Sandia National Laboratories

Department of Energy Office of Nuclear Energy (DOE-NE)
Spent Fuel and Waste Science and Technology (SFWST) Campaign

Test Plan

Passive Atmospheric Monitoring in a Vadose Zone Underground Research Laboratory

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1.0 DEFINITION OF ABBREVIATIONS AND ACRONYMS

AC	Alternating current
DIE	Determination of importance evaluation
DOE	Department of Energy
DOE-NE	DOE Office of Nuclear Energy
DQO	Data quality objective
ECRB	Enhanced Characterization of the Repository Block
ESF	Exploratory studies facility
ES&H	Environmental safety and health
LPS	Laboratory policy system
M&TE	Measuring and test equipment
NFSCS	Nuclear Fuel Cycle and Supply Chain
NNSS	Nevada National Security Site
NOAA	National Oceanic and Atmospheric Administration
PSL	Primary standards laboratory
QAPD	Quality assurance program document (DOE-NE)
QAPD	Quality assurance program definition (SNL)
QRL	Quality rigor level
SFWST	Spent Fuel and Waste Science and Technology
SNL	Sandia National Laboratories
SORD	Special Operations and Research Division
TFM	Tracers, fluids, and materials
URL	Underground research laboratory

2.0 REVISION HISTORY

This is the final version of this test plan, to satisfy the September 30, 2021 level-3 milestone M3SF-21SN010310012.

3.0 PURPOSE AND SCOPE

Underground Research Laboratories (URLs) present a unique opportunity to investigate physical phenomena relevant to the disposal of radioactive waste at the appropriate scale, location, or conditions of a future repository. This test plan lays out an approach to passively monitor atmospheric conditions in an existing vadose zone URL in Area 25 at the Nevada National Security Site (NNSS), under the influence of both environmental (i.e., passive air movement) and man-made (i.e., forced ventilation) conditions. A significant amount of testing and research has gone into understanding two-phase flow of air and water in the fractured vadose zone at this URL (e.g., Bodvarsson et al., 2003; Houseworth et al., 2003; Wang & Bodvarsson 2003; BSC, 2004; Rechard, et al., 2014).

The effects of topographic relief, a thick gas-permeable vadose zone, and density differences can lead to free convection of air through the vadose zone. In the winter, cool, dry desert air is denser than relatively warm, humid air in the subsurface. The density of dry air increases as it gets cooler, and humid air density decreases with increasing humidity. Dense air may flow in at the base of the mountain, while less dense moist air may then buoyantly rise out the top of the mountain. In the summer, the effect is lessened and reversed (warm, dry air flowing into the top of the mountain and relatively cooler, moist air flowing out the bottom of the mountain). This natural density-driven circulation system has been observed in deep vadose zone boreholes (Weeks, 1987; Kipp Jr., 1987; Ross et al., 1992). Barometric pumping can also contribute to advection of gases through thick vadose zones but is not dependent on the composition or density of the air, only time-variable barometric pressure, and a network of communicating more permeable fractures and less permeable surrounding rock (Nilson et al., 1991). Carbon dioxide (CO_2) concentrations in vadose zone air is variable in space and time, which can change markedly, owing to changes in temperature, aqueous-phase chemical changes and mineral-water reactions, and advective and diffusive transport (Yang et al., 1986; Sonnenthal & Spycher, 2001). Radon is derived from radioactive decay of naturally occurring uranium in the surrounding rock, and its concentration is related to the ventilation rate and air pressure difference between the drifts and the surrounding rock (Unger et al., 2004).

Humidity and concentrations of radon and CO_2 in the URL are generally expected to be impacted by the balance of air arriving in the drift through the tunnel and air permeating through the vadose zone, with each gas component possibly impacted differently by this balance. Measurements made in the URL in the 1990s and early 2000s show air temperature, radon concentration, and relative humidity vary with position in a bulkhead-isolated drift, while barometric pressure was largely uniform along the same drift (BSC, 2004; Unger et al., 2004). Water, radon, and CO_2 concentrations, air temperature, barometric pressure, and wind speed and direction may all be impacted by the relative proportion of air coming to the tunnel through the drift and air seeping through the vadose zone. These data at several locations in the URL, recorded at a high frequency through several seasons, will provide useful information about aspects unique to URLs in the vadose zone. One goal is to monitor long-term variation of atmospheric conditions through seasons, and a secondary goal is to monitor the short-term variation of atmospheric conditions associated with forced ventilation and the time it takes the system to return to background conditions after periods of forced ventilation.

The in-tunnel monitoring data collected in the URL will be interpreted in conjunction with analogous atmospheric condition data already being collected at nearby NNSS weather stations by the National Oceanic and Atmospheric Administration (NOAA) as part of their Special Operations and Research Division (SORD) program.

The passive monitoring work proposed in this test plan is non-site disturbing. Forced ventilation itself may subtly alter the state of the system, but little additional ventilation will be associated with the installation, monitoring, or removal of this test. The focus of this monitoring is to better understand the interaction between natural and forced ventilation with the state of the system. There may be a need to use water for dust control while installing or servicing/monitoring instrumentation installed into the URL, and controls are outlined in Appendix A for any of these non-site disturbing activities.

This test plan describes the planned activities in sufficient detail to enable an appropriately trained technical team to implement the test program in the URL. The general objective of these test activities is to characterize the time and space variability of atmospheric conditions in an underground research facility above the regional water table. The specific technical objectives of this test are as follows:

- Passively monitor air temperature, barometric pressure, and wind direction/speed through time at multiple locations in the URL;
- Passively monitor humidity and concentration of radon and CO_2 in the air through time at multiple locations in the URL;
- Record and save the above data streams through time (e.g., at 1- to 15-minute intervals) at each location, for later download and analysis.
- Collect passive parameters for at least one calendar year (possibly multiple years), to observe seasonal variations in contributions of ventilation from different components and response of the system to forced ventilation during different seasons.

Subsequent steps will analyze the data collected as part of this test plan, to improve understanding of contributions between active and passive ventilation in a vadose zone URL.

4.0 EXPERIMENTAL PROCESS DESCRIPTION

4.1 Overall Strategy and Process

4.1.1 Test Configuration – Atmospheric Monitoring Locations within the URL

The layout of the URL stations is shown in Figure 1. Passive monitoring will focus on the North Ramp (Stations 0+00 to 25+00). Three atmospheric monitoring locations will be distributed along the North Ramp, with one monitoring location inside the North Portal, one monitoring location near the south turn from the North Ramp to the Main Drift (past the connection to the ECRB), and one station between these two endpoints. Depending on access, a fourth monitoring point should be located out of the main tunnel in an alcove (possibly behind a bulkhead – e.g., Alcove 7), to get an additional estimate of the conditions away from active tunnel ventilation. If access to an alcove is not initially possible, it may be added later after assessing data from initial monitoring in the drift. Three atmospheric monitoring locations will be positioned at locations along the North Ramp where physical access is available, possibly locating dataloggers at or near existing alcoves (Figure 2), although sensors should be in the main drift. The location of a possible fourth monitoring station in an alcove would be based on availability and access. The location of the stations should be chosen considering the position of ventilation fans in the URL (Figure 2). Depending on the complexity of the ventilation system a ventilation network model may be developed to better understand the in-drift observations.

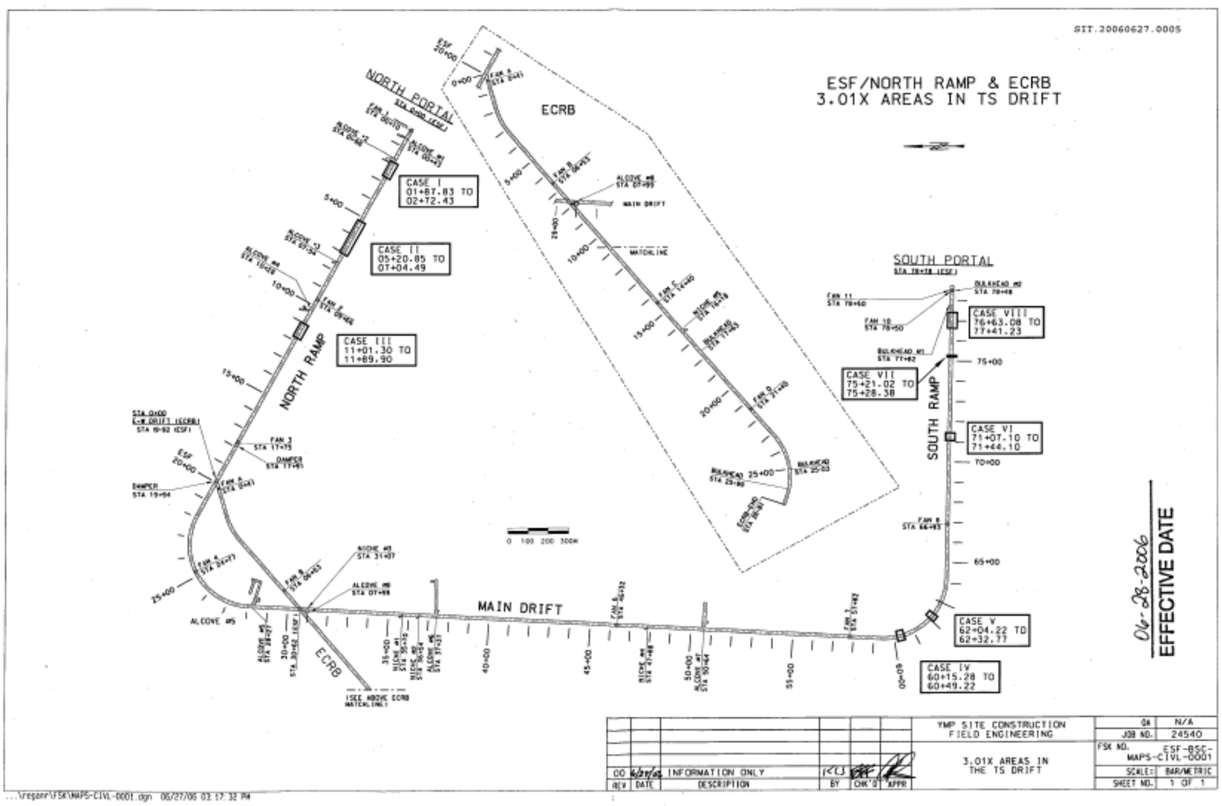

Figure 1. URL tunnel layout showing stations (BSC, 2008)

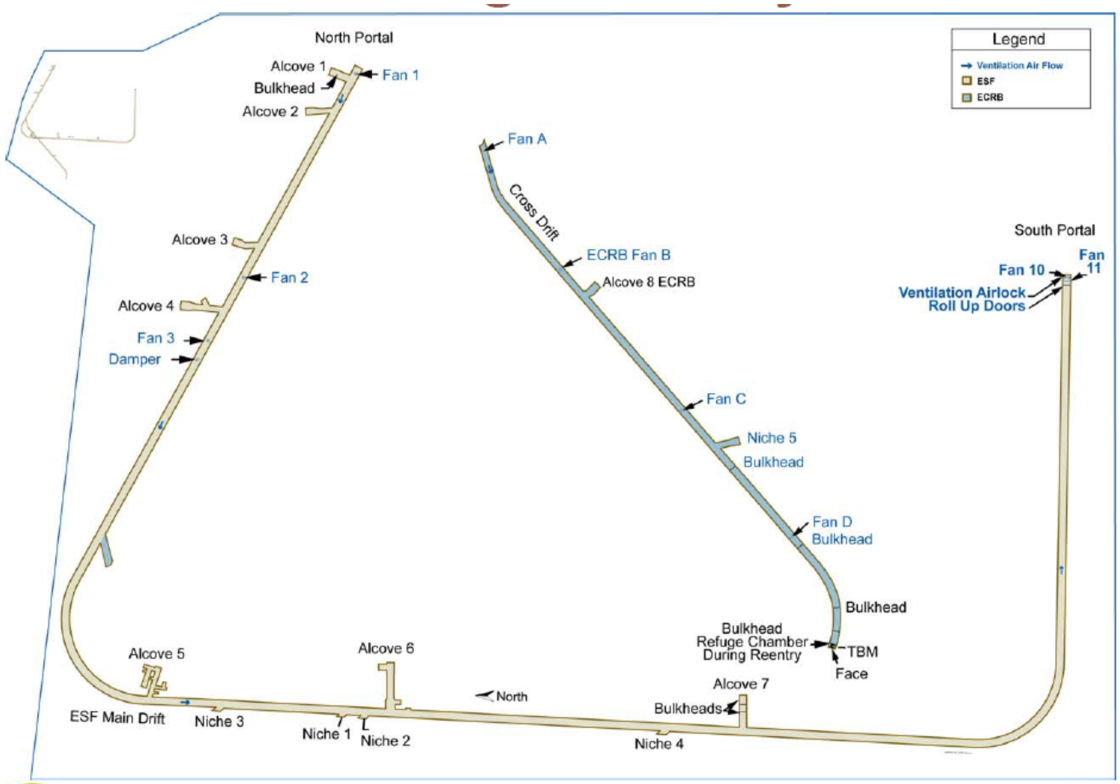

Figure 2. URL tunnel layout showing location of alcoves and fans (US DOE, 2007)

4.1.2 Test Configuration – Configuration of each Atmospheric Monitoring Location

Each monitoring location will consist of several typical "weather station" type measurements and atmospheric air composition measurements. The measurement instruments at each station will be connected to a stand-alone measurement and control datalogger that will take readings from the instruments at regular time intervals. The datalogger and some of the equipment will be mounted inside a weather-resistant enclosure that will either be mounted on the drift wall or placed on the drift floor. The sensors at each monitoring location should (to the extent possible) be located at comparable positions within the drift cross-section, to improve comparisons between data collected at different stations.

4.1.2.1 Air Temperature Sensors

Three air temperature measurements will be made at each station with a thermistor rated for operation in a wider range of temperatures than expected at the URL (e.g., −50 to +70 ºC). The air temperature sensors should have relatively fast response time (e.g., on the order of 10 sec) and an expected measurement resolution less than 0.2 ºC. The sensing parts of the temperature measuring instruments should be mounted outside the weather-resistant enclosure at consistent relative heights in the drift cross-section (e.g., one sensor near the invert or floor, one sensor near the back or ceiling, and one sensor in-between).

4.1.2.2 Barometric Pressure Gauges

Barometric pressure measurements will be made with a barometer rated for operation in a wider range of air pressures than expected in the URL (e.g., 600 to 1100 mbar). The barometer should have a relatively fast response time (e.g., less than one second) and resolution of better than 0.01 mbar. The barometer may be mounted inside the enclosure, but the sensing part of the barometer should be allowed to communicate freely with the air outside the enclosure at a consistent relative height in the drift cross-section.

4.1.2.3 Wind Speed and Direction Sensors

Wind speed will be measured across a wide range of expected conditions. Natural ventilation conditions are expected to be very low flow (i.e., nearly still air), while flowrates will be much higher during periods of forced ventilation. An ultrasonic anemometer (or similar) should be used, which can measure a wide range of wind magnitude and direction (especially low flowrates expected during natural ventilation) outside the weather-resistant enclosure at a consistent relative height in the drift cross-section and a consistent distance from the wall. Full three-dimensional wind direction and speed characterization is not required, but the sensor should be able to distinguish between flow in the tunnel towards and away from the portal (e.g., a 2D anemometer).

4.1.2.4 Relative Humidity Sensor

Relative humidity of the air will be monitored with a sensor sensitive to a range of humidity expected in the URL, likely elevated above those observed in the ambient air outside the URL. Air in the vadose zone may be close to 100% relative humidity. Air from the surface will be much drier under most conditions. Sensor accuracy should be at least 5% in the expected range of temperatures. The relative humidity sensors will be capacitive sensors (or equivalent) mounted outside the enclosure at consistent relative heights in the drift cross-section.

4.1.2.5 CO_2 concentration sensor

A CO_2 analyzer capable of running for months on battery power (i.e., low power demand) will be mounted inside the environmental enclosure and the sensor must be connected with access to the air outside the enclosure. CO_2 concentrations are expected to be higher in air from the vadose zone, as well as in air impacted by internal combustion engines or respiration by personnel. The CO_2 analyzer will be suited for the expected range of CO_2 concentrations (somewhat elevated above ambient atmospheric levels). The sensing part of the instrument will be mounted at a consistent height in the drift cross-section.

4.1.2.6 Radon concentration sensor

A radon analyzer, capable of running for months on battery power (i.e., low power demand) will test for radon concentration in air outside the environmental enclosure. The radon analyzer will be suited for the expected range of radon concentrations (i.e., elevated above ambient levels during periods of no ventilation). Radon is generated by radioactive decay of natural uranium in the rocks comprising the vadose zone. The radon analyzer will measure radon concentration of air at a consistent height in the drift cross-section.

4.1.2.7 Support Equipment

The measurement and control datalogger will be mounted in a rugged environmental enclosure to simplify installation and protect the equipment against dust or pests. The wind speed/direction sensor, the end of any tubes connected to the CO_2 and radon analyzers, the air temperature, relative humidity and barometric pressure sensors must be mounted outside the enclosure, but the portions of the gas composition analyzers can be mounted inside the enclosure for protection. The datalogger should also measure the temperature inside the enclosure (a typical thermistor or thermocouple is adequate), the available battery voltage, and log any errors encountered in the controlling program.

Each atmospheric monitoring location will be stand-alone (i.e., they will not be networked to one another), and each location will require its own battery power. Downloading the data will require physically visiting each monitoring location, opening the environmental enclosure, and connecting a laptop or portable computer to the datalogger with a USB cable. While connected, the dataloggers may be field reprogrammed (e.g., the frequency of data collection can be changed). The dataloggers should have adequate memory to save all the measurements that could be taken on a full discharge of the battery. Connecting to the datalogger will allow personnel to confirm operation, retrieve the collected data, and make any required modifications to the data collection program.

Since AC power will not be available, the dataloggers will be powered by 12 V deep-cycle marine batteries (e.g., ≥100 amp-hours), which should allow weeks of operation for the types of low current drain devices indicated here. Lead-acid batteries should be placed in a surrounding basin large enough to capture any possible spills or leaks (see Appendix A). To the degree possible, batteries will be located away from temperature and humidity sensors, as they could change the local temperature and relative humidity. If at some point AC power becomes available, the dataloggers will be connected to AC power at each location but should still have battery backup to ensure continuity of measurements, even when power is disrupted.

Out of all the measurement equipment, the CO_2 and radon analyzers at each station would likely use the most current. To minimize battery swap-out and maintenance, the lowest-power CO_2 and radon sensors should be selected. The frequency of data collection will also impact the lifetime of the systems on a single charge (i.e., higher frequency data collection uses more power). To run the systems for extended periods of time (i.e., multiple calendar years, to document winter/summer patterns in ventilation), at least two deep-cycle marine batteries will be needed for each station. One will be charged at a location with available AC power while the other is being used to power data collection in the URL. Depending on the details of power usage and logging frequency, the system should run several weeks to several months on a single discharge of the deep-cycle marine battery. To increase the useful life of the batteries, they should not be discharged below 50% (approximately 12.0 V) if possible.

4.1.3 Critical Variables

The critical variables and units for each of the weather stations include air temperature (degrees Celsius), air pressure (millibars), air speed and direction (meters per second and angle relative to north), relative humidity (percent), radon concentration (picocuries per liter), and CO_2 concentration (micromoles per mole). The air temperature inside the enclosure and the battery supply voltage should also be monitored.

4.1.4 Procedures to be Used or Developed

Example procedures to carry out this work are listed. The need for additional procedures may arise during implementation. Any procedures will be activity-specific procedures and will be created in alignment with Section 7 of Sandia's QA program (SNL, 2019) to document the construction, maintenance, or any data collection efforts associated with the work.

One or more procedures will be developed to address aspects of the implementation, including:

- Confirmation of the function and calibration of all the sensors and logging equipment before delivery to the site and installation.
- Identification and measurement of monitoring point locations in the URL tunnel coordinate system.
- Configuration of data logger clocks and recording frequency (e.g., every 1 to 15 minutes).
- Procedure for visiting monitoring locations to confirm operation, download data, and swap out batteries (documenting personnel and equipment used at each visit which may impact the readings).
- Management of ES&H concerns with working in an underground research facility.
- Maintenance of the measurement and control dataloggers and sensors at each monitoring location.
- Post-test removal of the monitoring equipment and as-found calibration checks on the sensors.

Procedures may be developed to include several of these needs, and if certain elements are not conducive to a formal procedure, techniques employed will be recorded in a scientific notebook.

4.1.5 Identification of Known or Expected Errors

Errors and uncertainties known to exist with the measurement systems include those associated with instrument accuracy, measurement point location, and the URL environment (Section 7.3, Criterion 3 of SNL, 2019: "Management/Quality Improvement"). These measurement systems will be composed of off-the-shelf commercial sensors; therefore, instrument error is typically well-known and well below the data quality objectives (DQO). As-built instrument location can be uncertain, but the uncertainty can be reduced to acceptable levels using careful measurements. Changes to the tunnel environment (i.e., visitation of the sites by personnel and motorized equipment) should be recorded in scientific notebooks, to document activities that may impact the observations. Since other activities may occur in the tunnel, it is anticipated that not all changes to the tunnel environment will be documented.

4.1.6 Records Retention

Records generated from fielding this test plan shall be checked and verified to be complete and accurate. Such records shall then be filed and retained following good records retention practices (Section 7.4, Criterion 4 of SNL, 2019: "Management/Documents and Records"). Records retention at Sandia will follow the Sandia Laboratory Polity System (LPS) Policy IT010 "Manage Records Policy" and the related policy IT012 "Unclassified Controlled Information Policy." The latest version of the LPS policies are available on the SNL internal network.

4.1.7 Coordination with Other Organizations

Implementation of the test activities described in this test plan will rely on the cooperation and support services provided by several organizations (Section 7.4, Criterion 1 of SNL, 2019: "Management/Program"). The details of roles and responsibilities are a function of the administrative and operations infrastructure of the underground facility and will need to be worked out when a test location has been selected. Organizations likely needing to participate are discussed here:

<u>Sandia Primary Standards Lab (PSL)</u> – For gauge calibration services: Gauges and sensors used in these tests will come factory calibrated but may have their calibration confirmed (i.e., as-found calibration after removal of instrumentation) and controlled in accordance with procedures to control measuring and test equipment. The implementer will certify that gauges procured from outside vendors have valid calibrations.

<u>The DOE-NE site Facility Manager</u> – For field services: The provision of any electrical power, lights, and ventilation will be provided through the DOE Facility Manager. This organization will control access to the underground, move equipment underground, and ensure field work activities are within facility operating limits. They will also make the necessary checks to confirm that all test activities are permitted within the operating constraints of the facility regulatory permits.

4.1.8 Test Duration and Interactions with Tunnel Activities

It is planned to run the passive monitoring test for a duration of at least one calendar year, but preferably for several years, to observe a number of seasonal variations. A longer dataset would better achieve the technical goals, to allow for inter-annual variation in conditions, but one calendar year is the minimum.

It is expected most of the time the instruments are installed there will be no ventilation. The ventilation will only be used when personnel are in the tunnel performing other activities. Passive ventilation is what the project is most interested in monitoring. The transient reaction of the system to ventilation is also of interest, especially observing how long it takes the system to return to the previous "steady" background condition after ventilating for a short period of time.

Any other activities in the tunnel should be documented to the degree possible, but they will not negatively impact the passive monitoring, as the reaction of the system to ventilation and the cessation of ventilation is also one of the monitoring goals of the project. The instruments and environmental enclosures will be installed temporarily to be removable, non-intrusive, and to not disturb other possible uses of the tunnel.

4.1.9 Estimated Level of Effort

The assembly, testing, programming, and demonstration of the setup will be done in a laboratory at Sandia National Laboratories before traveling to the URL site. The installation of four pre-assembled stations could likely proceed in less than 24 man-hours (i.e., three personnel working for one full day, installing four stations). Three personnel working together could install each station in approximately two hours.

The equipment will be configured to run unattended for several weeks or months at a time. Maintenance (i.e., swapping of batteries and downloading of data) would likely require approximately one-half man-hour per station per visit, approximately every two months. Some minor effort will also need to be directed towards charging the extra deep-cycle marine batteries in preparation for a site visit but charging the batteries with a commercial trickle charger should not be a time-consuming task.

Instrument removal at the end of the experiment should take approximately the same amount of effort as the installation, approximately 24 man-hours. Sensors and equipment will be returned to Sandia for post-test calibration checks.

4.2 Sample Control

As this is a passive monitoring campaign, there are currently no plans to retain physical samples of anything described in this test plan.

4.3 Data Quality Control

4.3.1 Data Quality Objectives

Data Quality Objectives (DQOs) are noted below with a brief justification.

- Air Temperature: ± 1° C. Variability in absolute temperature within 1° C is well within expected accuracy and reflective of expected small-scale differences in temperature across a drift (i.e., differences in temperature between nearby gauges). Relative temperature changes in temperature through time for a single gauge should be available at a higher resolution (e.g., <0.1° C).
- Barometric-ventilation pressure: 0.01 mbar. Pressure differentials in this range could move appreciable volumes of ventilation through the drift or vadose zone.
- Wind speed and direction: 0.01 m/sec and 1 degree. Wind speeds and direction should ideally be measurable under low-flow conditions expected during passive ventilation. During active ventilation, the absolute value of the wind speed and the exact direction are

less important (i.e., during ventilation it is more of an “on or off” indicator measurement); accuracy is more important at low-flow conditions.

- Relative humidity measurement: accuracy of $<$ 5 percentage points (readings are 0 to 100%). Along with barometric pressure and temperature, these measurements will be used to estimate air density and quantify contributions of air from different sources. Moist air is less dense than dry air, and air traveling through the vadose zone should have more moisture than outside air.
- Air CO_2 and radon composition measurements: accuracy $\leq$ 10% of reading. There will likely be a tradeoff between sensor accuracy and sensor power usage, which will have to be evaluated against the scientific goals and access limitations for the project (i.e., higher-accuracy sensors may require more frequent battery changes). These measurements will be used to quantify the impact of natural ventilation (i.e., seepage through the vadose zone) on the drift air, since the concentration of CO_2 and radon should be higher in air traveling through the vadose zone than outside air. Information about the spatial and temporal distribution of radon in the URL is also useful from an environmental safety and health perspective.
- Scan frequencies of up to once every minute may be needed, but less frequent scanning (i.e., every 15 minutes or hour) may be adequate for the scientific goals and allow simpler test logistics. More frequent scanning produces more data but also drains batteries faster, requiring more frequent personnel visits to download data and swap out batteries. A balance between battery life and data frequency should be chosen based on performance of the instruments and data loggers in the laboratory.

4.3.2 Measuring and Testing Equipment (M&TE)

A calibration program will be implemented for the work described in this test plan in accordance with an appropriate measurement and test equipment (M&TE) control program (Section 7.5, Criterion 5 of SNL, 2019: “Performance/Work Processes”). This calibration program will meet the procedural requirements for: (1) receiving and testing M&TE; (2) technical operating procedures for M&TE; (3) the traceability of standards to nationally recognized standards; and (4) maintaining calibration records. It is not expected that sensors will be re-calibrated during the period they are deployed in the field. They should have pre- and possibly post-deployment calibrations performed. Spreadsheet data and other computer-based data will be stored on backed-up servers.

4.3.3 Data Collection

Data collection procedures are specific to individual instruments or systems. Details of the data acquisition for a particular instrument will be provided in activity specific procedures or the user’s manual for that instrument or system (Section 7.5, Criterion 5 of SNL, 2019: “Performance/Work Processes”). Electronically collected data will be archived following records management and retention procedures. If possible, data files may be transferred to portable/removable media for submittal to a central storage location.

Scientific notebooks will primarily be used to record daily activities with respect to test implementation (a record of time, equipment used, and activities). Where scientific notebooks are used, quality control of the notebooks will be established (i.e., technical notebook review). Methods for justification, evaluation, approval, and documentation of deviation from test procedures or establishment of special procedures will be documented in scientific notebooks where appropriate.

4.3.3.1 Manual Data Collection

As noted above, it is not expected that data will be collected manually on data forms associated with activity specific procedures aside from recording the dates and times of specific activities. This could include times when tests are started and stopped, observations of any off-normal events, or to indicate when changes are made to data collection programs. Any data forms, once filled out, will be verified as complete and accurate and saved in a central laboratory notebook as soon as practically achievable.

4.3.3.2 Electronic Data Collection

Data will be collected by an automated data acquisition system while monitoring. This system shall monitor all gauges at each location at a similar frequency (unless power demand requires less frequent testing of some high-drain sensors). Data from this system will be collected and retrieved from the site on portable computers or removable media. The transfer of data from the field to the office will be done in a manner to reduce the likelihood of data being lost or corrupted (i.e., the data will be stored on a backed-up server).

4.3.4 Data Collection Software Qualification

As noted above, a programmable data collection system will be set up at each monitoring location to record data unsupervised from all the instruments at regular intervals (e.g., once every 1 to 15 minutes). Systems will have software written to control data collection and this software will be managed in a backed-up version control system (e.g., git or mercurial).

5.0 QUALITY ASSURANCE (QA)

5.1 Quality-Affecting Activities

Data and observations made in these studies are not expected to be used in repository design or repository performance assessments, rather it is to develop bases for characteristics of generic unsaturated systems. The work described here will follow a “graded approach,” which rationally tailors QA requirements to each activity (Section 7.5, Criterion 5 of SNL, 2019: “Performance/Work Processes”).

5.2 Quality Assurance Program Description (QAPD)

Activities are conducted in accordance with the requirements specified in the Nuclear Fuel Cycle and Supply Chain (NFCSC) Quality Assurance Program Document (QAPD) for Quality Rigor Level (QRL) 3 (DOE-NE, 2019). QRL-3 consists of the existing lab QA program, with an internal technical review before publication (SNL, 2019).

5.3 Data Integrity

Care will be taken while conducting these test activities to ensure the integrity of all data collected including scanning any hard-copy notebooks and putting electronic data collected on reliable, backed-up storage media. Duplicate copies of all data will be produced as quickly as possible, and the duplicate copies will be maintained at a location separate from the test site to minimize the possibility of lost data.

5.4 Records

Records will be maintained as described in this test plan and applicable SNL QAPD implementing procedures (Section 7.4, Criterion 4 of SNL, 2019). Records retention will follow Sandia LPS Policies IT010 “Manage Records Policy”, IT011 “Prepare and Release Information Policy” and IT012 “Unclassified Controlled Information Policy.” These records may consist of bound scientific notebook(s), loose-leaf pages, forms, printouts, or information stored on electronic storage media. The test principal investigator or designee will ensure that the required records are maintained, and electronic records are stored on backed-up servers.

5.4.1 Required Records

As a minimum, records will include:

- Forms or notebooks containing any manually collected data;
- Calibration records for all controlled equipment; and
- Equipment-specification sheets or information (if available).

5.4.2 Miscellaneous Records

Additional records that are useful in documenting the history of the activities should be maintained, if available. These records include:

- Logbooks of daily activities;
- Safety briefings;
- Environmental Safety and Health (ES&H) documentation;
- As-built diagrams of equipment; and
- Equipment manuals and specifications.

5.4.3 Submittal of Records

Records generated through the implementation of this test plan shall be stored on a backed-up server in accordance with the SNL Records Management Manual (SNL, 2021).

6.0 TRAINING

All personnel involved in the experiments described in this test plan (e.g., installing and operating instruments in the URL, data collection, and instrument maintenance) will be trained for their assigned work (Section 7.2, Criterion 2 of SNL, 2019: "Management/Personnel Training and Qualification"). Any personnel working underground shall either have current training credentials or be escorted by someone who does.

7.0 HEALTH AND SAFETY

All underground work described in this test plan shall follow all required facility specific environmental safety and health (ES&H) standard operating procedures for working underground (Section 7.5, Criterion 5 of SNL, 2019: "Performance/Work Processes"; and ESH001.1 from the SNL ES&H Manual "Integrate ES&H into Work Planning and Execution"). Activity specific procedures will have a section devoted to operations safety where appropriate. Additional procedures may be mandated by various organization ES&H requirements and their issuance will not require revision of this test plan.

Personnel shall read the facility specific ES&H requirements for working underground. Tunnel entry will be performed under the current DOE-NE YM site health and safety plan and all lab personnel will be escorted while underground, unless approval is received to develop Lab Health and Safety program and unescorted tunnel access is granted.

8.0 PERMITTING/LICENSING

No special licenses or permits will be needed for the work described in this test plan. Aside from batteries, no hazardous materials are planned to be used. The handling of batteries will include using recommended PPE during their handling, installation, and subsequent removal. The batteries will be placed in a surrounding basin large enough to contain any possible spills during operation and will be removed from the URL (brought back to Sandia for relevant recycling or disposal) at the end of the project. Any equipment placed in the URL will be passive and temporary and will be removed at the end of the monitoring phase (Appendix A).

9.0 REFERENCES

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APPENDIX A.

Preservation of Site Characteristics at the Nevada Site for Unsaturated Geology

Spent Fuel and Waste Science and Technology (SFWST) Campaign staff from Sandia National Laboratories are planning to execute underground research laboratory (URL) setup and testing activities for generic unsaturated systems in the exploratory studies facilities (ESF) tunnels (specifically the Topopah Spring (TS) Loop from the North Portal to some point near the first turn – see Figure 1 and Figure 2). These staff should be aware of, and perform their work consistent with, the previously defined controls on work activities for that site (e.g., see determination of importance (BSC reports and SNL 2009) documents and the US DOE Tracers, Fluids, and Materials [TFM] management procedure (DOE 2009) in References). Each of the areas at the site are covered in at least one of the DIEs, for example, the ESF surface areas (BSC 2005b) and the ESF subsurface (BSC 2005c; 2005d). The DOE TFM management plan covers the care directions to avoid/report inadvertent loss of fluids or materials into the site itself (with substantial structural or equipment that are planned to be removed needing only care for any fluids that may spill from them). The care of the site would include any site visits for reconnaissance and/or installation of equipment, though these sorts of activities are made easily compliant by following the "leave no trace" rules that govern usage of National Parks and Forests. Many of the site controls apply to site disturbing activities, such as physical disruption of rock units via drilling or excavation, and injection of substances into the formations. There are a small number of easily followed rules for simple site access and placement of non-invasive monitoring equipment, with one of them being usage of water for dust control in the underground of the ESF (BSC 2005c, evaluated in Section 11.1.8; controls in Section 13.2.16) as discussed below.

Any work to be done at the URL site should be assessed for site disturbing activities as mentioned above, and any such activities should be followed by an additional assessment of the specific activities via process/methods consistent with the previous SCI-PRO-007 Rev 07, Determination of Importance and Site Performance Protection Evaluations (SNL, 2009). That procedure was the existing Sandia process (at the time of site suspension) for evaluating proposed activities with respect to adverse impacts to the waste isolation capabilities of the site. A process consistent with that procedure would be used only for specific activities not already covered within the existing DIE and the US DOE AP-2.31Q.

For site access and non-site disturbing activities, most AP-2.31Q directions regarding fluids and materials can be easily met by applying the "carry out what you carry in" rule, which shall be applied in conducting this work.

s that applied for trips into National Forest areas with minor additions. As stated above, placing equipment or structural materials that are planned to be removed (i.e., can be readily concluded that they would not dissolve or leak into the rock units) requires no active monitoring except for any internal fluids. Placing and leaving any equipment underground that contain fluids that could leak into the rocks requires that the equipment have adequate spill controls (e.g., a basin) around it to contain any potentially leaking fluids. Another aspect in this regard is the use of water for dust control underground as needed for health and safety purposes (it is noted here that worker health and safety are always the proximal priority beyond any applied site protection processes). The usage of water for dust control underground (BSC 2005c; evaluated in Section 11.1.8; controls in Section 13.2.16) on these occasions is easily within the controls set out previously where it states (BSC 2005c; evaluated in Section 11.1.8):

> As part of the ESF construction operations, water may be sprayed onto the concrete inverts to reduce the concentration of dust in the tunnel atmosphere. The use of water has averaged 0.20 gallons/m-day, or 0.76 liters/m-day (Section 6.13). An analysis of water applied to the inverts (Attachment VIII) indicates that the evaporation rate should exceed this rate of water application over a distance of about 1100 m of the TS Loop (or 1440 m when ventilation is increased to 248,000 cubic feet of air per minute). Therefore, dust control water applied in a fine spray on the inverts at a rate of 0.76 liters/m-day over sections no longer than 1100 m is expected to evaporate and would not need to be counted as water lost to the geologic environment.

The DIE (BSC 2005c; in Section 13.2.16) applies the control:

> As discussed in Section 11.1.8, water applied in a fine spray to the concrete invert top surfaces for dust suppression purposes in the TS Loop, ECRB Cross Drift Starter Tunnel, and TTF, at a rate of no more than 0.20 gallons/m per day (0.76 liters/m per day) over no longer than 900 m, is expected to evaporate and need not be counted as water lost to the geologic environment. If the dust suppression water applied to the concrete invert top is only in the TS Loop, the length over which the water is expected to evaporate may be extended to 1100 m. (Note that Statton 1996 indicates that daily application lengths of approximately 1300 m are typical for the TS Loop. Based on the discussion in Section 11.1.8, as supported by Attachment VIII, any daily application in excess of 900 m [1100 m if only applied in the TS Loop] would have to be reported as water lost to the environment.)

For small groups entering the tunnel for setting up test equipment or monitoring data (or simply for touring the tunnel), this can be put into a simpler light for dust control water. A five (5) gallon sprayer could be used completely for dust control over a 25-meter section of tunnel (0.2 gal/m × 25 m = 5 gal) and still be within this limit on dust control usage (this assumes the ventilation system is running, which is likely due to OSHA requirements). Any usage of water for dust control lower than this value is easily negligible relative to the limits. Note that these limits are averaged over 1100 m (900 m if including the Enhance Characterization of the Repository Block cross drift and thermal test facility), which is likely a larger length than spot application would incur for testing purposes such that small ($<$ 50%) deviations would likely be a non-issue even on a 20 m basis.

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