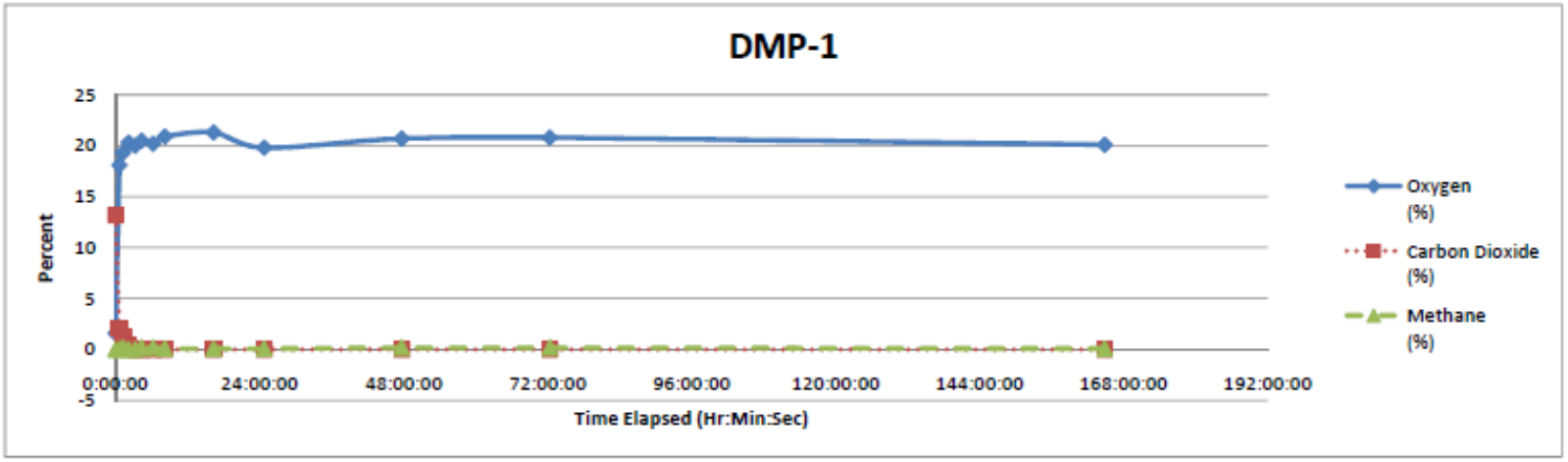
Deep Well ROI Testing Results

Date	Well	Time	Time Elapsed (Hr:Min:Sec)	Oxygen (%)	Carbon Dioxide (%)	Methane (%)	TVH (ppmv)	Pressure (inches H_2O)	Notes
9/20/10	SMP-1	9:01	0:00:00	19.1	1.2	0		0.3	Baseline Monitoring
9/20/10	SMP-1	10:44	0:49:00	17.4	2	0	8.2	0	
9/20/10	SMP-1	11:19	1:24:00	17.6	2.1	0	9.2	0	
9/20/10	SMP-1	12:16	2:21:00	16.7	2.2	0	13.8	0.03	
9/20/10	SMP-1	13:19	3:24:00	15.9	2.5	0.1	14.6	0.02	
9/20/10	SMP-1	14:23	4:28:00	15.8	2.7	0	11.3	0.04	
9/20/10	SMP-1	16:23	6:28:00	16.4	2.9	0	15	0.02	
9/20/10	SMP-1	18:21	8:26:00	18	2.8	0	14.6	0.03	
9/21/10	SMP-1	2:29	16:34:00	20.9	1.9	0	27.1	0.02	
9/21/10	SMP-1	10:50	24:55:00	20.1	0.8	0	25	0.03	
9/22/10	SMP-1	9:47	47:52:00	21.2	0.2	0.1	25.6	0.04	
9/23/10	SMP-1	10:26	72:31:00	20.8	0	0	19.4	0	
9/27/10	SMP-1	11:07	164:59:00	20.1	0	0	14.8	0.01	



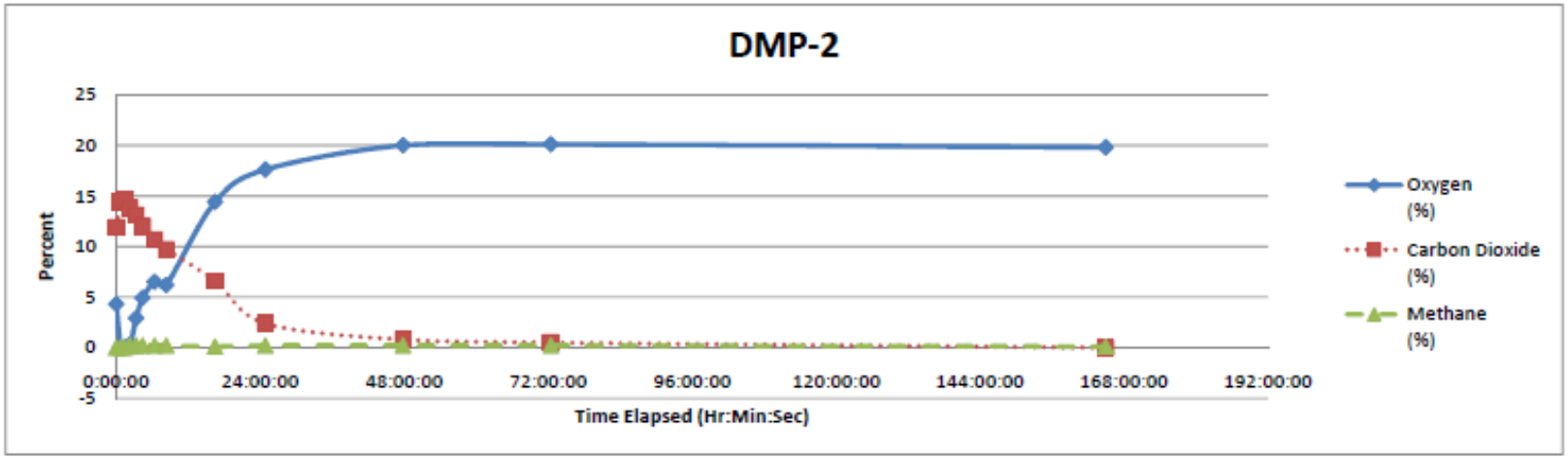
Deep Well ROI Testing Results

Date	Well	Time	Time Elapsed (Hr:Min:Sec)	Oxygen (%)	Carbon Dioxide (%)	Methane (%)	TVH (ppmv)	Pressure (inches H_2O)	Notes
9/20/10	DMP-1	8:47	0:00:00	1.6	13.2	0	22.2	-0.02	Baseline Monitoring
9/20/10	DMP-1	10:34	0:39:00	18.1	2.1	0.2	27.9	3.6	
9/20/10	DMP-1	11:09	1:14:00	19.3	1.3	0	28.9	3.8	
9/20/10	DMP-1	12:06	2:11:00	20.3	0.4	0	48.9	3.8	
9/20/10	DMP-1	13:11	3:16:00	20	0	0.2	45.8	3.7	
9/20/10	DMP-1	14:15	4:20:00	20.5	0	0.2	50.2	3.8	
9/20/10	DMP-1	16:11	6:16:00	20.2	0	0.1	50.8	3.7	
9/20/10	DMP-1	18:08	8:13:00	20.9	0	0.1	63.7	3.7	
9/21/10	DMP-1	2:15	16:20:00	21.3	0	0.1	76.9	3.9	
9/21/10	DMP-1	10:41	24:46:00	19.8	0	0.2	79.4	3.9	
9/22/10	DMP-1	9:36	47:41:00	20.7	0	0.2	60	3.8	
9/23/10	DMP-1	10:18	72:23:00	20.8	0	0.1	48	3.5	
9/27/10	DMP-1	10:58	164:50:00	20.1	0	0	36.1	3.7	



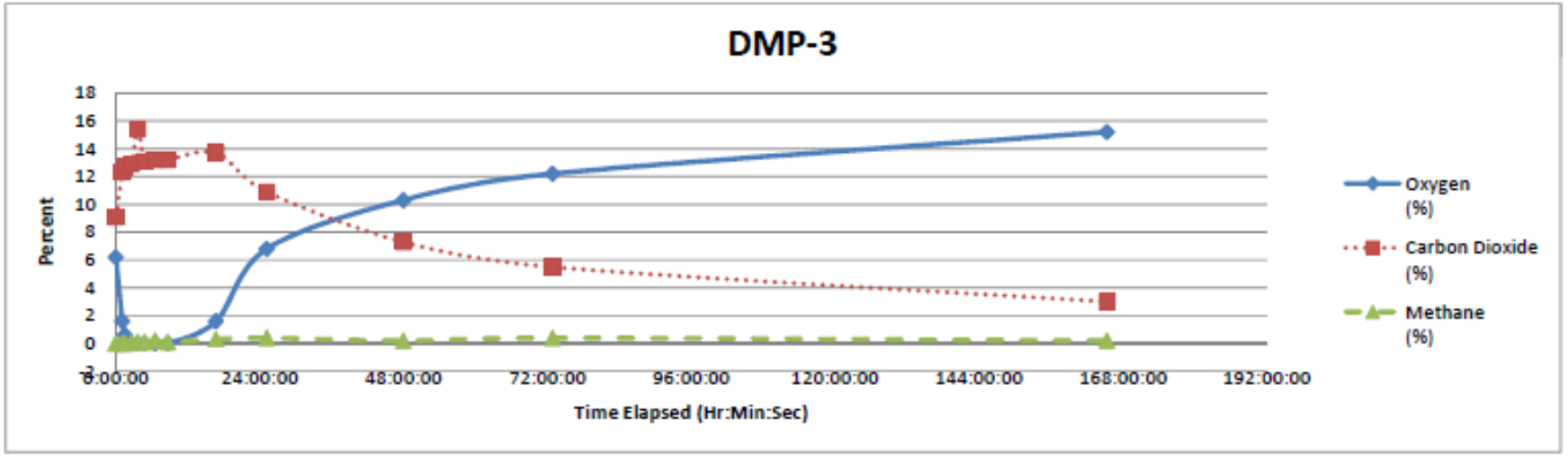
Deep Well ROI Testing Results

Date	Well	Time	Time Elapsed (Hr:Min:Sec)	Oxygen (%)	Carbon Dioxide (%)	Methane (%)	TVH (ppmv)	Pressure (inches H_2O)	Notes
9/20/10	DMP-2	8:50	0:00:00	4.3	11.9	0	17.3	-0.03	Baseline Monitoring
9/20/10	DMP-2	10:39	0:44:00	0	14.4	0	31.1	1.2	
9/20/10	DMP-2	11:19	1:24:00	0	14.6	0.2	32.8	1	
9/20/10	DMP-2	12:12	2:17:00	0.3	13.8	0.2	42	1.1	
9/20/10	DMP-2	13:15	3:20:00	2.9	13.1	0.2	38.1	1.1	
9/20/10	DMP-2	14:19	4:24:00	4.9	12	0.2	37.9	1.1	
9/20/10	DMP-2	16:19	6:24:00	6.5	10.7	0.2	44.3	1.1	
9/20/10	DMP-2	18:15	8:20:00	6.2	9.7	0.1	53.1	1	
9/21/10	DMP-2	2:23	16:28:00	14.4	6.6	0.2	72	1.1	
9/21/10	DMP-2	10:46	24:51:00	17.6	2.4	0.2	71.6	1.1	
9/22/10	DMP-2	9:42	47:47:00	20	0.8	0.2	78	1.1	
9/23/10	DMP-2	10:21	72:26:00	20.1	0.5	0.1	68.8	1	
9/27/10	DMP-2	11:02	164:54:00	19.8	0	0.1	60.7	1	



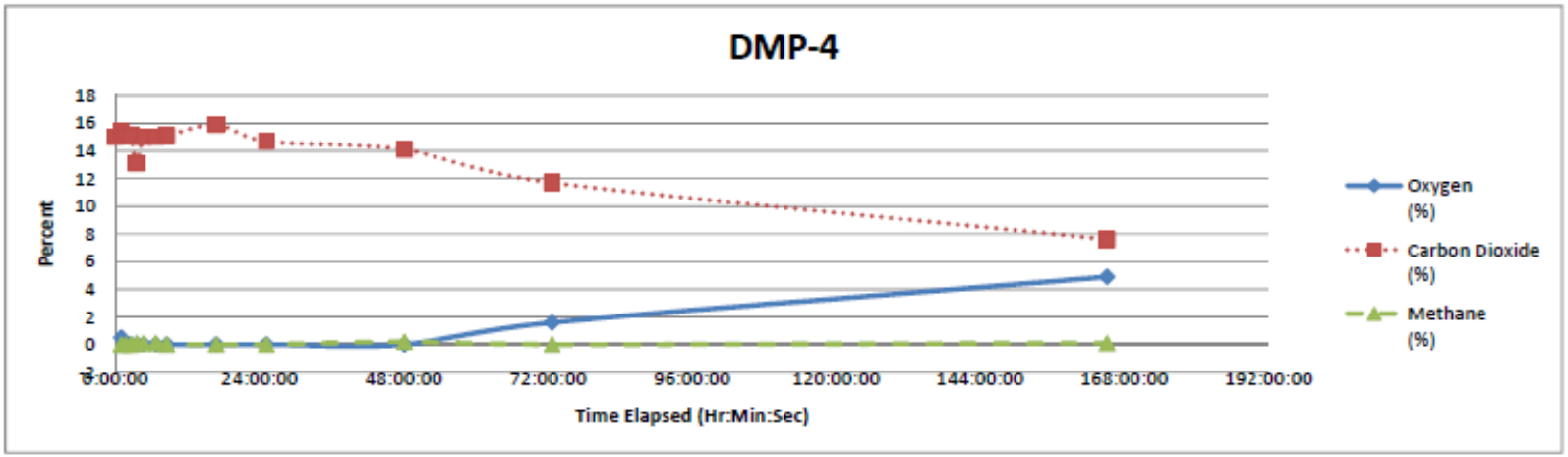
Deep Well ROI Testing Results

Date	Well	Time	Time Elapsed (Hr:Min:Sec)	Oxygen (%)	Carbon Dioxide (%)	Methane (%)	TVH (ppmv)	Pressure (inches H_2O)	Notes
9/20/10	DMP-3	9:27	0:00:00	6.2	9.1	0	13.3	-0.02	Baseline Monitoring
9/20/10	DMP-3	10:59	1:04:00	1.6	12.3	0	18.7	0.28	
9/20/10	DMP-3	11:26	1:31:00	0.6	12.7	0.1	21.6	0.1	
9/20/10	DMP-3	12:32	2:37:00	0	12.9	0.1	26.8	0.29	
9/20/10	DMP-3	13:34	3:39:00	0	15.4	0.1	16.4	0.1	
9/20/10	DMP-3	14:43	4:48:00	0	13.1	0.2	30.3	0.31	
9/20/10	DMP-3	16:29	6:34:00	0	13.2	0.1	48.2	0.29	
9/20/10	DMP-3	18:34	8:39:00	0	13.2	0.3	67.5	0.28	
9/21/10	DMP-3	2:37	16:42:00	1.6	13.7	0.4	90.5	0.29	
9/21/10	DMP-3	11:06	25:11:00	6.8	10.9	0.2	55.7	0.3	
9/22/10	DMP-3	9:52	47:57:00	10.3	7.3	0.4	54.6	0.29	
9/23/10	DMP-3	10:45	72:50:00	12.2	5.5	0.2	56.9	0.26	
9/27/10	DMP-3	11:25	165:17:00	15.2	3	0.2	42.6	0.29	



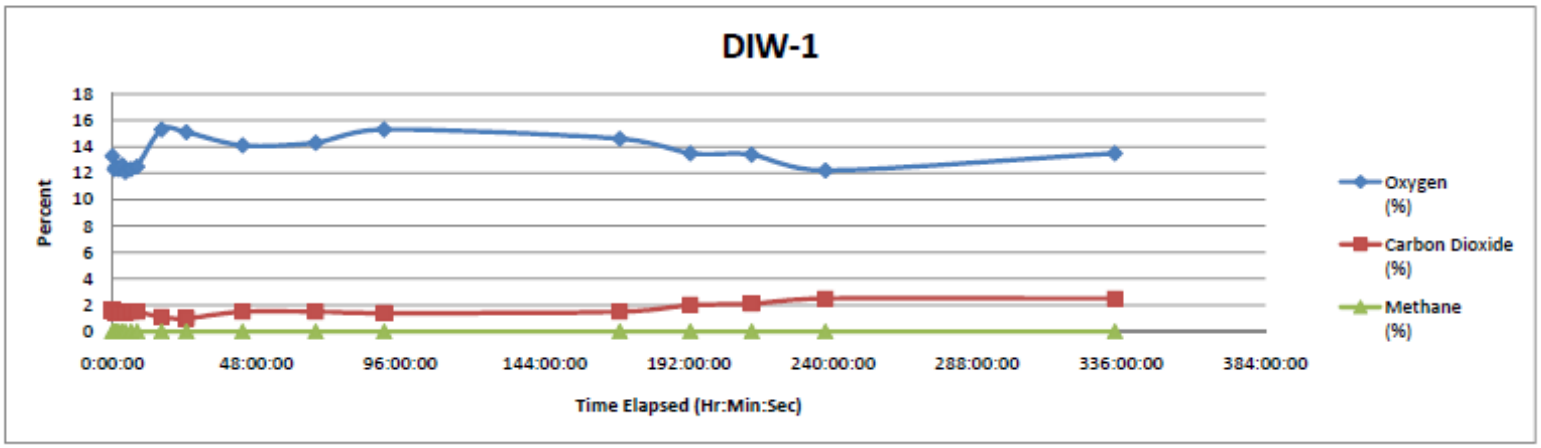
Deep Well ROI Testing Results

Date	Well	Time	Time Elapsed (Hr:Min:Sec)	Oxygen (%)	Carbon Dioxide (%)	Methane (%)	TVH (ppmv)	Pressure (inches H_2O)	Notes
9/20/10	DMP-4	9:11	0:00:00	0.5	15	0	14	-0.05	Baseline Monitoring
9/20/10	DMP-4	10:51	0:56:00	0	15.4	0	11.9	0.07	
9/20/10	DMP-4	11:36	1:41:00	0	15.1	0.1	14.4	0.28	
9/20/10	DMP-4	12:28	2:33:00	0	15.1	0.1	15.7	0.11	
9/20/10	DMP-4	13:24	3:29:00	0	13.1	0.1	25.3	0.29	
9/20/10	DMP-4	14:33	4:38:00	0	15	0	15.9	0.11	
9/20/10	DMP-4	16:36	6:41:00	0	15	0	19	0.1	
9/20/10	DMP-4	18:27	8:32:00	0	15.1	0	20	0.12	
9/21/10	DMP-4	2:42	16:47:00	0	15.9	0.2	24.1	0.11	
9/21/10	DMP-4	11:00	25:05:00	0	14.7	0	12.7	0.11	
9/22/10	DMP-4	10:01	48:06:00	1.6	14.1	0.1	17	0.1	
9/23/10	DMP-4	10:36	72:41:00	4.9	11.7	0	12.9	0.09	
9/27/10	DMP-4	11:16	165:08:00	7.6	7.6	0	11	0.11	



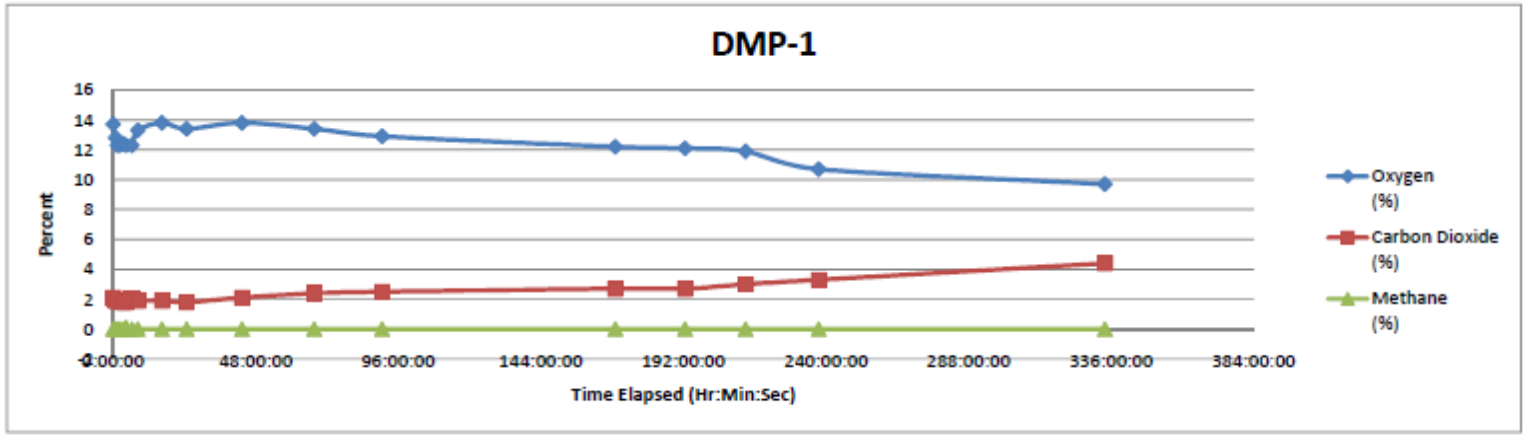
Shallow ROI Testing Results

Date	Well	Time	Time Elapsed (Hr:Min:Sec)	Oxygen (%)	Carbon Dioxide (%)	Methane (%)	TVH (ppmv)	Pressure (inches H_2O)	Notes
10/4/10	DIW-1	7:26	0:00:00	13.3	1.6	0	0.4	0	Baseline Monitoring
10/4/10	DIW-1	10:03	0:39:00	12.3	1.5	0	3.7	0.02	
10/4/10	DIW-1	10:39	1:15:00	12.5	1.4	0	5.1	0.03	
10/4/10	DIW-1	11:34	2:10:00	12.3	1.5	0	5.3	0.02	
10/4/10	DIW-1	12:38	3:14:00	12.6	1.4	0	4.9	0.02	
10/4/10	DIW-1	13:40	4:16:00	12.1	1.4	0	2.5	0.05	
10/4/10	DIW-1	15:35	6:11:00	12.3	1.5	0	0	0.03	
10/4/10	DIW-1	17:37	8:13:00	12.5	1.5	0	0.1	0.06	
10/5/10	DIW-1	1:45	16:21:00	15.3	1.1	0	3.5	0.02	
10/5/10	DIW-1	10:02	24:38:00	15.1	1	0	1.4	0.02	
10/6/10	DIW-1	9:00	43:20:00	14.1	1.5	0	2	0.04	
10/7/10	DIW-1	9:22	67:42:00	14.3	1.5	0	1.5	0.03	
10/8/10	DIW-1	8:11	90:31:00	15.3	1.4	0	1.7	0.01	
10/11/10	DIW-1	14:40	169:00:00	14.6	1.5	0	9.2	0.02	
10/12/10	DIW-1	14:10	192:30:00	13.5	2	0	3	0.04	
10/13/10	DIW-1	10:34	212:54:00	13.4	2.1	0	4.3	0.04	
10/14/10	DIW-1	11:07	237:27:00	12.2	2.5	0	2	0.05	
10/18/10	DIW-1	11:34	333:54:00	13.5	2.5	0	0.7	0.02	



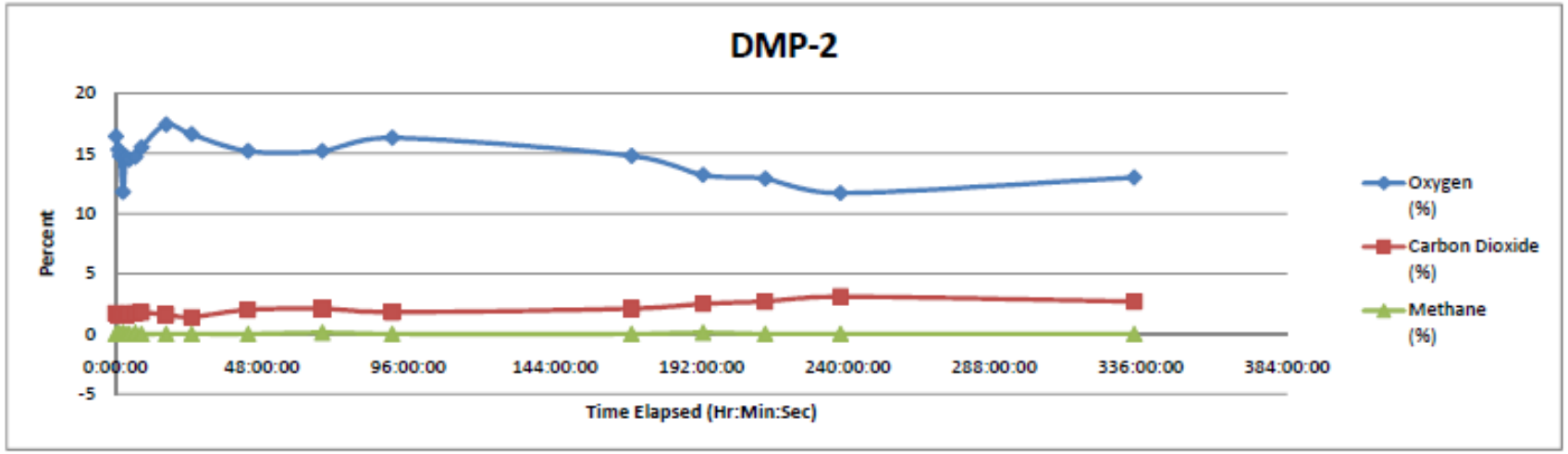
Shallow ROI Testing Results

Date	Well	Time	Time Elapsed (Hr:Min:Sec)	Oxygen (%)	Carbon Dioxide (%)	Methane (%)	TVH (ppmv)	Pressure (inches H_2O)	Notes
10/4/10	DMP-1	7:31	0:00:00	13.7	2.1	0	10.4	0	Baseline Monitoring
10/4/10	DMP-1	10:17	0:53:00	12.8	1.9	0	18.9	0.01	
10/4/10	DMP-1	10:48	1:24:00	12.3	1.9	0	29.5	0.01	
10/4/10	DMP-1	11:40	2:16:00	12.3	1.9	0	24.6	0.02	
10/4/10	DMP-1	12:44	3:20:00	12.4	1.8	0.1	20.9	0.02	
10/4/10	DMP-1	13:44	4:20:00	12.3	1.8	0	7.5	0.04	
10/4/10	DMP-1	15:41	6:17:00	12.3	2	0	3.7	0.02	
10/4/10	DMP-1	17:42	8:18:00	13.3	1.9	0	6.9	0.02	
10/5/10	DMP-1	1:48	16:24:00	13.8	1.9	0	23.4	0	
10/5/10	DMP-1	10:08	24:44:00	13.4	1.8	0	8.6	0.02	
10/6/10	DMP-1	9:06	43:22:00	13.8	2.1	0	23.6	0.04	
10/7/10	DMP-1	9:26	67:42:00	13.4	2.4	0	20.3	0.02	
10/8/10	DMP-1	8:16	90:32:00	12.9	2.5	0	15.2	0	
10/11/10	DMP-1	14:48	169:04:00	12.2	2.7	0	18.3	0.02	
10/12/10	DMP-1	14:16	192:32:00	12.1	2.7	0	31.1	0.04	
10/13/10	DMP-1	10:38	212:54:00	11.9	3	0	37.9	0.02	
10/14/10	DMP-1	11:15	237:31:00	10.7	3.3	0	39.5	0.04	
10/18/10	DMP-1	11:38	333:54:00	9.7	4.4	0	19.1	0.02	



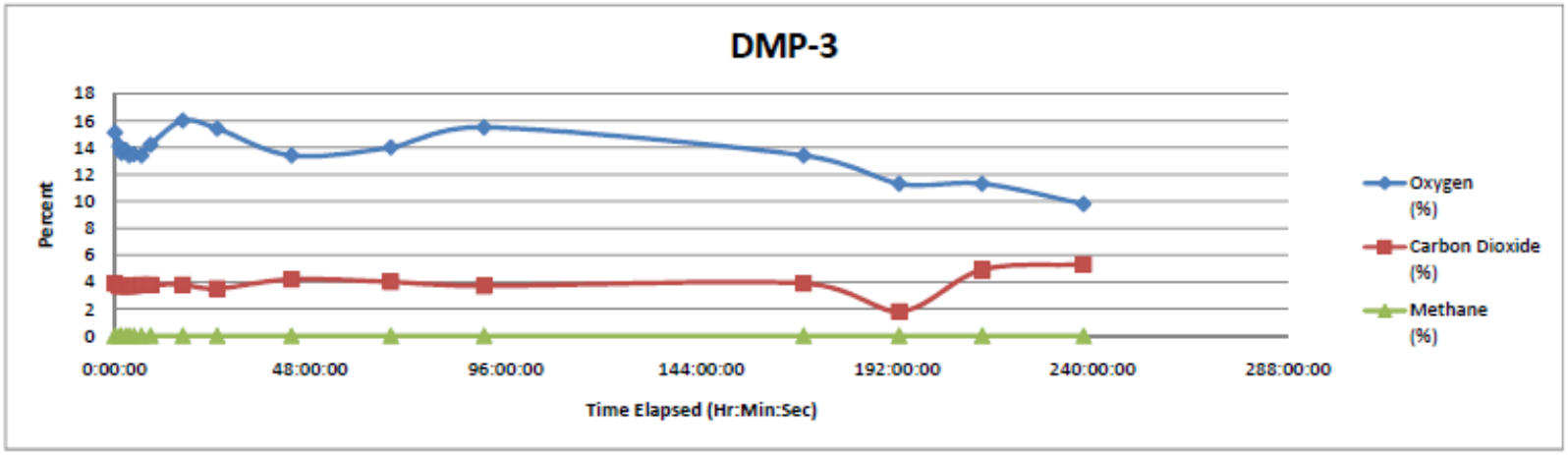
Shallow ROI Testing Results

Date	Well	Time	Time Elapsed (Hr:Min:Sec)	Oxygen (%)	Carbon Dioxide (%)	Methane (%)	TVH (ppmv)	Pressure (inches H_2O)	Notes
10/4/10	DMP-2	7:37	0:00:00	16.4	1.7	0.1	23.2	0	Baseline Monitoring
10/4/10	DMP-2	10:14	0:50:00	15.3	1.6	0	23.3	0.02	
10/4/10	DMP-2	10:51	1:27:00	14.8	1.6	0.1	32.5	0	
10/4/10	DMP-2	11:45	2:21:00	11.8	1.6	0	31.5	0.02	
10/4/10	DMP-2	12:48	3:24:00	14.7	1.6	0	28.3	0.02	
10/4/10	DMP-2	13:49	4:25:00	14.5	1.7	0.1	22.2	0.03	
10/4/10	DMP-2	15:46	6:22:00	14.7	1.7	0	7.2	0.03	
10/4/10	DMP-2	17:48	8:24:00	15.5	1.8	0	13.1	0.01	
10/5/10	DMP-2	1:53	16:29:00	17.4	1.6	0	35.1	0	
10/5/10	DMP-2	10:14	24:50:00	16.6	1.4	0	19.9	0.02	
10/6/10	DMP-2	9:09	43:20:00	15.2	2	0.1	36	0.03	
10/7/10	DMP-2	9:31	67:42:00	15.2	2.1	0	24.3	0.03	
10/8/10	DMP-2	8:24	90:35:00	16.3	1.8	0	25.9	0	
10/11/10	DMP-2	14:52	169:03:00	14.8	2.1	0.1	21.5	0.02	
10/12/10	DMP-2	14:20	192:31:00	13.2	2.5	0	42.7	0.04	
10/13/10	DMP-2	10:43	212:54:00	12.9	2.7	0	55.7	0.04	
10/14/10	DMP-2	11:24	237:35:00	11.7	3.1	0	51.2	0.05	
10/18/10	DMP-2	11:42	333:53:00	13	2.7	0.1	36	0.02	



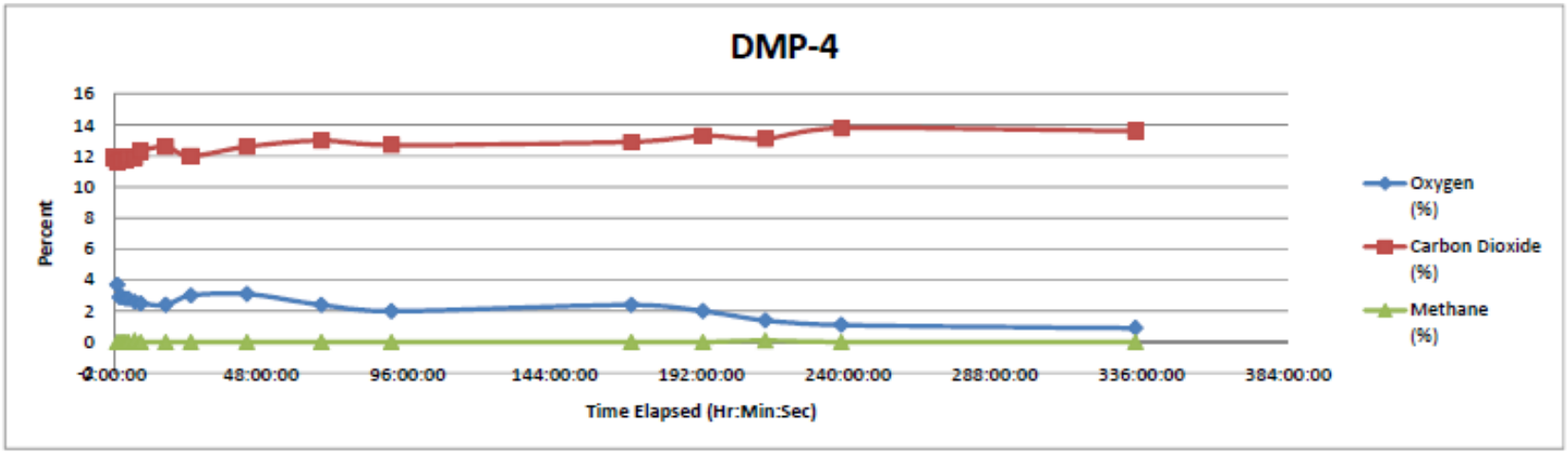
Shallow ROI Testing Results

Date	Well	Time	Time Elapsed (Hr:Min:Sec)	Oxygen (%)	Carbon Dioxide (%)	Methane (%)	TVH (ppmv)	Pressure (inches H_2O)	Notes
10/4/10	DMP-3	7:56	0:00:00	15.1	3.9	0	6.8	0	Baseline Monitoring
10/4/10	DMP-3	10:31	1:07:00	14.1	3.7	0	12	0	
10/4/10	DMP-3	11:01	1:37:00	13.6	3.7	0	16.9	0	
10/4/10	DMP-3	12:09	2:45:00	13.8	3.7	0	14.7	0.01	
10/4/10	DMP-3	12:58	3:34:00	13.4	3.7	0	14.6	0.02	
10/4/10	DMP-3	14:06	4:42:00	13.5	3.7	0	13	0.02	
10/4/10	DMP-3	15:56	6:32:00	13.4	3.8	0	7.4	0.03	
10/4/10	DMP-3	18:11	8:47:00	14.2	3.8	0	6.5	0.06	
10/5/10	DMP-3	2:06	16:42:00	16	3.8	0	16.9	-0.01	
10/5/10	DMP-3	10:33	25:09:00	15.4	3.5	0	9	0.01	
10/6/10	DMP-3	9:29	43:23:00	13.4	4.2	0	13.9	0.03	
10/7/10	DMP-3	9:52	67:46:00	14	4	0	13.9	0.01	
10/8/10	DMP-3	8:45	90:39:00	15.5	3.7	0	10.4	0	
10/11/10	DMP-3	15:12	169:06:00	13.4	3.9	0	15.9	0.02	
10/12/10	DMP-3	14:38	192:32:00	11.3	1.8	0	19.5	0.02	
10/13/10	DMP-3	11:02	212:56:00	11.3	4.9	0	22.7	0.02	
10/14/10	DMP-3	11:56	237:50:00	9.8	5.3	0.1	24.3	0.04	
10/18/10	DMP-3	12:04	333:58:00	12	4.6	0	16.3	0	



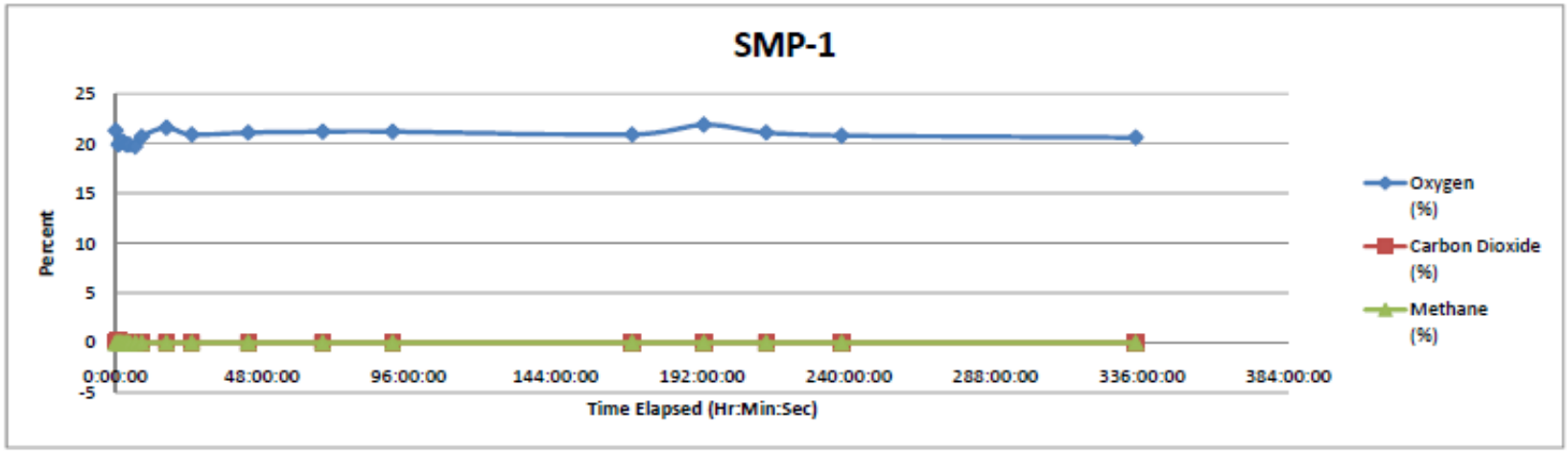
Shallow ROI Testing Results

Date	Well	Time	Time Elapsed (Hr:Min:Sec)	Oxygen (%)	Carbon Dioxide (%)	Methane (%)	TVH (ppmv)	Pressure (inches H_2O)	Notes
10/4/10	DMP-4	9:15	0:00:00	3.7	11.9	0	3.9	0	Baseline Monitoring
10/4/10	DMP-4	10:24	1:00:00	2.9	11.6	0	12.4	0	
10/4/10	DMP-4	11:09	1:45:00	2.9	11.8	0	11.6	0	
10/4/10	DMP-4	11:56	2:32:00	2.8	11.7	0	9.4	0	
10/4/10	DMP-4	13:04	3:40:00	2.8	11.7	0.1	8.3	0	
10/4/10	DMP-4	14:00	4:36:00	2.6	11.9	0	9.2	0	
10/4/10	DMP-4	16:05	6:41:00	2.5	11.9	0	8.7	0.01	
10/4/10	DMP-4	18:03	8:39:00	2.4	12.3	0	6.2	0.01	
10/5/10	DMP-4	2:14	16:50:00	3	12.6	0	18.2	-0.01	
10/5/10	DMP-4	10:28	25:04:00	3.1	12	0	9.4	0	
10/6/10	DMP-4	9:23	43:23:00	2.4	12.6	0	13.5	0.01	
10/7/10	DMP-4	9:45	67:45:00	2	13	0	9.6	0	
10/8/10	DMP-4	8:38	90:38:00	2.4	12.7	0	7.9	0	
10/11/10	DMP-4	15:04	169:04:00	2	12.9	0.1	6.7	0	
10/12/10	DMP-4	14:31	192:31:00	1.4	13.3	0	8.5	0.04	
10/13/10	DMP-4	10:54	212:54:00	1.1	13.1	0	8.8	0	
10/14/10	DMP-4	11:44	237:44:00	0.9	13.8	0	9	0	
10/18/10	DMP-4	11:57	333:57:00	1	13.6	0	4.5	0	



Shallow ROI Testing Results

Date	Well	Time	Time Elapsed (Hr:Min:Sec)	Oxygen (%)	Carbon Dioxide (%)	Methane (%)	TVH (ppmv)	Pressure (inches H_2O)	Notes
10/4/10	SMP-1	7:46	0:00:00	21.3	0.1	0	3	0	Baseline Monitoring
10/4/10	SMP-1	10:19	0:55:00	19.9	0.2	0	6.3	0.04	
10/4/10	SMP-1	10:55	1:31:00	20.1	0.1	0	8.3	0.06	
10/4/10	SMP-1	11:51	2:27:00	20.2	0	0	6	0.06	
10/4/10	SMP-1	12:52	3:28:00	19.9	0	0	7.4	0.07	
10/4/10	SMP-1	13:52	4:28:00	19.9	0	0	7.3	0.06	
10/4/10	SMP-1	15:49	6:25:00	19.7	0	0	1.9	0.07	
10/4/10	SMP-1	17:54	8:30:00	20.7	0	0	2.1	0.06	
10/5/10	SMP-1	1:59	16:35:00	21.6	0	0	6.5	0.05	
10/5/10	SMP-1	10:18	24:54:00	20.9	0	0	4.8	0.05	
10/6/10	SMP-1	9:15	43:23:00	21.1	0	0	8.1	0.06	
10/7/10	SMP-1	9:37	67:45:00	21.2	0	0	3.6	0.06	
10/8/10	SMP-1	8:31	90:39:00	21.2	0	0	2.8	0.05	
10/11/10	SMP-1	14:58	169:06:00	20.9	0	0	5.2	0.05	
10/12/10	SMP-1	14:24	192:32:00	21.9	0	0	6.9	0.07	
10/13/10	SMP-1	10:50	212:58:00	21.1	0	0	6.4	0.06	
10/14/10	SMP-1	11:33	237:41:00	20.8	0	0	5.7	0.07	
10/18/10	SMP-1	11:49	333:57:00	20.6	0	0	3.6	0.06	



APPENDIX C

SUPPORTING DATA FOR 6-MONTH OPERATION TESTING FINAL SAMPLING

WCH TASK INSTRUCTION — **Work Package No:. FRN 09 11 03 001**
Rev. 0
100N Bioremediation System Pilot Testing Operations — **ATTACHMENT 2**

FORM 2
OXYGEN/PRESSURE INFLUENCE TEST

SITE: 100 N Bioventing
PERSON SAMPLING: Knobiauch
SYSTEM TURN ON DATE: 10-21-10

O_2/CO_2 Meter Calibrated? YES X NO
TVH Meter Calibrated? YES X NO
Time:

Monitoring Point (MP)	Date	Time	Oxygen (%)	Carbon Dioxide (%)	Methane (%)	TVH (ppmv)	Comments (CO_2 PPM)
DMP-1	11-8-10	1354	20.9	0.014	0.0	21.2	2.9" W.C 140
DMP-2	11-8-10	1404	21.0	0.240	0.0	185	1.1" W.C 2400
DMP-3	11-8-10	1419	20.2	0.860	0.0	101	0.65" W.C. 8600

WCH TASK INSTRUCTION Work Package No:. FRN 09 11 03 001
Rev. 0
100N Bioremediation System Pilot Testing Operations ATTACHMENT 2

FORM 2
OXYGEN/PRESSURE INFLUENCE TEST

SITE: 100-N
PERSON SAMPLING: RP HARRISON
SYSTEM TURN ON DATE: 10/21/10 Time:

O_2/CO_2 Meter Calibrated? YES ✓ NO ___
TVH Meter Calibrated? YES ✓ NO ___

Monitoring Point (MP)	Date	Time	Oxygen (%)	Carbon Dioxide (%)	Methane (%)	TVH (ppmv)	Comments
DMP-2	11-22-10	2:48pm	19.2	3900	0	241	2.2" w.c.
DMP-3	11/22/10	2:58	18.7	1.32%	0	116	0.57" w.c.

WCH TASK INSTRUCTION Work Package No:. FRN 09 11 03 001
Rev. 0
100N Bioremediation System Pilot Testing Operations ATTACHMENT 3

FORM 3
IN-SITU RESPIRATION TEST

SITE: 100-N
PERSON SAMPLING: R. P HARRISON
SYSTEM TURN ON DATE: _____ **Time:** _____

O_2/CO_2 Meter Calibrated? YES X NO ___
TVH Meter Calibrated? YES X NO ___

Date	Time	Oxygen (%)	Carbon Dioxide (%)	Methane (%)	TVH (ppmv)	Comments
12/21/10	DMP-1 1:26 PM	21.2	730	0	24.5	PRESSURE = 2.5" w.c.
12/21/10	1:37 DMP-2	20.9	4050	0	405	1.1" w.c.
12/21/10	1:53 DMP-3	20.1	1.15%	0	286	0.56" w.c.

WCH TASK INSTRUCTION Work Package No:. FRN 09 11 03 001
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100N Bioremediation System Pilot Testing Operations ATTACHMENT 2

FORM 2
OXYGEN/PRESSURE INFLUENCE TEST

SITE: 100N
PERSON SAMPLING: DP, WD, RPH
SYSTEM TURN ON DATE: 10/21/10
O_2/CO_2 Meter Calibrated? YES X NO ___
TVH Meter Calibrated? YES X NO ___
Time: ___

Monitoring Point (MP)	Date	Time	Oxygen (%)	Carbon Dioxide ~~(%)~~ ppm	Methane (%) LEL	TVH (ppmv)	Comments
DMP-1	1/27/11	1033	20.9	250	0	20.9	2.4" wc
DMP-2	1/27/11	1050	20.9	2090	0	417	0.98" wc
DMP-3	1/27/11	1103	20.2	6050	0	374	0.57" wc

WCH TASK INSTRUCTION Work Package No:. FRN 09 11 03 001
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100N Bioremediation System Pilot Testing Operations ATTACHMENT 2

FORM 2
OXYGEN/PRESSURE INFLUENCE TEST

SITE: 100 N O_2/CO_2 Meter Calibrated? YES X NO ___
PERSON SAMPLING: DP, WD TVH Meter Calibrated? YES X NO ___
SYSTEM TURN ON DATE: 10/21/10 Time: ___

Monitoring Point (MP)	Date	Time	Oxygen (%)	Carbon Dioxide ~~(%)~~ ppm	Methane (%) LEL	TVH (ppmv)	Comments
DMP-1	2/22/11	11:13	21.3	370	0	14.3	2.5" wc
DMP-2	2/22/11	11:21	20.9	2260	0	395	1.0" wc
DMP-3	2/22/11	11:37	20.9	4860	0	152	0.52" wc

WCH TASK INSTRUCTION Work Package No:. FRN 09 11 03 001
Rev. 0
100N Bioremediation System Pilot Testing Operations ATTACHMENT 2

FORM 2
OXYGEN/PRESSURE INFLUENCE TEST

SITE: 100N O_2/CO_2 Meter Calibrated? YES X NO ___
PERSON SAMPLING: dp TVH Meter Calibrated? YES X NO ___
SYSTEM TURN ON DATE: 10/21/10 Time: ___

Monitoring Point (MP)	Date	Time	Oxygen (%)	Carbon Dioxide (%)	Methane (%) LEL	TVH (ppmv)	Comments
DMP-1	3/21/11		20.9	440	0	25.7	2.2" wc
DMP-2	3/21/11		20.5	2500	0	194	1.0" wc
DMP-3	3/21/11		20.1	5070	0	101	0.52" wc

WCH TASK INSTRUCTION Work Package No:. FRN 09 11 03 001
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100N Bioremediation System Pilot Testing Operations ATTACHMENT 2

FORM 2
OXYGEN/PRESSURE INFLUENCE TEST

SITE: 100N
PERSON SAMPLING: dp
SYSTEM TURN ON DATE: 10/21/11

O_2/CO_2 Meter Calibrated? YES X NO ___
TVH Meter Calibrated? YES X NO ___
Time: ___

Monitoring Point (MP)	Date	Time	Oxygen (%)	Carbon Dioxide (%)	Methane (%)	TVH (ppmv)	Comments
DMP-1	4/26/11	0950	20.9	430	0	50.2	1.8" wc
DMP-2	4/26/11	1010	20.6	2400	0	222	0.8" wc
DMP-3	4/26/11	1025	20.3	4590	0	104	0.9" wc

WCH TASK INSTRUCTION Work Package No:. FRN 09 11 03 001
Rev. 0
100N Bioremediation System Pilot Testing Operations ATTACHMENT 2

FORM 2
OXYGEN/PRESSURE INFLUENCE TEST

SITE: 100 N
O_2/CO_2 Meter Calibrated? YES X NO ___
PERSON SAMPLING: dp
TVH Meter Calibrated? YES X NO ___
SYSTEM TURN ON DATE: 10/21/11 Time: 0800

Monitoring Point (MP)	Date	Time	Oxygen (%)	Carbon Dioxide (%)	Methane (%)	TVH (ppmv)	Comments
DMP-2	5/18/11		18	7420	0	47	No we measurements
SMP-1	5/18/11		20.9	530	0	16.4	taken for this sampling
DMP-1	5/18/11		19.6	2060	0	9.7	since blower was off -
DIW-1	5/18/11		19.9	600	0	6.2	all wells read 0" we
SIW-1	5/18/11		20.6	550	0	3.1	
DMP-4	5/18/11		20.4	500	0	3.2	
DMP-3	5/18/11		19.4	7280	0	26.3	

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