DEPARTMENT OF THE AIR FORCE
377TH AIR BASE WING (AFGSC)

19 April 2021

Colonel David S. Miller, USAF
Commander
377th Air Base Wing
2000 Wyoming Blvd SE
Kirtland AFB NM 87117

Mr. Kevin M. Pierard
Hazardous Waste Bureau (HWB) Chief
New Mexico Environment Department (NMED)
2905 Rodeo Park Drive East, Building 1
Santa Fe NM 87505-6303

Dear Mr. Pierard

Attached please find the *Bioventilation Construction and Initiation Report Revision 1, Bulk Fuels Facility, Solid Waste Management Units ST-106/SS-111, Kirtland Air Force Base, New Mexico,* dated April 2021 (Report). This report was drafted in response to the 23 September 2020 disapproval of the January 2020 *Bioventilation Construction and Initiation Report*.

The New Mexico Environment Department (NMED) in a 25 February 2019 letter required the Air Force submit "...the results of the bioventing pilot tests by January 31, 2020". As detailed in the attached Report, the procurement and installation of the equipment and infrastructure necessary to support the bioventing pilot test were completed a month after this letter was received. The dry and wet respiration phase was not completed until the end of July 2019. Because it takes approximately two months or more to stabilize conditions in the vadose zone, the Air Force did not collect the first quarter of bioventing data until the last quarter of 2019. Although the NMED-approved work plan committed the Air Force to collecting eight quarters of data, the 25 February 2019 letter required that we prematurely submit a report after one quarter of data was collected. This fact is reflected in the Air Force's response to a number of NMED's comments on the January 2020 Report (see Attachment [Appendix A]).

In addition, the Air Force submitted a technical memorandum to NMED on 13 January 2021 that recommended that the bioventing pilot test be terminated because of low biodegradation rates and operational concerns. NMED concurred in an 11 February 2021 letter. Because the termination of the pilot test triggers the completion of a final report, the Air Force respectfully requests that NMED defer any additional revisions that may arise during your review of this Bioventilation Construction and Initiation Report to the final Bioventing Investigation Report that will be submitted no later than 29 October 2021.

If you have any questions or concerns, please contact Mr. Sheen Kottkamp at commercial (505) 846-7674 or by email sheen.kottkamp.1@us.af.mil.

Sincerely

DAVID S. MILLER, Colonel, USAF
Commander

Attachment:
Bioventilation Construction and Initiation Report Revision 1, Bulk Fuels Facility, Solid Waste Management Units ST-106/SS-111, Kirtland Air Force Base, New Mexico, dated April 2021

cc:
NMED Resource Protection Division (Stringer), letter and CD
NMED HWB (Pierard, Andress), letter and CD
NMED GWQB (Hunter), letter and CD
EPA Region 6 (King, Ellinger), letter and CD
SAF-IEE (Lynnes), electronic only
AFCEC/CZ (Clark, Kottkamp, Segura, Wortman), electronic only
USACE-ABQ District Office (Moayyad, Phaneuf, Dreeland, Kunkel, Lovato), electronic only
Public Info Repository, Administrative Record/Information Repository (AR/IR) and File

KIRTLAND AIR FORCE BASE
ALBUQUERQUE, NEW MEXICO

BIOVENTILATION CONSTRUCTION AND INITIATION REPORT
BULK FUELS FACILITY
SOLID WASTE MANAGEMENT UNITS ST-106/SS-111
REVISION 1

APRIL 2021

377 MSG/CEI
2050 Wyoming Boulevard SE
Kirtland Air Force Base, New Mexico 87117-5270

KIRTLAND AIR FORCE BASE
ALBUQUERQUE, NEW MEXICO

Bioventilation Construction and Initiation Report
Bulk Fuels Facility
Solid Waste Management Units ST-106/SS-111
Revision 1

APRIL 2021

Prepared for
Kirtland Air Force Base
2050 Wyoming Boulevard SE
Kirtland Air Force Base, New Mexico 87117-5270

Prepared by
EA Engineering, Science, and Technology, Inc., PBC
320 Gold Avenue Southwest, Suite 1300
Albuquerque, New Mexico 87102
Contract No. W9128F-13-D-0006
Delivery Order DM02

REPORT DOCUMENTATION PAGE				*Form Approved* *OMB No. 0704-0188*
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1. REPORT DATE *(DD-MM-YYYY)* 30-01-2020	**2. REPORT TYPE** Revision 1			**3. DATES COVERED *(From - To)*** 25-02-2019 – 05-11-2019
4. TITLE AND SUBTITLE Bioventilation Construction and Initiation Report Bulk Fuels Facility Solid Waste Management Units ST-106/SS-111 Kirtland Air Force Base, New Mexico				**5a. CONTRACT NUMBER** W9128F-13-D-0006-DM02 **5b. GRANT NUMBER** **5c. PROGRAM ELEMENT NUMBER**
6. AUTHOR(S) EA Engineering, Science, and Technology, Inc., PBC				**5d. PROJECT NUMBER** 62735DM02 **5e. TASK NUMBER** 1038 **5f. WORK UNIT NUMBER** Not applicable
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES) EA Engineering, Science, and Technology, Inc., PBC 320 Gold Avenue Southwest, Suite 1300 Albuquerque, New Mexico 87102				**8. PERFORMING ORGANIZATION REPORT NUMBER** Not assigned
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Corps of Engineers–Albuquerque District 4101 Jefferson Plaza Northeast Albuquerque, New Mexico 87109-3435				**10.SPONSOR/MONITOR'S ACRONYM(S)** **11. SPONSOR/MONITOR'S REPORT NUMBER(S)**
12. DISTRIBUTION/AVAILABILITY STATEMENT				
13. SUPPLEMENTARY NOTES				
14. ABSTRACT This Bioventilation Construction and Initiation Report details the events that occurred in both dry and wet respiration pilot tests and provides operational parameters that were used in the installation and implementation of the bioventing pilot test.				
15. SUBJECT TERMS Bulk Fuels Facility, Solid Waste Management Units ST-106/SS-111, bioventing, respiration testing				
16. SECURITY CLASSIFICATION OF:		**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Sheen Kottkamp
a. REPORT UNCLASSIFIED	**b. ABSTRACT** UNCLASSIFIED	**c. THIS PAGE** UNCLASSIFIED	ABSTRACT	1385
				19b. TELEPHONE NUMBER *(include area code)* 505-846-9017

Standard Form 298
(Rev. 8-98) Prescribed by ANSI Std. Z39.18

40 CFR 270.11
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I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fines and imprisonment for knowing violations.

DAVID S. MILLER, Colonel, U.S. Air Force
Commander, 377th Air Base Wing

04.19.21
Date

This document has been approved for public release.

KIRTLAND AIR FORCE BASE
377th Air Base Wing Public Affairs

4/20/21
Date

PREFACE

This report was prepared for Kirtland Air Force Base under U.S. Army Corps of Engineers Contract Number W9128F-13-D-0006, Delivery Order DM02 by EA Engineering, Science, and Technology, Inc., PBC. The report pertains to bioventing pilot testing performed at the Bulk Fuels Facility, Solid Waste Management Units ST-106/SS 111, located in Albuquerque, New Mexico. The dry and wet respiration pilot tests were conducted between April and July 2019. The data obtained from these tests were used to provide operational parameters that are being used for the implementation of the bioventing pilot test.

This report was prepared in accordance with applicable federal, state, and local laws and regulations, including the New Mexico Hazardous Waste Act, New Mexico Statutes Annotated 1978, New Mexico Hazardous Waste Management Regulations, Resource Conservation and Recovery Act, and regulatory correspondence between the New Mexico Environment Department Hazardous Waste Bureau and the U.S. Air Force, dated March 25 and May 20, 2016.

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LIST OF ACRONYMS AND ABBREVIATIONS

$\mu g/m^3$	microgram(s) per cubic meter
%	percent
AFB	Air Force Base
BFF	Bulk Fuels Facility
BTEX	benzene, toluene, ethylbenzene, and total xylenes
EDB	ethylene dibromide
EPA	U.S. Environmental Protection Agency
ft	foot (feet)
GRO	gasoline range organics
KAFB	Kirtland Air Force Base
mg/kg/day	milligram(s) per kilogram per day
NMED	New Mexico Environment Department
RCRA	Resource Conservation and Recovery Act
ROI	radius of influence
scfm	standard cubic feet per minute
SIM	selected ion monitoring
SVEW	soil vapor extraction well
SVMW	soil vapor monitoring well
SWMU	Solid Waste Management Unit
TPH	total petroleum hydrocarbons
USACE	U.S. Army Corps of Engineers
VOC	volatile organic compound

EXECUTIVE SUMMARY

The investigation and remediation of the Kirtland Air Force Base (AFB) Bulk Fuels Facility (BFF) leak (Solid Waste Management Units [SWMUs] ST-106/SS 111) are being implemented pursuant to the Resource Conservation and Recovery Act (RCRA) corrective action provisions in Part 6 of Kirtland AFB's Hazardous Waste Treatment Facility Operating Permit (Permit Number NM9570024423 [RCRA Permit]) (New Mexico Environment Department [NMED], 2010). A Notice of Disapproval of the Bioventilation Construction and Initiation Report, BFF SWMUs ST-106/SS-111 (NMED, 2020) was received on September 23, 2020. This revised report addresses the comments received from NMED and summarizes the installation of the bioventing system, baseline monitoring, and respiration testing performed to provide operational parameters and implementation of the long-term bioventing pilot test. NMED's September 23, 2020 letter and a response to comments matrix are provided in Appendix A.

A historic release of petroleum hydrocarbons occurred at the BFF and the use of bioventing is being evaluated to assess its effectiveness at site remediation. The goal of the bioventing respiration pilot test is to measure the oxygen utilization rate by microbes in the subsurface. The rate of oxygen utilization is directly proportional to the aerobic biodegradation rate of fuel hydrocarbons in the subsurface and can be used as an indication of the effectiveness of bioventing to achieve site cleanup.

The bioventing pilot test is being performed in accordance with the Bioventing Respiration Pilot Testing Procedure (Kirtland AFB, 2018) and the Work Plan for Bioventing and Air-Lift Enhanced Bioremediation Pilot Tests, dated November 2017 (Kirtland AFB, 2017a). These documents were approved by NMED in letters dated February 25, 2019 (NMED, 2019) and April 6, 2018 (NMED, 2018a), respectively, and are provided in Appendix A. The bioventing soil vapor monitoring wells (SVMWs) KAFB-106V1 and KAFB-106V2 were installed under the Work Plan for Vadose Zone Coring, Vapor Monitoring, and Water Supply Sampling, Revision 1 dated December 2017 (Kirtland AFB, 2017b). This Work Plan was approved by NMED in a letter dated February 23, 2018 (NMED, 2018b).

The scope of work described in the Work Plan included the following tasks:

1. Installation of bioventing monitoring wells
2. Installation of the bioventing pilot testing system
3. Collection of baseline respirometry parameters and analytical samples
4. Performance of short-term respiration tests, both dry and wet, in nine bioventing test wells
5. Performance of a long-term (2-year) bioventing pilot test utilizing the data from the short-term respiration tests to determine the air injection parameters.

This report describes the activities for Tasks 1 through 5 above that were performed at the BFF between March and November 2019. Currently, the long-term bioventing pilot test has been initiated and data are being collected.

ES-1 Installation of Bioventing Monitoring Wells

The bioventing respiration pilot test utilizes existing soil vapor extraction wells (SVEWs) and existing SVMWs for air injection. Installation of two nested SVMWs (KAFB-106V1 and KAFB-106V2) was completed in the first quarter of 2019 as part of the Work Plan. Each SVMW is comprised of six

0.75-inch outside diameter nested vapor probes with 2 feet (ft) of screen each targeting different depths of the vadose zone. Vapor probes were installed at depths varying between 102.1 and 262.6 ft below ground surface for well KAFB-106V1 and at depths varying between 102.2 and 269.5 ft below ground surface for KAFB-106V2. The variation in vapor probe depths allows discrete vertical monitoring of the vadose zone. Well installation activities were initiated in October 2018, and were concluded in March 2019. The SVMWs were used for baseline monitoring, post-dry respiration monitoring, post-wet respiration monitoring, and long-term bioventing pilot test monitoring. The SVMWs were installed in accordance with the Vadose Zone Coring, Vapor Monitoring, and Water Supply Sampling Work Plan (Kirtland AFB, 2017b).

ES-2 Installation of Bioventing System

Installation of the bioventing equipment was performed between February 25 and March 5, 2019. The bioventing equipment utilized for the pilot test includes a 1.5-horsepower regenerative blower used to inject air into the SVEWs and two 1-horsepower Gast rotary vane pumps used to inject air into the SVMWs. Power service to the equipment is provided via a 100-amp breaker from Building 1033 within the BFF. The service is equipped with a digital meter, a main disconnect, and service breakers to the blower and each rotary vane pump. The electrical service was inspected and tested prior to startup and was installed in accordance with local and state electrical code.

ES-3 Baseline Respirometry and Vapor Sampling

Baseline respirometry readings and laboratory analytical sampling were performed prior to the initiation of the respiration test to assess background respirometry parameters and hydrocarbon concentrations within the source area.

ES-4 Respiration Testing

Respiration testing was performed to determine the optimal air inflow rates and other operational parameters for bioventilation. Oxygen utilization rates and biodegradation rates were calculated based on respiration testing data to assess operational air and moisture inputs. Intrinsic permeability and radius of influence calculations were made to assess the effective zone or area of remedial effect for the pilot test. Analytical data were collected to determine contaminant concentrations and trends that will be assessed subsequent to further operation of the bioventilation pilot test.

The oxygen utilization rates and corresponding biodegradation rates were calculated for both dry and wet conditions as described. The overall average oxygen utilization rate for the dry respiration test was 0.414 percent (%) per day. The overall average oxygen utilization rate for the wet respiration test was 0.316% per day. Oxygen utilization rates were marginally higher during the dry respiration testing compared to the wet respiration testing. The need to add moisture will be further assessed during the long-term bioventing pilot test.

Biodegradation rates were generally low for both the dry and wet respiration tests. The dry respiration testing ranged between 0.096 and 0.378 milligrams per kilogram per day (mg/kg/day). Biodegradation rates during the wet respiration testing ranged between 0.081 and 0.371 mg/kg/day. In general, the dry respiration testing indicated slightly higher biodegradation rates.

Oxygen demand flow rates for the dry respiration test varied between 0.49 and 3.74 standard cubic feet per minute (scfm). Oxygen demand flow rates for the wet respiration test varied between 0.42 and 0.366 scfm. The oxygen demand flow rate was marginally higher for the dry respiration testing due to the higher oxygen utilization rates.

The radius of influence (ROI) was monitored using two methods: physical or pressure response and oxygen response. Due to low injection flow rates, pressures, and short injection periods, a reliable pressure ROI was not obtained. As a result, the oxygen ROI was calculated using the oxygen utilization. The oxygen ROI varied between 138 and 143 ft for the dry respiration test and between 140 and 152 ft for the wet respiration test. The ROI may have been marginally higher for the wet respiration test due to the overall lower oxygen utilization rates. ROI data will be assessed on a quarterly basis as the pilot test progresses.

ES-5 Long-Term Bioventing Pilot Test

The long-term bioventing pilot test was initiated on October 7, 2019, utilizing operational parameters obtained from the data analysis of the respiration tests. Monitoring of the long-term bioventing pilot test is ongoing. Data obtained from the first month of the long-term bioventing pilot test operation indicated that oxygen is being sufficiently delivered within the vadose zone. Pilot test operation and monitoring will continue in accordance with the Work Plan (Kirtland AFB, 2017a). Respiration and analytical data collected throughout the long-term pilot testing will be assessed in the Final Bioventilation Pilot Testing Report.

1. INTRODUCTION

Solid Waste Management Units (SWMUs) ST-106/SS-111 are located at Kirtland Air Force Base (AFB) in Bernalillo County, New Mexico. Kirtland AFB is located southeast of, and adjacent to, the City of Albuquerque and the Albuquerque International Sunport. The approximate area of the base is 52,287 acres. The Bulk Fuels Facility (BFF or Site) is located in the northwestern portion of Kirtland AFB (Figure 1-1).

1.1 Planning and Regulatory Framework

Environmental restoration efforts at the BFF are being performed pursuant to the corrective action provisions in Part 6 of the Resource Conservation and Recovery Act (RCRA) Permit Number NM9570024423 (RCRA Permit). The New Mexico Environment Department (NMED) is the lead regulatory agency (NMED, 2010). This work has been performed under U.S. Army Corps of Engineers (USACE) Contract Number W9128F-13-D-0006, Delivery Order DM02. This report is the compliance deliverable for the Work Plan for Bioventing and Air-Lift Enhanced Bioremediation Pilot Tests (Kirtland AFB, 2017a) per the February 25, 2019 NMED letter requirement (NMED, 2019).

The bioventing pilot test is being performed in accordance with the Bioventing Respiration Pilot Testing Procedure (Kirtland AFB, 2018) and the Work Plan for Bioventing and Air-Lift Enhanced Bioremediation Pilot Tests, dated November 2017 (Work Plan [Kirtland AFB, 2017a]). These documents were approved by NMED in letters dated February 25, 2019 (NMED, 2019) and April 6, 2018 (NMED, 2018a), respectively. The bioventing soil vapor monitoring wells (SVMWs) KAFB-106V1 and KAFB-106V2 were installed under the Work Plan for Vadose Zone Coring, Vapor Monitoring, and Water Supply Sampling, Revision 1 dated December 2017 (Kirtland AFB, 2017b). This Work Plan was approved by NMED in a letter dated February 23, 2018 (NMED, 2018b). This report is being submitted in accordance NMED's letter dated February 25, 2019; note that the bioventing pilot test has not been completed and further assessment of bioventing technology as a corrective measure will be performed in the Final Bioventilation Pilot Testing Report.

A Notice of Disapproval of the Bioventilation Construction and Initiation Report, BFF SWMUs ST-106/SS-111 (NMED, 2020) was received on September 23, 2020. This revised report addresses the comments received from NMED. The Notice of Disapproval letter and a response to comments matrix are provided in Appendix A.

1.2 Bioventing Pilot Test Objectives and Scope

The bioventing pilot test is being performed to evaluate the feasibility of this technology for the Corrective Measures Evaluation Report. The goal of the bioventing pilot test is to measure oxygen utilization rate by microbes in the subsurface. The rate of oxygen utilization is directly proportional to the aerobic biodegradation rate of fuel hydrocarbons in the subsurface and can be used as an indication of the effectiveness of bioventing to achieve site cleanup.

Dr. Robert Hinchee, co-author of Principles and Practices of Bioventing, Volume 2: Bioventing Design (Leeson and Hinchee, 1996), acted as subject matter expert for the pilot test. Dr. Hinchee provided technical guidance on pilot test operation, reviewed data, and assisted with the data interpretation.

The bioventing respiration pilot test utilizes existing soil vapor extraction wells (SVEWs) and existing SVMWs for air injection (Kirtland AFB, 2017a, 2018) and two new SVMW clusters at KAFB-106V1 and KAFB-106V2 (Kirtland AFB, 2017b) for observation. Well details are provided in Table 1-1 and well locations are shown on Figure 1-2. Components of the bioventing pilot test that have been implemented thus far include the following:

- Installation of bioventing SVMWs
- Installation of the bioventing pilot test system
- Collection of baseline respirometry field parameters and analytical soil vapor samples
- Short duration dry and wet bioventing respiration tests (approximately 3 weeks per test)
- Implementation of the long-term bioventing pilot test.

Data collected from the short-duration respiration tests were used to provide operational parameters for the long-term bioventing pilot test, which was started on October 7, 2019. Operation and monitoring of the long-term bioventing pilot test are currently ongoing and are being conducted in accordance with the approved Work Plan (Kirtland AFB, 2017a).

Respiration and analytical data collected over the course of the long-term bioventing pilot test will be analyzed in the Final Bioventilation Pilot Testing Report.

2. BACKGROUND INFORMATION

2.1 Site Description

Kirtland AFB is located in Bernalillo County, in central New Mexico, southeast of and adjacent to the City of Albuquerque and the Albuquerque International Sunport (Figure 1-1). The approximate area of the base is 52,287 acres. The BFF site is located in the northwestern portion of Kirtland AFB.

2.2 Site History

The BFF and associated infrastructure operated from 1953 until 1999. During this time, the fueling area was separated into a tank holding area where bulk shipments of fuel were received and a fuel loading area where individual fuels trucks were filled. Kirtland AFB removed the underground piping at the facility from service in 1999 due to discovery of underground leakage.

To comply with NMED Hazardous Waste Bureau requirements, Interim Measures were implemented for soil. Impacted soil was excavated in the release area to a depth of approximately 20 feet (ft) below ground surface in the area shown on Figure 1-2. Soil vapor extraction activities were performed at the site between 2003 and 2015 to reduce the mass of contaminants in the vadose zone. The soil vapor extraction system was shut down in the second quarter of 2015 due to low mass removal rates (Kirtland AFB, 2017a). The use of bioventing as a remedial method is being assessed to determine if additional contaminant mass destruction can be achieved in the vadose zone.

2.3 Ongoing Soil Vapor Monitoring

Semiannual soil vapor monitoring has been ongoing as part of the SWMUs ST-106/SS-111 investigation to monitor the nature and extent of soil vapor concentrations in the vadose zone. A total of 284 soil vapor monitoring points at 56 soil vapor monitoring locations are being sampled semiannually (Figure 2-1). The results from the vapor monitoring data indicate that the majority of the petroleum hydrocarbon concentrations found in the vadose zone are located in the vicinity of the release area.

3. SCOPE OF ACTIVITIES

This section describes the field activities for the bioventing pilot test. Section 3.1 provides a brief summary of the SVMW installation. Section 3.2 provides a summary of the bioventing equipment and installation. Section 3.3 provides a summary of the baseline respirometry and baseline vapor sampling activities. Section 3.4 provides a summary of the dry respiration field test, water injection, and wet respiration field test activities. Field activities were conducted in accordance with the NMED-approved Work Plan (Kirtland AFB, 2017a). Field forms documenting bioventing activities, excluding SVMW installation, are provided in Appendix B.

3.1 Soil Vapor Monitoring Well Installation

Implementation of the vadose zone coring and well installation project was initiated in October 2018 in accordance with the Vadose Zone Coring, Vapor Monitoring, and Water Supply Sampling Work Plan (Kirtland AFB, 2017b). Two nested SVMWs (KAFB-106V1 and KAFB-106V2) were completed in the first quarter of 2019 as part of the Work Plan (Figure 1-2). Each SVMW is comprised of six 0.75-inch outside diameter nested vapor probes with 2 ft of screen each targeting different depths of the vadose zone. Vapor probes were installed at depths varying between 102.1 and 269.5 ft below ground surface. Table 1-1 provides the screened intervals. Each probe is isolated from the others using a bentonite chip seal. The lithologic logs and well construction diagrams for KAFB-106V1 and KAFB-106V2 are provided in Appendix C.

3.2 Bioventing Equipment Installation

Installation of the bioventing system began in February 2019. A 230-volt, 3-phase electrical service was installed between February 25 and March 5, 2019. Power was pulled from panel B in Building 1033 within the BFF and consists of the following components:

- 100-amp breaker within Building 1033
- Overhead power line installed across the service road
- Electrical panel with disconnect
- Digital electric meter
- Connection of the 1.5-horsepower regenerative blower
- Buried electrical completed with surface-mounted outlets for rotary vane pump power supply.

Air injection is performed using a combination of a 1.5-horsepower regenerative blower and two 1-horsepower rotary vane pumps. Air injection is performed concurrently at all locations utilizing the regenerative blower and both rotary vane pumps.

The 1.5-horsepower regenerative blower is part of a turnkey Geotech air injection blower skid equipped with a high-pressure shutoff and pressure relief valve. The blower is used for the SVEWs that have a 2-inch diameter. These wells consist of SVEW-01-260, SVEW-02/03, and SVEW-04/05. The diameter of these wells reduces the head loss through the wells and allows for sufficient air injection. The blower unit provides injection air to the SVEWs through a 2-inch polyethylene conveyance line that manifolds to the individual SVEWs. Each SVEW is equipped with a direct read-out flowmeter located at the wellhead. Conveyance piping is connected to the wellhead via rubber couplings.

Due to head losses associated with high volume injection flow rates through the 0.5-inch diameter SVMWs (Appendix D-1), it was determined that the blower may not be capable of overcoming pressure losses within the SVMWs while maintaining the desired flow rates. As a result, injection air is provided to the SVMWs via a dedicated 1-horsepower Gast rotary vane pump located at each wellhead (total of two wellheads and pumps). These wells consist of SVMW-10 and SVMW-11. These rotary vane pumps are capable of producing a maximum pressure of approximately 15 pounds per square inch gauge. Each vane pump is equipped with a copper cooling coil, galvanized steel manifold, direct read-out rotameters, and quick connect fittings.

3.3 Baseline Respirometry and Vapor Sampling

Background respirometry was performed on the testing wells identified in Table 1-1. Respirometry field parameters were collected in accordance with Table 3-1. Respirometry readings were collected using the following method: a sample train, consisting of 0.5-inch fluorinated ethylene propylene tubing and 4-way stainless-steel cross equipped with quick connects, was connected to the wellhead. Well head pressures were collected using a digital manometer.

Well purging was performed by removing one well volume (casing volume plus the filter pack pore space volume of the screened interval) from the monitoring well utilizing a Gast rotary vane pump that is dedicated for sampling purposes. Each well was purged at a predetermined flow rate for a given amount of time to ensure adequate volume removal. Soil vapor relative humidity and temperature were collected during purging by placing an Amprobe TH 3 humidity meter inside a clear flow cell and positioning the instrument where the extracted soil vapor passes directly over the sensor. Relative humidity and temperature readings were collected just prior to completing the purge to allow stabilization. After purging was completed, volatile organic compound (VOC), oxygen, carbon dioxide, methane, and barometric pressure readings were collected. Barometric pressure and methane readings were collected using a calibrated Landtec GEM 5000 portable gas analyzer. Oxygen, carbon dioxide, and VOC readings were collected using the Horiba Mexa-584L. The range of oxygen detection of the instrument is between 0.0 and 30.0 percent (%) with a 0.1% accuracy as stated in Table 3-1. According to Principles and Practices of Bioventing (Leeson and Hinchee, 1996), oxygen utilization rates greater than 1% per day are a good indicator that bioventing may be feasible at the site. The low range on the instrument is 0.1%, indicating that it is capable of detecting changes in oxygen that would support biodegradation as a result of bioventing. Field calibration was performed prior to each use and is provided in the field forms (Appendix B). Baseline respirometry readings were recorded and are presented in Tables 3-2 through 3-10.

Immediately after collection of field parameters, analytical samples were collected from each well screen depth on SVMWs KAFB-106V1 and KAFB-106V2. Analytical samples were collected using 6-liter Summa cannisters and analyzed for benzene, toluene, ethylbenzene, and total xylenes (BTEX)/total petroleum hydrocarbons (TPH)-gasoline range organics (GRO) by U.S. Environmental Protection Agency (EPA) Method TO-3, VOCs by EPA Method TO 15 selected ion monitoring (SIM), and fixed gases/C1-C5 hydrocarbon compounds by ASTM International D1945 (Table 3-11). Samples were shipped to Eurofins Air Toxics under chain-of-custody documentation.

3.4 Respirometry Field Testing

The main objective of the bioventing respiration pilot testing was to assess oxygen utilization rates and corresponding biodegradation rates for both the natural state (dry) and moisture added (wet) conditions. Field activities are listed below and a chronology of events is provided in Table 3-12:

- The dry respiration pilot test was conducted between April 22 and May 9, 2019.
- Post-dry respiration sampling was performed on May 9, 2019.

- The water injection was performed on May 23 and 24, 2019. After the water was injected, the test cells were allowed approximately 4 weeks to acclimate prior to the start of the wet respiration testing. Prior to the start of air injection, another set of respirometry measurements was collected from the bioventing test wells to provide a baseline reading for the wet respiration pilot test.

- The wet respiration pilot test was conducted between June 20 and July 5, 2019.

- Post-wet respiration sampling was performed on July 5, 2019.

Analytical samples were collected after each of the respiration tests to evaluate hydrocarbon degradation (Table 3-13). No measurable degradation was observed due to the high concentration of hydrocarbons and the limited amount of ambient air supplied to the subsurface.

3.4.1 Dry Respirometry Testing

3.4.1.1 Air Injection and Pressure Monitoring

Table 3-14 presents the design inputs, prescribed injection volumes, and air injection volumes performed in the field. Injection of ambient air was performed between April 22 and 28, 2019, and consisted of the injection of air into each well sufficient to achieve the estimated pore volume of air (porosity assumed to be 35%). A 15-ft radius from the injection well was assumed for the calculation of each test cell control volume. The thickness of each test cell control volume was the filter pack length, plus 5 ft above and below to account for vertical air flow. The injection rate was calculated based on the addition of four pore volumes of the test cell in each well. Air injection was monitored and controlled using rotameters located at the injection wellhead. A 1-horsepower Gast rotary vane pump was used for air injection into wells SVMW-10 and SVMW-11. A skid-mounted, 1.5-horsepower Rotron 454 regenerative blower was used for air injection into wells SVEW-01, SVEW-02/03, and SVEW-04/05. Air injection flow rates and wellhead pressures were recorded daily and are presented in Tables 3-15 through 3-17. During air injection, wellhead pressures were monitored in wells KAFB-106V1 and KAFB-106V2 and are presented in Tables 3-18 and 3-19.

3.4.1.2 Dry Respirometry

Dry respirometry data collection began immediately after the air injection was completed and was performed in the same manner as the baseline monitoring, as described above. Respirometry data were collected between April 28 and May 8, 2019. Respirometry data are presented in Tables 3-2 through 3-10. Oxygen concentration within the subsurface was plotted against time for each well location and a linear regression was applied to determine the oxygen utilization rate. Collection of respirometry data was performed in accordance with the Work Plan (Kirtland AFB, 2017a).

3.4.1.3 Dry Respirometry Vapor Sampling

Vapor samples were collected following the dry respirometry testing from each well screen on wells KAFB-106V1 and KAFB-106V2 on May 9, 2019. Analytical samples were collected using 6-liter Summa cannisters and were analyzed for BTEX/TPH-GRO by EPA Method TO-3, VOCs by EPA Method TO-15 SIM, and fixed gases/C1-C5 hydrocarbon compounds by ASTM International D1945. Samples were shipped to Eurofins Air Toxics under chain-of-custody documentation. Analytical results are discussed and presented in Section 4.

3.4.2 Water Injection

Water was injected into the respiration testing wells on May 23 and 24, 2019 after completion of the dry respiration field test. The injection was performed in batches utilizing 250-gallon graduated polyethylene totes staged at the wellheads. The water utilized for injection was obtained from the Kirtland AFB BFF groundwater treatment system. The water was staged in lined roll-off containers until laboratory results were received and it was confirmed that no hydrocarbon contamination was present (Appendix E-1). Prior to injection, the water was field tested for residual chlorine in order to reduce the possibility that chlorinated water could inhibit microbial growth in the subsurface. This was performed in accordance with the NMED approval letter for Bioventing Air Lift Bioremediation (NMED, 2018a). Upon confirmation that residual chlorine was not present (field notes are provided in Appendix B), the water injection proceeded.

Water was delivered to the totes using a 500-gallon, trailer-mounted water tank. The totes were filled to a graduated marking and then gravity drained into the wells. Batch volumes were recorded in the field notes. Injections on wells SVMW-10 and SVMW-11 were performed directly down the well casing. Injections on wells SVEW-01, SVEW-02/03, and SVEW-04/05 were performed through a 1-inch diameter cross-linked polyethylene tremie pipe that was placed near the bottom of the screen. Injection totals for each well are provided in Table 3-20. Table 3-14 presents the design inputs, prescribed injection volumes, and water injection totals performed in the field.

3.4.2.1 Post-Water Injection Respirometry

Post-water injection respirometry was performed on the testing wells, prior to air injection, identified in Table 1-1. Respirometry field parameters were collected in accordance with Table 3-1. Respirometry readings were collected to provide a baseline for the wet respirometry testing; analytical vapor samples were not collected.

3.4.3 Wet Respirometry Testing

3.4.3.1 Air Injection and Pressure Monitoring

Table 3-14 presents the design inputs, prescribed injection volumes, and air injection totals performed in the field. Injection of ambient air was performed between June 20 and 26, 2019, and consisted of the injection of air into each well sufficient to achieve the estimated pore volume of air (porosity assumed to be 35%). A 15-ft radius from the injection well was assumed for the calculation of each test cell control volume. The thickness of each test cell control volume was equal to the filter pack length, plus 5 ft above and below to account for vertical air flow. The injection rate was calculated based on the addition of four pore volumes of the test cell in each well. Air injection was monitored and controlled using rotameters located at the injection wellhead. A Gast rotary vane pump was used for air injection into wells SVMW-10 and SVMW-11. A skid-mounted, 1.5-horsepower Rotron 454 regenerative blower was used for air injection into wells SVEW-01, SVEW-02/03, and SVEW-04/05. Air injection flow rates and wellhead pressures were recorded daily and are presented in Tables 3-15 through 3-17. During air injection, wellhead pressures were monitored in wells KAFB-106V1 and KAFB-106V2 and are presented in Tables 3-18 and 3-19.

3.4.3.2 Wet Respirometry

Wet respirometry data collection began immediately after the air injection was completed and was performed in the same manner as the baseline monitoring, as described above. Respirometry data were collected between June 26 and July 5, 2019. Respirometry data are presented in Tables 3-2 through 3-10.

Oxygen concentration within the subsurface was plotted against time for each well location and a linear regression was applied to determine the oxygen utilization rate. Collection of respirometry data was performed in accordance with the Work Plan (Kirtland AFB, 2017a).

3.4.3.3 Post-Wet Respirometry Vapor Sampling

Post-wet respirometry samples were collected from all depths on wells KAFB-106V1 and KAFB-106V2 on July 5, 2019. Analytical samples were collected using 6-liter Summa cannisters and analyzed for BTEX/TPH-GRO by EPA Method TO-3, VOCs by EPA Method TO-15 SIM, and fixed gases/C1-C5 hydrocarbon compounds by ASTM International D1945. Samples were shipped to Eurofins Air Toxics under chain-of-custody documentation.

3.5 DEVIATIONS FROM WORK PLAN

Deviations from the approved Work Plan are discussed below.

3.5.1 Soil Vapor Monitoring Wells

SVMWs KAFB-106V1 and KAFB-106V2 were constructed with 2-ft screened intervals (standard available length) in place of the 2.5-ft intervals as described in the Work Plan (Kirtland AFB, 2017b). The 2-ft screen length does not impact vapor sampling. Final placement of each screen within the nested well was determined in the field based on lithology and is correctly recorded in the well construction diagrams provided in Appendix C.

3.5.2 Bioventing Blowers

The 1.5-horsepower regenerative blower could not be used to provide injection air to SVMW-10 and SVMW-11 due to the head loss associated with air flow through the 0.5-inch wells. Using a flow rate of 4.0 standard cubic feet per minute (scfm) (SVMW-11-250 design flow rate from the testing procedure [Kirtland AFB, 2018]) and supply pressure of 1.6 pounds per square inch (maximum blower pressure), a total head loss of 1.39 pounds per square inch/100 ft of pipe was determined. Over the total length of the injection well this head loss is greater than the maximum applied pressure provided by the blower; thus, it was determined that the blower is not sufficient for air injection into the SVMWs. As a result, a dedicated rotary vane pump capable of producing 12.5 scfm at 10 pounds per square inch was placed at each SVMW. The vane pumps produced sufficient pressure to overcome losses while maintaining the needed flow rate. Head loss calculations for air flow through a 0.5-inch pipe are provided in Appendix D-1.

3.5.3 Air Injection Timeframe

Clean air injection for both the dry and the moist respiration tests occurred over a time period of approximately 7 days instead of the proposed 3 days. The injection timeframe was increased to ensure the full volume of air, as specified in the approved Work Plan testing procedure, was delivered to the subsurface. The total volume of air injected into each location is provided in Tables 3-14 through 3-17. This extended injection timeframe was used due to the limitations of injecting high volume of air through the 0.5-inch SVMWs as discussed in Section 3.5.2 above.

3.5.4 Intrinsic Permeability Calculation

Intrinsic permeability could not be calculated as specified in the Work Plan as the provided equation is not applicable under pressure injection situations. As a result, discussion of the intrinsic permeability is not included in this report. However, this does not affect the overall usability of the bioventing pilot test as oxygen utilization and biodegradation parameters can still be calculated and used to assess the viability of bioventing as a corrective remedy.

3.5.5 Vapor Sample Containers

During the bioventing pilot test, 6-liter summa cannisters were used in place of the 1-liter cannisters to provide sufficient volume to allow for analysis of all required parameters. Documentation of laboratory confirmation of the sample cannister size is provided in Appendix D-2.

4. FIELD INVESTIGATION RESULTS

Analysis of collected data and the calculation of the long-term bioventing operational parameters are discussed below.

4.1 Respiration Data Analysis

Field measurements were collected from each testing well over an 11-day period for the dry respiration test and over a 9-day period for the wet respiration test. Both tests were conducted with technical guidance from Dr. Robert Hinchee.

Upon collection of the data, it was observed that oxygen and carbon dioxide concentrations varied from day to day. This was more prevalent within the SVEWs (which have 15-ft long screens) than in the SVMWs (which have 2-ft long screens). The Horiba unit was field checked against atmospheric oxygen and carbon dioxide conditions any time a large change in the concentration of oxygen or carbon dioxide occurred to check that the instrument was functioning properly. To perform this check, the instrument was disconnected from the sample train and a fresh air sample was analyzed. If the oxygen and carbon dioxide readings were at atmospheric conditions of 20.9 and 0.0%, respectively, then the field readings were accepted as correct. None of the instrument readings collected during respirometry were considered suspect.

While diffusion of soil gas is a possibility for the variation in oxygen and carbon dioxide readings, a volume of air equivalent to four times the test cell volume was injected into each point to safeguard against diffusion. Volumes of injected air are provided in Tables 3-14 through 3-17. In addition, if diffusion was the primary reason for variation, increases in the oxygen concentration would not have been observed as the ambient soil vapor that is diffusing into the test cell is very low in oxygen.

Soil vapor variability of this kind is not unusual and can have a variety of causes including barometric pressure driven flow, temperature, precipitation, gravitational effects (e.g., Pitchford et al., 1989; Contaminated Land: Applications in Real Environments, 2011; Hartman, 2002). While variability of oxygen/carbon dioxide was observed in many of the wells during the respiration testing, the changes were more prevalent within the SVEWs. The subsurface is a porous media and thus subject to barometric pumping. Barometric pumping is more likely to be observed in longer screened wells (the SVEWs) as the long screen interval increases the likelihood of exposure to permeable zones that respond more rapidly to barometric pressure changes. If the well screen is subject to a permeable zone, it is likely that injection air or ambient soil vapor is pushed in and out of the test cell when barometric pressure swings occur.

Barometric pressure was plotted versus the oxygen data (Appendix F). While increases and decreases in barometric pressure may influence subsurface pumping, they do not account for all the variability observed; other factors, discussed above, likely also influenced the data. However, oxygen concentrations overall appear to decline during the respiration testing indicating oxygen utilization and hydrocarbon biodegradation. The impact of this variability is taken into account by applying a safety factor to the bioventing operational flow rate. A safety factor of four times the calculated oxygen utilization rate is being supplied to ensure oxygen is being delivered at a rate much greater than it is being utilized. While this may safeguard against variations due to influx and diffusion, the elevated flow rate may increase the chance of pushing contaminated soil vapor through the subsurface. However, this risk is mitigated by soil vapor sampling that will indicate if vapor migration is occurring.

4.2 Bioventing Parameters

Data collected during the respiration pilot tests were utilized to calculate oxygen utilization rates and corresponding biodegradation rates. These data were used to calculate long-term bioventing pilot test operational parameters including bioventing flow rate, and estimate intrinsic permeability, and radius of influence (ROI). Field data from both the dry and wet respiration tests are provided in Tables 3-2 through 3-10. Bioventing assessment and operational parameters were calculated using the field data that were collected and calculated as described in Work Plan (Kirtland AFB, 2017a). Discussion of the operational parameters is provided below.

4.2.1 Oxygen Utilization Rate

Oxygen utilization in aerobic degradation is generally estimated stoichiometrically using a representative straight chain aliphatic. Leeson and Hinchee (1996) use hexane degradation to establish oxygen utilization as such:

$$C_6H_{14} + 9.5O_2 \rightarrow 6CO_2 + 7H_2O$$

This stoichiometric relationship renders the relation that 1 pound of fuel hydrocarbon is degraded with 3.5 pounds of oxygen, and this mass relationship is applicable for all hydrogen-saturated alkanes. If the oxygen utilization rate due to biodegradation is known, the vent rate to supply required oxygen mass can be calculated.

The oxygen utilization rate is determined by the respiration test data by plotting oxygen content in soil gas versus time (Leeson and Hinchee 1996). The roughly linear slope during early oxygen depletion (decreasing from approximately 20 to 5% oxygen by volume) yields the oxygen utilization rate. Note that oxygen data collection ceased before oxygen concentrations reached 5%, with concurrence from Dr. Hinchee, due to the possibility of influx of ambient soil vapor.

Field measurements were collected during the respiration tests and data were plotted versus time (Figures 4-1 through 4-9 provide graphs of oxygen utilization and Figures 4-10 through 4-18 provide corresponding carbon dioxide production). A linear regression was applied to determine the oxygen utilization rate.

Oxygen utilization rates for the dry respiration testing varied between 0.163 and 0.475% per day for the SVMWs and between 0.497 and 0.639% per day for the SVEWs (Figures 4-1 through 4-9 and Table 4-1). The oxygen utilization rate averaged 0.340% per day for the SVMWs while averaging 0.563% per day for the SVEWs. The overall average oxygen utilization rate for the dry respiration test was 0.414% per day.

Oxygen utilization rates for the wet respiration testing ranged between 0.138 and 0.520% per day for the SVMWs and between 0.020 and 0.626% per day for the SVEWs (Figures 4-1 through 4-9, Table 4-1). The oxygen utilization rate averaged 0.307% per day for the SVMWs while averaging 0.335% per day for the SVEWs. The overall average oxygen utilization rate for the wet respiration test was 0.316% per day.

The oxygen utilization rates obtained from the respiration testing do not account for additional factors that would result in the decrease of oxygen concentrations. These factors include influx of ambient soil vapor into the test cell, diffusion of oxygen into the surrounding soil vapor, and high-volume movement of soil vapor as a result of barometric pressure influences. Further evaluation of the oxygen utilization rates will be performed throughout the long-term bioventing pilot test. Continuous air injection should alleviate some of the concerns associated with the additional factors as the ambient soil vapor will be displaced by the supplied air. Discussion of the oxygen utilization rates will be provided in the Final Bioventilation Pilot Testing Report.

4.2.2 Biodegradation Rate

Biodegradation rates for each well were calculated in accordance with the Work Plan (Kirtland AFB, 2017a) as specified in Leeson and Hinchee (1996). The formula below was used to calculate the biodegradation rates and calculations are provided in Appendix G.

$$k_b = \frac{-\frac{k_O}{100}\theta_a \frac{1\ L}{1000\ cm^3}\rho_{O_2} C}{\rho_k\left(\frac{1\ kg}{1000\ g}\right)} = \frac{-k_O \theta_a \rho_{O_2} C(0.01)}{\rho_k}$$

Where:

k_b	=	Biodegradation rate (milligrams per kilogram per day [mg/kg-day]).
k_o	=	Oxygen utilization rate (% percent day).
θ_a	=	Gas-filled pore space (volumetric content at the vapor phase, cubic meters $_{gas}$/cubic centimeter$_{soil}$).
ρ_{O2}	=	Density of oxygen (milligrams per liter).
C	=	Mass ratio of hydrocarbons to oxygen required for mineralization (=1/3.5 for hexane-equivalent).
ρ_k	=	Soil bulk density (grams per cubic centimeter).

Biodegradation rates during the dry respiration testing ranged between 0.096 and 0.281 mg/kg/day for the SVMWs and between 0.294 and 0.378 mg/kg/day for the SVEWs (Table 4-1). Biodegradation rates during the wet respiration testing ranged between 0.081 and 0.308 mg/kg/day for the SVMWs and between 0.012 and 0.371 mg/kg/day for the SVEWs.

These biodegradation rates may be affected by additional factors influencing oxygen utilization as discussed in Section 4.2.1 above. Further evaluation of the oxygen utilization rates and corresponding biodegradation rates will be performed throughout the long-term bioventing pilot test. Discussion of the oxygen utilization rates will be provided in the Final Bioventilation Pilot Testing Report.

4.2.3 Oxygen Demand Air Flow Rate

The required bioventing flow rate is determined from the oxygen utilization rate established from the respiration test (Leeson and Hinchee, 1996).

$$Q = \frac{k_O V \theta_a}{(20.9\% - 5\%)\ \times 60\frac{min}{hr}}$$

Where:

Q	=	Flow rate (cubic feet per minute).
k_O	=	Oxygen utilization rate (% per hour).
V	=	Volume of contaminated soil (cubic feet).
θ_a	=	Gas-filled pore space (cubic centimeters$_{air}$/cubic centimeters$_{soil,}$ ~ 0.2 or 0.3).

The oxygen demand flow rate represents the minimum ambient air injection flow rate required to maintain the biodegradation rates obtained in the respirometry calculations. The oxygen demand air flow rate was calculated based on the oxygen utilization rate and corresponding biodegradation rates for each well under both the dry and wet respiration conditions (Appendix G). The long-term operational bioventing flow rate is based on the oxygen demand air flow rate times a safety factor (in this case, four times the oxygen demand air flow rate [Section 5.2 below]).

Oxygen demand flow rates for the dry respiration test varied between 0.49 and 0.79 scfm for the SVMWs and between 2.50 and 3.74 scfm for the SVEWs. Oxygen demand flow rates for the wet respiration test varied between 0.42 and 0.86 scfm for the SVMWs and between 0.11 and 3.66 scfm for the SVEWs. The oxygen demand flow rate was marginally higher for the dry respiration testing due to the higher oxygen utilization rates. The calculated flow rate for each well is provided on Table 4-1.

These oxygen demand flow rates may be affected by additional factors influencing oxygen utilization as discussed in Section 4.2.1 above. Further evaluation of the oxygen utilization rates and corresponding oxygen demand flow rates will be performed throughout the long-term bioventing pilot test. Discussion of the oxygen demand flow rates will be provided in the Final Bioventilation Pilot Testing Report.

4.2.4 Radius of Influence

In accordance with the Work Plan (Kirtland AFB, 2017a), the ROI was monitored using two methods: physical or pressure response and oxygen response. Physical pressure monitoring was performed during the ambient air injections (Tables 3-15 through 3-17). However, due to low injection flow rates, pressures, and short injection periods that could not overcome the variability in barometric pressure, a reliable pressure ROI was not obtained.

As a result, the oxygen ROI was calculated using the oxygen utilization rates and long-term bioventing operation flow rates as described in the Work Plan (Kirtland AFB, 2017a). The oxygen ROI for each well under both the dry and wet respiration conditions is presented in Table 4-1 and calculations are provided in Appendix G. The oxygen ROI varied between 138 and 143 ft for the dry respiration test and between 140 and 152 ft for the wet respiration test. The ROI was marginally higher for the wet respiration test due to the overall lower oxygen utilization rates. ROI data will be assessed on a quarterly basis as the pilot test progresses.

4.2.5 Soil Vapor Analytical Results

Laboratory analytical samples were collected from each of the screened intervals in SVMWs KAFB-106V1 and KAFB-106V2 to evaluate the contaminant destruction rate and the degradation of BTEX, ethylene dibromide (EDB), and TPH-GRO. Field parameters collected during sampling are provided in Tables 4-2 through 4-13.

Analytical samples were collected prior to the air injection for the dry respiration test, after the dry respiration test was completed, and after the wet respiration test was completed. Soil vapor analytical data and the analytical laboratory reports are provided in Appendix E-2. TPH-GRO, BTEX, and EDB concentrations were collected and are provided in Table 3-13. A summary of all soil vapor analytical data is provided in Appendix E-3.

4.2.5.1 Baseline Respiration Sampling

The following is a summary of the laboratory analytical results for the samples collected in April 2019 prior to the dry respiration testing:

TPH-GRO ranged from 43,000,000 to 370,000,000 micrograms per cubic meter (µg/m^3).

- The sum of BTEX ranged from 2,400,000 to 9,130,000 µg/m^3.
- EDB ranged from 2,500 J to 23,000 µg/m^3.

4.2.5.2 Post-Dry Respiration Sampling

The following is a summary of the laboratory analytical results for the samples collected in May 2019 after the dry respiration testing but before the wet respiration testing:

- TPH-GRO ranged from 52,000,000 to 210,000,000 µg/m^3.
- The sum of BTEX ranged from 2,820,000 to 7,950,000 µg/m^3. These sums include a mixture of non-qualified and J-qualified results.
- EDB ranged from 1,900 J to 15,000 µg/m^3.

4.2.5.3 Post-Wet Respiration Sampling

The following is a summary of the laboratory analytical results for the samples collected in July 2019 after the wet respiration testing:

- TPH-GRO ranged from 76,000,000 to 220,000,000 µg/m^3.
- The sum of BTEX ranged from 2,270,000 to 9,530,000 µg/m^3. The results for each of the analytes included in the sum were J-qualified.
- EDB ranged from 1,600 J to 24,000 µg/m^3.

Significant changes in contaminant concentration due to biodegradation were not expected to be observed during the respiration pilot testing due to the limited injection periods. Data collected during the respiration tests will be used as baseline data to assess the biodegradation throughout the full-scale bioventing test.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Respirometry Testing Conclusions

Respiration pilot tests were completed for both dry and wet conditions. While oxygen and carbon dioxide concentrations varied from day to day for both the dry and wet respiration test, a clear decline in subsurface oxygen was observed. Data collected during the dry and wet respiration tests were utilized to determine the oxygen utilization rates and other operational parameters. Comparing the oxygen utilization rates and operational parameters between the dry respiration test and the wet respiration test, it appears that moisture addition is not beneficial for increasing biodegradation rates. As a result, the bioventing pilot test operational parameters were determined using the data obtained from the dry respiration test. Moisture will be added in the event that hydrocarbon concentration degradation does not appear to be occurring or stalls.

5.2 Long-Term Pilot Test Operational Parameters

The bioventing pilot test system is designed to supply oxygen to the remediation area at a rate equal to or greater than the oxygen utilization rates. The oxygen demand air flow rate is calculated from the oxygen utilization rate and is the minimum flow required to provide sufficient oxygen throughout the remediation area. The remediation area for the long-term bioventing test is defined as a control radius of 70 ft (the farthest distance between injection wells and observation wells) along with the filter pack thickness of the injection well to obtain a volume of impacted soil. Table 5-1 presents the design inputs and calculated pore volumes.

Due to the low oxygen utilization rates, the corresponding biodegradation rates and oxygen demand air flow rates were also low. As a result, a long-term bioventing pilot test operational design flow rate of approximately four times the oxygen demand flow rate is specified to ensure that oxygen is delivered to the subsurface at a rate greater than it is being utilized. Design operational flow rates for the bioventing pilot test are presented in Table 4-1. The air flow rates were calculated based on the method approved in the Work Plan (Kirtland AFB, 2017a). The calculations are presented in Appendix G and the flow rate for each well is presented on Table 4-1.

Utilizing the calculated oxygen utilization rates and long-term bioventing pilot test operation flow rates, the oxygen ROI was calculated for each well under both the dry and wet respiration conditions. These oxygen ROIs are presented in Table 4-1 and calculations are provided in Appendix G. The oxygen ROI varied between 138 and 143 ft for the dry respiration test and between 140 and 152 ft for the wet respiration test. The calculated oxygen ROIs are much greater that the 70-ft radius control area indicating that the long-term bioventing pilot test operational flow rates are adequate to provide oxygen throughout the remediation area.

5.3 Bioventing Pilot Test Implementation

Prior to startup of the bioventing pilot test, process piping and flowmeters were connected to the wellheads and inspected for leaks and loose fittings. On October 7, 2019, the bioventing blowers were started. The flow rates for the long-term bioventing pilot test were calculated as described in Section 4.1, above, and are provided on Table 4-1. The process piping and equipment were re-inspected for leaks and tightness after the startup of the bioventing equipment. Initial startup injection parameters of pressure, flow rate, oxygen, and carbon dioxide concentrations were collected.

5.4 Bioventing Pilot Test Performance Assessment

Performance monitoring of the long-term bioventing pilot test is being conducted in accordance with the Work Plan (Kirtland AFB, 2017a). Table 4-1 lists the wells to be used for air injection. Wells KAFB-106V1 and KAFB-106V2 will be used for monitoring. Field parameters are being collected from the screened intervals in Wells KAFB-106V1 and KAFB-106V2. Data collected during the long-term bioventing pilot test will consist of ambient temperature, barometric pressure, well pressures, and flow rates; hydrocarbon concentration, oxygen, and carbon dioxide concentrations; relative humidity; and vapor temperature. Vapor samples are being collected and submitted to an analytical laboratory for analysis of BTEX/TPH-GRO by EPA Method TO-3, VOCs by EPA Method TO-15 SIM, and fixed gases/C1-C5 hydrocarbon compounds by ASTM International D1945. Samples are collected on a quarterly basis and submitted to Eurofins Air Toxics under chain-of-custody documentation.

The first month of long-term bioventing pilot testing data is presented in Tables 4-2 through 4-13. The data collected during the first month of the long-term bioventing pilot test show elevated oxygen concentrations in each monitoring point within wells KAFB-106V1 and KAFB-106V2. This indicates that operational flow rates are sufficient to distribute oxygen throughout the bioventing pilot testing area.

Monitoring will continue in accordance with the Work Plan (Kirtland AFB, 2017a). Respiration and analytical data collected over the course of the long-term bioventing pilot test will be analyzed in the Final Bioventilation Pilot Testing Report. The report will include:

- Text describing quarterly activities and deviations from the Work Plan
- Summary tables for field and analytical laboratory data
- Calculations of assessment parameters
- Assessment of bioventing for use as a corrective measure
- Field data forms and laboratory reports.

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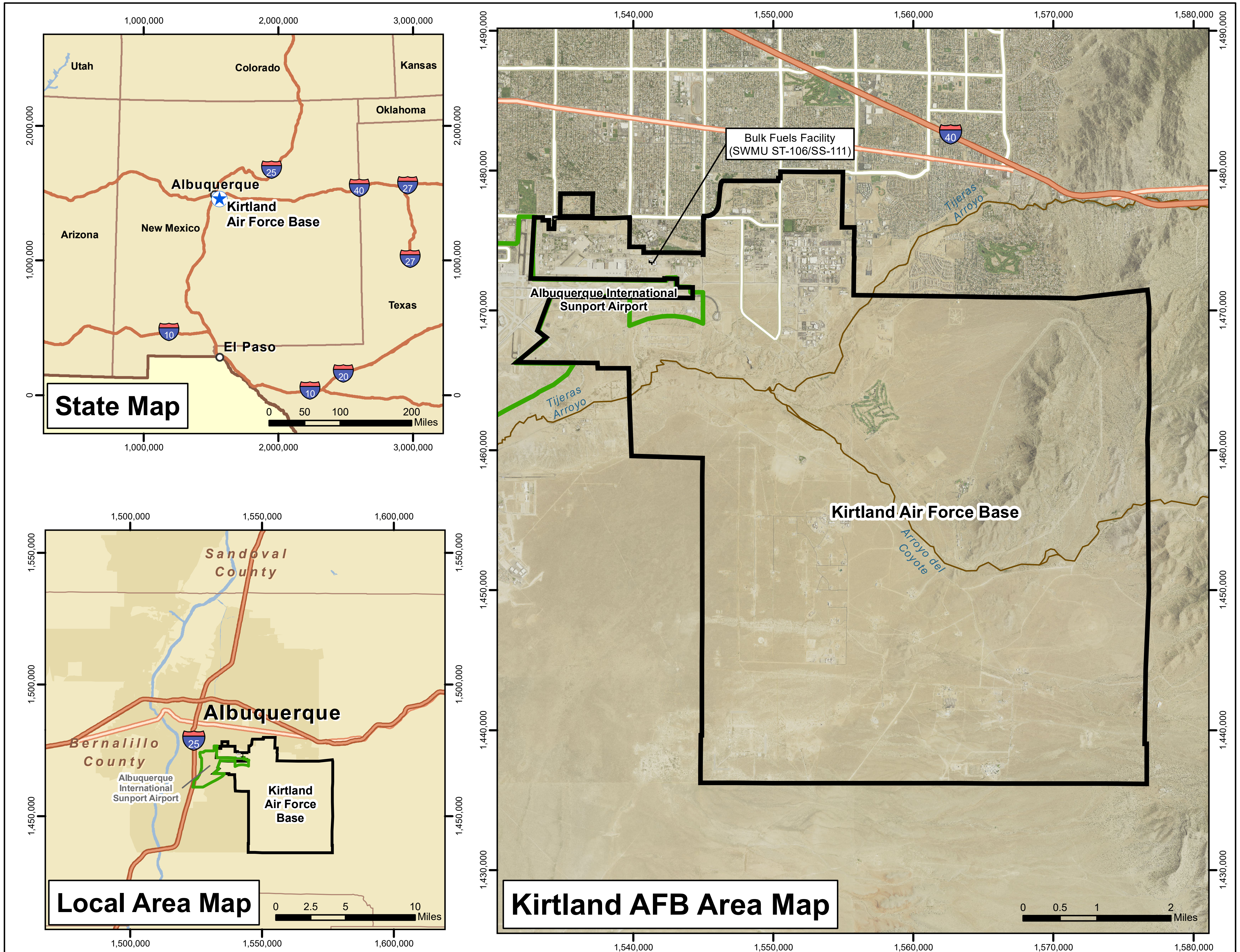
FIGURES



BIOVENTILATION CONSTRUCTION AND INITIATION REPORT
BULK FUELS FACILITY
SOLID WASTE MANAGEMENT UNITS ST-106/SS-111
KIRTLAND AIR FORCE BASE, NEW MEXICO

FIGURE 1-1

SITE LOCATION MAP

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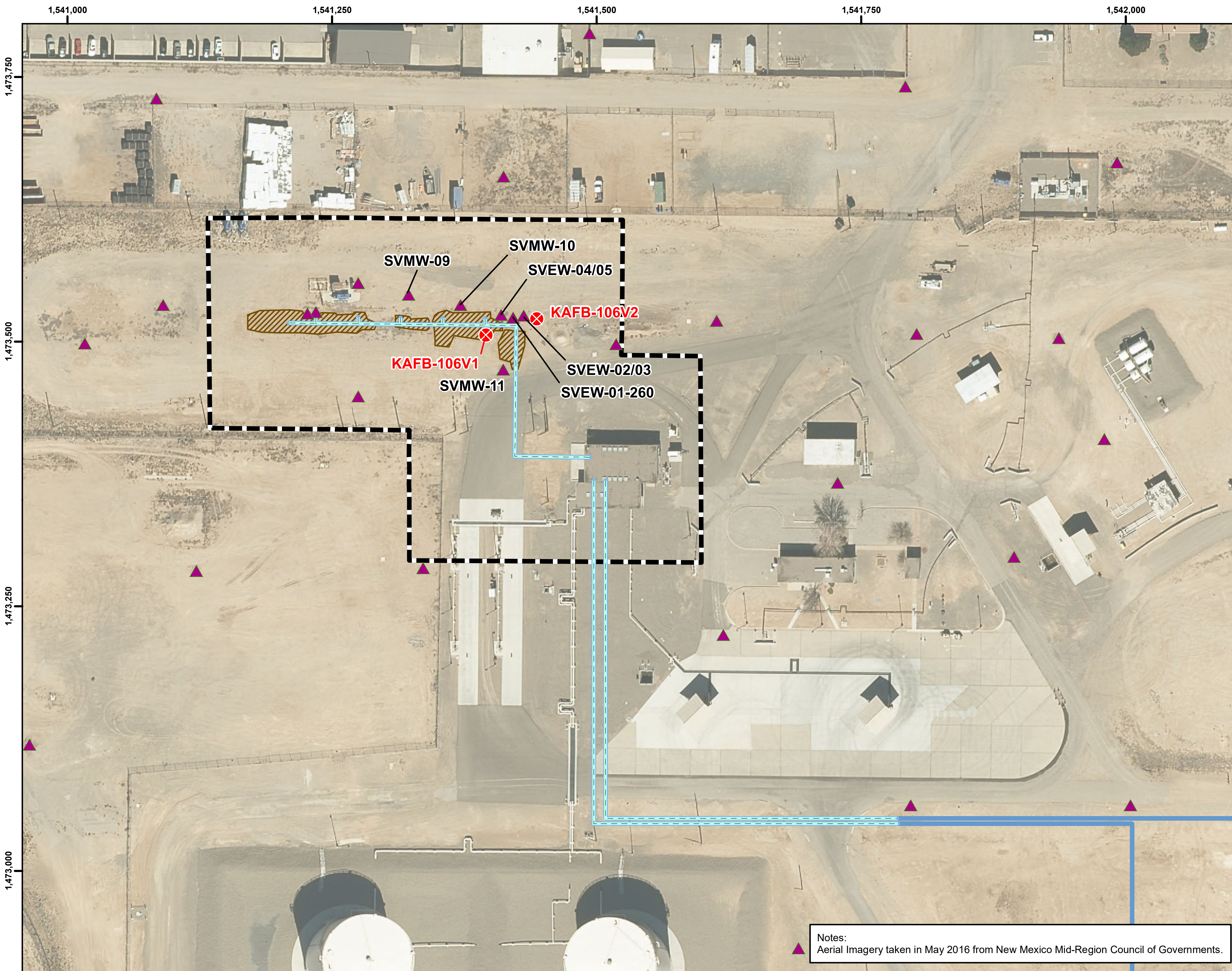
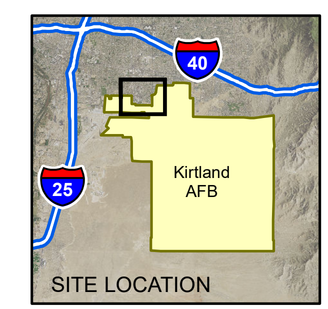


Notes:
Aerial Imagery taken in May 2016 from New Mexico Mid-Region Council of Governments.

Legend

- Existing Soil Vapor Well
- Bioventing Observation Well
- Former Buried Fuel Transfer Line
- Former Aboveground Fuel Transfer Line
- Final Excavation Boundary
- Bulk Fuels Facility (SWMU ST-106/SS-111)



N

0 50 100 200
Feet
1 inch = 100 feet

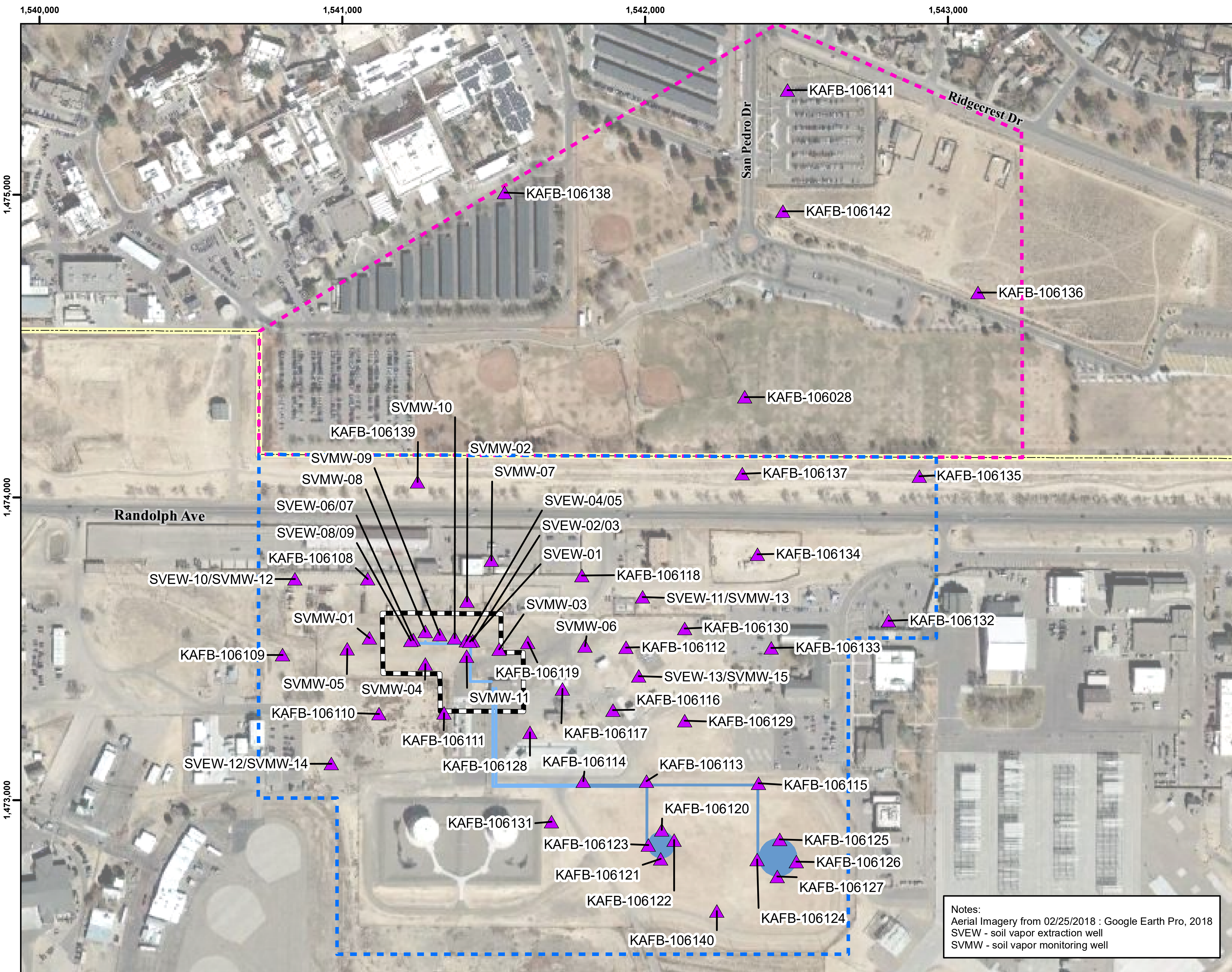
Projection: NAD83 State Plane New Mexico Central FIPS3002 Feet

BIOVENTILATION CONSTRUCTION AND INITIATION REPORT
BULK FUELS FACILITY
SOLID WASTE MANAGEMENT UNITS ST-106/SS-111
KIRTLAND AIR FORCE BASE, NEW MEXICO

FIGURE 1-2

BIOVENTING PILOT TEST AREA

P:\Projects\Kirtland\Figures\Coring Wells\Figure 1-2 Bioventing Pilot Test Area_REV01262021.mxd 1/26/2021 EA ecarpio



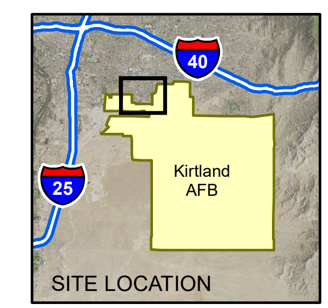
Notes:
Aerial Imagery from 02/25/2018 : Google Earth Pro, 2018
SVEW - soil vapor extraction well
SVMW - soil vapor monitoring well

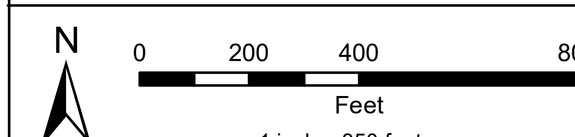
Legend

- Soil Vapor Monitoring Point
- Former Aboveground Storage Tank
- Former Buried Fuel Transfer Line
- Former Aboveground Fuel Transfer Line
- Installation Boundary

Area of Interest

- Off-Base
- On-Base Outside of Source Area
- Source Area





1 inch = 350 feet

Projection: NAD83 State Plane New Mexico Central FIPS3002 Feet

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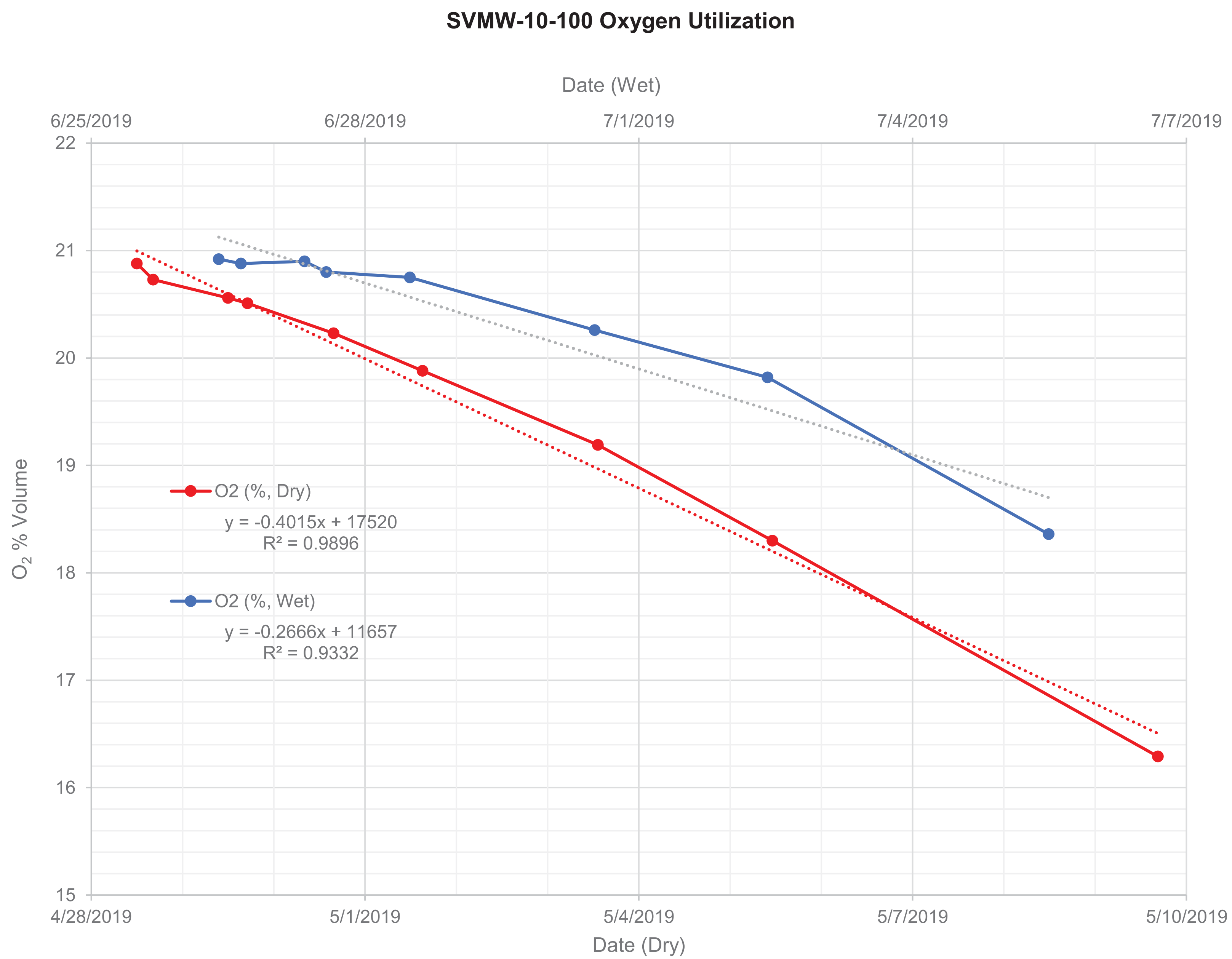
FIGURE 2-1

SOIL VAPOR MONITORING LOCATIONS

\\ABQ\Projects\gis\Projects\Kirtland\Figures\BFF Quarterly Report\2019_Q2\Section 2\2-2 Soil Vapor Monitoring Locations.mxd 7/22/2019 EA ecarpio



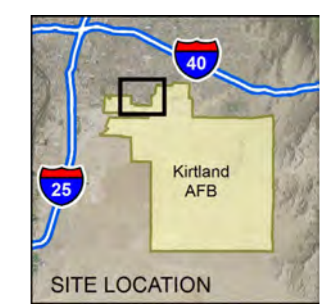


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FIGURE 4-1

SVMW-10-100 OXYGEN UTILIZATION

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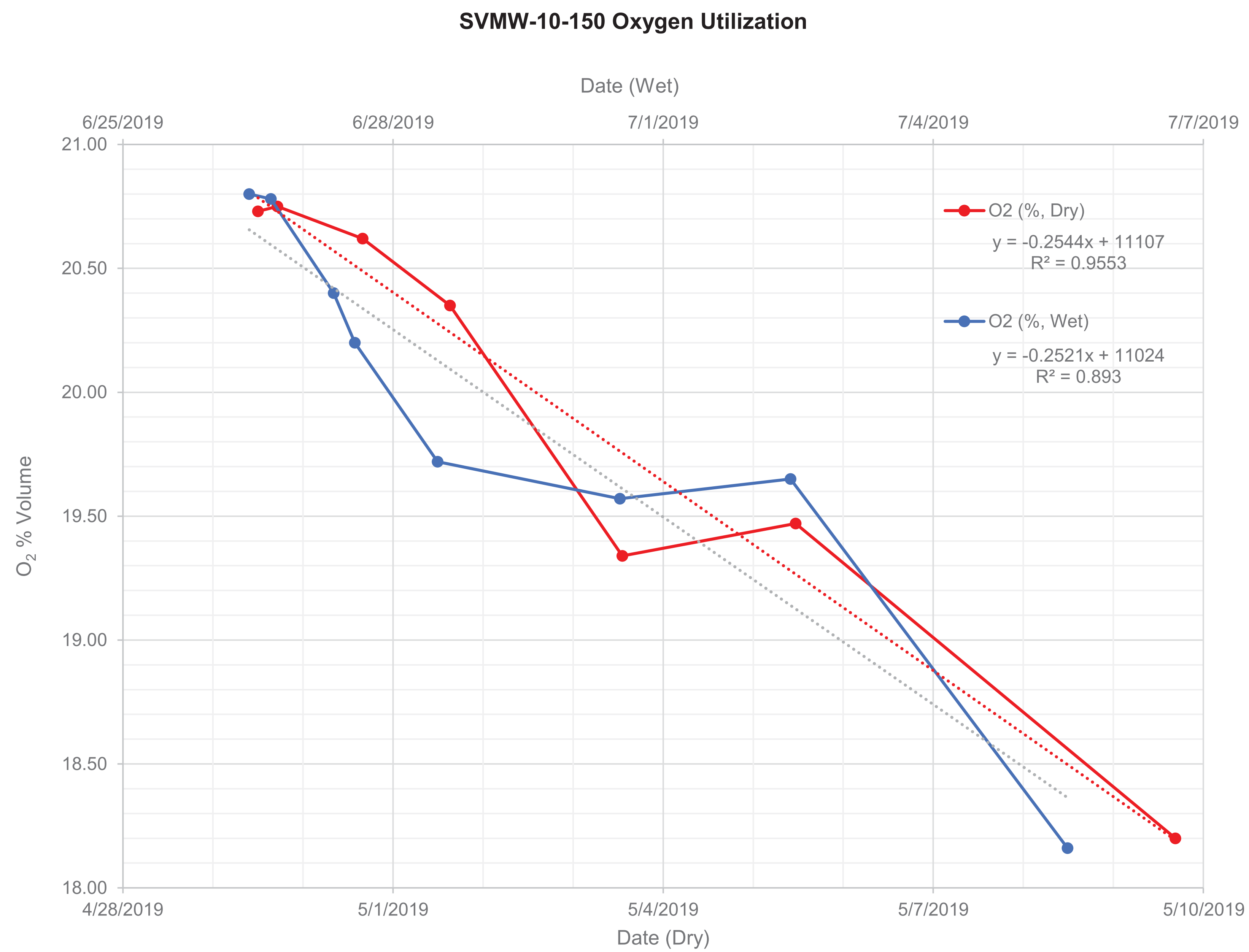

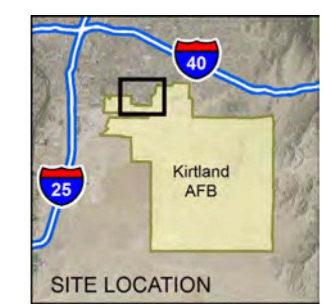

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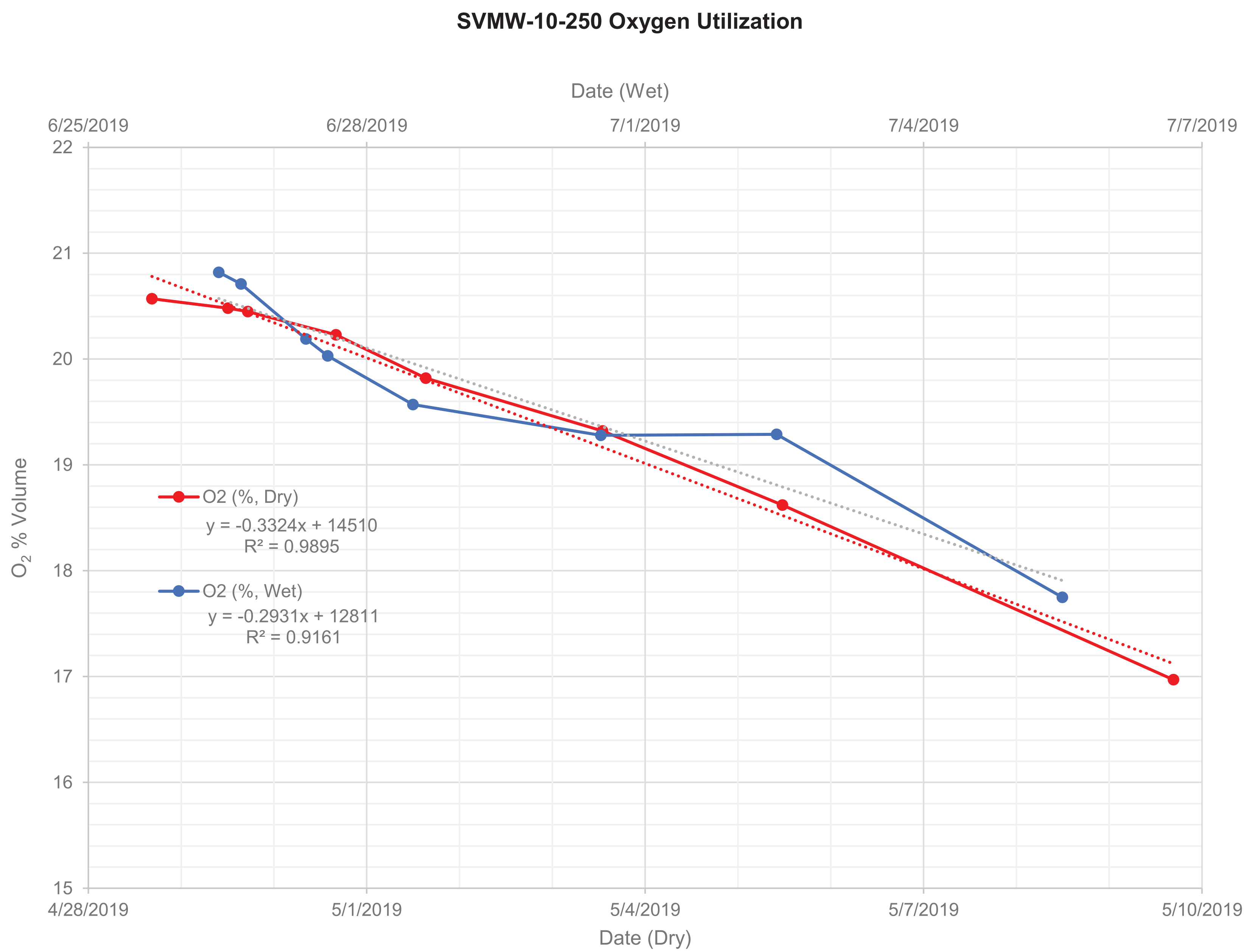
FIGURE 4-2

SVMW-10-150 OXYGEN UTILIZATION



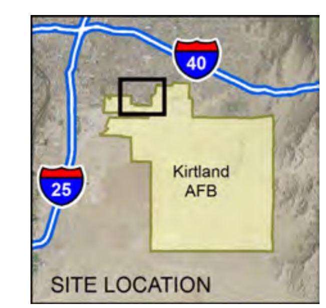


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FIGURE 4-3

SVMW-10-250 OXYGEN UTILIZATION

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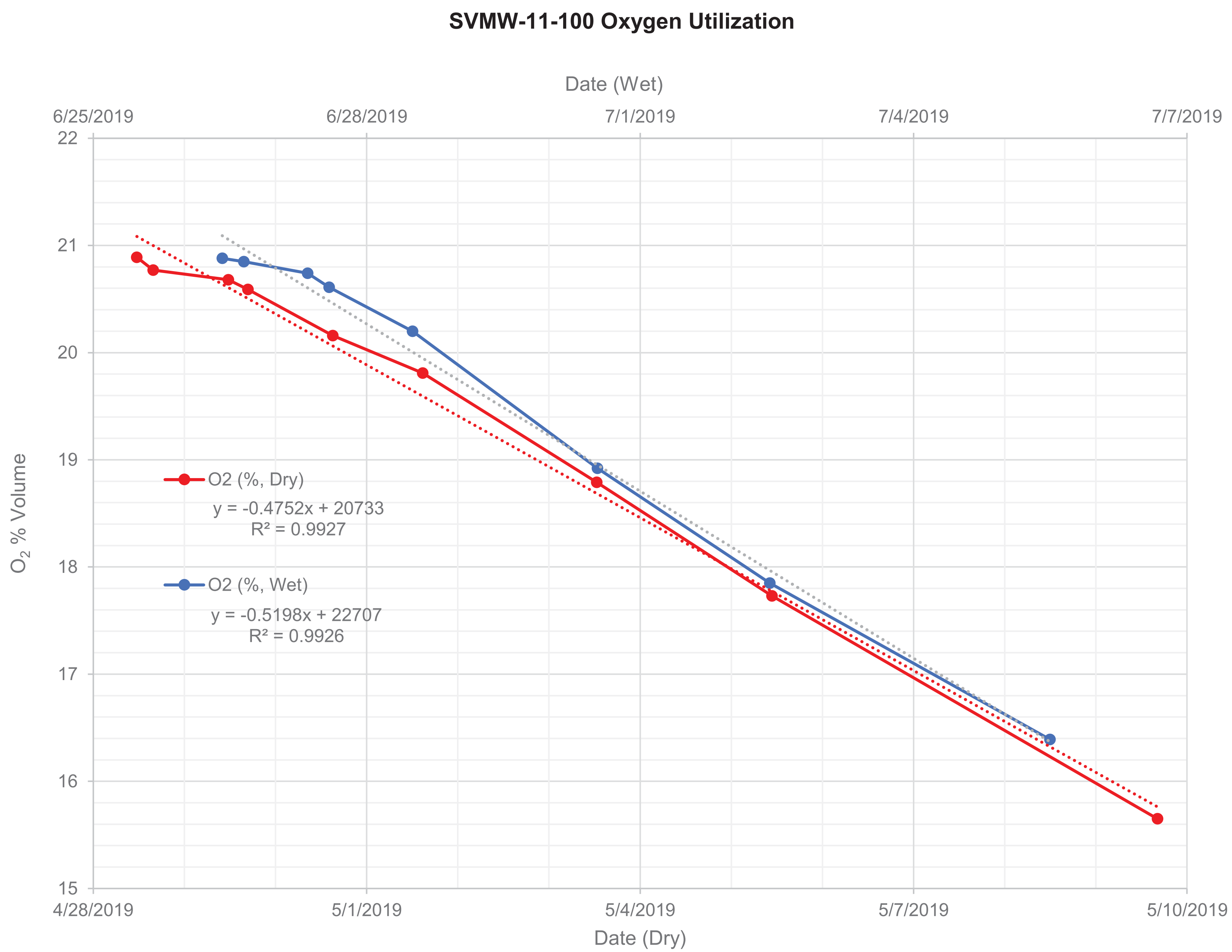

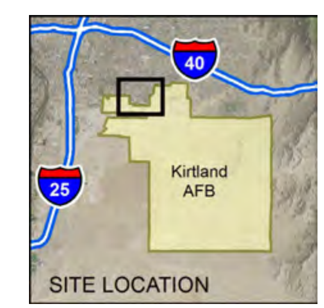

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FIGURE 4-4

SVMW-11-100 OXYGEN UTILIZATION

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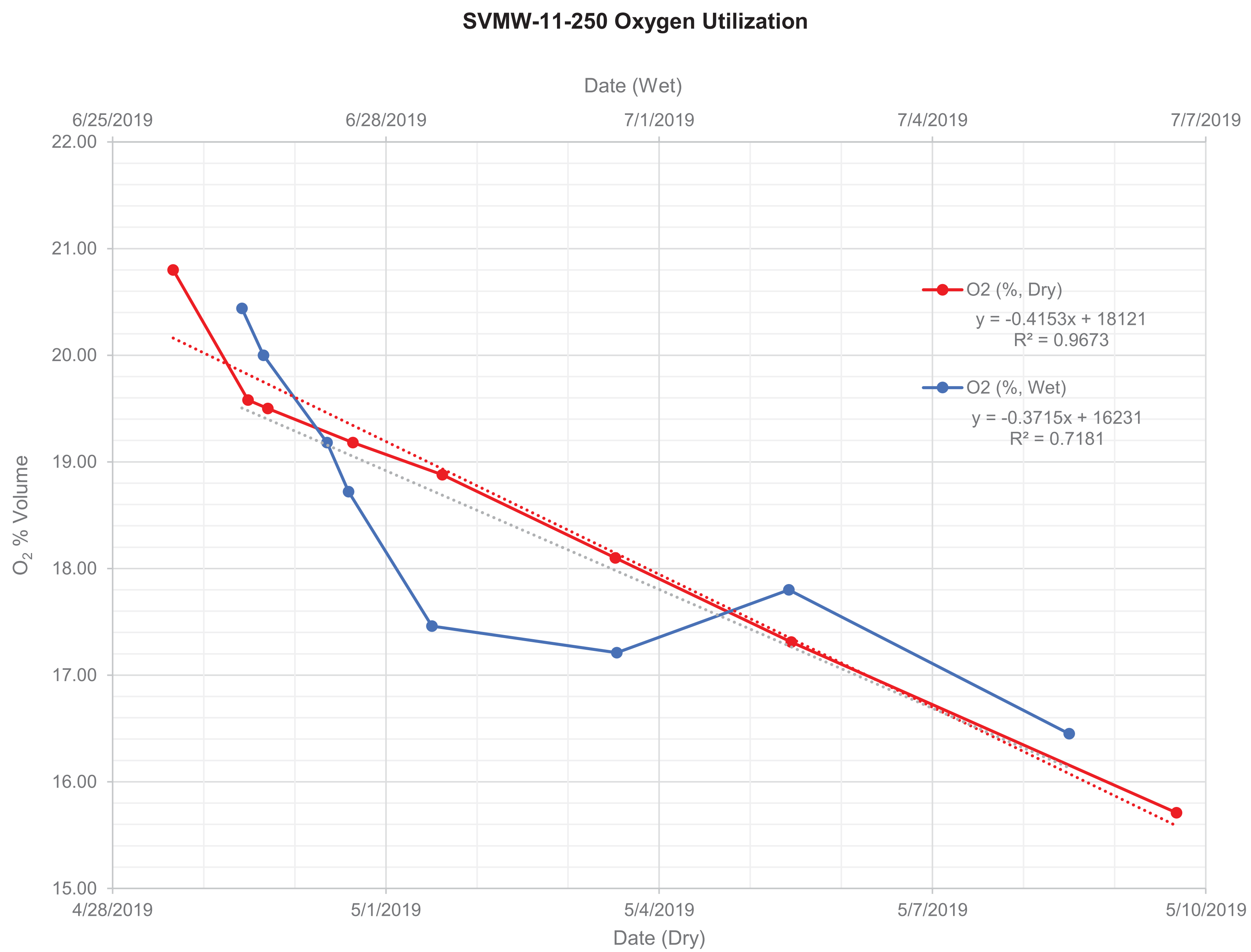

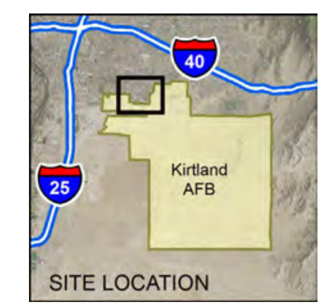

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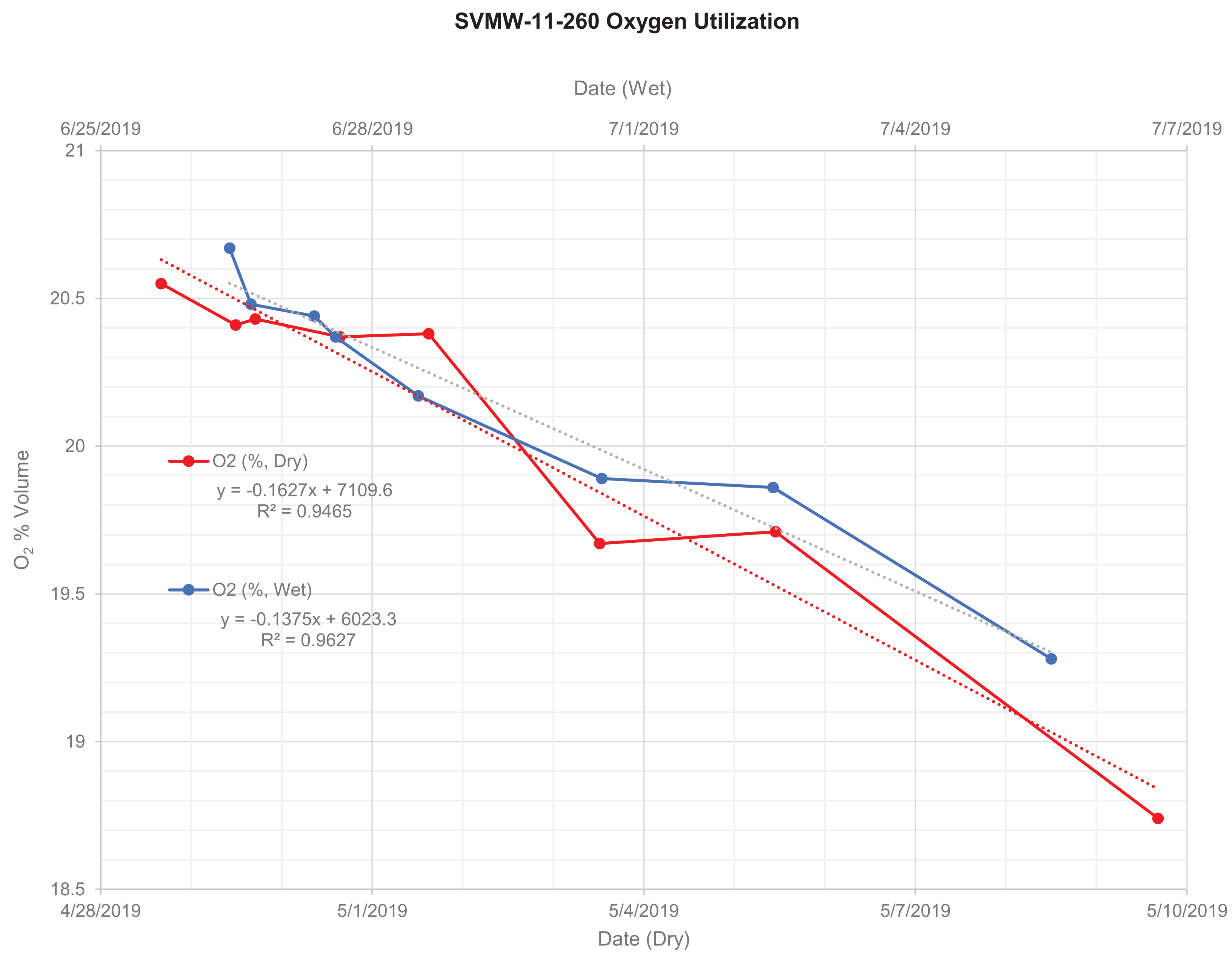
FIGURE 4-5

SVMW-11-250 OXYGEN UTILIZATION

C:\Users\ecarpio\Desktop\WORKING PROJECT FILES\KAFB_BIOVENTING_GRAPHS\D-1_SVMW-11-250.ai



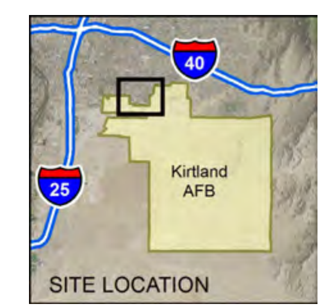


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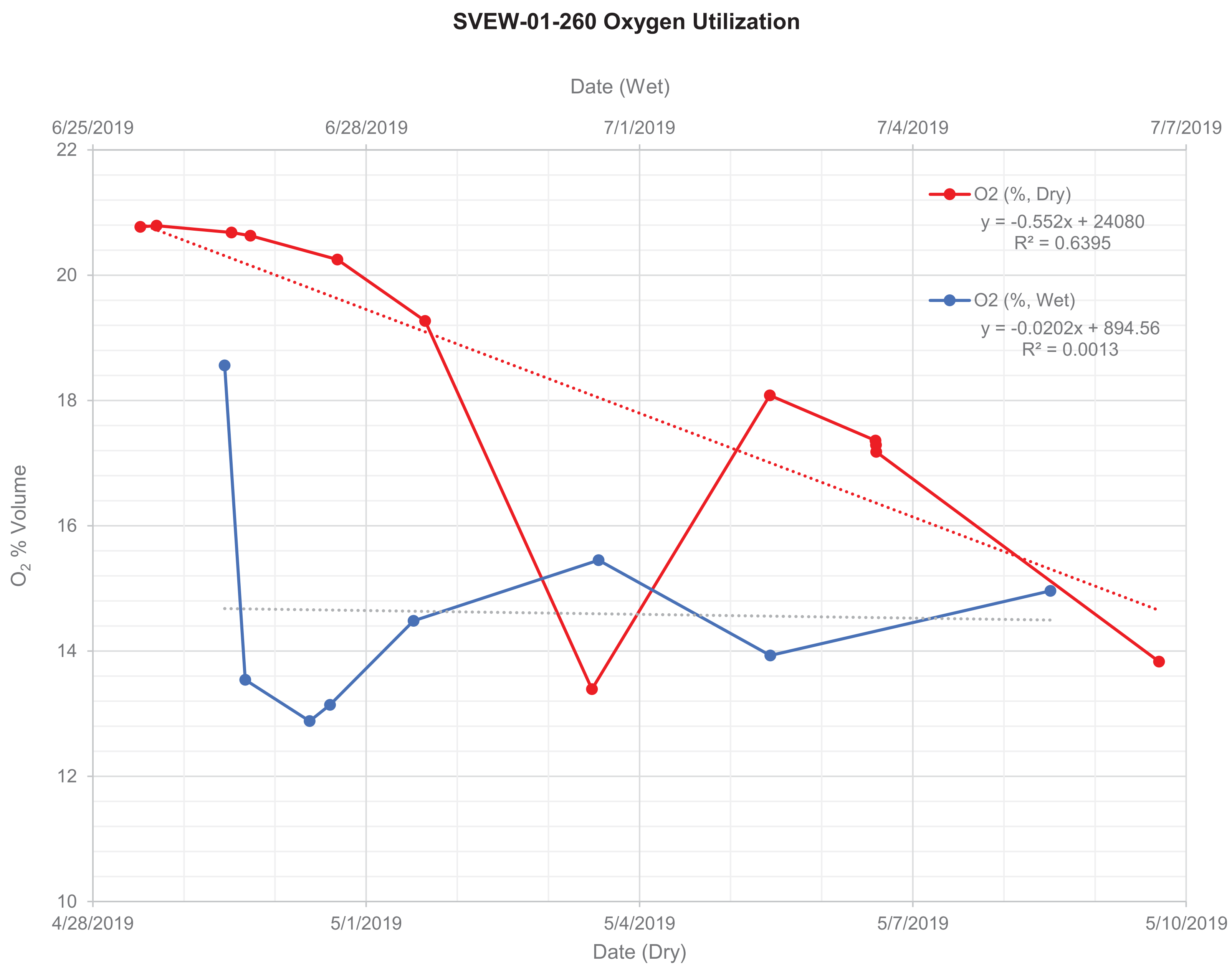
FIGURE 4-6

SVMW-11-260 OXYGEN UTILIZATION

C:\Users\ecarpio\Desktop\WORKING PROJECT FILES\KAFB_BIOVENTING_GRAPHS\D-1_SVMW-11-260.ai



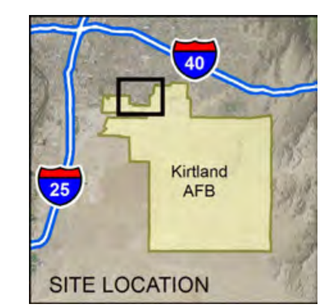


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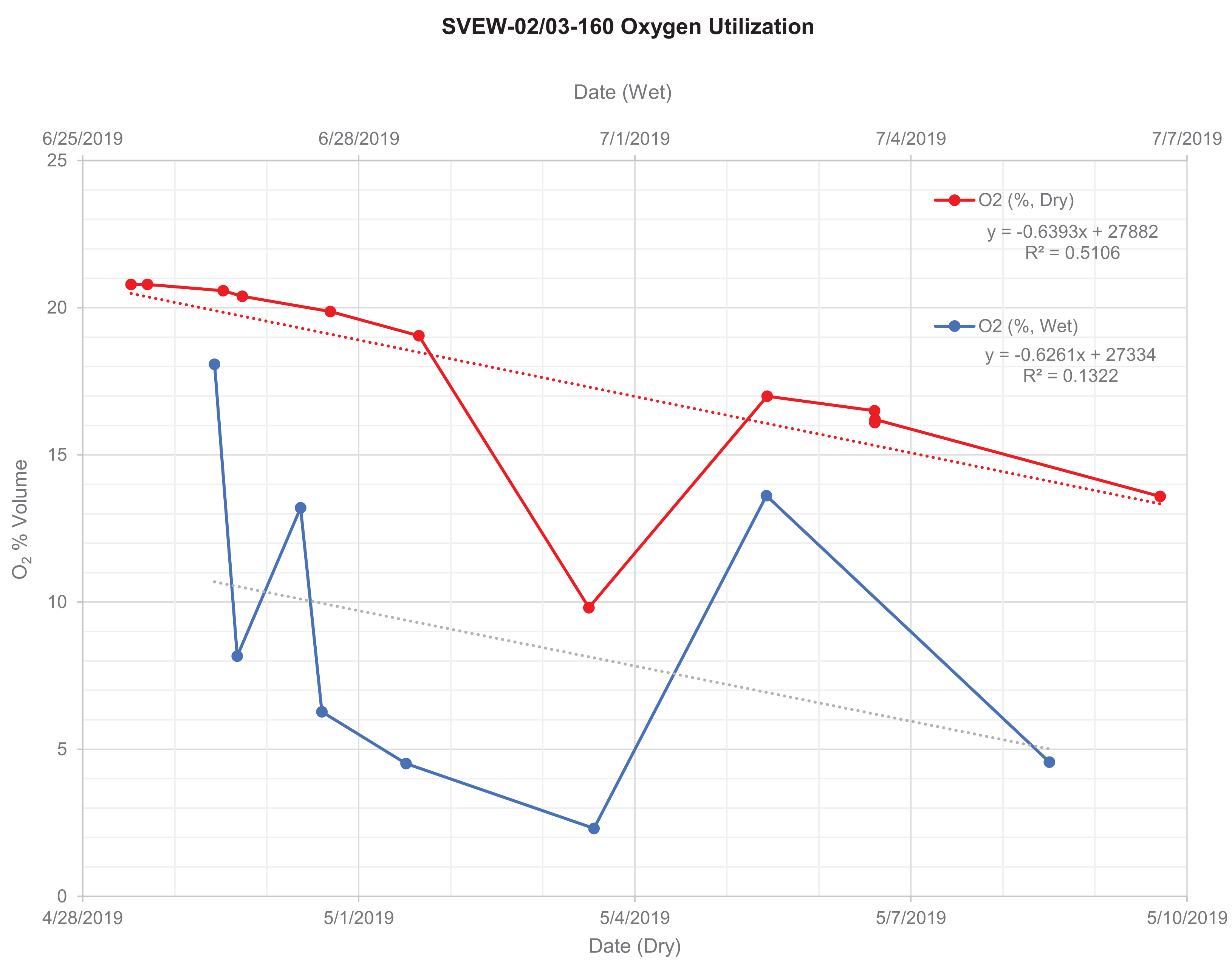
FIGURE 4-7

SVEW-01-260 OXYGEN UTILIZATION



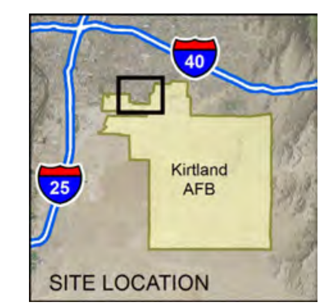


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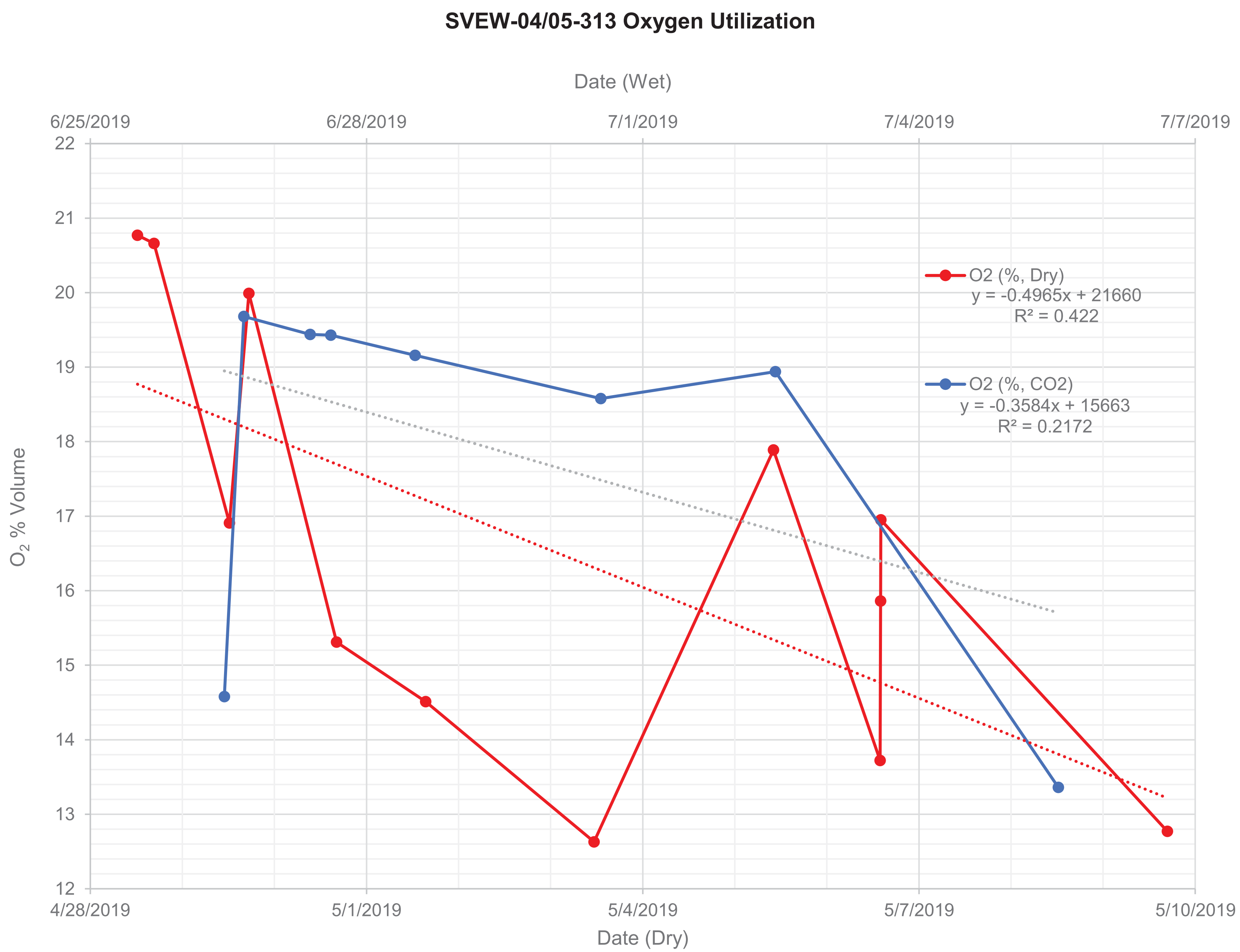
FIGURE 4-8

SVEW-02/03-160 OXYGEN UTILIZATION



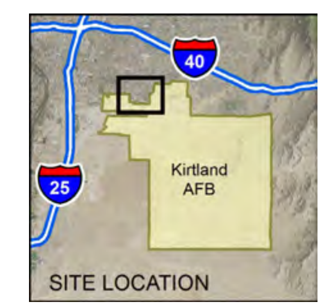


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FIGURE 4-9

SVEW-04/05-313 OXYGEN UTILIZATION

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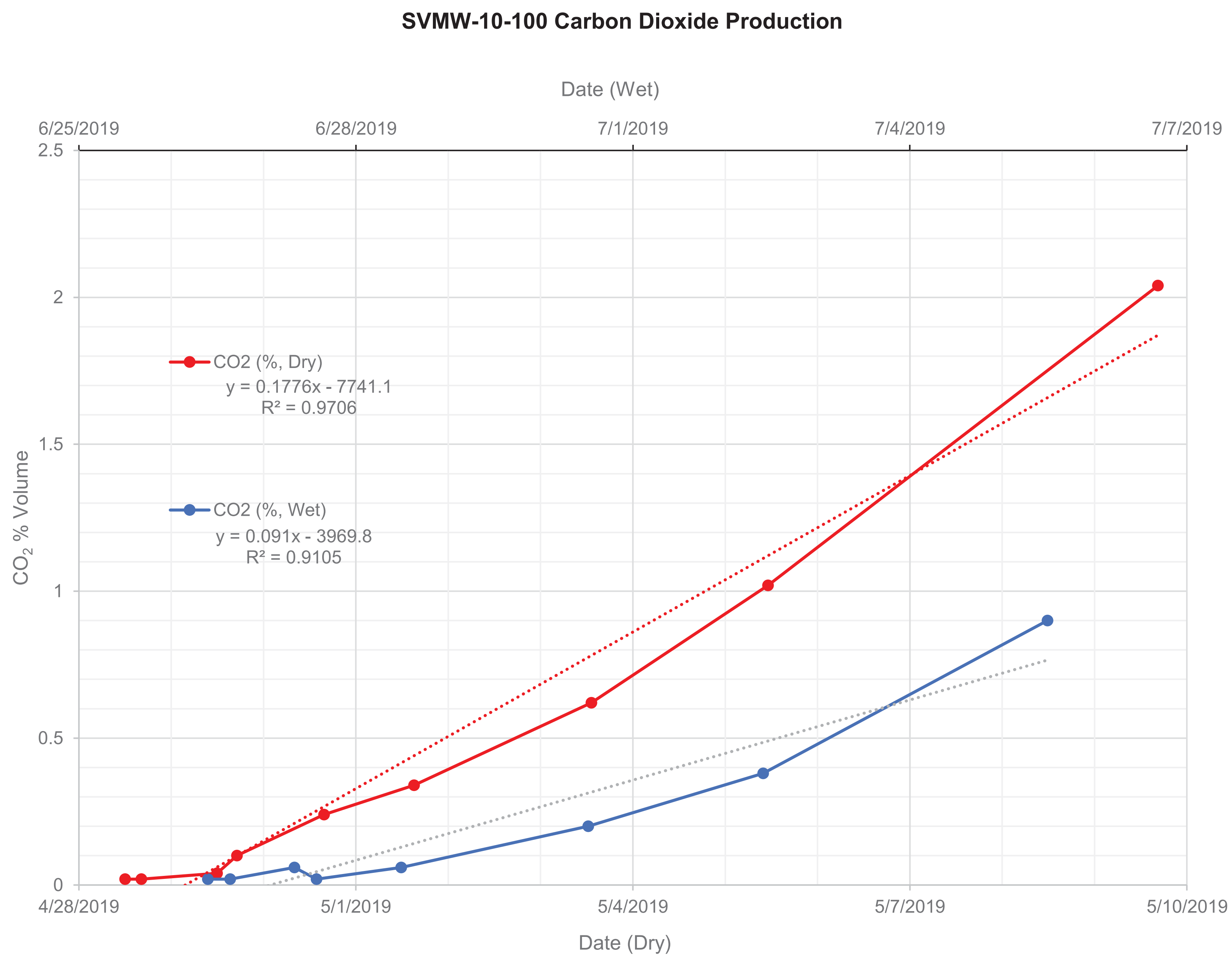

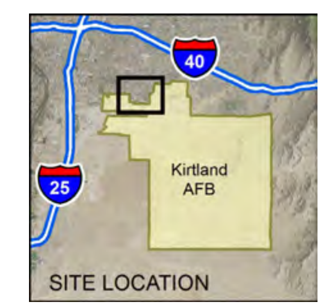

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FIGURE 4-10

SVMW-10-100 CARBON DIOXIDE PRODUCTION

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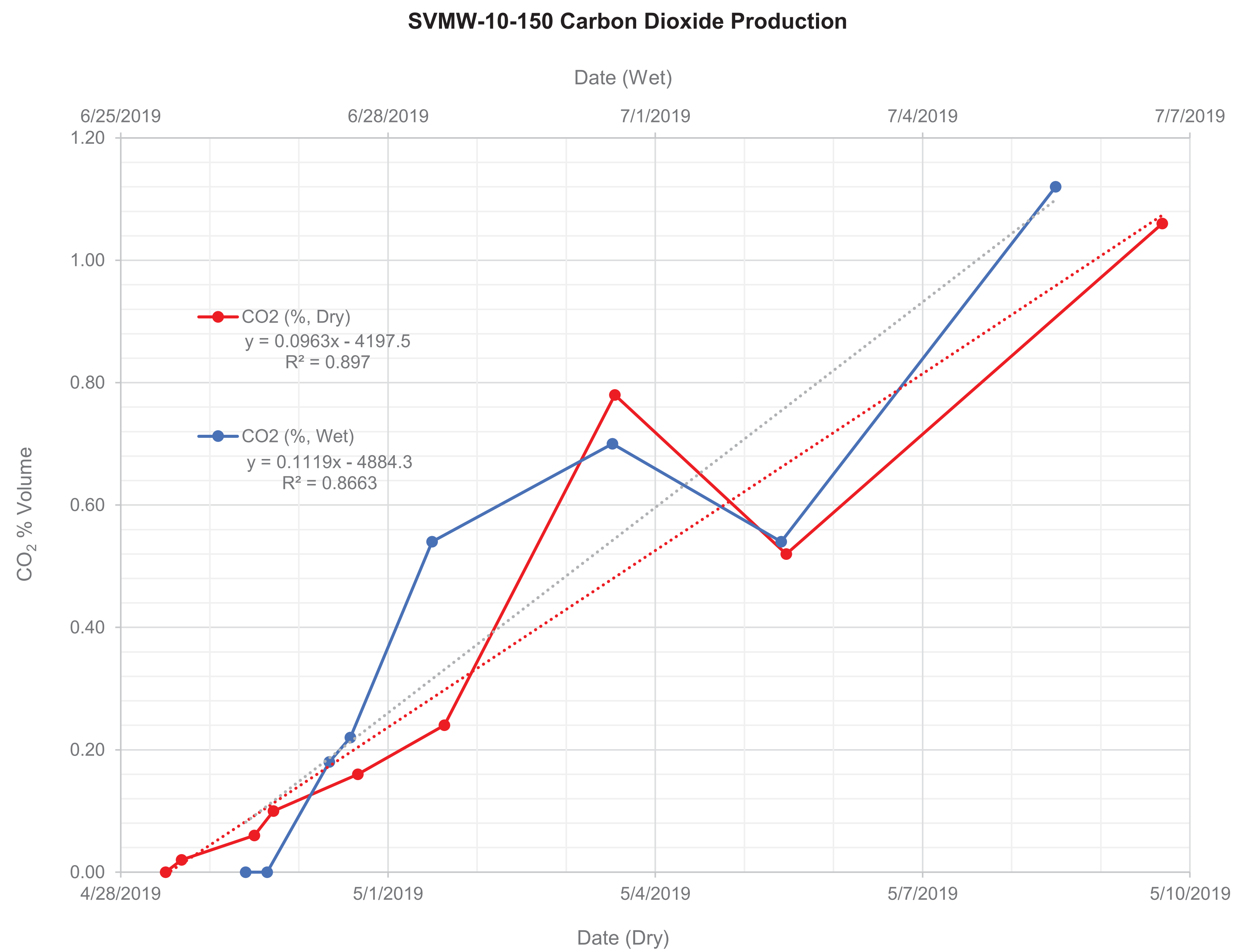

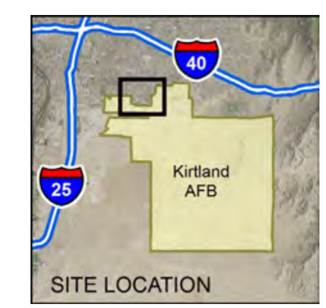

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FIGURE 4-11

SVMW-10-150 CARBON DIOXIDE PRODUCTION

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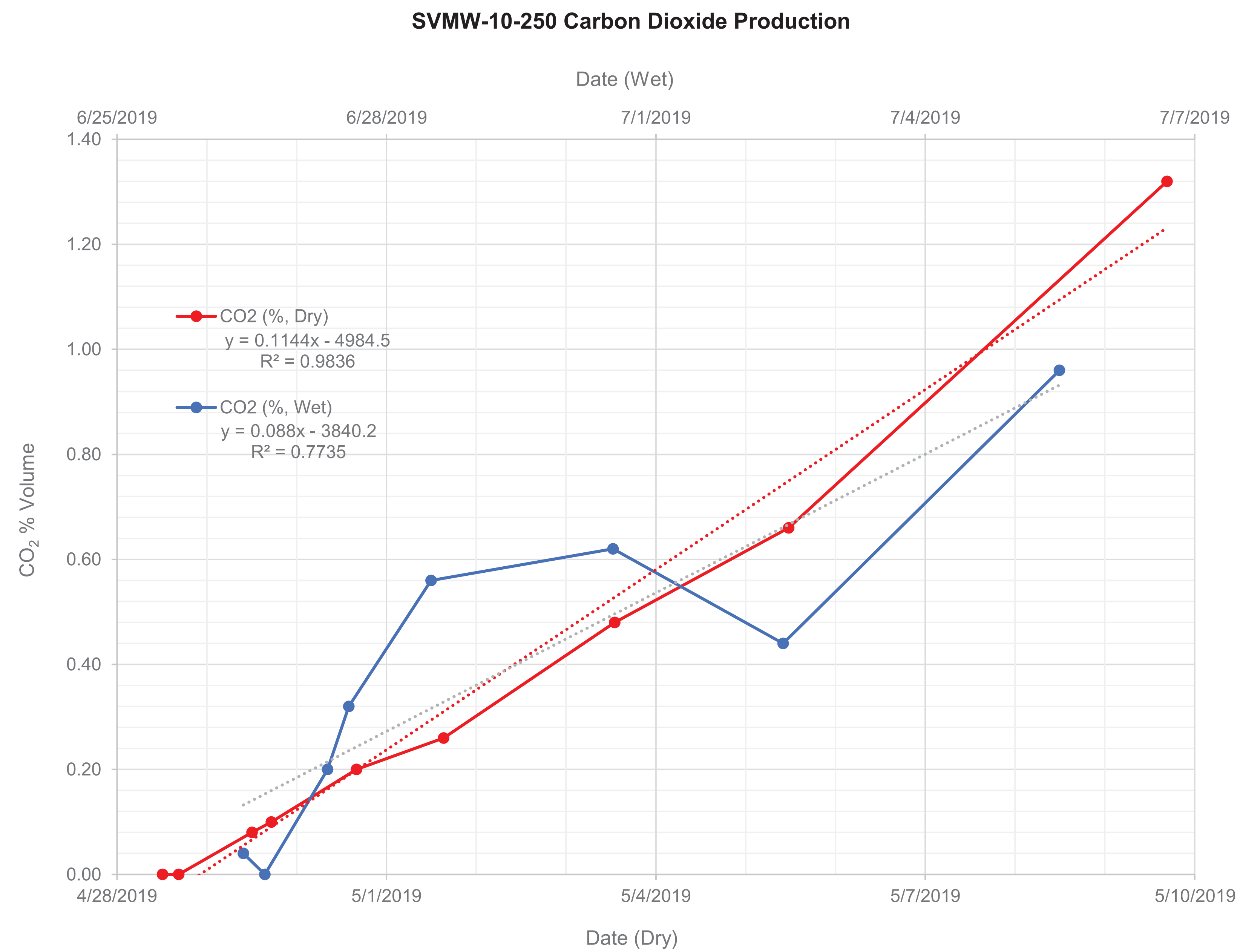

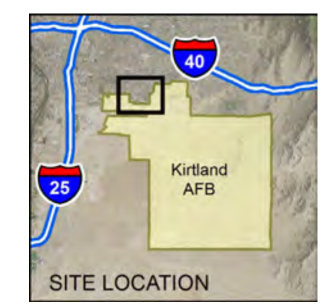

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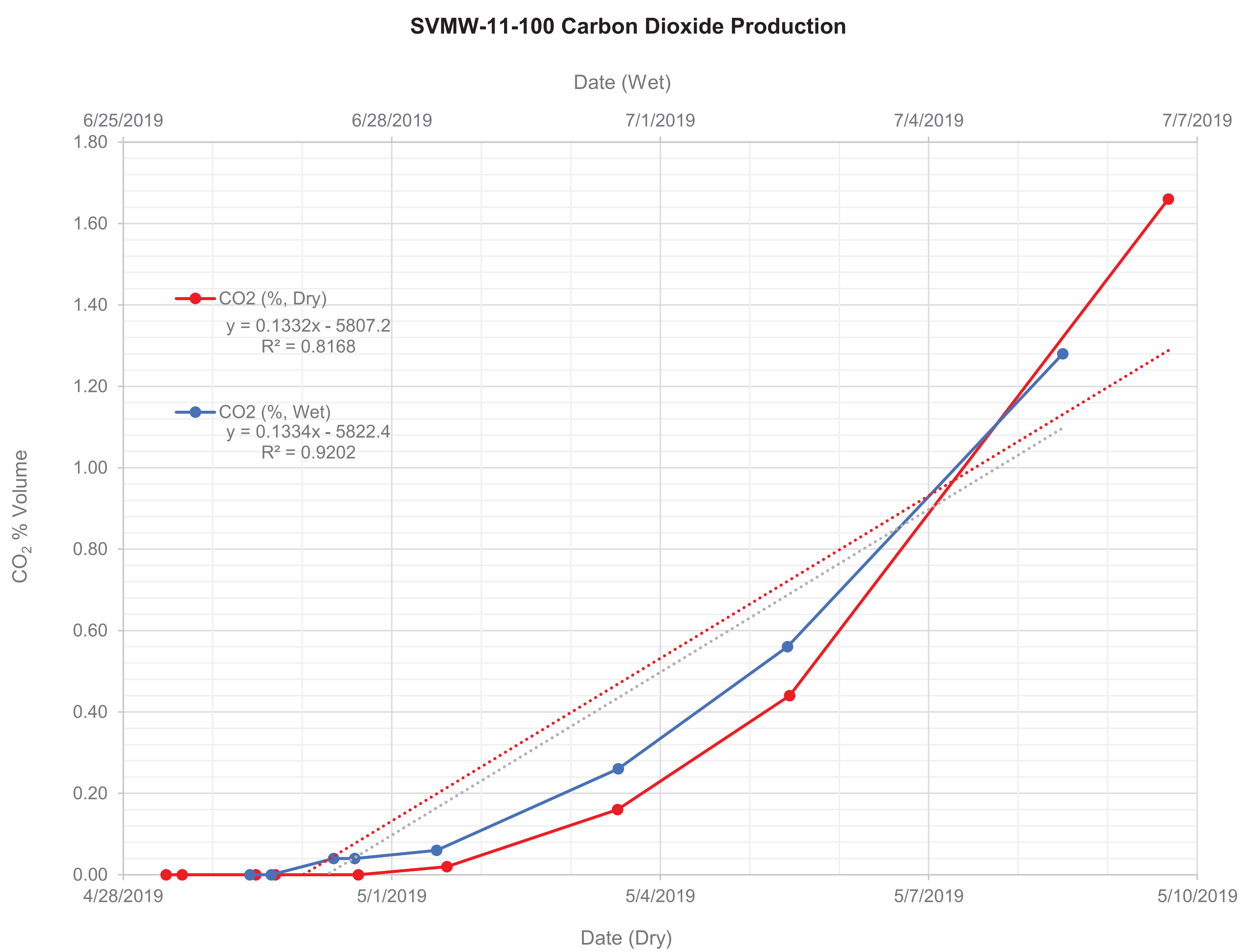
FIGURE 4-12

SVMW-10-250 CARBON DIOXIDE PRODUCTION



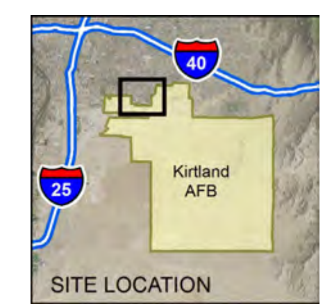


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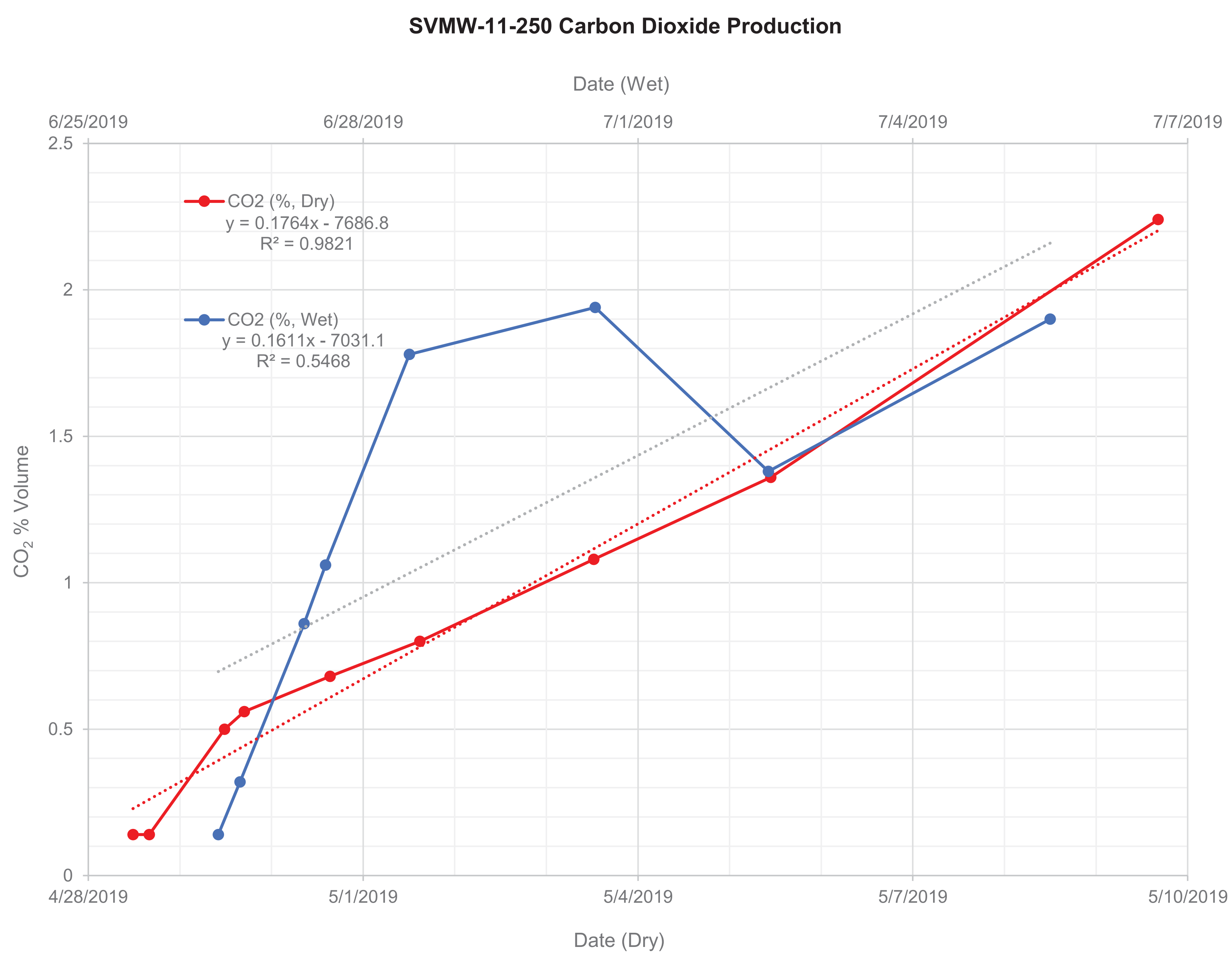
FIGURE 4-13

SVMW-11-100 CARBON DIOXIDE PRODUCTION

C:\Users\ecarpio\Desktop\WORKING PROJECT FILES\KAFB_BIOVENTING_GRAPHS\D-2_SVMW_11-100.ai



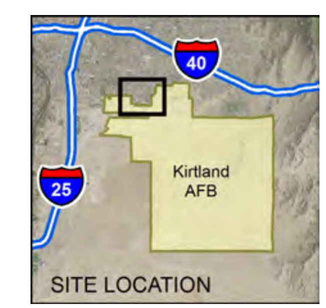


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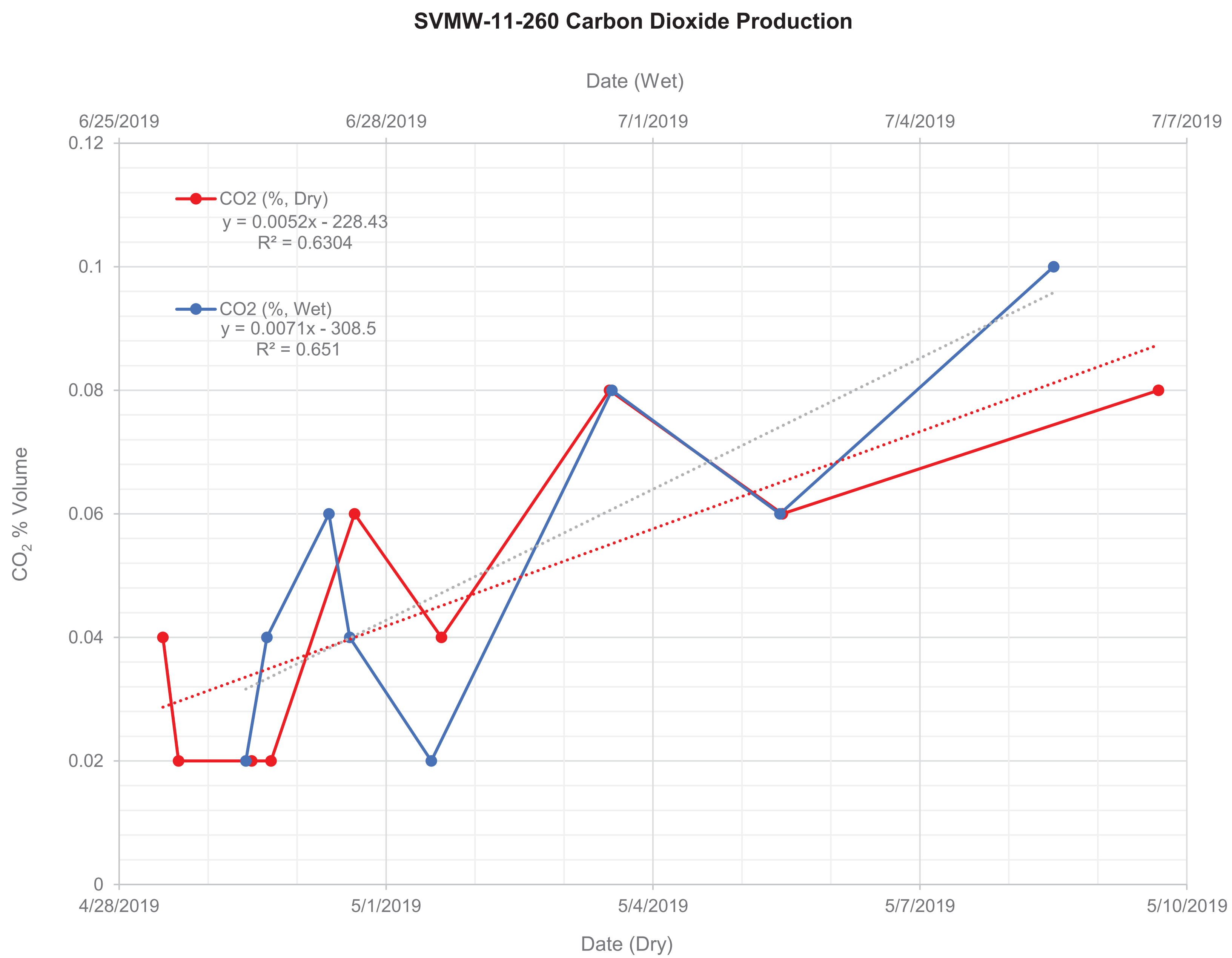
FIGURE 4-14

SVMW-11-250 CARBON DIOXIDE PRODUCTION

C:\Users\ecarpio\Desktop\WORKING PROJECT FILES\KAFB_BIOVENTING_GRAPHS\D-2_SVMW_11-250.ai



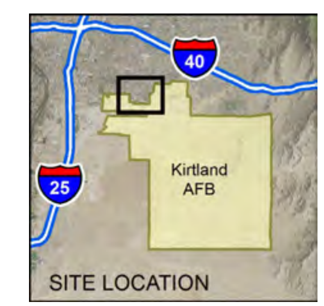


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FIGURE 4-15

SVMW-11-260 CARBON DIOXIDE PRODUCTION

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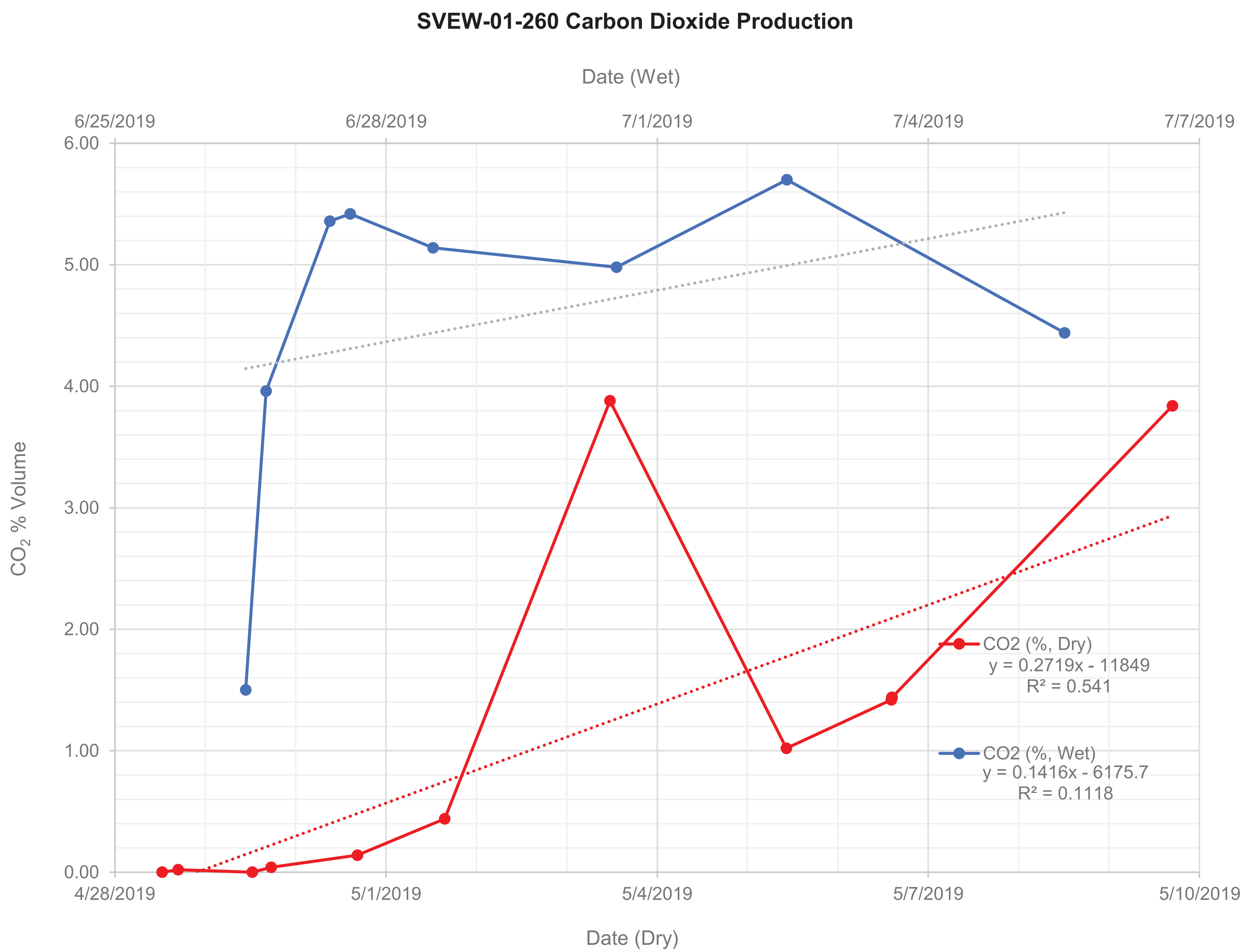

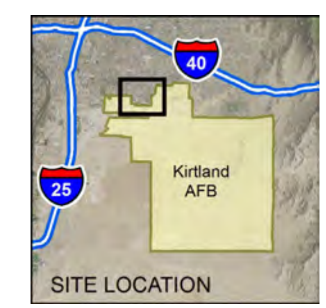

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FIGURE 4-16

SVEW-01-260 CARBON DIOXIDE PRODUCTION

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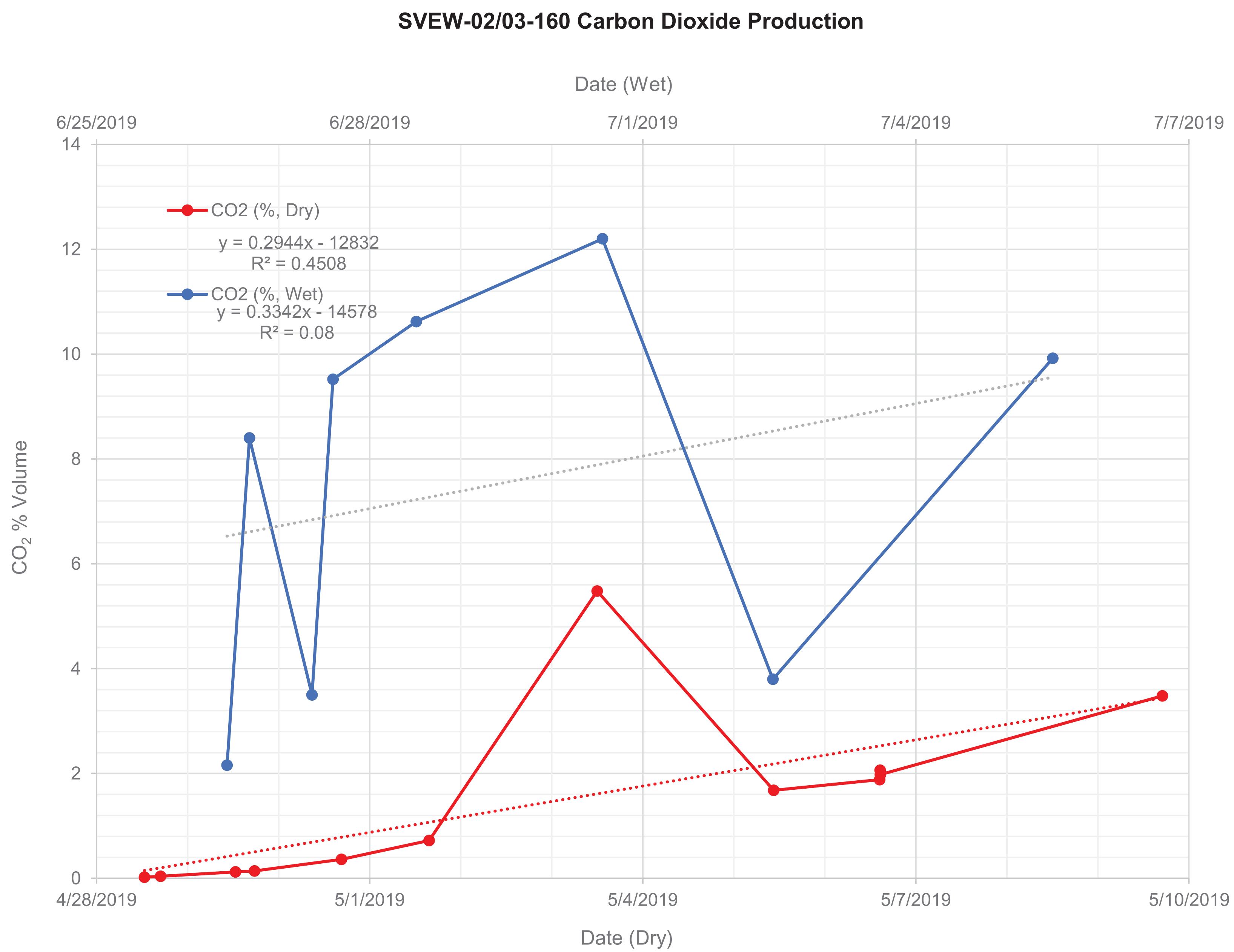

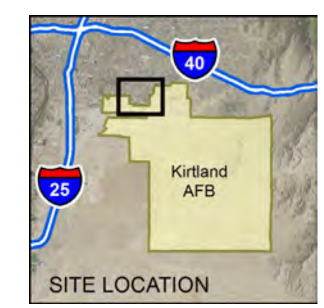

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FIGURE 4-17

SVEW-02/03-160 CARBON DIOXIDE PRODUCTION

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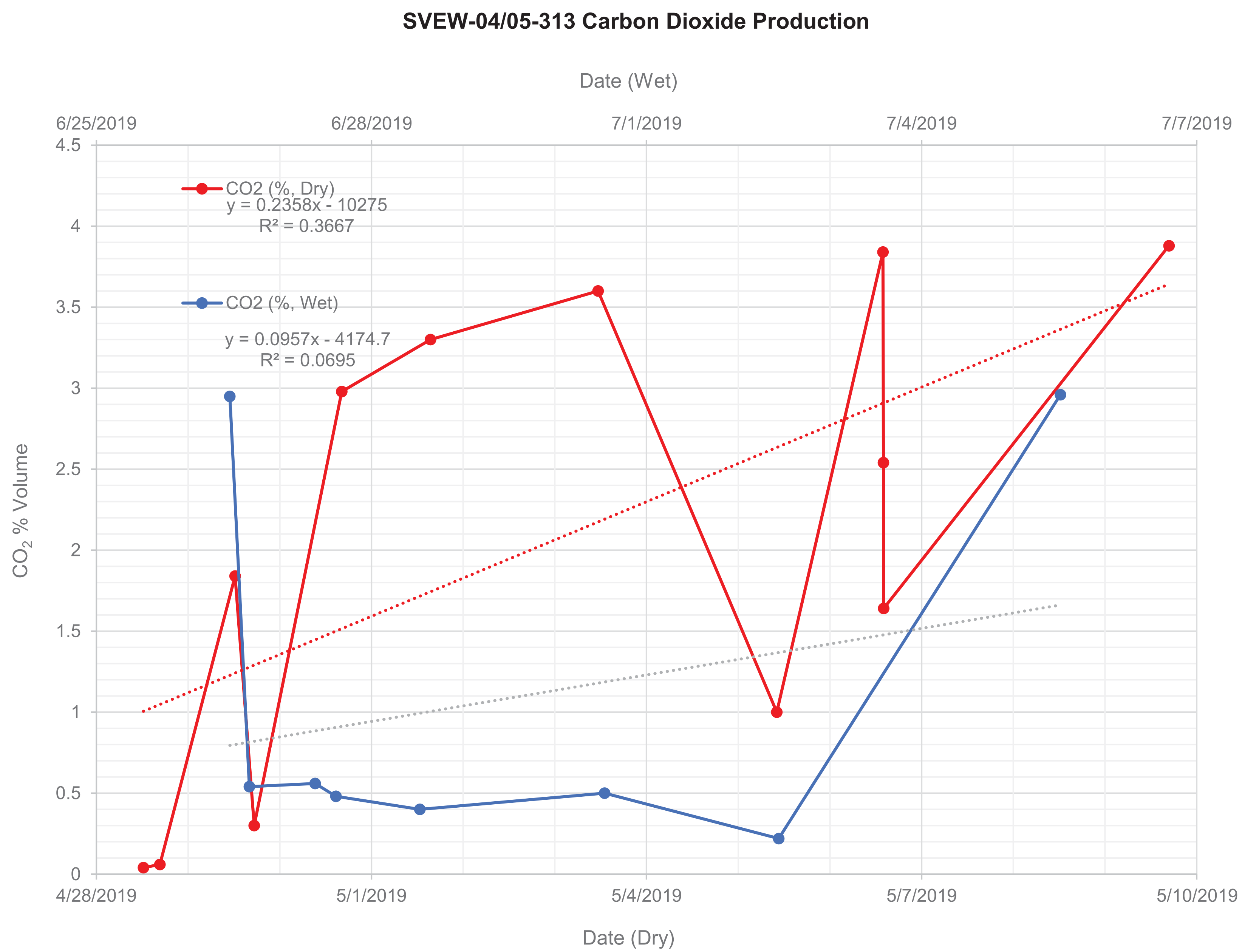

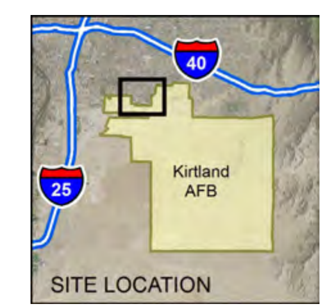

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FIGURE 4-18

SVEW-04/05-313 CARBON DIOXIDE PRODUCTION

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TABLES

Table 1-1
Bioventing Respiration Pilot Test Well Details and Function

Well ID	Screened Interval (ft bgs)	Diameter (inches)	USCS Soil Classification	Status	Well Use	Applicable Tests[a]	Attendant Observation Wells[b]	Radial Distance between Observation and Injection Well (ft)
SVMW-11-100	100-102.5	0.5	SP	Existing	Air Injection	"Dry" Respiration "Wet" Respiration Long-Term Bioventing	KAFB-106V1-102	36
							KAFB-106V2-102	57
SVMW-11-250	250-252.5	0.5	SP	Existing	Air Injection	"Dry" Respiration "Wet" Respiration Long-Term Bioventing	KAFB-106V1-252	36
							KAFB-106V2-252	57
SVMW-11-260	260-262.5	0.5	SP	Existing	Air Injection	"Dry" Respiration "Wet" Respiration Long-Term Bioventing	KAFB-106V1-252	36
							KAFB-106V2-252	57
SVEW-01-260	245-260	4	SP	Existing	Air Injection	"Dry" Respiration "Wet" Respiration Long-Term Bioventing	KAFB-106V2-252	31
							KAFB-106V1-252	22
SVMW-10-100	100-102.5	0.5	SW	Existing	Air Injection	"Dry" Respiration "Wet" Respiration Long-Term Bioventing	KAFB-106V1-102	37
							KAFB-106V2-102	73
SVMW-10-150	150-152.5	0.5	SW	Existing	Air Injection	"Dry" Respiration "Wet" Respiration Long-Term Bioventing	KAFB-106V1-160	37
							KAFB-106V2-160	73
SVMW-10-250	250-252.5	0.5	SP	Existing	Air Injection	"Dry" Respiration "Moist" Respiration Long-Term Bioventing	KAFB-106V1-252	37
							KAFB-106V2-252	73

Table 1-1
Bioventing Respiration Pilot Test Well Details and Function

Well ID	Screened Interval (ft bgs)	Diameter (inches)	USCS Soil Classification	Status	Well Use	Applicable Tests[a]	Attendant Observation Wells[b]	Radial Distance between Observation and Injection Well (ft)
SVEW-02/03-160	145-160	2	SP	Existing	Air Injection	"Dry" Respiration "Moist" Respiration Long-Term Bioventing	KAFB-106V2-160	41
							KAFB-106V1-160	13
SVEW-04/05-313	298-313	2	SW	Existing	Air Injection	"Dry" Respiration "Wet" Respiration Long-Term Bioventing	KAFB-106V1-263	24
							KAFB-106V2-270	34
KAFB-106V1	100.1-102.1	0.75	SP	Existing	Observation	Long-Term Bioventing	NA	NA
	110.6-112.6	0.75	SW/SC				NA	NA
	157.6-159.6	0.75	SP				NA	NA
	215.1-217.1	0.75	SP/SW				NA	NA
	250.1-252.1	0.75	SP				NA	NA
	260.6-262.6	0.75	SP				NA	NA
KAFB-106V2	100.2-102.2	0.75	SP	Existing	Observation	Long-Term Bioventing	NA	NA
	115.1-117.1	0.75	ML/CL				NA	NA
	157.9-159.9	0.75	SM/SW				NA	NA
	215.1-217.1	0.75	SP				NA	NA
	250.2-252.2	0.75	SP				NA	NA
	267.55-269.55	0.75	SW/CL				NA	NA

[a] Three types of treatability tests will be conducted: (1) single well "push-pull" respiration ***without*** moisture addition, (2) single well "push-pull" respiration
[b] Observation wells will be used during respiration tests for pressure measurements and physical radius of influence only. During the long-term bioventing
bgs = below ground surface
ft = foot/feet
ID = identification
NA = not applicable
USCS = unified soil classification system

Table 3-1
Bioventing Respiration Pilot Testing Field Measurement Equipment and Regimen

Parameter	Field Measurement	Media	Instrument[a]	Range/ Tolerance	Data Use	Respiration Test Frequency[b]	Long-Term Test Frequency[c]
Water Activity	Relative Humidity	Soil gas	Amprobe TH-3	0-100 % ± 3% R.H. at 23°C[d]	Determine relative humidity	Daily for first 3 days; days 5 and 7; biweekly thereafter	Daily for first 3 days; weekly for first month; quarterly thereafter
Pressure/ Vacuum	Injection/ Extraction Pressure	Vadose zone	Dwyer 477-A7	0.05 inches water column	Evaluate pressure	Daily for first 3 days; days 5 and 7; biweekly thereafter	Daily for first 3 days; weekly for first month; quarterly thereafter
Carbon Dioxide	Concentration in percent	Soil gas	Horiba	0-30% ± 0.3% by volume	Evaluate contaminant destruction rate	Daily for first 3 days; days 5 and 7; biweekly thereafter	Daily for first 3 days; weekly for first month; quarterly thereafter
Oxygen	Concentration in percent	Soil gas	Horiba	0-30% ± 0.1% by volume	Evaluate contaminant destruction rate	Daily for first 3 days; days 5 and 7; biweekly thereafter	Daily for first 3 days; weekly for first month; quarterly thereafter
Total Petroleum Hydrocarbons	Concentration in parts per million	Soil gas	Horiba	0-10,000 ppmv ± 10 ppmv	Evaluate soil vapor hydrocarbons	Daily for first 3 days; days 5 and 7; biweekly thereafter	Daily for first 3 days; weekly for first month; monthly thereafter
Methane	Concentration in percent	Soil gas	Landtec GEM 5000	0-5% ±0.3% by volume	Evaluate contaminant destruction rate	Daily for first 3 days; days 5 and 7; biweekly thereafter	NA
Flow Rate	Rotameter	Soil gas	Brooks 2520A4A37BNBN	0.3-3 scfm	Verify injection/purge rates	Daily for first 3 days; days 5 and 7; biweekly thereafter	Daily for first 3 days; weekly for first month; quarterly thereafter
Temperature	Temperature	Soil gas	Amprobe TH-3	-20-60°C ± 0.8°C	Evaluate temperature	Daily for first 3 days; days 5 and 7; biweekly thereafter	Daily for first 3 days; weekly for first month; quarterly thereafter

[a] The instrument may be substituted for an engineer approved equivalent.

[b] Schedule may be adjusted based on observed oxygen utilization rates; the goal is 5-10 data points in the early linear portion of the oxygen decay curve.

[c] Schedule may be adjusted based on observed oxygen utilization rates in short-term respiration tests.

[d] This range and tolerance are based on instrument performance. Due to temperature variation and condensation, the actual field measurements will be less accurate. Test will be terminated when oxygen percent measurements have five linear points and/or oxygen is less than 5%.

% = percent
° C = degree Celsius
ppmv = part per million (by volume)
R.H. = relative humidity
scfm = standard cubic feet per minute

Table 3-2
SVMW-10-100 Respiration Monitoring

Date and Time	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry										
4/11/2019 13:46	1	15.1	28,990	69.5	58.1	52	23.34	0.95	11.00	0.0
Dry Respirometry										
Post-Injection										
4/28/2019 11:59	2	65.2	10	9.2	80.5	72	24.6	20.88	0.02	0.0
4/28/2019 16:15	2	143	76	5.8	85.0	83	24.52	20.73	0.02	0.0
4/29/2019 11:56	2	58.8	355	18.4	77.3	72	24.62	20.56	0.04	0.0
4/29/2019 17:05	2	55.6	556	23.6	73.8	73	24.52	20.51	0.10	0.0
4/30/2019 15:44	2	63.1	966	27.1	73.5	72	24.55	20.23	0.24	0.0
5/1/2019 15:06	2	49.0	1,486	27.8	81.8	74	24.60	19.88	0.34	0.0
5/3/2019 13:13	2	49.1	2,190	36.8	77.4	70	24.70	19.19	0.62	0.0
5/5/2019 11:08	2	48.0	3,500	42.1	77.1	72	24.64	18.30	1.02	0.0
5/9/2019 16:30	2	61.4	5,660	48.7	70.0	64	24.56	16.29	2.04	0.0
Wet Respirometry										
Pre-Injection										
6/20/2019 9:40	2	51.7	18,530	43.1	83.5	77	24.68	6.62	7.52	0.0
Post-Injection										
6/26/2019 9:31	2	49.9	5	6.2	84.0	82	24.79	20.92	0.02	0.0
6/26/2019 15:19	2	48.0	10	5.3	89.2	92	24.74	20.88	0.02	0.0
6/27/2019 8:03	2	51.5	77	17.7	74.6	72	24.87	20.90	0.06	0.0
6/27/2019 13:46	2	50.3	121	14.8	85.7	91	24.84	20.80	0.02	0.0
6/28/2019 11:46	2	50.0	269	16.2	87.5	86	24.88	20.75	0.06	0.0
6/30/2019 12:23	2	50.1	974	18.2	93.0	90	24.83	20.26	0.20	0.0
7/2/2019 9:51	2	50.1	1,679	33.4	82.8	77	24.77	19.82	0.38	0.0
7/5/2019 11:45	2	50.0	2,400	26.6	90.4	88	24.81	18.36	0.90	0.0

% = percent
°F = degrees Fahrenheit
CH_4 = methane
CO_2 = carbon dioxide
in-Hg = inches of mercury
in-WC = inches of water column
O_2 = oxygen
ppmv = parts per million by volume
scfm = standard cubic feet per minute
VOC = volatile organic compound

Table 3-3
SVMW-10-150 Respiration Monitoring

Date and Time	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry										
4/11/2019 14:03	1	17.0	24,460	76.4	56.5	63	24.32	3.44	8.14	0.0
Dry Respirometry										
Post-Injection										
4/28/2019 12:05	2	52.0	11	13.6	78.5	73	24.60	21.27	0.00	0.0
4/28/2019 16:22	2	142.4	33	8.0	83.2	83	24.52	21.16	0.02	0.0
4/29/2019 12:00	2	104.4	215	13.1	76.9	72	24.62	20.73	0.06	0.0
4/29/2019 17:09	2	58.9	306	17.9	74.2	73	24.53	20.75	0.10	0.0
4/30/2019 15:52	2	61.0	519	23.3	71.5	72	24.55	20.62	0.16	0.0
5/1/2019 15:12	2	52.1	741	23.2	81.2	74	24.60	20.35	0.24	0.0
5/3/2019 13:06	2	52.0	1,413	34.6	77.7	70	24.70	19.34	0.78	0.0
5/5/2019 11:18	2	49.8	1,123	36.6	78.0	72	24.64	19.47	0.52	0.0
5/9/2019 16:34	2	72.3	1,541	44.2	69.8	64	24.56	18.20	1.06	0.0
Wet Respirometry										
Pre-Injection										
6/20/2019 9:59	2	49.1	3,880	47.3	83.0	79	24.68	7.56	6.04	0.0
Post-Injection										
6/26/2019 9:40	2	52.5	64	7.0	85.8	82	24.79	20.80	0.00	0.0
6/26/2019 15:25	2	53.1	166	5.5	89.6	92	24.74	20.78	0.00	0.0
6/27/2019 8:10	2	58.0	506	20.7	74.2	72	24.87	20.40	0.18	0.0
6/27/2019 13:50	2	53.0	462	13.3	87.3	91	24.84	20.20	0.22	0.0
6/28/2019 11:52	2	54.8	647	12.6	91.9	86	24.88	19.72	0.54	0.0
6/30/2019 12:29	2	47.9	616	15.5	95.0	90	24.83	19.57	0.70	0.0
7/2/2019 9:56	2	50.4	354	24.4	84.4	77	24.77	19.65	0.54	0.0
7/5/2019 11:49	2	51.8	835	22.8	91.0	88	24.81	18.16	1.12	0.0

% = percent
°F = degrees Fahrenheit
CH_4 = methane
CO_2 = carbon dioxide
in-Hg = inches of mercury
in-WC = inches of water column
O_2 = oxygen
ppmv = parts per million by volume
scfm = standard cubic feet per minute
VOC = volatile organic compound

Table 3-4
SVMW-10-250 Respiration Monitoring

Date and Time	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry										
4/11/2019 14:24	1	18.3	14,580	80.2	55.3	53	24.33	0.34	11.16	0.1[a]
Dry Respirometry										
Post-Injection										
4/28/2019 12:11	2	66.4	254	16.2	78.3	73	24.60	21.24	0.00	0.0
4/28/2019 16:27	2	164	535	9.7	83.1	83	24.52	20.57	0.00	0.0
4/29/2019 12:05	2	94.2	989	25.2	76.5	72	24.62	20.48	0.08	0.0
4/29/2019 17:13	2	62.1	1,316	34.2	74.1	73	24.53	20.45	0.10	0.0
4/30/2019 16:01	2	65.3	1,904	42.5	71.2	72	24.55	20.23	0.20	0.0
5/1/2019 15:16	2	58.2	2,450	34.5	80.9	74	24.60	19.82	0.26	0.0
5/3/2019 12:59	2	57.4	3,220	40.7	77.8	70	24.70	19.32	0.48	0.0
5/5/2019 11:29	2	53.8	3,730	40.2	78.5	72	24.64	18.62	0.66	0.0
5/9/2019 16:37	2	74.6	4,550	47.0	69.6	64	24.56	16.97	1.32	0.0
Wet Respirometry										
Pre-Injection										
6/20/2019 10:05	2	51.4	7,870	40.4	82.7	77	24.68	6.59	6.84	0.0
Post-Injection										
6/26/2019 9:45	2	56.2	118	8.1	86.8	82	24.79	20.82	0.04	0.0
6/26/2019 15:30	2	58.9	309	11.2	90.3	92	24.74	20.71	0.00	0.0
6/27/2019 8:15	2	59.9	894	30.9	73.8	72	24.87	20.19	0.20	0.0
6/27/2019 13:56	2	55.5	1,039	21.1	88.2	91	24.84	20.03	0.32	0.0
6/28/2019 11:57	2	56.0	1,546	21.6	93.2	86	24.88	19.57	0.56	0.0
6/30/2019 12:33	2	53.7	1,990	22.0	96.4	90	24.83	19.28	0.62	0.0
7/2/2019 10:00	2	58.7	2,010	33.3	85.0	77	24.77	19.29	0.44	0.0
7/5/2019 11:52	2	56.2	2,700	27.7	91.7	88	24.71	17.75	0.96	0.0

[a] CH_4 reading is suspect and likely the result of hydrocarbon breakthrough on the carbon filter.

% = percent
°F = degrees Fahrenheit
CH_4 = methane
CO_2 = carbon dioxide
in-Hg = inches of mercury
in-WC = inches of water column
O_2 = oxygen
ppmv = parts per million by volume
scfm = standard cubic feet per minute
VOC = volatile organic compound

Table 3-5
SVMW-11-100 Respiration Monitoring

Date and Time	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry										
4/11/2019 12:35	2	14.9	30,900	73.1	59.7	53	24.36	0.42	11.26	0.0
Dry Respirometry										
Post-Injection										
4/28/2019 11:28	2	50.8	188	10.0	81.5	72	24.60	20.89	0.00	0.0
4/28/2019 15:47	2	68.1	1,456	7.4	86.6	83	24.53	20.77	0.00	0.0
4/29/2019 11:33	2	39.9	3,290	18.1	80.0	72	24.63	20.68	0.00	0.0
4/29/2019 16:45	2	43.9	4,530	26.2	76.2	73	24.53	20.59	0.00	0.0
4/30/2019 15:04	2	62.9	5,970	33.6	73.4	68	24.57	20.16	0.00	0.0
5/1/2019 14:46	2	50.5	6,870	29.1	85.4	74	24.60	19.81	0.02	0.0
5/3/2019 12:33	2	53.9	8,100	43.8	75.2	70	24.70	18.79	0.16	0.0
5/5/2019 10:42	2	46.2	10,160	37.5	81.9	70	24.60	17.73	0.44	0.0
5/9/2019 16:15	2	63.2	12,270	45.7	72.6	65	24.56	15.65	1.66	0.0
Wet Respirometry										
Pre-Injection										
6/20/2019 10:16	2	47.2	21,650	48.5	83.0	81	24.68	5.34	8.56	0.0
Post-Injection										
6/26/2019 9:57	2	30.3	28	5.0	87.4	82	24.79	20.88	0.00	0.0
6/26/2019 15:40	2	50.0	179	4.8	89.8	92	24.74	20.85	0.00	0.0
6/27/2019 8:25	2	49.6	651	19.8	74.0	72	24.87	20.74	0.04	0.0
6/27/2019 14:05	2	49.2	896	12.0	88.4	91	24.84	20.61	0.04	0.0
6/28/2019 12:03	2	48.1	1,525	14.2	94.0	86	24.88	20.20	0.06	0.0
6/30/2019 12:44	2	47.0	3,220	18.6	98.2	90	24.83	18.92	0.26	0.0
7/2/2019 10:08	2	51.9	5,090	32.7	84.8	77	24.77	17.85	0.56	0.0
7/5/2019 11:57	2	51.6	6,170	27.3	92.3	88	24.81	16.39	1.28	0.0

% = percent
°F = degrees Fahrenheit
CH_4 = methane
CO_2 = carbon dioxide
in-Hg = inches of mercury
in-WC = inches of water column
O_2 = oxygen
ppmv = parts per million by volume
scfm = standard cubic feet per minute
VOC = volatile organic compound

Table 3-6
SVMW-11-250 Respiration Monitoring

Date and Time	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry										
4/11/2019 13:01	1	17.2	26,320	72.2	60.6	53	24.37	0.08	11.34	0.0
Dry Respirometry										
Post-Injection										
4/28/2019 11:42	2	108.3	240	13.6	79.4	72	24.60	21.05	0.14	0.0
4/28/2019 15:57	2	158.6	531	8.1	85.4	83	24.53	20.80	0.14	0.0
4/29/2019 11:40	2	64.6	2,170	29.4	78.2	72	24.63	19.58	0.50	0.0
4/29/2019 16:52	2	65.9	2,460	37.2	73.2	73	24.52	19.50	0.56	0.0
4/30/2019 15:20	2	64.8	3,260	43.9	72.1	68	24.37	19.18	0.68	0.0
5/1/2019 14:52	2	52.6	3,870	35.5	83.4	74	24.60	18.88	0.80	0.0
5/3/2019 12:25	2	56.0	4,960	48.5	74.9	70	24.70	18.10	1.08	0.0
5/5/2019 10:47	2	52.6	5,750	40.8	79.7	70	24.60	17.31	1.36	0.0
5/9/2019 16:16	2	65.5	7,480	49.3	71.5	65	24.56	15.71	2.24	0.0
Wet Respirometry										
Pre-Injection										
6/20/2019 10:21	2	55.0	15,220	48.6	83.2	81	24.71	5.77	7.90	0.0
Post-Injection										
6/26/2019 10:03	2	57.2	101	8.3	87.5	82	24.79	20.44	0.14	0.0
6/26/2019 15:46	2	56.3	362	10.7	89.1	92	24.74	20.00	0.32	0.0
6/27/2019 8:31	2	57.4	1,476	38.2	74.3	72	24.87	19.18	0.86	0.0
6/27/2019 14:08	2	58.3	2,030	26.3	88.5	91	24.84	18.72	1.06	0.0
6/28/2019 12:07	2	56.2	4,180	24.6	95.3	86	24.88	17.46	1.78	0.0
6/30/2019 12:49	2	53.9	4,890	25.1	98.0	90	24.83	17.21	1.94	0.0
7/2/2019 10:11	2	54.6	3,060	39.0	84.2	77	24.77	17.80	1.38	0.0
7/5/2019 12:00	2	56.8	3,940	29.0	92.8	90	24.81	16.45	1.90	0.0

% = percent
°F = degrees Fahrenheit
CH_4 = methane
CO_2 = carbon dioxide
in-Hg = inches of mercury
in-WC = inches of water column
O_2 = oxygen
ppmv = parts per million by volume
scfm = standard cubic feet per minute
VOC = volatile organic compound

Table 3-7
SVMW-11-260 Respiration Monitoring

Date and Time	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry										
4/11/2019 13:22	1	14.4	18390	76.4	59.4	53	24.36	1.15	13.20	0.0
Dry Respirometry										
Post-Injection										
4/28/2019 11:48	2	142.0	5.0	16.4	80.0	72	24.60	21.32	0.04	0.0
4/28/2019 16:02	2	124.6	11	22.6	86.3	83	24.53	20.55	0.02	0.0
4/29/2019 11:46	2	58.5	29	39.8	78.4	73	24.63	20.41	0.02	0.0
4/29/2019 16:57	2	57.2	49	44.1	74.1	73	24.52	20.43	0.02	0.0
4/30/2019 15:28	2	57.7	131	47.7	72.2	70	24.56	20.37	0.06	0.0
5/1/2019 14:57	2	47.3	219	37.8	82.3	74	24.60	20.38	0.04	0.0
5/3/2019 12:16	2	48.3	374	50	73.4	70	24.70	19.67	0.08	0.0
5/5/2019 10:55	2	49.8	846	41.5	78.4	70	24.60	19.71	0.06	0.0
5/9/2019 16:23	2	61.1	2,110	50.1	71.0	65	24.56	18.74	0.08	0.0
Wet Respirometry										
Pre-Injection										
6/20/2019 10:28	2	46.6	7380	49.0	83.5	82	24.71	6.35	2.24	0.0
Post-Injection										
6/26/2019 10:10	2	47.5	3	22.0	87.5	82	24.82	20.67	0.02	0.0
6/26/2019 15:50	2	58.7	8	28.5	88.8	92	24.74	20.48	0.04	0.0
6/27/2019 8:36	2	48.8	16	52.5	74.5	72	24.87	20.44	0.06	0.0
6/27/2019 14:13	2	47.8	16	34.0	88.4	91	24.84	20.37	0.04	0.0
6/28/2019 12:13	2	47.4	22	24.2	94.3	86	24.88	20.17	0.02	0.0
6/30/2019 12:54	2	58.1	61	23.7	98.5	90	24.83	19.89	0.08	0.0
7/2/2019 10:15	2	49.2	175	42.6	83.3	77	24.77	19.86	0.06	0.0
7/5/2019 12:04	2	47.8	382	30.5	93.3	90	24.81	19.28	0.10	0.0

% = percent
°F = degrees Fahrenheit
CH_4 = methane
CO_2 = carbon dioxide
in-Hg = inches of mercury
in-WC = inches of water column
O_2 = oxygen
ppmv = parts per million by volume
scfm = standard cubic feet per minute
VOC = volatile organic compound

Table 3-8
SVEW-01-260 Respiration Monitoring

Date and Time	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry										
4/13/2019 13:09	3	64.6	16,970	33.1	71.4	60	24.51	0.30	12.02	0.1
Dry Respirometry										
Post-Injection										
4/28/2019 12:30	3	66.1	7	10.4	80.6	78	24.60	20.77	0.00	0.0
4/28/2019 16:45	3	181.1	30	1.7	83.5	83	24.50	20.79	0.02	0.0
4/29/2019 12:29	3	65.4	216	15.9	77.3	72	24.62	20.68	0.00	0.0
4/29/2019 17:30	3	65.5	320	20.6	73.3	73	24.54	20.63	0.04	0.0
4/30/2019 16:25	3	67.8	641	30.3	71.1	72	24.55	20.25	0.14	0.0
5/1/2019 15:33	3	69.9	728	25.3	79.8	74	24.60	19.27	0.44	0.0
5/3/2019 11:29	3	63.8	1,055	35.0	73.4	70	24.67	13.39	3.88	0.0
5/5/2019 10:19	3	65.8	1,442	30.0	80.1	70	24.60	18.08	1.02	0.0
5/6/2019 14:11	3	67.6	1,852	20.7	88.8	81	24.58	17.36	1.42	0.0
5/6/2019 14:18	3	68.1	1,918	21.1	88.4	81	24.58	17.29	1.44	0.0
5/6/2019 14:23	3	68.4	1,953	21.5	88.5	81	24.58	17.18	1.44	0.0
5/9/2019 16:52	3	77.7	1,823	40.1	68.3	64	24.56	13.83	3.84	0.0
Wet Respirometry										
Pre-Injection										
6/20/2019 10:49	3	65.5	4,720	26.7	89.6	82	24.71	6.55	8.06	0.0
Post-Injection										
6/26/2019 10:43	3	67.7	540	17.5	91.0	82	24.82	18.56	1.50	0.0
6/26/2019 16:09	3	80.5	270	21.6	91.2	88	24.74	13.54	3.96	0.0
6/27/2019 9:05	3	70.0	87	43.1	77.8	73	24.87	12.88	5.36	0.0
6/27/2019 14:28	3	69.3	89	29.7	88.5	91	24.84	13.14	5.42	0.0
6/28/2019 12:29	3	70.0	65	23.5	95.9	86	24.88	14.48	5.14	0.0
6/30/2019 13:13	3	68.0	106	20.7	100.9	91	24.83	15.45	4.98	0.0
7/2/2019 10:29	3	69.9	1,404	35.9	82.4	77	24.77	13.93	5.70	0.0
7/5/2019 12:14	3	68.3	275	23.9	95.4	90	24.81	14.96	4.44	0.0

% = percent
°F = degrees Fahrenheit
CH_4 = methane
CO_2 = carbon dioxide
in-Hg = inches of mercury
in-WC = inches of water column
O_2 = oxygen
ppmv = parts per million by volume
scfm = standard cubic feet per minute
VOC = volatile organic compound

Table 3-9
SVEW-02/03-160 Respiration Monitoring

Date and Time	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry										
4/13/2019 13:35	2	40.7	14,640	48.2	71.9	60	24.82	0.24	12.52	0.0
Dry Respirometry										
Post-Injection										
4/28/2019 12:38	3	163.3	66	1.9	80.3	78	24.60	20.79	0.02	0.0
4/28/2019 16:54	3	178.3	163	3.5	82.6	83	24.50	20.79	0.04	0.0
4/29/2019 12:38	3	65.2	316	17.0	75.8	72	24.62	20.58	0.12	0.0
4/29/2019 17:38	3	65.2	444	21.7	72.8	73	24.53	20.39	0.14	0.0
4/30/2019 16:36	3	66.8	622	26.5	70.3	72	24.55	19.87	0.36	0.0
5/1/2019 15:42	3	67.3	826	26.9	80.0	74	24.60	19.05	0.72	0.0
5/3/2019 12:00	3	64.9	4,220	36.8	73.3	70	24.70	9.81	5.48	0.0
5/5/2019 10:31	3	66.8	1,354	28.4	86.3	70	24.60	16.99	1.68	0.0
5/6/2019 14:30	3	65.4	1,343	19.5	89.0	81	24.58	16.50	1.88	0.0
5/6/2019 14:35	3	65.2	1,429	19.5	89.5	81	24.58	16.10	2.06	0.0
5/6/2019 14:39	3	65.7	1,395	19.5	89.5	81	24.59	16.20	1.98	0.0
5/9/2019 17:01	3	71.5	2,090	42.3	66.7	63	24.56	13.59	3.48	0.1
Wet Respirometry										
Pre-Injection										
6/20/2019 10:39	3	64.8	7,200	29.2	86.2	81	24.71	2.15	10.66	0.0
Post-Injection										
6/26/2019 10:24	3	68.0	855	19.5	88.9	82	24.82	18.08	2.16	0.0
6/26/2019 16:17	3	72.2	5,480	22.0	91.3	88	24.74	8.16	8.40	0.0
6/27/2019 8:49	3	69.2	3,480	41.1	76.5	73	24.87	13.20	3.50	0.0
6/27/2019 14:22	3	69.5	7,230	26.0	88.3	91	24.84	6.27	9.52	0.0
6/28/2019 12:20	3	68.0	7,250	20.6	96.6	86	24.88	4.51	10.62	0.0
6/30/2019 13:22	3	67.1	9,060	17.9	102.9	92	24.83	2.31	12.20	0.0
7/2/2019 10:21	3	69.0	1,951	33.3	82.0	77	24.77	13.61	3.80	0.0
7/5/2019 12:08	3	68.0	4,950	24.8	94.8	90	24.81	4.56	9.92	0.0

% = percent
°F = degrees Fahrenheit
CH_4 = methane
CO_2 = carbon dioxide
in-Hg = inches of mercury
in-WC = inches of water column
O_2 = oxygen
ppmv = parts per million by volume
scfm = standard cubic feet per minute
VOC = volatile organic compound

Table 3-10
SVEW-04/05-313 Respiration Monitoring

Date and Time	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry										
4/11/2019 14:44	3	65.0	1757	59.5	55.6	53	24.33	14.43	2.70	0.0
Dry Respirometry										
Post-Injection										
4/28/2019 12:18	3	80.5	4	5.6	79.5	73	24.60	20.77	0.04	0.0
4/28/2019 16:36	3	180.7	5	6.5	83.9	83	24.52	20.66	0.06	0.0
4/29/2019 12:17	3	66.8	26	28.9	77.3	72	24.62	16.91	1.84	0.0
4/29/2019 17:20	3	65.7	12	32.7	73.9	72	24.54	19.99	0.30	0.0
4/30/2019 16:13	3	66.3	41	39.0	71.2	72	24.55	15.31	2.98	0.0
5/1/2019 15:25	3	68.7	25	29.4	80.8	74	24.60	14.51	3.30	0.0
5/3/2019 11:19	3	66.3	148	36.5	72.4	70	24.67	12.63	3.60	0.0
5/5/2019 10:05	3	66.9	55	29.8	79.2	70	24.60	17.89	1.00	0.0
5/6/2019 13:54	3	68.8	21	21.5	88.1	81	24.58	13.72	3.84	0.0
5/6/2019 14:00	3	68.6	43	21.8	88.5	81	24.58	15.86	2.54	0.0
5/6/2019 14:05	3	68.0	57	21.7	89.3	81	24.58	16.95	1.64	0.0
5/9/2019 16:44	3	81.6	100	39.6	69.5	64	24.56	12.77	3.88	0.0
Wet Respirometry										
Pre-Injection										
6/20/2019 10:59	3	65.6	1311	24.7	91.2	82	24.71	12.77	3.29	0.0
Post-Injection										
6/26/2019 10:56	3	62.9	78	20.11	90.9	82	24.82	14.58	2.95	0.0
6/26/2019 16:01	3	81.0	25	22.0	90.4	92	24.74	19.68	0.54	0.0
6/27/2019 9:17	3	69.8	56	37.8	79.5	73	24.87	19.44	0.56	0.0
6/27/2019 14:40	3	70.2	52	27.4	88.6	91	24.84	19.43	0.48	0.0
6/28/2019 12:41	3	69.8	146	21.2	97.6	86	24.88	19.16	0.40	0.0
6/30/2019 13:03	3	69.6	295	20.3	99.3	91	24.83	18.58	0.50	0.0
7/2/2019 10:36	3	69.1	72	36.4	83.7	77	24.77	18.94	0.22	0.0
7/5/2019 12:20	3	67.4	342	25.1	95.1	90	24.81	13.36	2.96	0.0

% = percent
°F = degrees Fahrenheit
CH_4 = methane
CO_2 = carbon dioxide
in-Hg = inches of mercury
in-WC = inches of water column
O_2 = oxygen
ppmv = parts per million by volume
scfm = standard cubic feet per minute
VOC = volatile organic compound

Table 3-11
Bioventing Respiration Pilot Test Analytical Requirements and Frequency

Parameter	Method	Media	Number of Samples Per Event[a]	Sample Container	Data Use	Respiration Test Frequency	Long-Term Test Frequency
BTEX/TPH-GRO	EPA TO-3	Soil Vapor	12	1-liter Summa canister	Evaluate soil vapor hydrocarbons	Baseline and end of test	Weekly for first month; quarterly to end of test
VOCs	EPA TO-15 SIM	Soil Vapor	12	1-liter Summa canister	Evaluate soil vapor EDB concentrations	Baseline and end of test	Weekly for first month; quarterly to end of test
Fixed Gases[b]	ASTM D1945	Soil Vapor	12	1-liter Summa canister	Verify field instrument reading	Baseline and end of test	Weekly for first month; quarterly to end of test
C1-C5 Hydrocarbon Compounds[c]	ASTM D1945	Soil Vapor	12	1-liter Summa canister	Evaluate degradation of EDB	Baseline and end of test	Weekly for first month; quarterly to end of test

[a] Soil vapor samples collected from each of the six nested wells in both KAFB-106V1 and KAFB-106V2 (does not include quality control samples).
[b] Fixed gases: nitrogen, oxygen, hydrogen, carbon monoxide, and carbon dioxide.
[c] C1-C5 hydrocarbon compounds: methane, ethane, propane, butane, and pentane.
ASTM = ASTM International
BTEX = benzene, toluene, ethylbenzene, and total xylenes
EDB = ethylene dibromide (1,2-dibromoethane)
EPA = U.S. Environmental Protection Agency
GRO = gasoline range organics
SIM = selective ion monitoring
TPH = total petroleum hydrocarbons
VOC = volatile organic compound

Table 3-12
Chronology of Events

Dates	Activity
December 11, 2018 - January 24, 2019	Installation of soil vapor monitoring wells KAFB-106V1 and KAFB-106V2.
February 25, 2019 - March 6, 2019	Installation of electrical service and air injection blowers at the bioventing pilot test area.
April 10, 2019 - April 11, 2019	Collection of baseline respirometry readings.
April 22, 2019 - April 28, 2019	Dry respirometry air injection.
April 28, 2019 - May 9, 2019	Collection of dry respirometry data.
May 23, 2019 - May 24, 2019	Injection of water for wet respiration pilot testing.
May 24, 2019 - June 20, 2019	Soil moisture acclimation period.
June 20, 2019 - June 26, 2019	Wet respirometry air injection.
June 26, 2019 - July 5, 2019	Collection of wet respirometry data.
October 7, 2019	Initiation of the long-term bioventing pilot test.

Respirometry data collected include both field data and analytical samples.
Bioventing parameter assessment is performed on a quarterly basis.

Table 3-13
Summary of Hydrocarbon Analytical Results

			Analyte													
			1,2-Dibromoethane (EDB)		Benzene		Ethylbenzene		Toluene		Xylenes, Total		Total BTEX		TPH-GRO (C6-C10)	
	Sample	Sample	µg/m^3		µg/m^3		µg/m^3		µg/m^3		µg/m^3		µg/m3		µg/m^3	
Well ID	Event	Date	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
KAFB-106V1-102	Baseline	4/10/2019	3,800	J	2,100,000	--	170,000	--	1,900,000	--	350,000	--	4,520,000	--	120,000,000	--
	Post-Dry	5/9/2019	3,500	J	2,300,000	--	280,000	--	2,100,000	--	610,000	--	5,290,000	--	120,000,000	--
	Post-Wet	7/5/2019	3,100	J	2,000,000	--	190,000	J	1,800,000	--	400,000	J	4,390,000	J	110,000,000	--
KAFB-106V1-113	Baseline	4/10/2019	3,800	J	1,600,000	--	190,000	--	1,700,000	--	410,000	--	3,900,000	J	120,000,000	--
	Post-Dry	5/9/2019	2,800	J	1,400,000	--	200,000	--	1,500,000	--	420,000	--	3,520,000	--	74,000,000	--
	Post-Wet	7/5/2019	5,000	J	1,500,000	--	220,000	J	2,200,000	--	460,000	J	4,380,000	J	110,000,000	--
KAFB-106V1-160	Baseline	4/10/2019	2,800	J	1,300,000	--	280,000	--	2,200,000	--	790,000	--	4,570,000	--	110,000,000	--
	Post-Dry	5/9/2019	2,600	J	1,600,000	--	390,000	--	2,800,000	--	1,200,000	--	5,990,000	--	130,000,000	--
	Post-Wet	7/5/2019	2,700	J	1,600,000	J	330,000	J	1,800,000	J	920,000	J	4,650,000	J	130,000,000	--
KAFB-106V1-217	Baseline	4/10/2019	4,500	--	1,700,000	--	460,000	--	4,200,000	--	1,800,000	--	8,160,000	--	160,000,000	--
	Post-Dry	5/9/2019	3,000	J	1,600,000	--	360,000	--	3,400,000	J	1,400,000	--	6,760,000	J	170,000,000	--
	Post-Wet	7/5/2019	4,400	J	1,600,000	--	470,000	J	3,200,000	J	1,800,000	J	7,070,000	J	170,000,000	--
KAFB-106V1-252	Baseline	4/10/2019	18,000	--	870,000	--	400,000	--	5,400,000	--	1,500,000	--	8,170,000	--	140,000,000	--
	Post-Dry	5/9/2019	12,000	--	810,000	--	360,000	--	4,200,000	J	1,400,000	--	6,770,000	J	150,000,000	--
	Post-Wet	7/5/2019	18,000	J	800,000	--	470,000	J	4,200,000	J	1,800,000	J	7,270,000	J	150,000,000	--
KAFB-106V1-263	Baseline	4/10/2019	23,000	--	920,000	--	410,000	--	6,400,000	--	1,400,000	--	9,130,000	--	160,000,000	--
	Post-Dry	5/9/2019	15,000	--	840,000	--	320,000	--	4,700,000	J	1,100,000	--	6,960,000	J	160,000,000	--
	Post-Wet	7/5/2019	24,000	J	780,000	J	460,000	J	5,500,000	J	1,500,000	J	8,240,000	J	150,000,000	--
KAFB-106V2-102	Baseline	4/11/2019	20,000	J	2,100,000	J	280,000	J	5,100,000	--	890,000	J	8,370,000	J	370,000,000	--
	Post-Dry	5/9/2019	15,000	--	1,800,000	--	330,000	--	4,400,000	J	1,000,000	--	7,530,000	J	210,000,000	--
	Post-Wet	7/5/2019	24,000	J	1,800,000	--	440,000	J	4,500,000	J	1,400,000	J	8,140,000	J	200,000,000	--
KAFB-106V2-117	Baseline	4/11/2019	9,700	--	1,800,000	--	390,000	--	3,300,000	--	1,200,000	--	6,690,000	--	180,000,000	--
	Post-Dry	5/9/2019	9,900	J	2,100,000	--	350,000	--	3,900,000	J	1,600,000	--	7,950,000	J	210,000,000	--
	Post-Wet	7/5/2019	17,000	J	2,300,000	J	430,000	J	5,200,000	J	1,600,000	J	9,530,000	J	220,000,000	--
KAFB-106V2-160	Baseline	4/11/2019	2,500	J	550,000	--	150,000	--	1,200,000	--	500,000	--	2,400,000	--	43,000,000	--
	Post-Dry	5/9/2019	1,900	J	630,000	--	170,000	--	1,300,000	--	720,000	--	2,820,000	--	52,000,000	--
	Post-Wet	7/5/2019	1,600	J	660,000	J	120,000	J	990,000	J	500,000	J	2,270,000	J	76,000,000	--
KAFB-106V2-217	Baseline	4/11/2019	6,000	--	1,500,000	--	230,000	--	2,800,000	--	690,000	--	5,220,000	--	140,000,000	--
	Post-Dry	5/9/2019	4,800	J	1,600,000	--	300,000	--	3,000,000	J	900,000	--	5,800,000	J	140,000,000	--
	Post-Wet	7/5/2019	7,300	J	1,400,000	--	340,000	J	2,600,000	J	1,000,000	J	5,340,000	J	140,000,000	--
KAFB-106V2-252	Baseline	4/11/2019	12,000	--	650,000	--	230,000	--	3,400,000	--	680,000	--	4,960,000	--	90,000,000	--
	Post-Dry	5/9/2019	11,000	--	770,000	--	310,000	--	3,500,000	--	980,000	--	5,560,000	--	89,000,000	--
	Post-Wet	7/5/2019	13,000	J	950,000	J	300,000	J	2,800,000	J	930,000	J	4,980,000	J	87,000,000	--
KAFB-106V2-270	Baseline	4/11/2019	9,200	--	440,000	--	190,000	--	3,000,000	--	540,000	--	4,170,000	--	94,000,000	--
	Post-Dry	5/9/2019	7,500	--	590,000	--	180,000	--	3,900,000	J	550,000	--	5,220,000	J	120,000,000	--
	Post-Wet	7/5/2019	14,000	J	1,200,000	J	320,000	J	4,400,000	J	1,000,000	J	6,920,000	J	140,000,000	--

µg/m^3 = microgram per cubic meter
BTEX = Sum of benzene, toluene, ethylbenzene, and total xylenes
EDB = ethylene dibromide (1,2-dibromoethane)
GRO = gasoline range organics
ID = identification
TPH = total petroleum hydrocarbons
J = Qualifier denotes the analyte was positively identified, but the associated numerical value is estimated.
-- = Validation qualifier not assigned.

Table 3-14
Respiration Flow Design

Respiration Testing Design Inputs								
Injection Well	Screened Interval (ft bgs)	Screen Length (ft)	Screen Diameter (in.)	Casing Volume (ft^3)	Filter Pack Thickness (ft)	Assumed Venting Thickness (ft)[1]	Control Radius (ft)	Test Cell Pore Volume (ft^3)
SVMW-11-100	100-102.5	2.5	0.5	0.140	8.2	18.2	15	4,500
SVMW-11-250	250-252.5	2.5	0.5	0.344	7.3	17.3	15	4,278
SVMW-11-260	260-262.5	2.5	0.5	0.358	22.5	32.5	15	8,036
SVEW-01-260	245-260	15	4	22.678	26	36	15	8,902
SVMW-10-100	100-102.5	2.5	0.5	0.140	7.9	17.9	15	4,426
SVMW-10-150	150-152.5	2.5	0.5	0.208	9.5	19.5	15	4,822
SVMW-10-250	250-252.5	2.5	0.5	0.344	10.3	20.3	15	5,020
SVMW-02/03-160	145-160	15	2	3.489	29	39	15	9,644
SVEW-04/05-313	298-313	15	2	6.825	25	35	15	8,655

[1] Vertical leakance into formation assumed 5 feet above and 5 below filter pack interval
Assumed porosity = 35%

Respiration Testing Air Injection Parameters									
	Prescribed in Work Plan				Performed in Field				
Injection Well	Target Moisture Volume (gallons)[1]	Air Injection Period (days)	Design Flow Rate (cfm)	Target Air Injection Volume (ft^3)[2]	Added Moisture Volume (gallons)	Air Injection Period (days)	Flow Rate (cfm)	Air Injection Volume (ft^3) Dry	Air Injection Volume (ft^3) Wet
SVMW-11-100	337	3	4.2	18,002	350	6	2.3	18,833	18,709
SVMW-11-250	320	3	4.0	17,111	325	6	2.3	18,833	18,709
SVMW-11-260	601	3	7.4	32,146	625	6	4.0	33,480	33,260
SVEW-01-260	666	3	8.2	35,608	675	6	5.0	36,625	35,775
SVMW-10-100	331	3	4.1	17,705	350	6	2.3	18,821	18,709
SVMW-10-150	361	3	4.5	19,287	375	6	2.5	20,913	20,787
SVMW-10-250	375	3	4.6	20,079	375	6	2.5	20,913	20,787
SVMW-02/03-160	721	3	8.9	38,575	725	6	5.5	40,287	39,353
SVEW-04/05-313	647	3	8.0	34,619	650	6	5.0	36,625	35,775

[1] Moisture added at 1 % of pore volume
[2] Prescribed air injection volume is 4 times the test cell pore volume

Table 3-15
Bioventing Respiration Pilot Test Air Injection Summary - SVMW-10

Well ID	SVMW-10-100		SVMW-10-150		SVMW-10-250	
Pore Volume[a] (ft^3)	4,426		4,822		5,020	
Target Air Injection Volume[b] (ft^3)	17,704		19,288		20,080	
Dry Respiration Testing						
Date and Time	Flow Rate (scfm)	Total Volume Injected (ft^3)	Flow Rate (scfm)	Total Volume Injected (ft^3)	Flow Rate (scfm)	Total Volume Injected (ft^3)
4/22/2019 14:40	2.5	0	2.75	0	3.0	0
4/22/2019 15:20	2.25	90	2.5	100	2.5	100
4/23/2019 8:35	2.25	2,419	2.5	2,688	2.5	2,688
4/23/2019 15:45	2.25	3,386	2.5	3,763	2.5	3,763
4/24/2019 9:55	2.25	5,839	2.5	6,488	2.5	6,488
4/24/2019 14:56	2.25	6,516	2.5	7,240	2.5	7,240
4/25/2019 8:55	2.25	8,944	2.5	9,938	2.5	9,938
4/26/2019 13:05	2.25	12,746	2.5	14,163	2.5	14,163
4/27/2019 10:10	2.25	15,593	2.5	17,325	2.5	17,325
4/28/2019 10:05	2.25	18,821	2.5	20,913	2.5	20,913
Wet Respiration Testing						
Date and Time	Flow Rate (scfm)	Total Volume Injected (ft^3)	Flow Rate (scfm)	Total Volume Injected (ft^3)	Flow Rate (scfm)	Total Volume Injected (ft^3)
6/20/2019 13:40	2.25	0	2.5	0	2.5	0
6/21/2019 9:30	2.25	2,678	2.5	2,975	2.5	2,975
6/22/2019 15:25	2.25	6,716	2.5	7,462	2.5	7,462
6/23/2019 13:35	2.25	9,709	2.5	10,787	2.5	10,787
6/24/2019 10:50	2.25	12,578	2.5	13,975	2.5	13,975
6/25/2019 9:25	2.25	15,627	2.5	17,362	2.5	17,363
6/26/2019 8:15	2.25	18,709	2.5	20,787	2.5	20,787

Table 3-15
Bioventing Respiration Pilot Test Air Injection Summary - SVMW-10

Long-Term Bioventing Pilot Test						
Date and Time	**Flow Rate (scfm)**	**Total Volume Injected (ft^3)**	**Flow Rate (scfm)**	**Total Volume Injected (ft^3)**	**Flow Rate (scfm)**	**Total Volume Injected (ft^3)**
10/7/2019 8:30	2.5	0	2.0	0	2.8	0
10/8/2019 11:43	2.5	4,083	2.0	3,266	2.8	4,572
10/9/2019 11:49	2.5	7,697	2.0	6,158	2.8	8,621
10/15/2019 13:00	2.5	29,475	2.0	23,580	2.8	33,012
10/22/2019 11:51	2.5	54,503	2.0	43,602	2.8	61,043
10/31/2019 10:58	2.5	86,770	2.0	69,416	2.8	97,182
11/5/2019 11:38	2.5	104,870	2.0	83,896	2.8	117,454

[a] Pore volume is the test cell pore volume as determined from Table 2 in the Bioventing Respiration Pilot Test Injection Design in the Bioventing Respiration Pilot Testing Procedure (Kirtland AFB, 2018).

[b] Target volume is the target volume for air injection, approximately 4 times the pore volume.

ft^3 = cubic feet

ID = identification

in-WC = inches of water column

scfm = standard cubic feet per minute

Kirtland AFB, 2018. *Bioventing Respiration Pilot Testing Procedure, Rev.0.* Prepared by EA Engineering, Science, and Technology, Inc., PBC for Kirtland AFB under USACE-Albuquerque District Contract No. W9128F-

Table 3-16
Bioventing Respiration Pilot Test Air Injection Summary - SVMW-11

Well ID	SVMW-11-100		SVMW-11-250		SVMW-11-260	
Pore Volume[a] (ft^3)	4,500		4,278		8,036	
Target Air Injection Volume[b] (ft^3)	18,002		17,111		32,146	
Dry Respiration Testing						
Date and Time	Flow Rate (scfm)	Total Volume Injected (ft^3)	Flow Rate (scfm)	Total Volume Injected (ft^3)	Flow Rate (scfm)	Total Volume Injected (ft^3)
4/22/2019 14:30	2.25	0	2.25	0	4.25	0
4/22/2019 15:15	2.25	101	2.25	101	4.0	180
4/23/2019 8:40	2.25	2,453	2.25	2,453	4.0	4,360
4/23/2019 15:40	2.25	3,398	2.25	3,398	4.0	6,040
4/24/2019 10:00	2.25	5,873	2.25	5,873	4.0	10,440
4/24/2019 14:51	2.25	6,527	2.25	6,527	4.0	11,604
4/25/2019 9:03	2.25	8,984	2.25	8,984	4.0	15,972
4/26/2019 13:10	2.25	12,780	2.25	12,780	4.0	22,720
4/27/2019 10:15	2.25	15,626	2.25	15,626	4.0	27,780
4/28/2019 10:00	2.25	18,833	2.25	18,833	4.0	33,480
Wet Respiration Testing						
Date and Time	Flow Rate (scfm)	Total Volume Injected (ft^3)	Flow Rate (scfm)	Total Volume Injected (ft^3)	Flow Rate (scfm)	Total Volume Injected (ft^3)
6/20/2019 13:45	2.25	0	2.25	0	4.0	0
6/21/2019 9:28	2.25	2,662	2.25	2,662	4.0	4,732
6/22/2019 15:35	2.25	6,728	2.25	6,728	4.0	11,960
6/23/2019 13:30	2.25	9,686	2.25	9,686	4.0	17,220
6/24/2019 11:00	2.25	12,589	2.25	12,589	4.0	22,380
6/25/2019 9:15	2.25	15,593	2.25	15,593	4.0	27,720
6/26/2019 8:20	2.25	18,709	2.25	18,709	4.0	33,260

Table 3-16
Bioventing Respiration Pilot Test Air Injection Summary - SVMW-11

Long-Term Bioventing Pilot Test						
Date and Time	**Flow Rate (scfm)**	**Total Volume Injected (ft^3)**	**Flow Rate (scfm)**	**Total Volume Injected (ft^3)**	**Flow Rate (scfm)**	**Total Volume Injected (ft^3)**
10/7/2019 8:30	3.3	0	2.5	0	3.0	0
10/8/2019 11:45	3.3	5,396	2.5	4,088	3.0	4,905
10/9/2019 11:52	3.3	10,171	2.5	7,705	3.0	9,246
10/15/2019 13:02	3.3	38,914	2.5	29,480	3.0	35,376
10/22/2019 11:54	3.3	71,953	2.5	54,510	3.0	65,412
10/31/2019 11:43	3.3	114,685	2.5	86,883	3.0	104,259
11/5/2019 11:41	3.3	138,438	2.5	104,878	3.0	125,853

[a] Pore volume is the test cell pore volume as determined from Table 2 in the Bioventing Respiration Pilot Test Injection Design in the Bioventing Respiration Pilot Testing Procedure (Kirtland AFB, 2018).
[b] Target volume is the target volume for air injection, approximately 4 times the pore volume.
ft^3 = cubic feet
ID = identification
in-WC = inches of water column
scfm = standard cubic feet per minute
Kirtland AFB, 2018. *Bioventing Respiration Pilot Testing Procedure, Rev.0.* Prepared by EA Engineering, Science, and Technology, Inc., PBC for Kirtland AFB under USACE-Albuquerque District Contract No. W9128F-

Table 3-17
Bioventing Respiration Pilot Test Air Injection Summary - SVEWs

Well ID	SVEW-01-260		SVEW-02/03-160		SVEW-04/05-313	
Pore Volume[a] (ft^3)	8,902		9,644		8,655	
Target Air Injection Volume[b] (ft^3)	35,608		38,575		34,619	
Dry Respiration Testing						
Date and Time	Flow Rate (scfm)	Total Volume Injected (ft^3)	Flow Rate (scfm)	Total Volume Injected (ft^3)	Flow Rate (scfm)	Total Volume Injected (ft^3)
4/22/2019 14:50	5.0	0	5.5	0	5.0	0
4/22/2019 15:15	5.0	125	5.5	137	5.0	125
4/23/2019 8:30	5.0	125	5.5	137	5.0	125
4/23/2019 13:30	5.0	1,625	5.5	1,788	5.0	1,625
4/24/2019 10:05	5.0	7,800	5.5	8,580	5.0	7,800
4/24/2019 15:00	5.0	9,275	5.5	10,203	5.0	9,275
4/25/2019 10:25	5.0	15,100	5.5	16,610	5.0	15,100
4/26/2019 13:15	5.0	23,150	5.5	25,465	5.0	23,150
4/27/2019 10:20	5.0	29,475	5.5	32,423	5.0	29,475
4/28/2019 10:10	5.0	36,625	5.5	40,287	5.0	36,625
Wet Respiration Testing						
Date and Time	Flow Rate (scfm)	Total Volume Injected (ft^3)	Flow Rate (scfm)	Total Volume Injected (ft^3)	Flow Rate (scfm)	Total Volume Injected (ft^3)
6/21/2019 9:10	5.0	0	5.5	0	5.0	0
6/22/2019 15:40	5.0	9,150	5.5	10,065	5.0	9,150
6/23/2019 13:25	5.0	15,675	5.5	17,243	5.0	15,675
6/24/2019 11:10	5.0	22,200	5.5	24,420	5.0	22,200
6/25/2019 9:30	5.0	28,900	5.5	31,790	5.0	28,900
6/26/2019 8:25	5.0	35,775	5.5	39,353	5.0	35,775

Table 3-17
Bioventing Respiration Pilot Test Air Injection Summary - SVEWs

Long-Term Bioventing Pilot Test						
Date and Time	**Flow Rate (scfm)**	**Total Volume Injected (ft^3)**	**Flow Rate (scfm)**	**Total Volume Injected (ft^3)**	**Flow Rate (scfm)**	**Total Volume Injected (ft^3)**
10/7/2019 8:30	12	0	15.0	0	10.0	0
10/8/2019 11:45	12	19,620	15.0	0	10.0	16,350
10/9/2019 11:52	12	36,984	15.0	21,705	10.0	30,820
10/15/2019 13:02	12	141,504	15.0	152,355	10.0	117,920
10/22/2019 11:54	12	261,648	15.0	302,535	10.0	218,040
10/31/2019 11:43	12	417,036	15.0	496,770	10.0	347,530
11/5/2019 11:41	12	503,412	15.0	604,740	10.0	419,510

[a] Pore volume is the test cell pore volume as determined from Table 2 in the Bioventing Respiration Pilot Test Injection Design in the Bioventing Respiration Pilot Testing Procedure (Kirtland AFB, 2018).

[b] Target volume is the target volume for air injection, approximately 4 times the pore volume.

On October 7, 2019 at 1330, the flowmeter to SVEW-02/03-160 was damaged. Air injection on that well was shut off. On October 8, 2019 at 0720, the flowmeter was repaired and air injection was resumed.

ft^3 = cubic feet
ID = identification
in-WC = inches of water column
NM = not measured
scfm = standard cubic feet per minute

Kirtland AFB, 2018. *Bioventing Respiration Pilot Testing Procedure, Rev.0.* Prepared by EA Engineering, Science, and Technology, Inc., PBC for Kirtland AFB under USACE-Albuquerque District Contract No. W9128F-13-D-0006.

Table 3-18
Bioventing Dry Respiration Pilot Test Wellhead Pressure Response

Well ID	KAFB-106V1-102	KAFB-106V1-113	KAFB-106V1-160	KAFB-106V1-217	KAFB-106V1-252	KAFB-106V1-263	KAFB-106V2-102	KAFB-106V2-117	KAFB-106V2-160	KAFB-106V2-217	KAFB-106V2-252	KAFB-106V2-270
Date and Time	**Wellhead Pressure Response[a] (in-WC)**											
4/24/2019 10:10	0.0	0.0	-0.5	-0.5	-0.5	-0.5	0.0	0.0	0.0	0.0	0.0	0.0
4/24/2019 15:15	0.5	0.5	0.6	0.5	0.7	0.7	0.0	0.5	0.6	0.6	0.9	0.7
4/25/2019 11:30	0.0	0.0	-0.6	-0.7	-0.5	-0.5	0.0	0.0	-0.6	-0.8	-0.6	-0.7
4/26/2019 15:20	0.9	1.2	0.0	0.0	0.0	0.0	0.5	0.6	0.0	0.0	0.0	0.0
4/27/2019 10:25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4/28/2019 10:15	0.0	0.0	0.5	0.5	0.5	0.5	0.0	0.0	0.7	0.5	0.7	0.7

[a]Negative values indicate vacuum was observed in the well.
ID = identification
in-WC = inches of water column

Table 3-19
Bioventing Wet Respiration Pilot Test Wellhead Pressure Response

Well ID	KAFB-106V1-102	KAFB-106V1-113	KAFB-106V1-160	KAFB-106V1-217	KAFB-106V1-252	KAFB-106V1-263	KAFB-106V2-102	KAFB-106V2-117	KAFB-106V2-160	KAFB-106V2-217	KAFB-106V2-252	KAFB-106V2-270
Date and time	**Wellhead Pressure Response[a] (in-WC)**											
6/21/2019 9:50	0.5	0.6	0.8	0.7	0.8	0.8	0.5	0.5	0.9	0.8	1.0	0.9
6/22/2019 15:50	1.0	1.0	1.4	1.4	1.5	1.5	0.8	0.8	1.5	1.4	1.4	1.5
6/23/2019 13:40	0.7	0.6	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
6/24/2019 11:10	0.0	0.0	-0.9	-1.0	-0.9	-0.9	0.0	0.0	-0.9	-1.1	-0.8	-1.0
6/25/2019 9:38	0.0	0.0	-0.7	-0.9	-0.7	-0.7	0.0	0.0	-0.7	-0.9	-0.6	-0.8
6/26/2019 8:28	0.0	0.0	-1.3	-1.4	-1.4	-1.5	0.0	-0.5	-1.5	-1.4	-1.4	-1.5

[a] Negative values indicate vacuum was observed in the well.
ID = identification
in-WC = inches of water column

Table 3-20
Bioventing Respiration Pilot Test Water Injection Summary

Well ID		SVMW-10-100	SVMW-10-150	SVMW-10-250	SVMW-11-100	SVMW-11-250	SVMW-11-260	SVEW-01	SVEW-02/03-160	SVEW-04/05-313
Target Volume[a] (gallons)		**331**	**361**	**375**	**337**	**320**	**601**	**666**	**721**	**647**
Date	**Batch Number**	**Batch Volume[b,c] (gallons)**								
5/23/2019	1	-	-	-	75	200	200	-	-	-
	2	-	-	-	125	125	250	-	-	-
5/24/2019	1	-	-	-	150	-	175	-	-	-
	2	200	125	200	-	-	-	-	-	-
	3	150	250	175	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-	650
	5	-	-	-	-	-	-	675	-	-
	6	-	-	-	-	-	-	-	725	-
Total Volume		**350**	**375**	**375**	**350**	**325**	**625**	**675**	**725**	**650**

[a] The target volume is the added moisture volume specified in Table 2 of the approved Bioventing Respiration Testing Procedure (Kirtland AFB, 2018).

[b] Water injection was performed in batches using 250-gallon graduated polyethylene totes located at the well head.

[c] The batch volume is the fluid volume placed in the polyethylene tote.

- = not applicable

ID = identification

Kirtland AFB, 2018. *Bioventing Respiration Pilot Testing Procedure, Rev.0.* Prepared by EA Engineering, Science, and Technology, Inc., PBC for Kirtland AFB under USACE-Albuquerque District Contract No. W9128F-13-D-0006. September.

Table 4-1
Operational Parameter Summary

Well ID	Oxygen Utilization Rate (% per day)		Biodegradation Rate (mg/kg/day)		Oxygen Demand Flow Rate (scfm)		Oxygen Radius of Influence (ft)		Long-Term Operational Flow Rate (scfm)	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
SVMW-10-100	0.4015	0.2666	0.238	0.158	0.64	0.42	138	144	2.5	1.8
SVMW-10-150	0.2544	0.2521	0.151	0.149	0.49	0.48	142	142	2.0	2.0
SVMW-10-250	0.3324	0.2931	0.197	0.174	0.69	0.61	141	142	2.8	2.5
SVMW-11-100	0.4752	0.5198	0.281	0.308	0.79	0.86	143	141	3.3	3.5
SVMW-11-250	0.4153	0.3715	0.246	0.220	0.61	0.55	142	144	2.5	2.3
SVMW-11-260	0.1627	0.1375	0.096	0.081	0.74	0.62	141	140	3.0	2.5
SVEW-01-260	0.552	0.0202	0.327	0.012	2.90	0.11	143	152	12.0	0.5
SVEW-02/03-160	0.6393	0.6261	0.378	0.371	3.74	3.66	140	142	15.0	15.0
SVEW-04/05-313	0.4965	0.3584	0.294	0.227	2.50	1.81	140	147	10.0	8.0

% = percent
cm = centimeter
ft = foot/feet
ID = Identification
mg = milligram(s)
kg = kilogram(s)
NC = not calculated
scfm = standard cubic feet per minute

Table 4-2
KAFB-106V1-102 Respiration Monitoring

Date and Time	Well Head Pressure Pre/Post Purge (in-WC)	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry											
4/10/2019 9:46	1.0/0.0	1	2.0	21,430	66.2	64.0	61	24.24	0.20	12.38	0.0
Dry Respirometry - Post-Injection											
5/9/2019 14:35	0.0/0.0	2	50.4	19,480	56.8	69.7	65	24.60	8.02	9.18	0.0
Wet Respirometry - Pre-Injection											
6/20/2019 12:02	0.0/0.0	2	43.3	19,650	31.7	92.8	87	24.70	5.61	9.44	0.0
Wet Respirometry - Post-Injection											
7/5/2019 8:08	0.0/0.0	2	47.2	18,810	51.8	77.8	79	24.81	10.81	7.38	0.0
Bioventing											
10/7/2019 12:42	0.8/0.9	2	42.1	18,690	35.6	75.7	66	30.35	4.20	9.60	NM
10/8/2019 12:21	0.0/0.0	2	44.1	18,440	47.2	72.9	72	30.13	4.18	9.50	NM
10/9/2019 12:03	0.8/0.9	2	41	19,430	52.1	79.0	70	30.10	4.09	9.58	NM
10/15/2019 9:23	0.0/0.0	2	44.5	19,440	52.2	65.8	56	30.07	12.18	7.32	NM
10/22/2019 8:25	0.0/0.0	2	44.3	18,260	69.4	45.4	36	30.27	16.80	3.96	NM
10/31/2019 8:09	0.0/0.0	2	46.3	17,380	52.0	24.5	22	30.51	18.65	2.42	NM
11/5/2019 8:13	0.0/0.0	2	46.5	18,820	59.0	44.5	41	30.22	19.06	1.88	NM

% = percent

°F = degrees Fahrenheit

CH_4 = methane

CO_2 = carbon dioxide

in-Hg = inches of mercury

in-WC = inches of water column

NM = not measured

O_2 = oxygen

ppmv = parts per million by volume

scfm = standard cubic feet per minute

VOC = volatile organic compound

Table 4-3
KAFB-106V1-113 Respiration Monitoring

Date and Time	Well Head Pressure Pre/Post Purge (in-WC)	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry											
4/9/2019 10:05	1.3/1.2	1	10.6	22,800	78.9	64.2	63	24.23	0.10	12.26	0.0
Dry Respirometry - Post-Injection											
5/9/2019 14:50	0.0/0.0	2	57.7	15,230	55.5	70.9	65	24.60	8.16	8.70	0.0
Wet Respirometry - Pre-Injection											
6/20/2019 11:58	0.0/0.0	2	43.0	21,420	32.6	92.4	86	24.70	4.10	10.54	0.0
Wet Respirometry - Post-Injection											
7/5/2019 8:32	0.0/0.0	2	47.8	20,800	51.1	75.0	79	24.81	8.90	8.68	0.0
Bioventing											
10/7/2019 12:48	1.2/1.2	2	40.3	20,900	58.7	74.5	66	30.35	4.26	9.40	NM
10/8/2019 12:25	0.0/0.0	2	44	20,330	47.2	72.9	72	30.13	4.11	9.38	NM
10/9/2019 12:08	1.0/1.0	2	43.2	21,350	54.3	78.3	70	30.10	3.08	10.36	NM
10/15/2019 9:32	0.0/0.0	2	46.8	21,280	55.5	63.4	56	30.07	12.08	7.90	NM
10/22/2019 8:49	0.0/0.0	2	46.9	20,280	69.9	47.1	36	30.27	15.98	4.96	NM
10/31/2019 8:29	0.0/-0.5	2	45.2	18,710	52.0	24.6	22	30.51	17.77	3.58	NM
11/5/2019 8:29	0.0/0.0	2	45.3	20,760	61.1	45.3	41	30.22	18.30	2.90	NM

% = percent

°F = degrees Fahrenheit

CH_4 = methane

CO_2 = carbon dioxide

in-Hg = inches of mercury

in-WC = inches of water column

NM = not measured

O_2 = oxygen

ppmv = parts per million by volume

scfm = standard cubic feet per minute

VOC = volatile organic compound

Table 4-4
KAFB-106V1-160 Respiration Monitoring

Date and Time	Well Head Pressure Pre/Post Purge (in-WC)	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry											
4/10/2019 10:32	5.0/4.9	1	5.6	21,450	71.4	64.6	63	24.22	0.16	12.22	0.0
Dry Respirometry - Post-Injection											
5/9/2019 15:03	0.0/0.0	2	57.1	22,030	47.7	73.3	65	24.60	10.80	7.40	0.0
Wet Respirometry - Pre-Injection											
6/20/2019 11:51	0.0/0.0	2	44.3	22,900	32.0	92.3	86	24.71	2.70	9.96	0.0
Wet Respirometry - Post-Injection											
7/5/2019 8:50	-1.1/-1.1	2	50.1	21,640	54.1	79.5	79	24.81	11.48	6.78	0.0
Bioventing											
10/7/2019 12:51	-1.4/-1.4	2	45.0	21,840	58.2	73.8	66	30.35	0.18	10.94	NM
10/8/2019 12:28	0.7/0.7	2	44.5	21,040	47.2	72.9	72	30.13	0.25	10.72	NM
10/9/2019 12:11	2.4/2.3	2	42.7	21,710	55.6	77.8	71	29.77	2.69	10.68	NM
10/15/2019 9:52	-1.4/-1.3	2	44.8	21,150	62.6	62.3	56	30.07	19.16	1.82	NM
10/22/2019 9:00	-2.1/-2.1	2	46.5	19,130	70.0	47.7	36	30.27	19.92	0.46	NM
10/31/2019 8:45	-3.5/-3.5	2	47.6	10,170	55.5	25.4	22	30.51	20.34	0.42	NM
11/5/2019 8:41	-0.9/-0.9	2	45.6	17,560	66.2	46.4	41	30.22	20.00	0.28	NM

% = percent

°F = degrees Fahrenheit

CH_4 = methane

CO_2 = carbon dioxide

in-Hg = inches of mercury

in-WC = inches of water column

NM = not measured

O_2 = oxygen

ppmv = parts per million by volume

scfm = standard cubic feet per minute

VOC = volatile organic compound

Table 4-5
KAFB-106V1-217 Respiration Monitoring

Date and Time	Well Head Pressure Pre/Post Purge (in-WC)	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry											
4/10/2019 10:56	5.2/4.9	2	37.9	24,270	62.6	64.3	63	24.22	0.09	11.40	0.0
Dry Respirometry - Post-Injection											
5/6/2019 15:26	0.0/0.0	2	65.2	24,970	47.1	74.5	65	24.60	0.11	11.50	0.0
Wet Respirometry - Pre-Injection											
6/20/2019 11:42	0.0/0.0	2	45.0	25,730	33.6	92.1	84	24.71	0.17	12.02	0.0
Wet Respirometry - Post-Injection											
7/5/2019 9:21	-1.1/-1.2	2	50.1	24,980	49.3	80.5	81	24.81	0.47	11.98	0.0
Bioventing											
10/7/2019 12:57	-1.5/-1.5	2	53.9	25,170	61.7	71.6	66	30.35	0.12	12.20	NM
10/8/2019 12:33	0.6/0.6	2	48.2	24,420	55.3	75.1	72	30.13	0.35	11.72	NM
10/9/2019 12:15	2.3/2.3	2	48.1	25,530	57.0	77.4	71	29.77	1.66	11.38	NM
10/15/2019 10:20	-1.2/-1.3	2	48.6	23,160	65.1	62.2	59	30.07	12.96	5.02	NM
10/22/2019 9:20	-2.1/-2.2	2	50.6	9,800	65.6	49.9	44	30.25	18.77	1.42	NM
10/31/2019 9:12	-3.5/-3.5	2	54.2	996	60.7	27.4	27	30.53	20.65	0.18	NM
11/5/2019 9:09	-0.6/-0.6	2	47.6	6,420	69.1	49.3	45	30.20	19.84	0.64	NM

% = percent

°F = degrees Fahrenheit

CH_4 = methane

CO_2 = carbon dioxide

in-Hg = inches of mercury

in-WC = inches of water column

NM = not measured

O_2 = oxygen

ppmv = parts per million by volume

scfm = standard cubic feet per minute

VOC = volatile organic compound

Table 4-6
KAFB-106V1-252 Respiration Monitoring

Date and Time	Well Head Pressure Pre/Post Purge (in-WC)	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry											
4/10/2019 11:13	4.8/4.8	2	42.1	22,740	62.9	65.4	63	24.22	0.13	11.56	0.0
Dry Respirometry - Post-Injection											
5/9/2019 15:39	0.0/0.0	2	63.2	22,570	47.0	74.1	65	24.60	9.80	7.80	0.0
Wet Respirometry - Pre-Injection											
6/20/2019 11:36	0.0/0.0	2	44.8	23,030	33.3	91.6	84	24.71	6.12	7.92	0.0
Wet Respirometry - Post-Injection											
7/5/2019 9:37	-1.1/-1.1	2	53.6	22,420	46.7	81.5	81	24.81	12.62	5.34	0.0
Bioventing											
10/7/2019 13:00	-1.3/-1.3	2	44.0	21,540	63.0	73.3	66	30.35	2.63	9.20	NM
10/8/2019 12:35	0.8/0.7	2	50.8	21,690	54.0	78.7	72	30.13	3.11	8.88	NM
10/9/2019 12:19	2.5/2.5	2	44.9	22,430	57.3	77.0	71	29.77	10.25	7.80	NM
10/15/2019 10:35	-1.2/-1.1	2	47.6	22,350	69.0	62.9	59	30.07	19.60	0.14	NM
10/22/2019 9:33	-2.0/-2.0	2	47.5	19,870	71.4	51.1	44	30.25	20.07	0.00	NM
10/31/2019 9:28	-3.3/-3.3	2	51.4	15,290	64.4	28.8	27	30.53	20.28	0.00	NM
11/5/2019 9:23	-0.9/-0.9	2	47.7	18,990	70.8	51.0	46	30.20	20.04	0.00	NM

% = percent

°F = degrees Fahrenheit

CH_4 = methane

CO_2 = carbon dioxide

in-Hg = inches of mercury

in-WC = inches of water column

NM = not measured

O_2 = oxygen

ppmv = parts per million by volume

scfm = standard cubic feet per minute

VOC = volatile organic compound

Table 4-7
KAFB-106V1-263 Respiration Monitoring

Date and Time	Well Head Pressure Pre/Post Purge (in-WC)	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry											
4/10/2019 11:30	5.1/5.1	2	40.3	23,530	64.0	64.4	63	24.22	0.31	11.26	0.0
Dry Respirometry - Post-Injection											
5/9/2019 15:50	0.0/0.0	2	62.9	23,310	45.9	74.7	65	24.60	9.74	7.54	0.0
Wet Respirometry - Pre-Injection											
6/20/2019 11:25	0.0/0.0	2	44.9	23,830	33.5	90.7	84	24.71	6.92	7.32	0.0
Wet Respirometry - Post-Injection											
7/5/2019 9:52	-0.9/-1.0	2	49.7	23,160	43.9	82.3	81	24.81	12.80	5.10	0.0
Bioventing											
10/7/2019 13:05	-1.3/-1.3	2	44.4	22,910	63.6	72.9	66	30.35	3.35	8.38	NM
10/8/2019 12:39	0.6/0.6	2	50.7	22,220	54.0	78.2	72	30.13	3.17	8.36	NM
10/9/2019 12:23	2.5/2.4	2	44.0	22,990	54.7	76.7	71	29.77	5.44	8.36	NM
10/15/2019 10:51	-1.1/-1.0	2	45.3	23,150	70.8	63.8	59	30.07	18.82	1.10	NM
10/22/2019 9:47	-2.0/-2.0	2	47.2	20,650	71.0	54.0	44	30.25	19.96	0.02	NM
10/31/2019 9:50	-3.2/-3.3	2	47.5	16,670	68.0	30.5	30	30.50	20.28	0.00	NM
11/5/2019 9:43	-0.7/-0.7	2	47.1	21,470	70.7	53.5	49	30.18	19.99	0.00	NM

% = percent

°F = degrees Fahrenheit

CH_4 = methane

CO_2 = carbon dioxide

in-Hg = inches of mercury

in-WC = inches of water column

NM = not measured

O_2 = oxygen

ppmv = parts per million by volume

scfm = standard cubic feet per minute

VOC = volatile organic compound

Table 4-8
KAFB-106V2-102 Respiration Monitoring

Date and Time	Well Head Pressure Pre/Post Purge (in-WC)	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry											
4/11/2019 8:23	0.0/0.0	2	44.5	20,350	66.5	48.4	44	24.33	0.20	12.14	0.0
Dry Respirometry - Post-Injection											
5/9/2019 12:36	0.0/0.0	2	55.5	27,600	61.5	63.8	61	24.62	3.40	9.96	0.0
Wet Respirometry - Pre-Injection											
6/20/2019 12:50	0.0/0.0	2	46.2	29,260	23.9	98.7	88	24.70	2.12	11.06	0.0
Wet Respirometry - Post-Injection											
7/5/2019 10:22	0.0/0.0	2	45.8	27,940	40.0	83.5	82	24.81	3.69	10.32	0.0
Bioventing											
10/7/2019 13:30	0.0/0.0	2	41.3	27,780	61.4	74.2	66	30.35	1.98	10.80	NM
10/8/2019 13:00	0.0/0.0	2	45.9	28,800	49.6	80.0	72	30.13	2.09	10.82	NM
10/9/2019 12:32	0.6/0.5	2	45.7	27,710	52.4	78.0	73	29.72	2.30	10.50	NM
10/15/2019 11:19	0.0/0.0	2	47.7	28,190	69.9	66.3	64	30.03	5.34	9.80	NM
10/22/2019 10:23	0.0/0.0	2	46.1	26,110	52.4	60.0	50	30.23	12.98	6.26	NM
10/31/2019 10:18	0.0/0.0	2	46.2	22,060	62.0	32.5	32	30.47	16.74	4.04	NM
11/5/2019 10:14	0.0/0.0	2	47.8	27,590	63.4	57.9	53	30.19	17.31	2.96	NM

% = percent

°F = degrees Fahrenheit

CH_4 = methane

CO_2 = carbon dioxide

in-Hg = inches of mercury

in-WC = inches of water column

NM = not measured

O_2 = oxygen

ppmv = parts per million by volume

scfm = standard cubic feet per minute

VOC = volatile organic compound

Table 4-9
KAFB-106V2-117 Respiration Monitoring

Date and Time	Well Head Pressure Pre/Post Purge (in-WC)	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry											
4/11/2019 8:56	0.9/0.9	2	44.3	26,840	63.4	52.9	44	24.34	0.22	12.02	0.0
Dry Respirometry - Post-Injection											
5/9/2019 12:52	0.0/0.0	2	54.0	27,820	63.3	64.5	61	24.62	4.23	8.96	0.0
Wet Respirometry - Pre-Injection											
6/20/2019 12:45	0.0/0.0	2	46.8	30,890	24.6	98.1	88	24.70	0.70	11.40	0.0
Wet Respirometry - Post-Injection											
7/5/2019 10:26	0.0/0.0	2	46.4	29,660	34.1	89.6	82	24.81	3.48	10.02	0.0
Bioventing											
10/7/2019 13:33	0.0/0.0	2	42.5	29,440	58.4	74.8	66	30.35	1.97	10.54	NM
10/8/2019 13:05	0.5/0.5	2	49.1	31,350	48.4	80.1	72	30.13	1.49	10.74	NM
10/9/2019 12:37	0.0/0.0	2	47.2	30,530	50.0	78.9	73	29.72	5.58	8.64	NM
10/15/2019 11:45	0.0/0.0	2	49.4	31,250	66.0	67.5	64	30.03	4.01	9.90	NM
10/22/2019 10:37	0.0/0.0	2	48.5	27,990	55.3	59.0	50	30.23	11.01	7.32	NM
10/31/2019 10:35	0.0/0.0	2	47.4	23,500	58.2	33.0	32	30.47	15.05	5.52	NM
11/5/2019 10:29	0.0/0.0	2	48.3	29,640	65.1	59.1	53	30.19	14.21	5.16	NM

% = percent

°F = degrees Fahrenheit

CH_4 = methane

CO_2 = carbon dioxide

in-Hg = inches of mercury

in-WC = inches of water column

NM = not measured

O_2 = oxygen

ppmv = parts per million by volume

scfm = standard cubic feet per minute

VOC = volatile organic compound

Table 4-10
KAFB-106V2-160 Respiration Monitoring

Date and Time	Well Head Pressure Pre/Post Purge (in-WC)	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry											
4/11/2019 9:27	2.7/2.6	2	41.6	9,060	64.7	53.4	46	24.34	0.53	12.88	0.0
Dry Respirometry - Post-Injection											
5/9/2019 13:13	0.0/0.0	2	56.9	9,770	59.5	64.7	62	24.62	13.78	4.08	0.0
Wet Respirometry - Pre-Injection											
6/20/2019 12:40	0.5/0.0	2	45.1	10,120	25.5	97.3	88	24.70	0.84	11.36	0.0
Wet Respirometry - Post-Injection											
7/5/2019 10:52	-1.2/-1.2	2	47.2	9,630	37.5	86.3	86	24.81	12.80	4.22	0.0
Bioventing											
10/7/2019 13:37	-1.6/-1.8	2	43.4	11,120	59.0	74.3	66	30.35	13.97	8.40	NM
10/8/2019 13:08	1.1/1.1	2	46.3	11,080	49.2	80.3	72	30.13	19.23	2.32	NM
10/9/2019 12:44	2.6/2.6	2	42.8	9,390	48.7	79.9	73	29.72	19.94	0.48	NM
10/15/2019 12:08	-0.5/-0.5	2	47.2	4,990	65.0	69.4	67	30.04	20.12	0.04	NM
10/22/2019 10:55	-2.0/-1.9	2	46.9	3,470	57.0	59.6	55	30.21	20.40	0.08	NM
10/31/2019 11:00	-2.4/-2.4	2	48.9	2,340	58.2	34.0	35	30.44	20.56	0.16	NM
11/5/2019 10:50	0.0/0.0	2	47.1	2,400	64.4	59.9	57	30.14	20.33	0.10	NM

% = percent

°F = degrees Fahrenheit

CH_4 = methane

CO_2 = carbon dioxide

in-Hg = inches of mercury

in-WC = inches of water column

NM = not measured

O_2 = oxygen

ppmv = parts per million by volume

scfm = standard cubic feet per minute

VOC = volatile organic compound

Table 4-11
KAFB-106V2-217 Respiration Monitoring

Date and Time	Well Head Pressure Pre/Post Purge (in-WC)	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry											
4/11/2019 10:08	2.2/2.2	2	42.8	21,340	66.6	52.6	32	24.35	0.38	12.08	0.0
Dry Respirometry - Post-Injection											
5/9/2019 13:25	0.0/0.0	2	60.6	21,960	58.3	64.8	62	24.62	1.39	11.82	0.0
Wet Respirometry - Pre-Injection											
6/20/2019 12:33	0.5/0.0	2	45.2	23,260	28.6	95.7	88	24.70	0.87	12.10	0.0
Wet Respirometry - Post-Injection											
7/5/2019 11:06	-1.3/-1.3	2	50.9	22,650	39.1	87.5	87	24.81	1.40	11.92	0.0
Bioventing											
10/7/2019 13:41	-1.3/-1.4	2	44.5	22,860	62.2	73.6	66	30.35	0.45	12.46	NM
10/8/2019 13:12	0.9/0.9	2	45.7	23,610	55.6	80.2	72	30.13	0.43	12.56	NM
10/9/2019 12:47	2.3/2.3	2	42.1	22,730	55.1	80.7	73	29.72	0.71	12.20	NM
10/15/2019 12:22	-0.8/-0.8	2	48.0	23,450	64.4	71.2	67	30.04	7.00	10.12	NM
10/22/2019 11:08	-2.2/-2.2	2	47.7	21,890	60.4	59.1	55	30.21	12.17	6.80	NM
10/31/2019 11:13	-3.3/-3.4	2	49.6	19,600	64.0	35.0	35	30.44	16.11	4.18	NM
11/5/2019 11:03	-0.5/-0.5	2	48.8	22,840	66.3	60.5	57	30.14	17.33	2.42	NM

% = percent

°F = degrees Fahrenheit

CH_4 = methane

CO_2 = carbon dioxide

in-Hg = inches of mercury

in-WC = inches of water column

NM = not measured

O_2 = oxygen

ppmv = parts per million by volume

scfm = standard cubic feet per minute

VOC = volatile organic compound

Table 4-12
KAFB-106V2-252 Respiration Monitoring

Date and Time	Well Head Pressure Pre/Post Purge (in-WC)	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry											
4/11/2019 10:36	2.3/2.4	2	41.6	14,710	69.3	55.5	48	24.33	7.19	7.74	0.0
Dry Respirometry - Post-Injection											
5/9/2019 13:38	0.0/0.0	2	59.2	14,010	61.4	65.0	62	24.62	12.85	5.04	0.0
Wet Respirometry - Pre-Injection											
6/20/2019 12:28	0.5/0.5	2	46.9	14,790	29.2	95.7	88	24.70	5.47	8.58	0.0
Wet Respirometry - Post-Injection											
7/5/2019 11:17	-0.9/-0.9	2	47.7	14,430	41.5	88.4	88	24.81	15.09	2.92	0.0
Bioventing											
10/7/2019 13:44	-1.0/-1.3	2	44.6	15,100	63.4	73.4	66	30.35	2.00	10.38	NM
10/8/2019 13:15	1.1/1.1	2	46.2	15,590	54.0	79.6	72	30.13	16.15	5.02	NM
10/9/2019 12:51	2.6/2.7	2	41.0	15,190	53.4	81.3	74	29.71	19.50	0.92	NM
10/15/2019 12:35	0.0/0.0	2	48.3	15,360	62.8	72.2	70	30.00	19.90	0.00	NM
10/22/2019 11:22	-1.7/-1.8	2	49.2	14,680	67.0	58.1	55	30.24	20.19	0.00	NM
10/31/2019 11:28	-3.0/-3.1	2	49.2	12,730	66.4	36.2	36	30.41	20.46	0.00	NM
11/5/2019 11:14	0.0/0.0	2	46.7	14,490	67.2	60.9	59	30.16	20.13	0.00	NM

% = percent

°F = degrees Fahrenheit

CH_4 = methane

CO_2 = carbon dioxide

in-Hg = inches of mercury

in-WC = inches of water column

NM = not measured

O_2 = oxygen

ppmv = parts per million by volume

scfm = standard cubic feet per minute

VOC = volatile organic compound

Table 4-13
KAFB-106V2-270 Respiration Monitoring

Date and Time	Well Head Pressure Pre/Post Purge (in-WC)	Flow Rate (scfm)	Vacuum (in-WC)	VOC (ppmv)	Relative Humidity (%)	Vapor Temperature (ºF)	Ambient Temperature (°F)	Barometric Pressure (in-Hg)	O_2 (%)	CO_2 (%)	CH_4 (%)
Baseline Respirometry											
4/11/2019 11:09	2.4/2.4	2	41.1	14,610	64.4	55.6	NM	24.36	8.63	6.98	0.0
Dry Respirometry - Post-Injection											
5/9/2019 13:50	0.0/0.0	2	59.8	18,180	59.0	65.1	62	24.62	11.73	5.66	0.0
Wet Respirometry - Pre-Injection											
6/20/2019 12:21	0.0/0.0	2	47.3	20,420	29.3	94.5	88	24.70	5.37	8.56	0.0
Wet Respirometry - Post-Injection											
7/5/2019 11:29	-1.3/-1.2	2	50.0	20,050	35.2	89.2	88	24.81	13.54	4.58	0.0
Bioventing											
10/7/2019 13:48	-1.2/-1.3	2	45.4	19,600	63.4	73.5	66	30.35	2.18	9.72	NM
10/8/2019 13:19	1.0/1.0	2	45.3	19,680	52.3	78.5	72	30.13	9.99	8.82	NM
10/9/2019 12:55	2.6/2.6	2	44.1	18,890	46.2	81.7	74	29.71	18.58	2.08	NM
10/15/2019 12:46	0.0/0.0	2	48.8	18,950	60.7	73.0	70	30.00	19.64	0.08	NM
10/22/2019 11:35	-1.7/-1.7	2	49.8	17,420	67.8	58.7	55	30.24	19.99	0.00	NM
10/31/2019 11:36	-3.0/-3.0	2	50.5	14,470	65.1	37.0	36	30.41	20.22	0.00	NM
11/5/2019 11:25	0.0/0.0	2	49.8	17,560	67.5	61.5	59	30.16	19.98	0.00	NM

% = percent

°F = degrees Fahrenheit

CH_4 = methane

CO_2 = carbon dioxide

in-Hg = inches of mercury

in-WC = inches of water column

NM = not measured

O_2 = oxygen

ppmv = parts per million by volume

scfm = standard cubic feet per minute

VOC = volatile organic compound

Table 5-1
Long-Term Bioventing Flow Design

Injection Well	Screened Interval (ft bgs)	Screen Length (ft)	Screen Diameter (in.)	Casing Volume (cubic ft)	Filter Pack Thickness (ft)	Control Radius (ft)	Control Area (square ft)	Control Cell Pore Volume (cubic ft)	Total Volume Injected (cubic ft)[1]
SVMW-11-100	100-102.5	2.5	0.5	0.140	8.2	70	15,400	37,884	138,438
SVMW-11-250	250-252.5	2.5	0.5	0.344	7.3	70	15,400	33,726	104,878
SVMW-11-260	260-262.5	2.5	0.5	0.358	22.5	70	15,400	103,950	125,853
SVEW-01-260	245-260	15	4	22.678	26	70	15,400	120,120	503,412
SVMW-10-100	100-102.5	2.5	0.5	0.140	7.9	70	15,400	36,498	104,870
SVMW-10-150	150-152.5	2.5	0.5	0.208	9.5	70	15,400	43,890	83,896
SVMW-10-250	250-252.5	2.5	0.5	0.344	10.3	70	15,400	47,586	117,454
SVMW-02/03-160	145-160	15	2	3.489	29	70	15,400	133,980	604,740
SVEW-04/05-313	298-313	15	2	6.825	25	70	15,400	115,500	419,510

[1] = Total injected volume during the long-term bioventing pilot test as of November 5, 2019
Control cell volume is calculated using a venting thickness equivalent to the filter pack thickness
Assumed porosity = 30% (KAFB-106V air filled porosity = 32.6%, KAFB-106V2 air filled porosity = 21.4%)
Control radius is equal to the farthest distance between injection and observation wells
bgs = below ground surface
ft = foot/feet
in. = inch(es)