EMID-703084

DEPARTMENT OF ENERGY

Environmental Management Los Alamos Field Office (EM-LA)
Los Alamos, New Mexico 87544

EMLA-24-BF115-2-1

Received
FEB 01 2024
NMED Hazardous Waste Bureau

February 1, 2024

Mr. Rick Shean
Designated Agency Manager
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Drive East, Building 1
Santa Fe, NM 87505-6313

Subject: Submittal of the Work Plan for Hydrogeologic Testing of Regional Aquifer Groundwater Monitoring Well R-42 at Los Alamos National Laboratory

Dear Mr. Shean:

Enclosed please find two hard copies with electronic files of the "Work Plan for Hydrogeologic Testing of Regional Aquifer Groundwater Monitoring Well R-42 at the Los Alamos National Laboratory." This work plan has been prepared in response to a New Mexico Environment Department (NMED) letter dated April 17, 2023, that requested a work plan for hydrogeologic testing at well R-42.

The work plan addresses the two requests in the NMED letter of April 17, 2023, providing work activities for (1) a low-flow 24-hr aquifer performance test, and (2) flow logging to determine the vertical flow profile along the length of the well R-42 21.1-ft screen. The work plan has followed the aquifer performance testing guidelines provided in NMED's "Aquifer Performance Test Procedures for Hazardous Waste Facilities in New Mexico" (November 2022) (https://www.env.nm.gov/hazardous-waste/guidance-documents/).

If you have any questions, please contact Mike Erickson at (505) 309-1349 (michael.erickson@em-la.doe.gov) or Susan Wacaster at (505) 709-8704 (susan.wacaster@em.doe.gov).

Sincerely,

ARTURO DURAN

Digitally signed by ARTURO DURAN
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Arturo Q. Duran
Compliance and Permitting Manager
U.S. Department of Energy
Environmental Management
Los Alamos Field Office

Enclosure(s):

1. Two hard copies with electronic files:
   Work Plan for Hydrogeologic Testing of Regional Aquifer Groundwater Monitoring Well R-42 at Los Alamos National Laboratory (EM2024-0041)

cc (letter and enclosure[s] emailed):
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February 2024
EM2024-0041

Work Plan for Hydrogeologic Testing of Regional Aquifer Groundwater Well R-42 at Los Alamos National Laboratory

EM2024-0041

Work Plan for Hydrogeologic Testing of Regional Aquifer Groundwater Well R-42 at Los Alamos National Laboratory

February 2024

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Arturo Q. Duran	ARTURO DURAN Digitally signed by ARTURO DURAN Date: 2024.01.31 13:58:07 -07'00'	Compliance and Permitting Manager	Office of Quality and Regulatory Compliance	
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EXECUTIVE SUMMARY

Well R-42 is located in the regional aquifer within the chromium investigation area at the Los Alamos National Laboratory (LANL or the Laboratory), near the centroid of the chromium plume. Well R-42 is the location where sodium dithionite was deployed in 2017 to evaluate in situ chemical reduction of hexavalent chromium as a potential remedial action to immobilize chromium. The injection of sodium dithionite not only succeeded in creating reducing conditions that decreased concentrations of hexavalent chromium, but also resulted in non-representative water quality data. Since the amendment injection, two rehabilitation efforts were performed at well R-42. Testing in 2022 determined that the well has been rehabilitated geochemically, but that more information on the hydraulic communication with the regional aquifer was needed.

Hence, two activities are described in this work plan to investigate the hydraulic connection of well R-42 with the surrounding aquifer. The first activity is a 24-hr, low-flow aquifer test that will minimize drawdown within the well screen where the static water level is just above the top of the screen. To the extent possible, this activity will operate as an aquifer test and follow the guidance provided in the New Mexico Environment Department (NMED) “Aquifer Performance Test Procedures for Hazardous Waste Facilities in New Mexico”; however, interpretation of the drawdown data may be limited by the low flow rate (2–3 gpm). Time-series geochemical data will also be collected during the test. These data will also be used to compare the geochemistry of water samples collected after a typical purge of three casing volumes.

The second activity is to conduct flow logging to determine the vertical velocity profile over the saturated length of the 21-ft screen. Because there are limitations associated with the low-flow velocities at well R-42, two flow-logging methods will be deployed: (1) a high-resolution impeller (spinner) flowmeter, and (2) a hydrophysical logging technique. Because the impeller flow-meter data are questionable at low flow rates, the hydrophysical approach will also be deployed as an alternative technique for detecting flow rates into the well as a function of location within the screen.

These activities will be used to determine the hydraulic communication between well R-42 and the regional aquifer. Although quantitative analyses may be limited by the low flow rates needed to minimize drawdown, qualitative analysis will also be used to evaluate if hydraulic communication with the regional aquifer can be determined with these field activities.

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1.0 INTRODUCTION

Well R-42 is located in the regional aquifer within the chromium investigation area at the Los Alamos National Laboratory (LANL or the Laboratory), near the centroid of the chromium plume (see Figure 1). Well R-42 is also the location where sodium dithionite was deployed in August 2017 to evaluate in situ chemical reduction of hexavalent chromium [Cr(VI)] as a potential remedial action to immobilize chromium. Prior to the sodium dithionite injection, R-42 had the highest measured concentrations of hexavalent Cr(VI) (approximately 700 µg/L to 1000 µg/L) within the chromium investigation area at LANL (analytical data are available on the Intellus New Mexico database [https://intellusnm.com/]). The injection of sodium dithionite succeeded in creating reducing conditions that resulted in low concentrations of hexavalent chromium, as documented in several progress reports (LANL 2018, 602862; LANL 2018, 603031; N3B 2018, 700032; N3B 2018, 700108; N3B 2019, 700214; N3B 2019, 700420; N3B 2019, 700723; N3B 2020, 700954). However, the amendment injection also reduced the near-well permeability due to chromium precipitation.

1.1 Conceptual Model of Rehabilitation Activities at R-42

Two rehabilitation efforts have been conducted since 2020 at well R-42. The first effort was a re-development, conducted in late 2020, resulting in a significant increase in the specific capacity of the well, followed by an increasing trend in Cr(VI) concentrations, measured in 2021, that indicated the initiation of a return to pre-dithionite injection conditions (N3B 2021, 701731). In 2020, the static water level at R-42 was about a foot below the top of the filter pack and about 4 ft above the top of the well screen. Based on the water level relative to the top of the well screen, a pump with a capacity of 2–3 gpm was installed, representing the maximum flow rate that could be pumped while still keeping the well screen submerged. It was also the maximum pumping rate for all sampling and purging that had been conducted since late 2014.

The second rehabilitation was an extended purge that occurred during 2021, withdrawing approximately 104,000 gal. under continuous pumping conditions (N3B 2021, 701731). Monthly sampling at well R-42 since then has demonstrated the continued evolution of reducing to more oxidizing geochemical conditions. The specific capacity was also measured during sampling events to determine if permeability changes were occurring in the immediate vicinity of the well and to compare the specific capacity to conditions prior to dithionite injection. Since the 2020 redevelopment of well R-42, the specific capacity of the well during sampling or purging events has been consistently near or above specific capacity estimates prior to the 2017 dithionite deployment (N3B 2021, 701731; N3B 2022, 702099).

In 2022, a borehole dilution tracer test was conducted at well R-42 to estimate the ambient groundwater flow rate in the immediate vicinity of the well and compare that flow rate with a borehole dilution tracer test flow rate estimate from 2014 (N3B 2022, 702099). However, the previous test was performed prior to the installation and operation of the interim measures (IM) extraction and injection wells. To lessen the impact of pumping on the borehole tracer test, extraction well CrEX-4, located approximately 600 ft to the southeast of R-42, was turned off three days prior to testing. Results indicated a volumetric groundwater flow rate estimate that was approximately 20% higher than the estimate from 2014.

As documented in the 2022 report (N3B 2022, 702099), geochemical analysis of data collected at R-42 demonstrated that R-42 has been rehabilitated as a monitoring well. As a result, DOE recommended that R-42 be reinstated into the Interim Facility Groundwater Monitoring Plan (IFGMP) in monitoring year 2024 (N3B 2023, 702924.11). NMED provided concurrence on the geochemical rehabilitation of R-42 from New Mexico Environment Department (NMED) in a December 2022 meeting, which was documented in a letter dated April 17, 2023. This letter also established the requirements to perform the testing described in this work plan.

1.2 Study Objectives

The goal of the activities described in this work plan is to provide both qualitative and quantitative estimates of the hydraulic communication between well R-42 and the surrounding aquifer. These estimates will be generated using a 24-hr aquifer test under low pumping conditions and flow logging to obtain a vertical flow profile within the well screen, if a profile can be measured at these low-flow conditions. During the aquifer test, time-series sampling will be conducted to identify any geochemical trends that may occur over the 24-hr period that would indicate that a typical 3-casing-volume (CV) purge does not provide representation of geochemical conditions in the aquifer a short distance from R-42. Concentration trends at larger purge volumes would not necessarily indicate poor hydraulic communication between the well and the aquifer, but would provide insight into how groundwater geochemistry evolves after a typical 3-CV purge.

1.3 Scope of Activities

Although the 2022 report (N3B 2022, 702099) demonstrated that R-42 had a well specific capacity that was nearly equivalent to pre-amendment (sodium dithionite injection) values, the New Mexico Environment Department (NMED) requested additional testing to evaluate the hydraulic communication between R-42 and the regional aquifer. To this end, a low-flow aquifer test is planned for monitoring well R-42. Although NMED had initially requested aquifer testing that replicated the June 17, 2013 test conditions (24-hr test at a constant extraction rate of 9 gpm), in the April 17, 2023 letter (NMED 2023, 702698), NMED revised the conditions for aquifer testing due to the water level decline at well R-42.

Current static water level is at an elevation of approximately 5830 ft. The surface elevation of well R-42 is approximately 6759 ft, yielding a depth of approximately 929 ft to the water table. The top of the screen is at a depth of 931.8 ft, so the water level is currently about 3 ft above the top of the 21.1-ft well screen (see as-built shown in Figure 2). Hence, based on historical pumping at this well, the low-flow aquifer test anticipated rate is approximately 2–3 gpm for a period of 24 hr, which will likely result in a drawdown of approximately 3 ft, or just below the top of the screen. The low flow rate will not only limit drawdown and dewatering within the well screen, but will also provide longer-term, time-series geochemical data that can be used for comparison at 3 CVs.

In addition to the aquifer test, flow logging will also be performed to further evaluate groundwater flow through the well screen. The logging method will need to operate at low-flow rates to avoid dewatering the well screen and potentially entrapping air. Air entrapment could occur at higher flow rates if the water level is drawn into the screened interval. If air entrapment occurs, then it may later adversely affect hydraulic communication in the upper portion of the screen once water levels have recovered. To this end, two flow-logging methods will be deployed: (1) a high-resolution impeller flowmeter, and (2) a hydrophysical logging technique. Because the impeller flow meter data are questionable at low flow rates, the hydrophysical approach will also be deployed as an alternative technique for detecting flow rates into the well as a function of location within the screen.

To the extent possible, the 24-hr aquifer test will be conducted following the guidance provided in “Aquifer Performance Test Procedures for Hazardous Waste Facilities in New Mexico” (NMED 2022, 702652). Results of the aquifer test and the flow logging will be documented in a stand-alone report.

2.0 FIELD ACTIVITIES

Two field activities will occur sequentially at R-42. The aquifer test will be conducted first, followed by the flow logging activities. While the aquifer test will occur over a 10-day period (background data collection of 7 days, 1 day pumping, 2 days recovery), the flow logging is anticipated to occur over a 1-2 day time period. However, before the flow logging can be initiated, downhole equipment will first be removed (such as the existing pump, transducers and transducer access tubes, etc.). The pump will then be re-installed, and the flow logging will be conducted with the use of a 2-in. tremie pipe to convey the flow-logging tools to the screened interval. An additional tube may be installed to introduce the DI water at the top of the screen.

2.1 Aquifer Test

As outlined in the NMED April 17, 2023 letter (NMED 2023, 702698), a 24-hr aquifer test will be conducted in an equivalent manner to a small-scale pump test. Therefore, the test will be performed once a 7-day background-data-collection period has been established. A 2-day recovery period, which is 2 times the pumping period (NMED 2022, 702652), will occur once pumping has ceased.

All required information including the date, pump, and transducer installation details will be recorded in a field notebook. All weather-related information will also be recorded, including temperature, cloud conditions, precipitation type and amount (if any), wind speed and direction, and atmospheric pressure conditions. Testing during unfavorable weather conditions (e.g., rain and snow) will be avoided to the extent possible.

2.1.1 Equipment

The aquifer test will be conducted with the following equipment, some of which already exists at R-42:

- **Electric Generator:** An electric generator with the voltage and amperage capacity to power the selected pump.
- **Drop Pipe:** The existing 1-in. stainless-steel threaded pipe.
- **Downhole Pump:** A 2–3 gpm submersible pump set in the sump of the well below the bottom of the well screen.
- **Pressure Gauge:** A pressure gauge at the wellhead to measure the backpressure on the pump during operation. The pressure gauge is located first in line in the discharge assembly, i.e., ahead of all other components.
- **Flow-Control Valve:** A stainless-steel ball valve installed immediately downstream from the pressure gauge to control the discharge rate. An additional automated valve may be used to control pumping rates and backpressures during preliminary pumping performance assessment (Figure 3).
- **Flow Meters:** A volume-totalizing flow meter placed in the discharge line immediately downstream from the flow control valve to track production volume and provide the data needed to document discharge rates. In addition, at this location, a flow measuring and recording device will be plumbed into the discharge line to supplement the manual readings and provide an electronic record of discharge rates as well as inform the flow control system.
- **Variable Frequency Drive (VFD) with Automated Data Acquisition System (DAS):** Provides control of the discharge flow rate. The DAS uses a digital electronic magnetic-inductive flow

meter; the flow-meter output is sent to the VFD, which adjusts the speed of the pump as needed to maintain a consistent pumping rate.

- **Check Valve:** The pumping string is equipped with an existing check valve. This will prevent water from the drop pipe draining back into the well following pump shutoff.
- **Transducers:** There are two types of pressure transducers—vented and non-vented. Vented transducers (e.g., In-Situ Level TROLL 500) measure the actual height of water above the transducer sensor by recording the difference between total pressure on the transducer and atmospheric pressure. Non-vented transducers (e.g., Level TROLL 700) measure total pressure (the sum of the water height above the sensor and atmospheric pressure). At R-42, the existing vented transducer will be removed and replaced with two non-vented transducers.
- **Transducer Access Tubes:** The PVC transducer tube is used to suspend the communication cables connected to the transducers. The PVC tube may need to be extended to reach the bottom of the screen where the transducers will be placed.
- **Logbooks and Forms:** Logbooks and forms are used to record test details and measurements. Data recorded includes a statement of the objective(s), a description of test, a list of all personnel authorized to enter information into the logbook, weather conditions, a list of equipment (serial numbers) and all work activities, a description of standards used for on-site instrument calibration and calibration results (and references), and a sketch showing the downhole equipment configuration and associated measurements. In addition, all manually collected data and names of all data files collected electronically will also be recorded. All entries in the logbooks will be signed.

2.1.2 Pump Operations

The discharge rate will be controlled via the VFD, which will also be connected to the DAS. The VFD will maintain a constant flow rate in the discharge line at the surface and help prevent exaggerated drawdown, and the DAS will record the discharge rate data. All discharge water will be diverted to a frac tank.

2.1.3 Water-Level Measurements

Water-level data at R-42 will be recorded throughout all testing using In-Situ Level TROLL 700 non-vented pressure transducers. Two pressure transducers will be deployed, with one transducer serving as backup (NMED 2022, 702652).

In general, water levels in the pumped screen will be recorded at the highest frequency the device allows during the first 100 s of the test (including both the startup and shutdown of the pump). The recording interval will then be increased to once every min for the remainder of the test for both pumping and recovery. The Level TROLL 700 non-vented pressure transducer allows the option of assigning multiple data collection frequencies.

Although testing at R-42 is for a single well, a response to pumping at R-42 may be observed at nearby wells. If extraction and injection from the interim measures system continues to be halted at the time of R-42 testing, there may be increased sensitivity to pumping of R-42 at nearby monitoring wells. For the duration of the aquifer test, data collection frequency in nearby monitoring wells (based on the distance to R-42) will be increased from a measurement interval of 2 hr to 15 min to record transient responses. Wells that have been identified for increased frequency of water-level measurements include wells located within approximately 1000 ft of R-42 (CrPZ-2a, CrPZ-3, and CrEX-4).

2.1.4 Background Data Collection

Water levels at R-42 will be monitored for a period of 7 days to establish background water level conditions (NMED 2022, 702652). Since active pumping and injection is not currently occurring in the regional aquifer beneath the LANL site, the only pumping that likely impacts water levels at R-42 is from Los Alamos County production wells (e.g., PM-4). Communication with Los Alamos County will take place prior to testing to identify PM-4 operations that may impact testing.

2.1.5 Step-drawdown Test

The step-drawdown test involves pumping the well for a short period at different discharge rates to determine the pump size and the appropriate discharge rate for the aquifer test. Although it is anticipated that the pumping rate will be approximately 2–3 gpm, the step-drawdown test will be performed to identify a constant pumping rate that limits drawdown at the 21-ft well screen to 2–3 ft. The duration of each step should be long enough to minimize casing and filter pack storage effects. To this end, the step-drawdown testing will consist of at least four 60-min constant-rate steps that are conducted sequentially at incrementally higher flow rates. The pumping rates will be determined by multiplying the maximum design rate by 0.50, 0.75, and 1.25. The discharge rate will be controlled by the VFD.

Transducer data will be collected every 30 s during testing based on NMED guidelines (NMED 2022, 702652). Recovery data will be collected at the same frequency and will commence once pumping of the last step has terminated and will cease once water levels have returned to within 95 percent of the pre-pumping static water level or twice the total pumping duration has elapsed, whichever is longer.

2.1.6 Aquifer Testing

The pumping duration for the aquifer test is planned for 24 hr, per NMED direction. Data downloads will occur during the aquifer test to evaluate the data in real time. The slope of the plot of drawdown versus time on a semi-log scale will be used to evaluate the real-time data collected at R-42. Derivative plots may also be used to test for infinitely acting radial flow (IARF).

2.1.7 Recovery

Following pump shutdown, recovery data will be recorded for 2 days at both R-42 and monitoring wells identified as observation wells for this test. The recovery period ends once water levels at R-42 have returned to within 95 percent of the pre-pumping static water level or until twice the total pumping duration has elapsed, whichever is longer.

2.1.8 Water Quality Sampling

Water quality samples will be collected throughout the 24-hr aquifer test, with a first sample collected after 30 min, followed by a second sample at 1 hr. The extended time-series includes samples at 2, 4, 8, 12, 16, 20, and 24 hr (see Table 1). All samples will be analyzed for filtered metals, filtered and non-filtered general inorganics, and the standard suite of anions and cations (N3B 2023, 702924.11). In addition, samples will be analyzed for tracers that have been previously used at the chromium investigation area at LANL. Other fixed-laboratory analyses will include nitrogen and oxygen isotopic analyses. Field parameters, such as pH, temperature, oxidation-reduction potential, dissolved oxygen, specific conductivity, and turbidity will also be measured at each point in the time series (see Tables 2 and 3).

2.2 Flow Logging

Vertical flow logging can be used to determine locations of higher fluid production within the screened interval. Different tools are available for collecting vertical flow data, including heat pulse and electromagnetic or spinner flow meters. The tool selected is dependent on the borehole environment and anticipated flow velocities. At R-42, the water level is just above the top of the well screen, and pumping at even a low rate will increase drawdown, which, in turn, will limit the screen length over which data can be collected. Because logging tools may not function well at low pumping rates, two logging methods will be used to maximize the success of obtaining vertical velocity profiles at R-42.

Flow logging will utilize much of the same equipment as the aquifer test, although the transducers and transducer tubes will be pulled to provide a more open screened interval for flow logging, and a 2-in. tube will be tied to the drop pipe and extended to the top of the screen to allow access for the flow logging equipment. The flow logging equipment and methods are described in the following two subsections.

2.2.1 Spinner Flowmeter

A high-resolution impeller flowmeter will be deployed to perform the spinner logging. The flowmeter probe operates as a fluid turbine with the impeller coupled to a detection system that allows for the measurement of the impeller rotation rate and direction. The flowmeter head is a precision mechanism with very low friction, capable of rotating reliably at speeds as slow as one revolution per min (rpm). The speed of the propeller and the period between depth samples are transmitted from the probe, allowing post-calculation of logging velocity and flow rates.

Logs may be made either with the probe stationary in the borehole, to record flow at specific locations, or in a continuous mode to record a flow profile. Deployment of the probe in continuous mode is planned at well R-42.

Ambient testing will be conducted under non-pumping conditions to identify natural flow patterns, whereas dynamic testing will be conducted under the low-flow pumping conditions to determine the relative flow under pumping conditions. Differences under pumping versus non-pumping conditions must be accounted for to fully understand the vertical velocity profile induced by the pumping.

The performance of the probe is limited by the force needed to turn the impeller at low flow rates. Due to the anticipated low flow rate (2–3 gpm), groundwater flow velocities through the well screen may not be high enough to successfully measure groundwater inflow with a spinner log.

2.2.2 Hydrophysical Logging

The hydrophysical logging (HpL) method involves first establishing a baseline electrical conductivity profile with no pumping or injection of water. During these logging runs, precautions are taken to preserve the existing ambient hydrogeological and geochemical regime. These ambient water quality logs are performed to provide baseline values for the undisturbed borehole fluid conditions prior to testing. Next, deionized (DI) water will be added at the top of the screen at the same rate that water is being pumped from the bottom. Then once the water reaching the surface has the conductance of deionized water, the test can begin by stopping the injection of DI water and extracting water from the well at the low pumping rate. This procedure will minimize the amount of DI water pushed into the filter pack or formation as it is injected. Once the DI water has been injected, the low flow pumping will draw the formation water back into the well screen, which can be identified by a contrast in electrical conductivity (EC). During this process, profiles of the changes in fluid electrical conductivity of the fluid column are recorded. A downhole wireline HpL tool, which simultaneously measures fluid EC and temperature, is employed to log the EC changes of the emplaced fluid.

3.0 DATA EVALUATION

This section provides an overview of potential data quality issues and actions to assure data reliability so that the objectives of the field activities will be met.

3.1 Aquifer Test

3.1.1 Real-Time Data Evaluation

As described in Section 2.1.6, water-level data will be evaluated for any potential issues that may affect the data quality. This evaluation will identify corrective actions that are consistent with the objectives of the testing (hydraulic communication with the aquifer). The evaluation of data, and any actions taken to assure data quality, will be documented in the field logbook.

3.1.2 Barometric Pressure Corrections

Barometric pressure will be monitored using a 30-psi In-Situ Level TROLL 700 non-vented pressure transducer. Since barometric pressure may be sensitive to ambient temperature, a barometric transducer will be installed in CrPZ-2a 10–20 ft below land surface, where temperatures are stable. Barometric pressure measurement intervals will match the measurement intervals (15 min) for the observation wells.

Barometric pressure will be compared with the background response in the observation wells to determine a unique barometric correction factor for each observation well. Barometric pressure data will be monitored at the same time intervals as the observation wells to simplify the barometric pressure correction process.

The existing monitoring wells in the area are equipped with vented pressure transducers. Because the aquifer is highly barometrically efficient, the resulting hydrographs from these wells have large barometrically induced water-level fluctuations, likely several times greater than the drawdown that will be induced by test pumping. The correction factors developed for these wells will consider both barometric efficiency and any linear background trend that may be present.

3.2 Flow Logging

For both flow logging methods, the pump must be placed below the screened interval so that the instrument can move vertically along the saturated screened interval. However, pump placement below the screened interval may compromise data quality because the logging tools will not be centered within the well bore due to the pump column and power cable. Therefore, flow will only be measured through one side of the well screen.

3.2.1 Spinner Flow Meter

Although spinners can make measurements over a wide range of flow rates, the tool may have poor resolution at very low flow rates. If the tool stalls at low flow velocities, then only a qualitative interpretation may be performed.

3.2.2 HpL Meter

The data output of the hydrophysical log may be affected by electrical interference from the pump power cable. Also, any inadvertent injection of DI water into the filter pack or formation will affect data quality and interpretations.

4.0 DATA ANALYSIS

4.1 Aquifer Test

Aquifer tests can be used to estimate hydraulic properties by (1) manual curve-fitting methods, (2) manual straight-line methods, and (3) commercial software that provide automated access to the curve-fitting and straight-line methods and numerical techniques.

Curve-fitting methods typically involve displaying drawdown (and/or recovery data) vs. time on a log-log graph. The data usually form a characteristic shape, which is then overlain with a theoretical ‘type curve,’ and the relative positions of the two curves are adjusted until the best match of the shape of the two curves is obtained [e.g., Theis method (Theis 1934-1935, 098241)]. This allows permeability and storativity to be determined by substituting match-point values into the appropriate equations.

Straight-line methods involve plotting data to generate a best-fit straight line, and determining the transmissivity and storativity from the slope and position of the line [e.g., Cooper-Jacob method (Cooper and Jacob 1946, 098236)]. The Cooper-Jacob method was based on horizontal, radial flow to fully penetrating wells in confined aquifers, but it can also be used in unconfined aquifers in which the drawdown is a small proportion of the saturated thickness of the aquifer. A logarithmic derivative of drawdown data can also be used to determine if the assumptions of the straight-line method are valid during any part of the test. Alternatively, the straight-line slope on the semilog drawdown data plot can be identified. Transmissivity can then be estimated from sections of the data where the straight line is consistent.

The applicability of these methods will be determined based on the data collected. Although it is possible to determine hydraulic properties during low-flow purging events, the limited drawdown that occurs during testing may not sufficiently inform the estimates of hydraulic properties. However, the drawdown data may be used to estimate the specific capacity (defined as the pumping rate divided by the drawdown). The specific capacity can also be compared with estimates measured prior to the sodium dithionite injection in 2017.

The time-series sampling will provide the longer-term, time-series geochemical data that can be compared with geochemical data after three CVs. This information will be used to evaluate if a typical 3-CV purge provides representation of geochemical conditions in the aquifer a short distance from R-42.

4.1.1 Data Pre-Processing

Observation wells that may be incorporated in the aquifer tests are generally monitored using vented transducers, which yield hydrographs with large background fluctuations that must be filtered out before analysis. Data from such wells will be corrected to remove extraneous background noise. The algorithm used for this will account for barometric pressure changes, well-specific barometric efficiency, and a constant linear background trend.

To accomplish this, changes in the observed water level over time will be adjusted by a fixed percentage of the observed change in barometric pressure (equal to the barometric efficiency of the well) and replotted. This fixed percentage will be adjusted iteratively, and the data replotted, to remove sinusoidal fluctuations from the modified hydrograph to the extent possible. The resulting modified hydrograph is expected to form a straight line except for the drawdown induced by the pumping test. If the resulting straight line is sloped (i.e., if it shows a linear background trend), that trend will be removed mathematically so that the final hydrograph is essentially horizontal. This will make it possible to observe and quantify the drawdown effects associated with running the test.

Drawdown data obtained from observation wells that show a response to pumping will be summarized in tabular form, and a map showing the resulting spatial distribution of drawdown response will be included in the report.

4.1.2 Methods

The exact methods that are most applicable to the analysis at R-42 depend on the local-scale aquifer characteristics. Therefore, data collected and observations made during the test will drive decisions regarding appropriate methods for analysis. Although the analytical method most applicable to a given test cannot be specified in advance, analytical methods such as Theis (1934-1935, 098241), Cooper-Jacob (1946, 098236), and Neuman (1974, 085421) may be used. The hydraulic properties that can be determined are not only specific to the test method, but are also dependent upon the instrumentation of the field test, knowledge of the aquifer system at the field site, and conformance of the hydrogeologic conditions at the field site to the assumptions of the test method. Other methods for interpreting the data may be used based on the conceptual understanding of the local hydrogeologic conditions at the test site.

Analytical methods can be used to analyze the data using Excel spreadsheets. Violations of simplifying assumptions (e.g., homogeneous and isotropic aquifer, fully penetrating well screen, etc.) may limit the use of analytical methods. Hence, the more complex solutions, incorporating partial penetration, delayed yield, or wellbore skin (well inefficiency) are generally computed using reputable, commercially available software such as AQTESOLVE (Advanced Aquifer Test Analysis Software) from HydroSOLVE, Inc. (http://www.aqtesolv.com/).

4.2 Flow Logging

Vertical flowmeter measurements can provide both qualitative and quantitative aquifer characteristics. Qualitative measurement can be associated with inflow and outflow attribution to geologic units. Methods commonly used for quantitative hydraulic analysis of flow zones from flowmeter log data include proportion, analytical solution, and numerical modeling approaches.

Computer programs such as FLOWCALC and BORE II (Hale and Tsang 1988, 703058; Doughty and Tsang 2014, 703044) can be utilized to evaluate the inflow quantities of the formation water for each specific inflow location. FLOWCALC is used to estimate the interval-specific flow rates for the production test results based on select values of EC and depth. The values are determined from the ambient EC logs, the logs obtained during pumping and DI injection. Numerical modeling of the reported data may be performed using code BORE II. These methods can be used to determine the flow quantities for the identified water bearing intervals.

Ideally, flow-logging results would be compared to pre-amendment (sodium dithionite injection) vertical velocity profiles. However, these pre-amendment surveys were not performed, so the flow-logging data will be used in conjunction with the hydrologic and geochemical data from the aquifer test to assess the hydraulic connection of R-42 with the surrounding aquifer.

5.0 REPORTING AND SCHEDULE

All activities and data analyses associated with testing at R-42 will be documented in a stand-alone report. The report will include:

- a description of the field conditions, test durations, and equipment configuration;
- the uncorrected and barometrically corrected transducer data from R-42 and observation wells in electronic format;
- the total volume of water extracted;
- drawdown versus time data from the aquifer test, which will be evaluated to determine if aquifer properties can be estimated at R-42;
- estimates of specific capacity;
- graphics that support the analysis;
- the rationale for any analytical or numerical approaches used to analyze the data; and
- flow log results.

A brief overview of major field activities and schedule is provided in Table 4.

6.0 REFERENCES

The following reference list includes documents cited in this plan. Parenthetical information following each reference provides the author(s), publication date, and ERID, ESHID, or EMID. ERIDs were assigned by Los Alamos National Laboratory's (the Laboratory's) Associate Directorate for Environmental Management (IDs through 599999); ESHIDs were assigned by the Laboratory's Associate Directorate for Environment, Safety, and Health (IDs 600000 through 699999); and EMIDs are assigned by N3B (IDs 700000 and above).

Cooper, H.H., Jr., and C.E. Jacob, August 1946. "A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well-Field History," *American Geophysical Union Transactions,* Vol. 27, No. 4, pp. 526-534. (Cooper and Jacob 1946, 098236)

Doughty, C., and C.-F. Tsang, July 2014. "BORE II - A Code to Computer Dynamic Wellbore Electrical Conductivity Logs with Multiple Inflow/Outflow Points Including the Effects of Horizontal Flow across the Well," Lawrence Berkeley National Laboratory document LBNL-46833, Berkeley, California. (Doughty and Tsang 2014, 703044)

Hale, F.V., and C.-F. Tsang, March 1988. "A Code to Compute Borehole Fluid Conductivity Profiles with Multiple Feed Points," NAGRA - DOE Cooperative Project Report, Lawrence Berkeley National Laboratory document LBL-24298, NDC-2, Baden, Switzerland, and Berkeley, California, U.S. (Hale and Tsang 1988, 703058)

LANL (Los Alamos National Laboratory), January 2018. "Quarterly Report on Pilot-Scale Amendments Testing for Chromium in Groundwater beneath Mortandad Canyon," Los Alamos National Laboratory document LA-UR-18-20467, Los Alamos, New Mexico. (LANL 2018, 602862)

LANL (Los Alamos National Laboratory), April 2018. "Second Quarterly Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon," Los Alamos National Laboratory document LA-UR-18-23418, Los Alamos, New Mexico. (LANL 2018, 603031)

N3B (Newport News Nuclear BWXT-Los Alamos, LLC), July 2018. "Third Quarterly Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon," Newport News Nuclear BWXT-Los Alamos, LLC, document EM2018-0019, Los Alamos, New Mexico. (N3B 2018, 700032)

N3B (Newport News Nuclear BWXT-Los Alamos, LLC), October 2018. "Fourth Quarterly Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon," Newport News Nuclear BWXT-Los Alamos, LLC, document EM2018-0069, Los Alamos, New Mexico. (N3B 2018, 700108)

N3B (Newport News Nuclear BWXT-Los Alamos, LLC), January 2019. "Fifth Quarterly Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon," Newport News Nuclear BWXT-Los Alamos, LLC, document EM2019-0011, Los Alamos, New Mexico. (N3B 2019, 700214)

N3B (Newport News Nuclear BWXT-Los Alamos, LLC), April 2019. "Sixth Quarterly Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon," Newport News Nuclear BWXT-Los Alamos, LLC, document EM2019-0133, Los Alamos, New Mexico. (N3B 2019, 700420)

N3B (Newport News Nuclear BWXT-Los Alamos, LLC), December 2019. "Seventh Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon, April to September 2019," Newport News Nuclear BWXT-Los Alamos, LLC, document EM2019-0427, Los Alamos, New Mexico. (N3B 2019, 700723)

N3B (Newport News Nuclear BWXT-Los Alamos, LLC), June 2020. "Eighth Report on Pilot-Scale Amendments Testing for Chromium in Groundwater Beneath Mortandad Canyon, October 2019 to March 2020," Newport News Nuclear BWXT-Los Alamos, LLC, document EM2020-0253, Los Alamos, New Mexico. (N3B 2020, 700954)

N3B (Newport News Nuclear BWXT-Los Alamos, LLC), October 2021. "Results from Extended Purging of Monitoring Wells R-42 and R-28," Newport News Nuclear BWXT-Los Alamos, LLC, document EM2021-0715, Los Alamos, New Mexico. (N3B 2021, 701731)

N3B (Newport News Nuclear BWXT-Los Alamos, LLC) (B Willis), June 2022. "Evolution of Geochemical and Hydrologic Conditions in Monitoring Well R-42," Newport News Nuclear BWXT-Los Alamos, LLC, document EM2022-0297, Los Alamos, New Mexico. (N3B 2022, 702099)

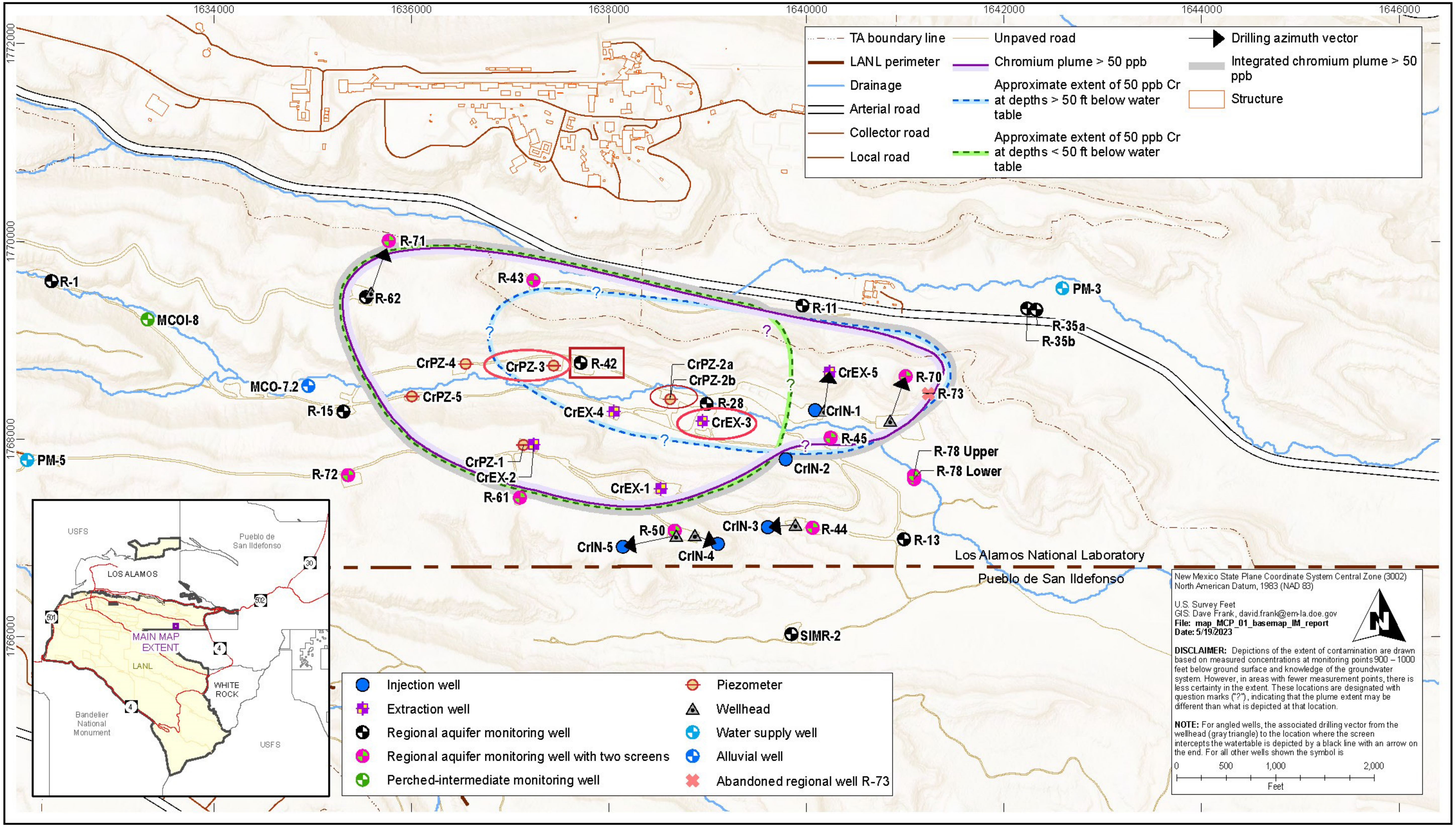
N3B (Newport News Nuclear BWXT-Los Alamos, LLC), October 2023. “Interim Facility-Wide Groundwater Monitoring Plan for the 2024 Monitoring Year, October 2023–September 2024, Revision 1,” Newport News Nuclear BWXT-Los Alamos, LLC, document EM2023-0634, Los Alamos, New Mexico. (N3B 2023, 702924.11)

Neuman, S.P., April 1974. “Effect of Partial Penetration on Flow in Unconfined Aquifers Considering Delayed Gravity Response,” *Water Resources Research,* Vol. 10, No. 2, pp. 303-312. (Neuman 1974, 085421)

NMED (New Mexico Environment Department), November 16, 2022. “Aquifer Performance Test Procedures for Hazardous Waste Facilities in New Mexico,” Los Alamos, New Mexico. (NMED 2022, 702652)

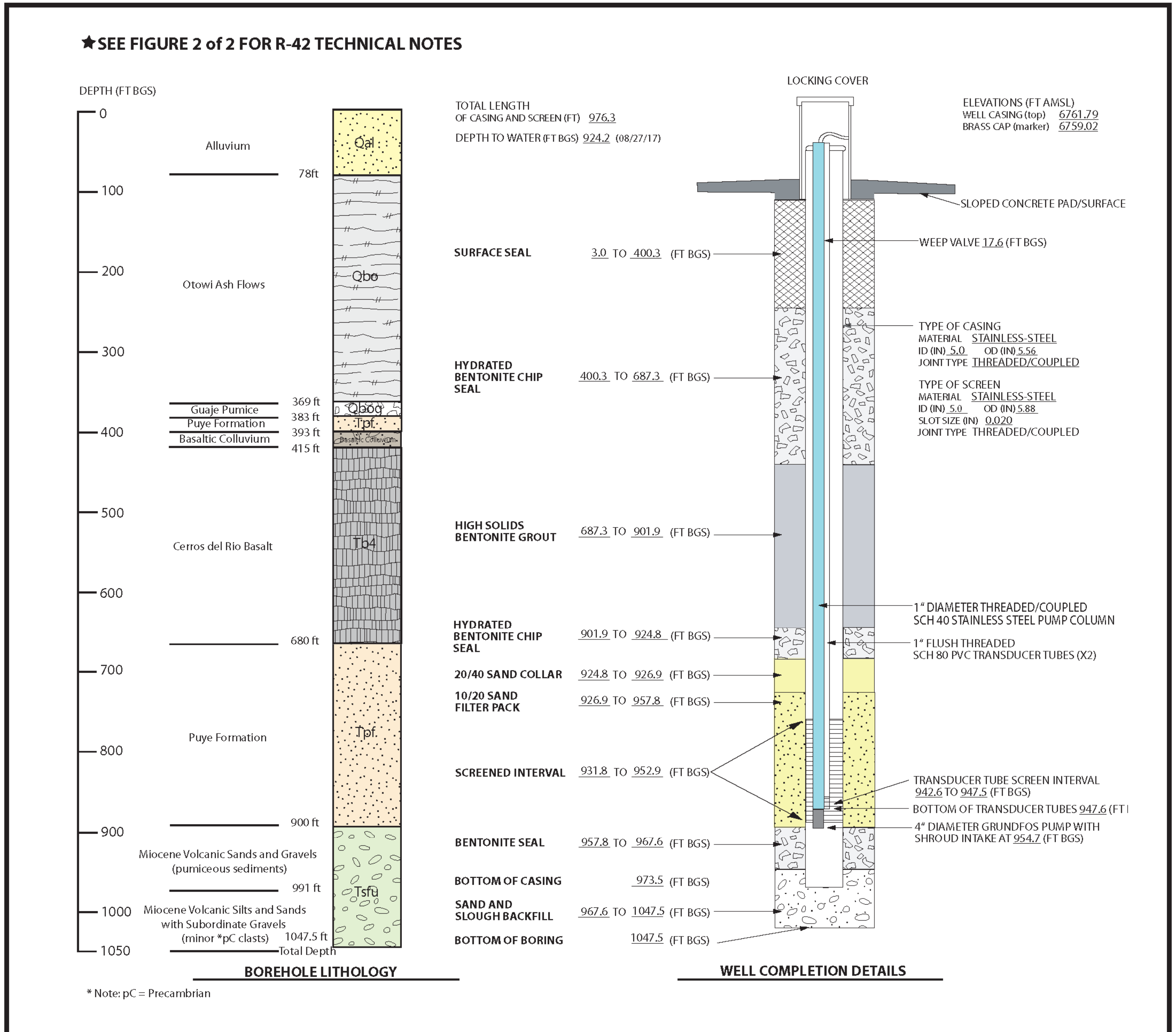
NMED (New Mexico Environment Department), April 17, 2023. “Request for Supplemental Information, Evaluation of Geochemical and Hydrologic Conditions in Monitoring Well R-42,” New Mexico Environment Department letter to A. Duran (DOE-EM-LA) from R. Shean (NMED-HWB), Santa Fe, New Mexico. (NMED 2023, 702698)

Theis, C.V., 1934-1935. “The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Ground-Water Storage,” *American Geophysical Union Transactions,* Vol. 15-16, pp. 519-524. (Theis 1934-1935, 098241)



Note: The location of R-42 is highlighted in yellow and observation wells are encircled in red.

Figure 1 Locations of R-42 and observation wells



Note: The bottom of the upper transducer tube was extended to a few feet below the water table during the borehole dilution test in 2020. Current water table depth is approximately 929 ft.

Figure 2 Stratigraphic column and as-built diagram for well R-42

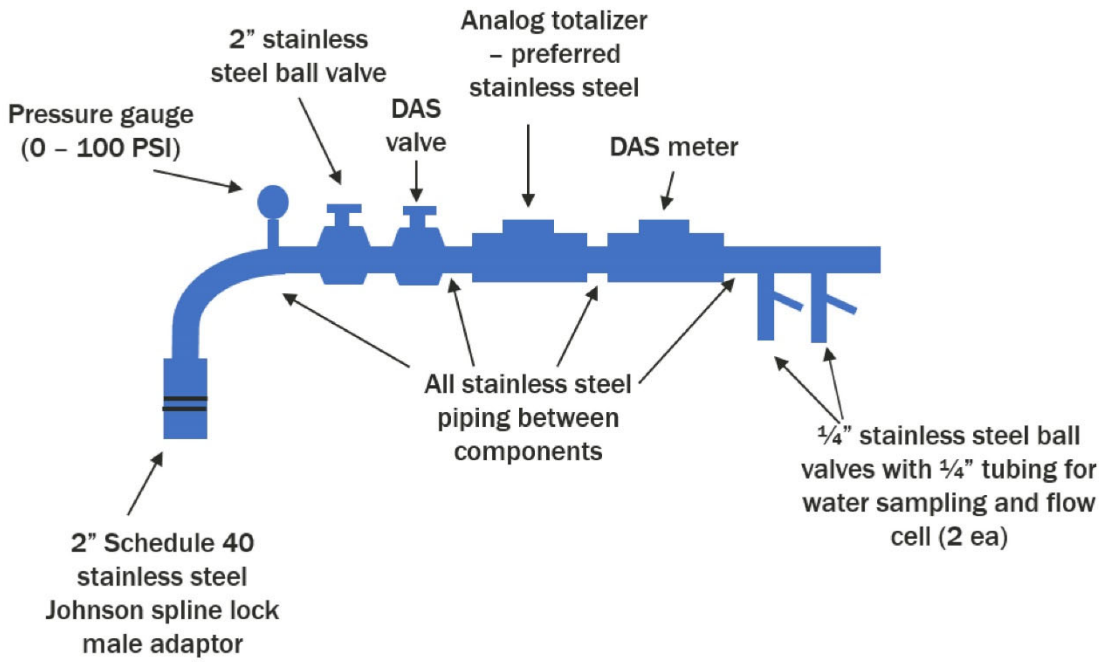


Figure 3 Conceptual diagram of automated flow control system

Table 1
List of Requested Sampling and Analyses for Aquifer Testing at Regional Well R-42

Location	Estimated Cumulative Purge Volume (gal.)	Estimated Casing Volume	GGRL Total Organic Carbon Non-Filtered; SW-846:9060 (see Table 3)	GGRL Isotopes $^{18}O/^{16}O$ and Deuterium (H_2O), $^{15}N/^{14}N$ (NO_3), $^{18}O/^{16}O$ (NO_3); Filtered (see Table 3)	GGRL Deuterated Water Tracer (deuterium) (see MY 2024 IFGMP, p. 62, Table 3.4-1; also see Table 3)	GEL Metals Filtered: SW-846:6010 and 6020; and Hardness: SM-A2340; SW-846:IFGMP_Metals (see Table 2)	GEL General Inorganics; Filtered and Non-Filtered; various methods (see Table 2)	GEL and ARSL IFGMP suite (see MY 2024 IFGMP, p. 62, Table 3.4-1)	GEL Naphthalene Sulfonate Tracers and Sodium Perrhenate Tracer (Re) (see MY 2024 IFGMP, p. 62, Table 3.4-1)	Field Parameters: pH, Temp, ORP, DO, Spec Cond, Turb, Discharge Rate, and Cumulative Purge Volume
R-42 Aquifer test at 0.5 hr	75	2	1[a]	1	n/a[b]	1	1	n/a	n/a	With sample
R-42 IFGMP sample	132	3	1	n/a	1	n/a	n/a	1	1	With sample
R-42 Aquifer test at 2 hr	300	7	1	1	n/a	1	1	n/a	n/a	With sample
R-42 Aquifer test at 4 hr	600	14	1	n/a	n/a	1	1	n/a	n/a	With sample
R-42 Aquifer test at 8 hr	1200	27	1	1	n/a	1	1	n/a	n/a	With sample
R-42 Aquifer test at 12 hr	1800	41	1	n/a	n/a	1	1	n/a	1	With sample
R-42 Aquifer test at 16 hr	2400	55	1	1	n/a	1	1	n/a	n/a	With sample
R-42 Aquifer test at 20 hr	3000	68	1	n/a	n/a	1	1	n/a	n/a	With sample
R-42 Aquifer test at 24 hr	3600	82	1	1	n/a	1	1	n/a	1	With sample

Notes: One casing volume equals approximately 44 gal. Cumulative purge and casing volumes based on a 2.5-gpm discharge rate.

[a] 1 = 1 sample for the specified analyte to be taken at the location shown.

[b] n/a = Not applicable (specified samples are not taken at that location).

Table 2
GEL and ARSL Analytical Services for Extended Pumping Test at R-42

Analytical Suite	Field Preparation	Analytical Method	Analytes	Analytical Group	Lab
Metals	Unfiltered	SW-846:7470 series	Mercury	SW-846:6020_Al+Se+7470_Hg	GEL
		SW-846:6020 series	Aluminum, selenium		
	Filtered	SM:A2340	Hardness	SW-846:IFGMP_Metals	GEL
		SW-846:6010 series	Barium, beryllium, boron, calcium, iron, magnesium, manganese, potassium, silicon dioxide, sodium, strontium, tin, vanadium, zinc		
		SW-846:6020 series	Aluminum, antimony, arsenic, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, selenium, silver, thallium, uranium		
		SW-846:7470 series	Mercury		
General inorganics	Filtered	EPA:120.1	Specific conductance	EPA:SC_pH_TDS_ Alk+SW-846:ClO4_Anions	GEL
		EPA:150.1	Acidity or alkalinity of a solution		
		EPA:160.1	Total dissolved solids		
		SW-846:9056 series	Bromide, chloride, fluoride, sulfate		
		EPA:310.1	Alkalinity-CO_3, alkalinity-CO_3+HCO_3		
		SW-846:6850 series	Perchlorate		
		EPA:350.1	Ammonia as nitrogen	EPA:350.1_NH3+353.2_ NO3/NO2+365.4_PO4	GEL
		EPA:353.2	Nitrate-nitrite as nitrogen		
		EPA:365.4	Total phosphate as phosphorus		
	Unfiltered	EPA:351.2	Total Kjeldahl nitrogen	EPA:351.2_TKN+ SW-846:9060_TOC	GEL
		SW-846:9060 series	Total organic carbon		
		SW-846:9012 series	Cyanide (Total)	SW-846:9012_CN(T)	GEL
Napthalene Sulfonate Tracers	Unfiltered	SW-846:8330B_MOD	Numerous	SW-846:8330B_MOD	GEL
Sodium Perrhenate Tracer (Re)	Unfiltered	SW-846:6020B	Rhenium	SW-846:6020B	GEL

Table 2 (continued)

Analytical Suite	Field Preparation	Analytical Method	Analytes	Analytical Group	Lab
**Low-level tritium for Quarterly Sampling at R-42	Unfiltered	Generic: Low-Level Tritium	Tritium	EE_LS:H3_LL	ARSL
Field parameters	n/a*	n/a	pH, specific conductance, dissolved oxygen, turbidity, oxidation-reduction potential, temperature, discharge rate, and cumulative purge volume		

Table 3
GGRL Analytical Services for Extended Pumping Test at R-42

Analytical Suite	Normal Field Preparation	Analytical Method	Analytes
Organics GGRL	Non-filtered	SW-846:9060	Total organic carbon
Stable isotopes GGRL	Filtered	HRMS	Deuterated water tracer - deuterium (H_2O); IFGMP Sample
Stable isotopes GGRL	Filtered	HRMS	$^{15}N/^{18}O$ (NO3), and deuterium and $^{18}O/^{16}O$ (H_2O)
Field parameters	Via flow-through cell or chamber	Not applicable	pH, specific conductance, dissolved oxygen, turbidity, oxidation-reduction potential, temperature, discharge rate, and cumulative purge volume

Table 4
R-42 Field Activities Schedule

Task Description	Duration (days)
Prepare pumping string and discharge piping system Connect VFD, DAS, flow-control valve Install pump Setup VFD, DAS, flow-control valve Set pump	3
Background water-level monitoring including step-drawdown testing	7
Constant-rate pumping	1
Turn off pump Recovery water-level monitoring	2
Download pressure transducer data Prepare for flow logging with equipment removal Re-install pump	2
Perform flow logging (physical impeller and hydrophysical methods)	14
Total	29