BUREAU OF RECLAMATION

Technical Memorandum No. 86-68330-2025-4

2024 Annual Report
Paradox Valley Seismic Network
Paradox Valley Unit, Colorado

Colorado River Basin Salinity Control Program
Upper Colorado Region

U.S. Department of the Interior August 2025

Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; honors its trust responsibilities or special commitments to American Indians, Alaska Natives, Native Hawaiians, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Prepared by:

Bureau of Reclamation
Technical Service Center
Denver, Colorado

U.S. Department of the Interior **August 2025**

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Peer Review Certification

This document has been reviewed and is believed to be in accordance with the scope of the service agreement and the standards of the profession.

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Acknowledgments

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Acronyms and Abbreviations

approx.	approximately
AP	Access Point
BOB	Break out box
dB	decibel
EPA	Environmental Protection Agency
ft	feet
g	standard acceleration of gravity, equivalent to 9.80665 meters per second squared
gpm	gallons per minute
GPS	Global Positioning System
km	kilometers
l/min	liters per minute
LVD	low voltage disconnect
MASIP	maximum allowable surface injection pressure
M_D	duration magnitude
Mgal	millions of gallons
ML	local magnitude
MPa	megapascal(s)
MSL	mean sea level
MW	Moment magnitude
m/s^2	meters per second squared
psi	pounds per square inch
PVB	Paradox Valley Brine
PVSN	Paradox Valley Seismic Network
PVU	Paradox Valley Unit
RSSI	Received Signal Strength Indicator
SE	Southeast
SPM	station power monitoring
USGS	U.S. Geological Survey

Symbols

=	equal to
>	greater than
≥	greater than or equal to
≤	less than or equal to
%	percent

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1.0 Introduction

The Paradox Valley Seismic Network (PVSN) monitors earthquakes induced by injection operations at the Bureau of Reclamation's (Reclamation) Paradox Valley Unit (PVU) deep disposal well, in addition to naturally occurring earthquakes. This report summarizes PVSN operations and data recorded during the calendar year 2024. We provide project background information in Section II, including the history of PVU injection operations and details of the seismic network. In Section III, we present PVSN network operations during 2024, including maintenance of the seismic stations and data acquisition systems and annual network performance. The earthquake data recorded during the year are discussed in Section IV and compared to historical seismicity trends.

2.0 Project Background

2.1 Paradox Valley Unit

Reclamation's PVU, a component of the Colorado River Basin Salinity Control Program, intercepts salt brine that would otherwise flow into the Dolores River, a tributary of the Colorado River. PVU is in western Montrose County, approximately (approx.) 90 kilometers (km) southwest of Grand Junction, Colorado and 16 km east of the Colorado-Utah border (figure 1). The Dolores River flows from southwest to northeast across Paradox Valley (figure 2), which was formed by the collapse of a salt-cored anticline (figure 3). Due to the presence of the salt diapir underlying Paradox Valley, groundwater within the valley is nearly eight times more saline than ocean water. To prevent this highly saline groundwater from entering the Dolores River and degrading water quality downstream, the brine is extracted from nine shallow wells within the valley near the Dolores River. The diverted brine is injected at high pressure into a deep disposal well, designated as PVU Salinity Control Well No. 1. The disposal well is located approx. 1.5 km southwest of Paradox Valley, near the town of Bedrock (figure 2).

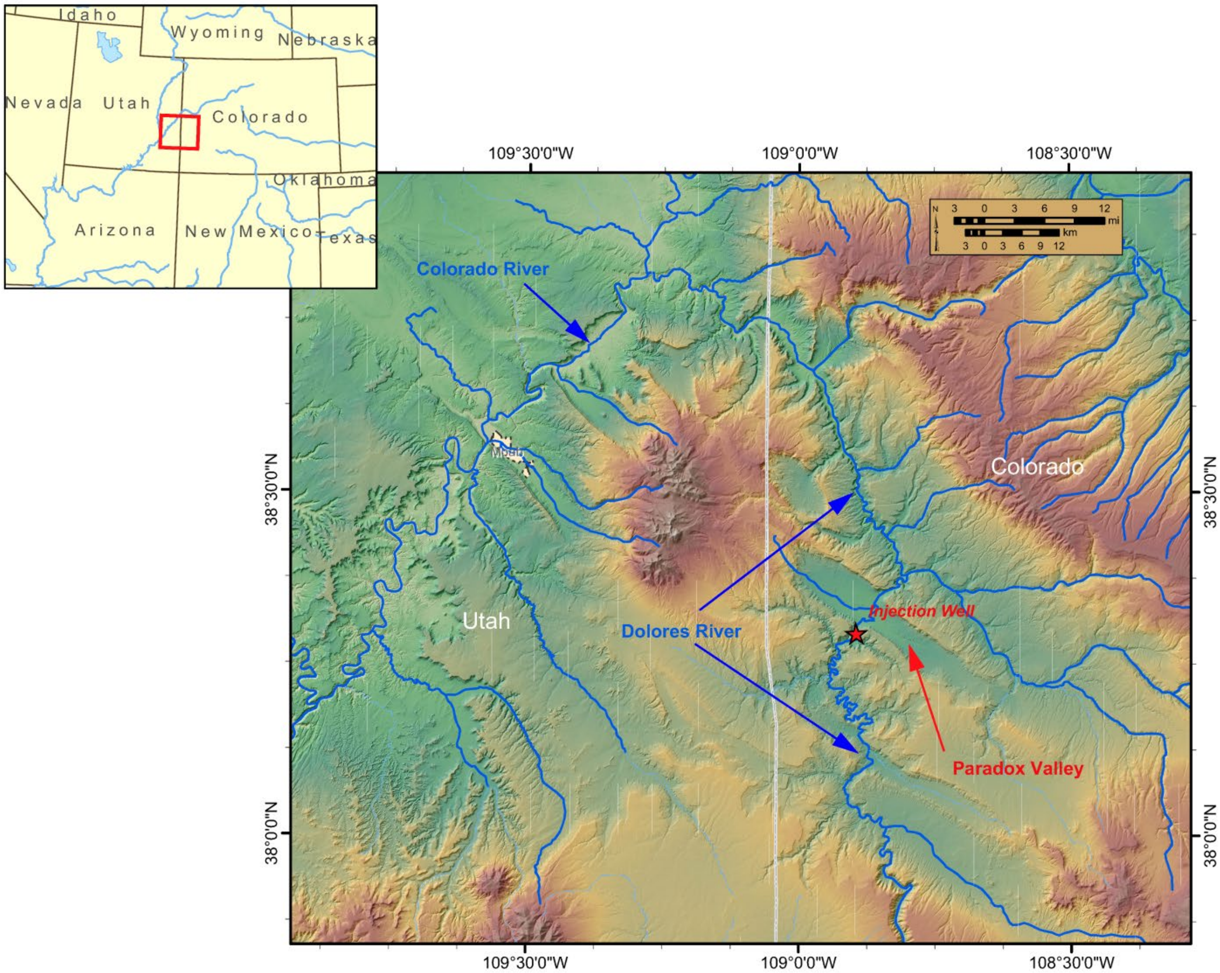

Figure 1.—Location of the deep injection well at Reclamation's Paradox Valley Unit in western Colorado (red star).

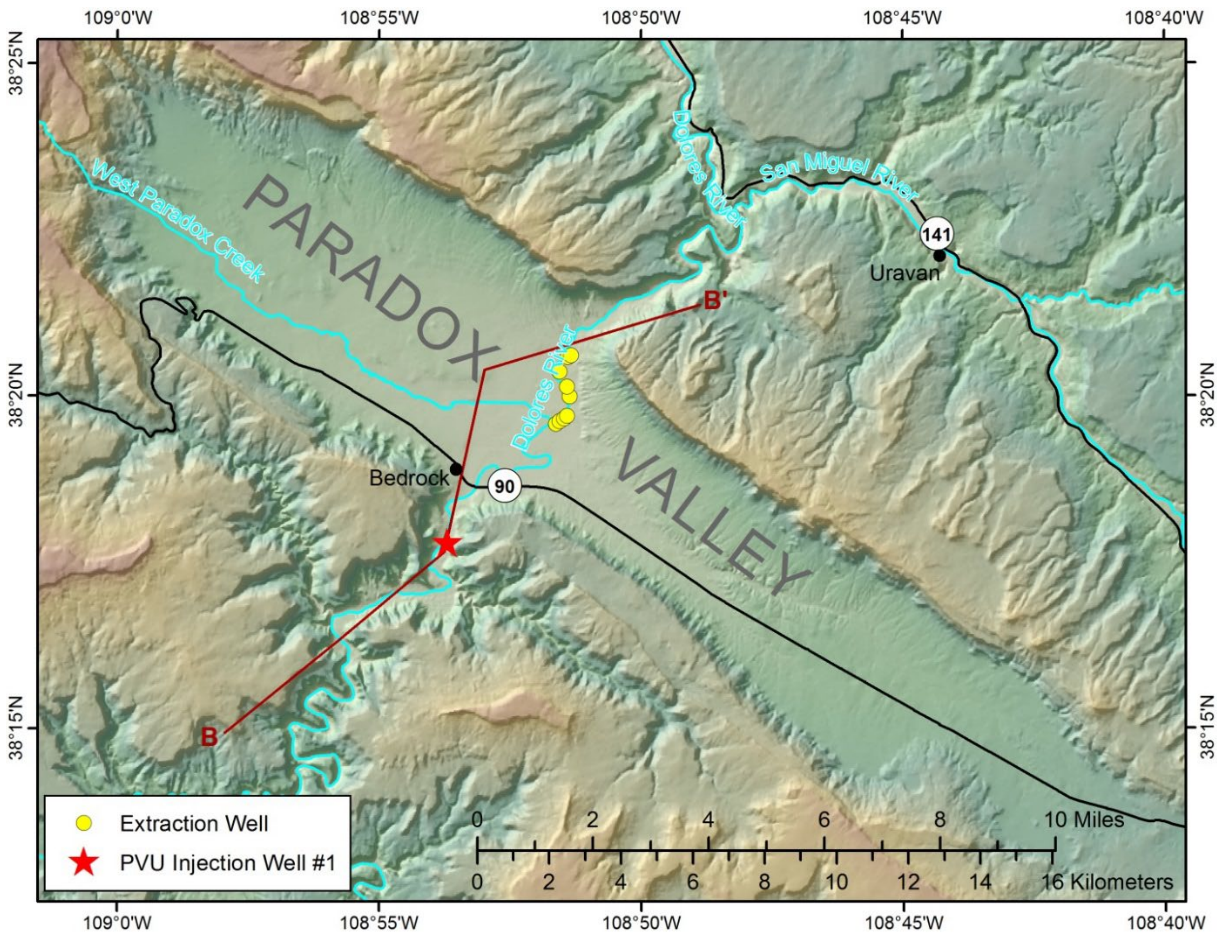

Figure 2.—Location of the Paradox Valley Unit extraction wells (yellow circles) and injection well (red star). Cross section B-B´ is shown in figure 3.

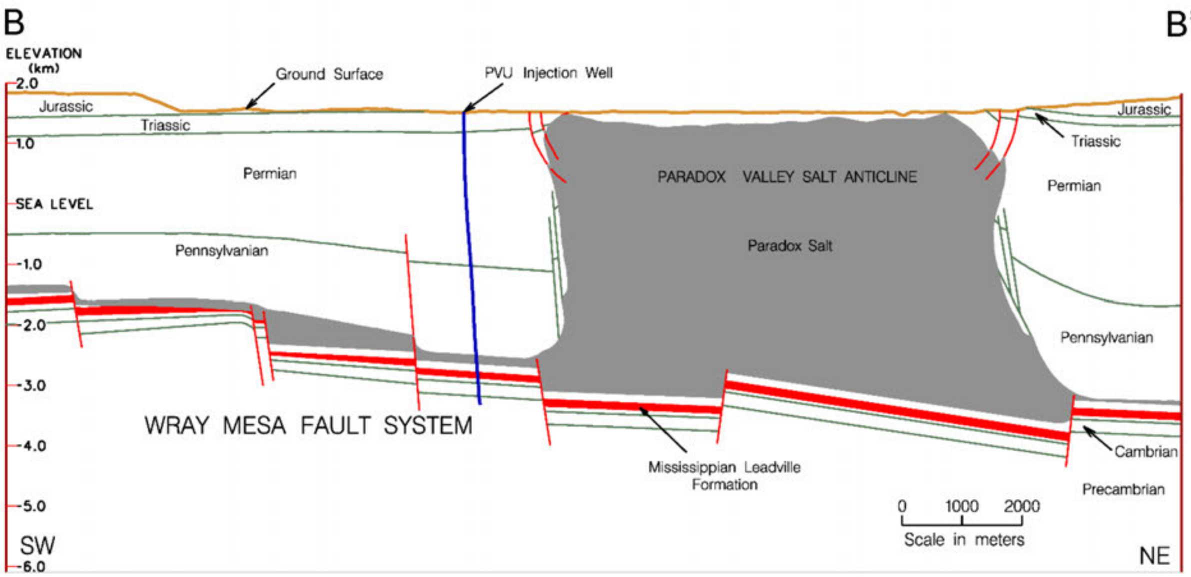

Figure 3.—Vertical cross section roughly perpendicular to Paradox Valley, looking to the northwest. The location of the cross section is shown in figure 2. Based on figure from Bremkamp and Harr (1988).

The PVU Salinity Control Well No. 1 was completed in 1987 to a total depth of 4.88 km (approx. 16,000 ft). The well was built to Environmental Protection Agency (EPA) Underground Injection Code Class I standards ("Isolate hazardous, industrial and municipal wastes through deep injection") but was permitted in 1995 by EPA as a Class V disposal well ("Manage the shallow injection of non-hazardous fluids"). The well penetrates Triassic- through Cambrian-age sedimentary rock layers and into granitic Precambrian basement (figure 3). Based on regional core and log data interpretation, the Mississippian Leadville carbonate was selected as the primary injection zone with the upper Precambrian as a secondary zone (Bremkamp and Harr 1988). The overlying Paradox salt formation acts as a confining layer. The well casing of PVU Well No. 1 (constructed of Hastelloy C-276, a nickel-molybdenum-chromium alloy) was perforated at a spacing of approx. 20 perforations per meter in three major intervals between 4.3 km and 4.8 km depth. Plan and vertical views of the wellbore, with near-wellbore stratigraphy and the perforation intervals, are shown in figure 4.

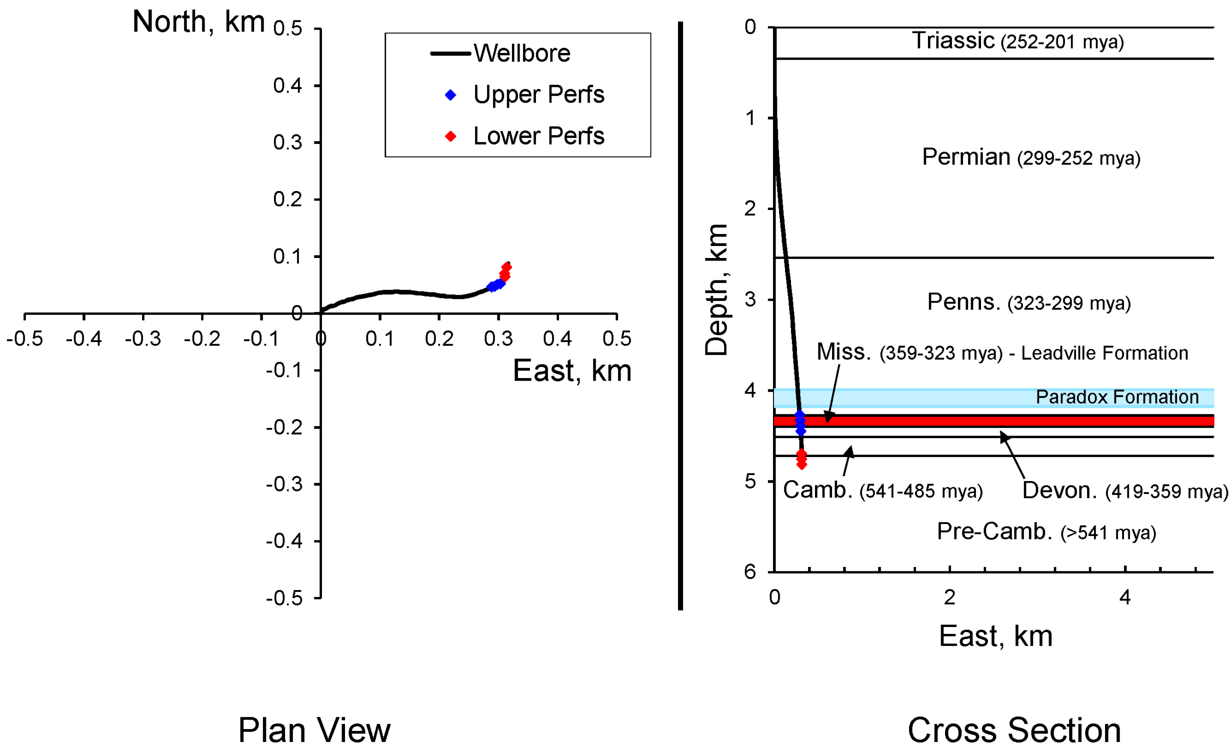

Figure 4.—PVU injection well in plane view (left) and north-viewing vertical cross section (right). Figure includes the near-wellbore stratigraphy and locations of the upper and lower casing perforations. The primary target injection formation, the Leadville, is shown in red, and the Paradox formation confining layer is shown in blue. The ages of the geologic time periods are taken from the Geological Society of America Geologic Time Scale version 4.0 (Walker et al. 2013). The ages shown represent the entire span of any given geologic Period and do not necessarily represent the precise ages of the rocks present at the PVU injection well.

2.2 PVU Injection Operations

Between 1991 and 1995, Reclamation conducted a series of seven injection tests, an acid stimulation test, and a reservoir integrity test at PVU. These tests were conducted to qualify for a Class V permit for deep disposal from the EPA. Near-continuous, long-term brine disposal began in July 1996, after the EPA granted the permit. During long-term injection, Reclamation instituted six major changes in operations. Five of these changes were implemented to mitigate the potential for unacceptable seismicity, and one change was made to improve injection economics. The seven time periods defined by these operational changes are considered separate injection phases, as described below. Plots of the daily average injection flow rates, daily average surface injection pressures, daily average downhole pressures (at a depth of 4.3 km), and cumulative injected fluid volumes during PVU injection operations are shown in figure 5. The downhole pressures shown were computed from measured surface pressures using the density of the brine column in the wellbore.

2.2.1 Phase I - July 22, 1996 to July 7, 1999

During this initial phase of near-continuous injection, brine was injected at a nominal flow rate of 345 gallons per minute (gpm) (approx. 1306 liters per minute [l/min]), resulting in an average surface pressure of about 4,950 pounds per square inch (psi) (approx. 34.1 megapascals [MPa]). This corresponded to approximately 11,800 psi (approx. 81.4 MPa) downhole pressure at 4.3 km depth, computed based on the density of the brine in the borehole. To maintain this flow rate, three constant-rate pumps were used, each operating at 115 gpm. The surface pressure occasionally approached the wellhead pressure safety limit of 5,000 psi. This safety limit was based on the operational specifications of the injection and wellhead equipment. It also corresponded to the maximum allowable surface injection pressure (MASIP) defined in the injection permit issued by EPA, which is intended to prevent a breach of the geologic confining layer (the Paradox salt). When the surface pressure approached the MASIP, the injection rate was reduced by shutting down one or two of the injection pumps, allowing the pressure to drop a few hundred psi before returning to a three-pump operation. These partial shutdowns occurred frequently and had typical durations of a few minutes to a few days. This operational protocol resulted in relatively constant surface and downhole pressures (figure 5). Periodic maintenance shutdowns of all pumps also occurred and lasted for one to two weeks. In mid-1997, a 71-day total shutdown was needed to replace the operations and maintenance contractors. The *Phase I* protocols resulted in an overall average injection rate of roughly 300 gpm (1136 l/min), and the total volume of fluid injected was 427 millions of gallons (Mgal) (1.6×10^9 liters).

The injectate during *Phase I* was a mixture of 70% Paradox Valley Brine (PVB) and 30% freshwater from the Dolores River. A geochemical study had predicted that if 100% PVB were injected, it would interact with connate fluids and the dolomitized Leadville Limestone at the initial formation temperatures and pressures, resulting in the precipitation of calcium sulfate. This precipitation would lead to reduced permeability (Kharaka et al. 1997).

2.2.2 Phase II - July 8, 1999 to May 27, 2000

Following a local magnitude M_L 3.6 earthquake in June 1999 and an M_L 3.5 earthquake in July 1999, PVU altered the injection schedule to include a 20-day total shutdown (shut-in) every six months. Prior to these events, it was noted that the rate of seismicity in the near-wellbore region (i.e., within about a 2-km radius around the wellbore) decreased during and following unscheduled maintenance shutdowns. Similar decreases in seismicity also were observed during the shutdowns following the injection tests of 1991 through 1995. It was therefore hypothesized that the biannual shutdowns might reduce the potential for inducing large-magnitude earthquakes by allowing extra time for the injectate to diffuse from the pressurized fractures and faults into the formation rock matrix. When injecting during this phase, the average flow rate was the same as during Phase I. One hundred and eighteen Mgal (4.5×10^8 liters) of fluid were injected during Phase II.

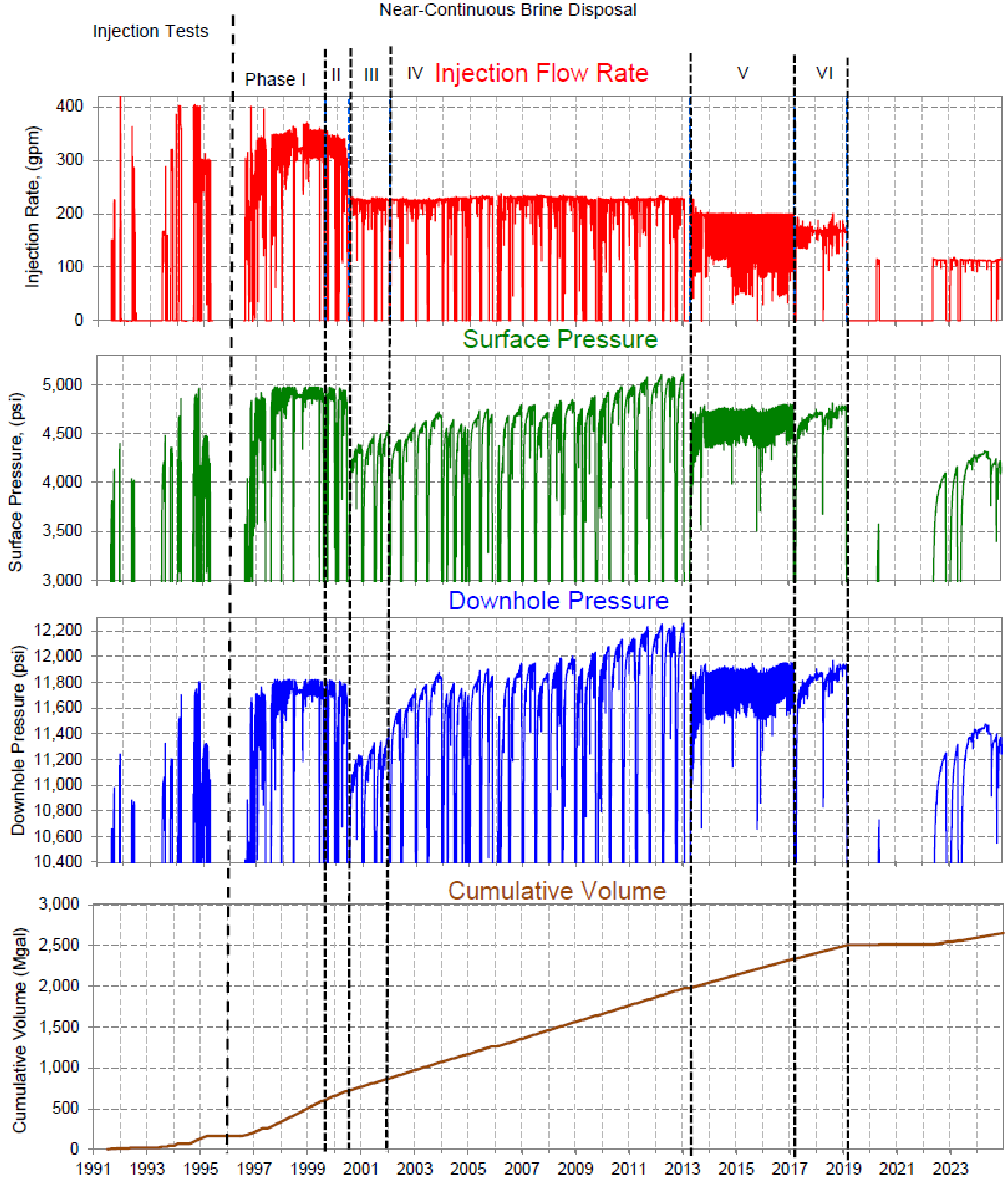

Figure 5.—Daily average injection flow rate, surface injection pressure, and downhole pressure at 4.3 km depth, and cumulative volume of brine injected during PVU injection operations. The downhole pressures are computed from the measured surface pressures using the density of the brine column in the well. The vertical dashed lines delineate the injection phases discussed in the text.

2.2.3 Phase III - June 23, 2000 to January 6, 2002

Immediately following an M_L 4.3 earthquake on May 27, 2000, injection ceased for 28 days. During this shutdown period, Reclamation evaluated the existing injection protocol and its effect on induced seismicity. The decision was made to reduce the injection flow rate, expecting that this change would likely reduce the potential for inducing large-magnitude earthquakes. On June 23, 2000, PVU injection resumed using two pumps rather than alternating between two and three pumps. The biannual 20-day shutdowns were maintained. The nominal flow rate during *Phase III*, while injecting using two pumps, was 230 gpm (approx. 871 l/min). Accounting for the two 20-day shut-ins per year, the average injection flow rate was approximately 205 gpm (776 l/min), a decrease of about 32% compared to *Phase I*. During this phase, 156 Mgal (5.9×10^8 liters) of fluid were injected.

2.2.4 Phase IV - January 7, 2002 to January 24, 2013

During October 2001, the need to dilute PVB with fresh water prior to injection was re-evaluated. Lab testing of drill cores conducted in 1993 detected no evidence of precipitation or plugging for either a 70% brine / 30% freshwater mixture or for a 100% brine mixture, at temperatures of 270 °F or 300 °F (Envirocorp Services and Technology Inc. 1993). In addition, temperature logging was performed multiple times between 1992 and June 2001 and recorded substantial near-wellbore cooling at the depth of the Leadville Formation (approx. 70° to approx. 130° F decrease) (Subsurface Technology 2001). The temperature measurements recorded in the upper Leadville in 2001 indicated “a super-cooled buffer zone, some distance from the well, which will prevent the creation of conditions favorable to calcium sulfate precipitation” (Subsurface Technology 2001, pg. 18). Hence, if precipitation were to occur, it would not be near the wellbore perforations where clogging might be a concern (Nicholas 2001). In addition, the high PVU injection pressures would likely act to keep fractures open within the target injection formations, even if some precipitation were to occur (McKinley 2001). Further analyses indicated that, if precipitation occurs, its maximum expected rate is approx. 8 tons of calcium sulfate per day (Mahrer et al. 2003). To put this amount into perspective, injecting at approx. 230 gpm and assuming a brine density of 9.86 lbs/gal (17% denser than freshwater) results in a daily injection mass of approx. 1633 tons. The maximum expected precipitate, therefore, is only approx. 0.5% of the daily injection mass.

After considering this new information, the decision was made to begin injecting 100% PVB to partially offset the reduction in salt disposal rates resulting from the decreased injection rate implemented in *Phase III*. Injection of 100% PVB began on January 7, 2002, following the December-January 20-day shutdown, and has been maintained since. The injection rate implemented in *Phase III* (230 gpm) and biannual 20-day shutdowns were continued. The volume of fluid injected during *Phase IV* was 1,110 Mgal (4.2×10^9 liters).

Because of the decreased flow rate in *Phase III* and *Phase IV* compared to the earlier phases, the surface pressure remained below the MASIP of 5,000 psi for over a decade (mid-2000 to 2011). Hence, there was no need to frequently alter flow rates, as had been done during *Phases I* and *II*.

Nevertheless, the continued injection during *Phases III* and *IV* resulted in a trend of increasing maximum surface and downhole pressures (figure 5). In addition, because of the increased density of the 100% PVB injected during *Phase IV* over the 70% PVB/30% freshwater mix injected previously, the computed downhole pressures increased by approx. 300 psi immediately following the change to 100% brine in January 2002.

In response to the increasing surface injection pressures, Reclamation submitted a request to EPA in 2004 to increase the MASIP. EPA approved the request, pending infrastructure upgrades to increase the injection equipment pressure safety limit. In 2009, the PVU injection wellhead equipment was upgraded to a pressure safety limit of 10,000 psi. An increase in the MASIP to 5350 psi was formally incorporated into the injection permit reauthorization issued by EPA in August 2011.

2.2.5 Phase V - April 17, 2013 to March 12, 2017

An induced earthquake with M_L 4.4 (corresponding to moment magnitude [M_W] 4.0) occurred approx. 8 km northwest of the PVU injection well on January 24, 2013 (Block et al. 2014). In response to this earthquake, injection was halted while a reassessment of the seismic hazard associated with PVU injection was performed. Analyses of the seismic and injection data indicated that the potential for inducing large felt events would be reduced by decreasing the long-term average injection pressures (Block and Wood 2009; Wood et al. 2016). Pressure-flow modeling indicated that reducing the flow rate would lead to a corresponding reduction in wellhead pressures. Forward modeling was used to evaluate the effect of different flow rates on wellhead pressures (Wood et al. 2016). In addition, the pressure-flow modeling indicated that changing the injection well shut-in schedule to one with shorter, more frequent shut-ins would result in a reduction in the average wellhead pressure, compared to the biannual 20-day shut-ins previously used.

As a result of these analyses, the decision was made in April 2013 to reduce the injection flow rate and increase the frequency of injection well shut-ins. Due to the lag time in obtaining pump plungers that would allow injection at a lower flow rate, injection was initially resumed on April 17, 2013, maintaining the flow rate at 230 gpm and implementing a 36-hour shut-in every week. On June 6, 2013, following the installation of the new plungers, the flow rate was reduced to 200 gpm, and the shut-in length was reduced to 18 hours, maintaining the frequency of one shut-in per week. A shut-in duration of 18 hours was chosen so that the total annual shut-in time would be approximately equivalent to that scheduled previously with the biannual 20-day shut-ins. Hence, the nominal flow rate during *Phase V* (200 gpm) was decreased by 13% from that during *Phase IV* (230 gpm), and the total duration of planned shut-ins remained the same.

Because of the frequency of the new shut-in schedule, the durations of any unplanned shut-ins (such as those periodically required for equipment maintenance) were tracked, and those hours were subtracted from the weekly scheduled 18-hour shut-ins. The durations of unplanned shut-ins had not been tracked and subtracted from the biannual 20-day shut-ins during earlier injection phases, and hence the total shut-in time during previous years had sometimes varied substantially, depending on the number and duration of unplanned shut-ins required. Hence, while the nominal flow rate during *Phase V* was decreased by 13% from that during *Phase IV*, the effective decrease in flow rate was less than this value due to the difference in total shut-in time. The average flow rate during *Phase V* was 177 gpm, which is approx. 9.7% less than the average flow rate of 196 gpm during the preceding three years (2010–2012). Three hundred and sixty-four Mgal (1.4 x 10^9 liters) of fluid were injected during this phase.

2.2.6 Phase VI - April 8, 2017 to March 4, 2019

Beginning on March 12, 2017, the injection well was shut in for 27 days. Injection was resumed on April 8 at an approx. 5% reduced effective flow rate. These changes were made partially in response to the observation that the rates and magnitudes of PVU-induced earthquakes had been increasing for ~1.5 years. The occurrence of an M_D 2.9 earthquake nearly 13 km from the injection well (on 3/12/17) further influenced the decision to reduce the effective flow rates.

The reduced effective flow rate was initially achieved by changing the size of the plungers from 2.000" to 1.875", which reduced the nominal flow rate from 200 gal/min to 174 gal/min. At the same time, the duration of the weekly shut-ins was reduced from 18 hours to 6 hours. Two pumps were run continuously, except for the weekly plant shutdowns. Considering the weekly shut-ins, the effective average flow rate was 168 gal/min.

In September 2017, premature wear of the new 1.875" plungers forced the reinstallation of larger plungers in two of the three pumps (one 2.125" plunger and one 2.000" plunger). As a result, injection operations were changed to accommodate the larger plungers (and corresponding rate increase) by eliminating the six-hour weekly plant shutdown and starting daily pump shutdowns on the pumps with larger plungers. The weekly shutdown of the single pump with the 1.875" plunger continued. Injection was then continuous, with either one or two pumps running at any given time. The target daily injection volume was 242,000 gallons, corresponding to a target average injection rate of 168 gpm. Hence, the effective average flow rate remained the same as with the smaller plungers. The total volume of fluid injected during *Phase VI* was 167 Mgal (6.3 x 10^8 liters).

An induced earthquake with moment magnitude M_W 4.5 occurred approx. 1.6 km southwest of the PVU injection well on March 4, 2019 (Block et al. 2020). This earthquake was the largest PVU-induced earthquake to date and was substantially larger than the M_W 4.0 earthquake of January 2013. More than 2,000 aftershocks occurred in the first five months following the main shock, resulting in the highest near-well seismicity rates in 20 years. Analyses indicate that aftershocks will continue to occur for several years at gradually decreasing rates (Block et al. 2020). The PVU injection well had been shut down for a few hours at the time of the M_W 4.5 earthquake to accommodate equipment maintenance activities. The well remained shut down for more than a year while detailed analyses of the M_W 4.5 earthquake and its numerous aftershocks were conducted. This extended shutdown also allowed formation pressures and aftershock rates to decay substantially.

2.2.7 Post- March 2019 Operations

Injection resumed on April 21, 2020, for a planned six-month test period. The purpose of the test was to evaluate how the well would perform after being shut in for more than a year. Specifically, the pressure response of the well was monitored to determine whether any potential near-wellbore precipitation in the injection formations during the extended shutdown had altered the injection pressure response. In addition, seismicity was closely monitored for any changes in the induced seismicity response. Injection during this test occurred at a near-constant rate of 115 gpm, representing a 32% reduction compared to the flow rate during *Phase VI*.

The injection test was prematurely terminated on May 29, 2020, in response to a request from Reclamation management for an external peer review of injection operations. According to a transient analysis of the wellhead pressure data recorded immediately following the injection test and a comparison to historical PVU pressure data, "parallel early-time slopes and equal durations of storage effects from 2017 to 2020 suggest that the extended 2019 shut-in did not significantly alter the early-time transient behavior of the well" (Petrotek 2021). In other words, the pressure data do not show evidence of near-wellbore precipitation. However, the injection test report also states, "It is clear that a comprehensive falloff analysis would require a significantly longer period of time and the application of downhole pressure gauges". No change in the induced seismicity attributable to the injection test was observed. Following this test, the well remained shut down for more than a year.

A second, longer injection test was initiated on June 2, 2022. The test was conducted for six months, at a continuous target flow rate of 115 gpm (the effective flow rate was approx. 113 gpm). The test ended on the morning of December 2, 2022. Similar to the shorter test in 2020, this test was conducted to evaluate well and reservoir performance following the extended injection well shut-in, and induced seismicity was closely monitored. Analyses of the injection data indicate that the extended injection well shut-in "did not result in any apparent plugging or other impairment of the injection wellbore, communication through the tubing, or plugging of the perforations" (Petrotek 2023). In addition, the data do not indicate "significant changes in the properties of the near wellbore region" (Petrotek 2023). Analyses of the seismic data recorded during the test indicated "no anomalous changes in the rates or magnitudes of induced earthquakes" (Nicholas 2023).

Following the six-month injection test, fluid-flow and geomechanical modeling was performed to evaluate the changes in pore pressures and stresses that occurred during the test and to model trends for five different scenarios for future injection operations. The results indicate that pressures in areas close to the injection well (within approx. 4–6 km) would remain below their pre-2019 values for several years at all flow rates modeled, helping to keep the seismic hazard reduced in that area. Pressures at larger distances from the well (> approx. 7–8 km) were predicted to continue increasing regardless of flow rate, and the pressure trends in some areas at intermediate distances from the well were found to be very sensitive to the selection of injection flow rate (Block and Kang 2023).

Based on the injection data analyses, observed induced seismicity, and flow/geomechanical modeling results, the decision was made to continue operating the injection well in test status at a target flow rate of 115 gpm, until BOR management completes its assessment of future injection well operations. Injection was resumed at this rate on January 23, 2023. Injection is continuous, except for shut-ins needed for maintenance activities. During 2023, injection was suspended for most days from May 8th to June 21st, to accommodate upgrade of the injection well SCADA system.

In 2024, the injection well continued to operate in test status with an average flow rate of 111 gpm. The flow rate ranged from a low of 43 gpm to a high of 116 gpm. There were four days when the flow rate dropped to 0 gpm: August 15 and October 28–30, 2024.

2.3 Seismic Monitoring

2.3.1 Paradox Valley Seismic Network

During the planning for PVU, it was recognized that earthquakes could be induced by the high-pressure, deep-well injection of brine. This was based on a comparison to other deep-well injection projects in Colorado, including the Rocky Mountain Arsenal, near Denver, and oil and gas extraction projects near Rangely (Gibbs et al. 1973; Hsieh and Bredehoeft 1981; Nicholson and Wesson 1990; Raleigh et al. 1976).

In 1983, eight years before the first injection at PVU, Reclamation commissioned a seismic monitoring network to characterize the pre-injection, naturally occurring seismicity in the Paradox Valley region, and to monitor earthquakes that might be induced once injection operations began. The Paradox Valley Seismic Network (PVSN) was the product of these efforts. Field equipment for an initial 10-station network was acquired and installed in 1983 by the U.S. Geological Survey (USGS), under a Memorandum of Agreement with Reclamation. Nine of these original seismic stations were vertical-component, and the remaining station (PV08) was three-component. All stations used short-period seismometers (natural frequency of 1 Hz), and analog telemetry. Continuous data recording and archiving began in 1985. For the first several years of monitoring, seismic data from this network were acquired and processed by the USGS at their facilities in Golden, Colorado. In 1990, responsibility for data acquisition and analysis was assumed by Reclamation. The USGS continued to assist Reclamation with the maintenance of the field instrumentation and radio telemetry.

PVSN has been upgraded and expanded several times to modernize its instrumentation and improve the coverage of seismically active areas. In addition, some stations have been de-commissioned, either due to repeated vandalism or changing telemetry requirements. The locations of the original and current PVSN seismograph stations are shown in figure 6. Details about the stations are provided in table 1, including dates of operation, station type, and number of seismometer components. table 2 lists the station location names.

Upgrade and expansion of the original 10-station continuously telemetered, high-gain seismic network began in 1989. First, a three-component station (PV11) was installed on the mesa just south of the injection well to provide better focal depth control and to allow for more sensitive event detection. Three vertical-component stations (PV12–PV14) were added in 1989 to increase the density of stations surrounding the well. Station PV08 was downgraded in 1989 from a three-component station to a vertical-component-only station because it was determined that the equipment could be better used at the new stations closer to the injection well. Station PV15 was installed in 1995 to replace PV06, which had been vandalized in 1991, 1992, and 1994, when it was finally abandoned. A second three-component station (PV16) was installed on the mesa north of the injection well in 1999 to further improve near-well coverage.

In October 2000, a major upgrade to the data telemetry and acquisition was implemented. Up until this time, analog data from all stations had been radio-telemetered through PV08, which then relayed the data stream to Reclamation offices in Montrose, where it was transmitted via microwave and analog telephone links to Denver. In Denver, the analog data from all stations were digitized (using 12-bit digitizers) and processed. In October 2000, a wide-area network link was established at the Hopkins Field Airport, near Nucla, CO, and new 16-bit digitizers were installed there. All analog radio links from the stations were reconfigured to terminate at Hopkins Field, and the use of analog telephone circuits to relay data was discontinued. Station PV08 was no longer used as a radio-telemetry relay. Station PV08 was temporarily removed in October 2003 to accommodate nearby construction activities and reinstalled in October 2007, at which time it was returned to a three-component configuration.

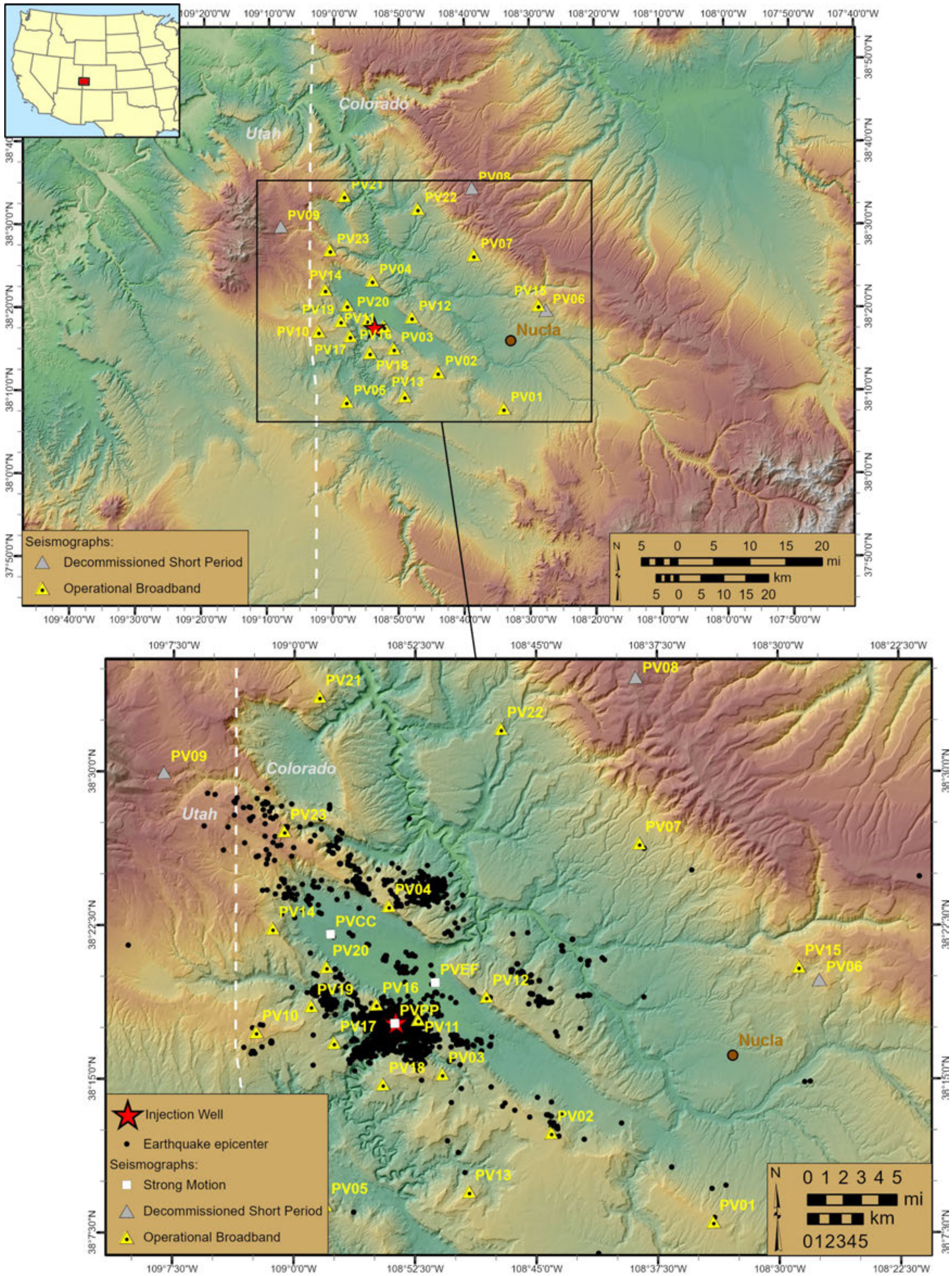

Figure 6.—Locations of the PVSN seismic stations, PVU injection well, and epicenters of earthquakes ≤ 10 km deep. PVCC, PVEF, & PVPP are the strong motion stations. Station PV06 was replaced by PV15. Stations PV08 and PV09 were decommissioned when the network was upgraded to broadband digital instrumentation.

Table 1.—PVSN station locations and characteristics

Station Name	Latitude degree, N	Longitude degree, W	Elevation m	Dates of Operation	Station Type	Sensor Direction
PV01	38.13	108.57	2191	5/83–7/16/15 5/10–present	short-period broadband	vertical triaxial
PV02	38.21	108.74	2177	5/83–8/27/11 10/08–present	short-period broadband	vertical triaxial
PV03	38.25	108.85	1972	5/83–7/16/15 10/08–present	short-period broadband	vertical triaxial
PV04	38.39	108.90	2176	5/83–6/06 5/07–present	short-period broadband	vertical triaxial
PV05	38.15	108.97	2142	5/83–7/16/15 5/10–present	short-period broadband	vertical triaxial
PV06	38.33	108.46	2243	5/83–8/94	short-period	vertical
PV07	38.44	108.64	2040	6/83–8/27/11 5/10–present	short-period broadband	vertical triaxial
PV08	38.58	108.65	2950	6/83–9/89 9/89–10/03 10/07–7/12/11	short-period short-period short-period	triaxial vertical triaxial
PV09	38.50	109.13	2662	6/83–7/16/15	short-period	vertical
PV10	38.29	109.04	2266	6/83–7/16/15 10/08–present	short-period broadband	vertical triaxial
PV11	38.30	108.87	1882	12/89–10/13 10/08–present	short-period broadband	triaxial triaxial
PV12	38.32	108.80	2092	12/89–7/05 11/05–present	short-period broadband	vertical triaxial
PV13	38.16	108.82	2158	12/89–7/16/15 5/10–present	short-period broadband	vertical triaxial
PV14	38.37	109.02	2234	12/89–4/02 6/07–present	short-period broadband	vertical triaxial
PV15	38.34	108.48	2234	6/95–8/27/11 7/11–present	short-period broadband	vertical triaxial
PV16	38.31	108.92	2025	7/99–7/16/15 5/10–present	short-period broadband	triaxial triaxial
PV17	38.28	108.96	1991	11/05–present	broad-and	triaxial
PV18	38.25	108.91	1999	7/11–present	broadband	triaxial
PV19	38.31	108.98	2041	7/11–present	broadband	triaxial
PV20	38.34	108.97	1852	7/11–present	broadband	triaxial
PV21	38.56	108.97	2235	7/11–present	broadband	triaxial

Station Name	Latitude degree, N	Longitude degree, W	Elevation m	Dates of Operation	Station Type	Sensor Direction
PV22	38.54	108.79	1925	7/11–present	broadband	triaxial
PV23	38.45	109.01	2456	11/11–present	broadband	triaxial
PVPP	38.30	108.90	1524	12/97–present	strong motion	triaxial
PVEF	38.33	108.85	1513	10/03–present	strong motion	triaxial
PVCC	38.37	108.96	1617	6/05–present	strong motion	triaxial

Notes: Elevations are relative to mean sea level (MSL). The surface elevation of the injection well is 1540 m above MSL. Stations with vertical sensor direction are single-component; triaxial are 3-component (vertical, north, and east).

Table 2.—Location names of PVSN seismic stations

Station	Station Location Name
PV01	The Burn
PV02	Monogram Mesa
PV03	Wild Steer
PV04	Carpenter Flats
PV05	E. Island Mesa
PV07	Long Mesa
PV08	Uncompahgre Butte
PV09	North LaSalle
PV10	Wray Mesa
PV11	Davis Mesa
PV12	Saucer Basin
PV13	Radium Mtn
PV14	Lion Creek
PV15	Pinto Mesa
PV16	Nyswonger Mesa
PV17	Wray Mesa East
PV18	Skein Mesa
PV19	Morning Glory Mine
PV20	W. Nyswonger Mesa
PV21	Cone Mountain
PV22	Blue Mesa
PV23	Carpenter Ridge
PVPP	Paradox Valley Pumping Plant
PVEF	Paradox Valley Extraction Field
PVCC	Paradox Valley Community Center

Starting in 2005, upgrades to the high-gain seismic network focused on replacing the analog short-period seismic instrumentation with digital broadband instrumentation. The short-period instrumentation had become obsolete, both in terms of the data quality needed for ongoing analyses and in terms of maintaining equipment that was no longer manufactured. Two key characteristics of the instrumentation constrain data quality: bandwidth and dynamic range. The short-period instrumentation had an effective seismic signal bandwidth of 1–20 Hz. The low end of this range was determined by the natural frequency (1 Hz) of the seismometers used (Geotech model S-13), and the high end by the analog low-pass filter setting (nominally 25 Hz). The bandwidth of the analog stations was insufficient for many analysis purposes, such as accurately identifying complex seismic phases, accurately computing seismic moments of induced earthquakes (which require determination of long-period spectral levels), waveform modeling, or extracting time-domain Green's functions from ambient noise. Furthermore, the effective dynamic range of the analog stations constrained the ratio of the largest to smallest seismic signal that could be recorded on-scale to only a factor of about 1000, which corresponds to approximately two earthquake magnitude units. This resulted in seismic signals of earthquakes greater than about M 1.5 being clipped, which limited the use of this important data for magnitude and moment calculations, waveform cross-correlation, and identification of the S-wave arrival. Although 16-bit digitizers (with a dynamic range of 90 dB) were used after 2000, the effective dynamic range of the analog stations remained much less, approximately 10 or 11 bits (60 dB), because of the limited sensitivity of the voltage-controlled oscillators used at the stations to modulate the seismic signals onto the carrier tones used for analog radio telemetry. Modern broadband instrumentation provides much better characteristics, with typical bandwidths of 0.03 to 50 Hz, 24-bit digitizers providing a dynamic range of 135 dB or more, and seismometers typically packaged as a single unit with internal three-component sensors.

In November 2005, the first three-component broadband seismometer (Guralp model CMG-40TD) was installed at a new station southwest of the injection well (PV17). This instrument uses a 24-bit digitizer integrated within the seismometer case to minimize potential cable noise (digitizers and seismometers separated by a long analog cable can be sensitive to cross-talk at the microvolt level, which is difficult to protect against). Station PV12 was similarly upgraded at about the same time, and stations PV04 and PV14 were converted in May and July of 2007. These first-generation digital stations used digital radios that effectively behaved as a remote RS232 serial data link and which required the use of "combiner-repeater" modules (Guralp model CRM-6) to combine the serial signals from multiple stations. The first-generation stations exhibited a number of data quality problems, the most severe of which was crosstalk between the GPS antenna cabling (which provided timing for the internal digitizer) and the system providing power to the seismometer (O'Connell 2008). Although not readily apparent in single-trace waveform data, the crosstalk inherent in the first-generation design resulted in significant spectral spikes in the stacked waveform data at frequencies of 1 Hz and greater, as illustrated in figure 7.

A second-generation station design was developed in 2010–2011 based on experience from similarly instrumented seismic networks deployed in 2007 and 2008 at B.F. Sisk and Hungry Horse Dams (O'Connell 2008). The new stations incorporated features designed to minimize the GPS antenna crosstalk problems, as well as to make the system more modular and robust. A third-generation station design was developed in 2010 that included entirely new seismometer vaults, station enclosures, antennas, solar panels, and Ethernet packet radios. Deployment of the second-generation digital instrumentation occurred in 2010–2011, with upgrades of PV01, PV02, PV03, PV05, PV07, PV10, PV11, PV13, PV15, and PV16. In addition, six broadband digital seismic stations (PV18 to PV23) were installed at new sites in 2011 to improve station coverage as the distribution of induced seismicity expanded. Two of these stations, PV22 and PV23, are improved locations for the old analog stations PV08 and PV09, which were decommissioned because they were noisy sites founded on thick alluvial deposits (all other sites are on rock). The other four new seismic stations (PV18, PV19, PV20, and PV21) were installed entirely to improve coverage in seismically active areas of interest (including seismicity occurring within 9 km of the injection well and at the northern end of Paradox Valley).

The third-generation digital broadband upgrade of PVSN seismic stations was completed in late 2011. Consequently, Reclamation discontinued maintenance of the obsolete analog seismic stations. Four of those stations permanently went offline during 2011 (PV02, PV07, PV08, and PV15), and an additional analog station (PV11) ceased functioning in late 2013. The remaining analog stations were decommissioned in July 2014, when the data acquisition center at Hopkins Field was relocated into a new building.

A fourth-generation digital upgrade began in 2018, with replacement of the Guralp model CMG-40TD broadband seismometers with Guralp model 3ESPCDE seismometers, because the original seismometers had begun to fail and were no longer supported. For example, compatible GPS antennas could no longer be obtained for the oldest CMG-40TDs in the network, making continued maintenance of the stations with these old instruments impractical. The 3ESPCDE seismometers also had several advantages over the CMG-40TD seismometers, including substantially less self-noise, considerably less power usage than the oldest CMG-40TDs, and Ethernet capability for future communications upgrades. Due to the increased sensitivity of the new seismometers, fourth-generation power-conditioning electronics were developed to minimize GPS cross-talk problems. In April 2018, the CMG-40TD seismometers at stations PV02, PV10, PV18, PV20, and PV23 were replaced with new 3ESPCDE seismometers. The seismometers at stations PV12 and PV19 were upgraded in May 2019. The seismometers at the remaining stations were upgraded in September 2020 (PV03, PV04, PV05, PV11, PV13, PV14, PV15, PV17, PV21, PV22) and October 2020 (PV01, PV07, PV16).

In addition to the continuously telemetered high-gain seismic array, three event-triggered strong-motion instruments were added to PVSN. The first strong-motion instrument (PVPP) was installed near the PVU injection wellhead in December 1997. A second strong-motion instrument was installed near the PVU extraction facilities (PVEF) in January 1998, and the third was installed at the nearby community of Paradox, Colorado (PVCC) in June 2005. Telemetry for the strong-motion instruments were provided by dial-up phone lines. The strong-motion array is designed to measure earthquake ground motions that are large enough to be felt or cause damage and which could saturate high-gain array stations closest to the epicenter.

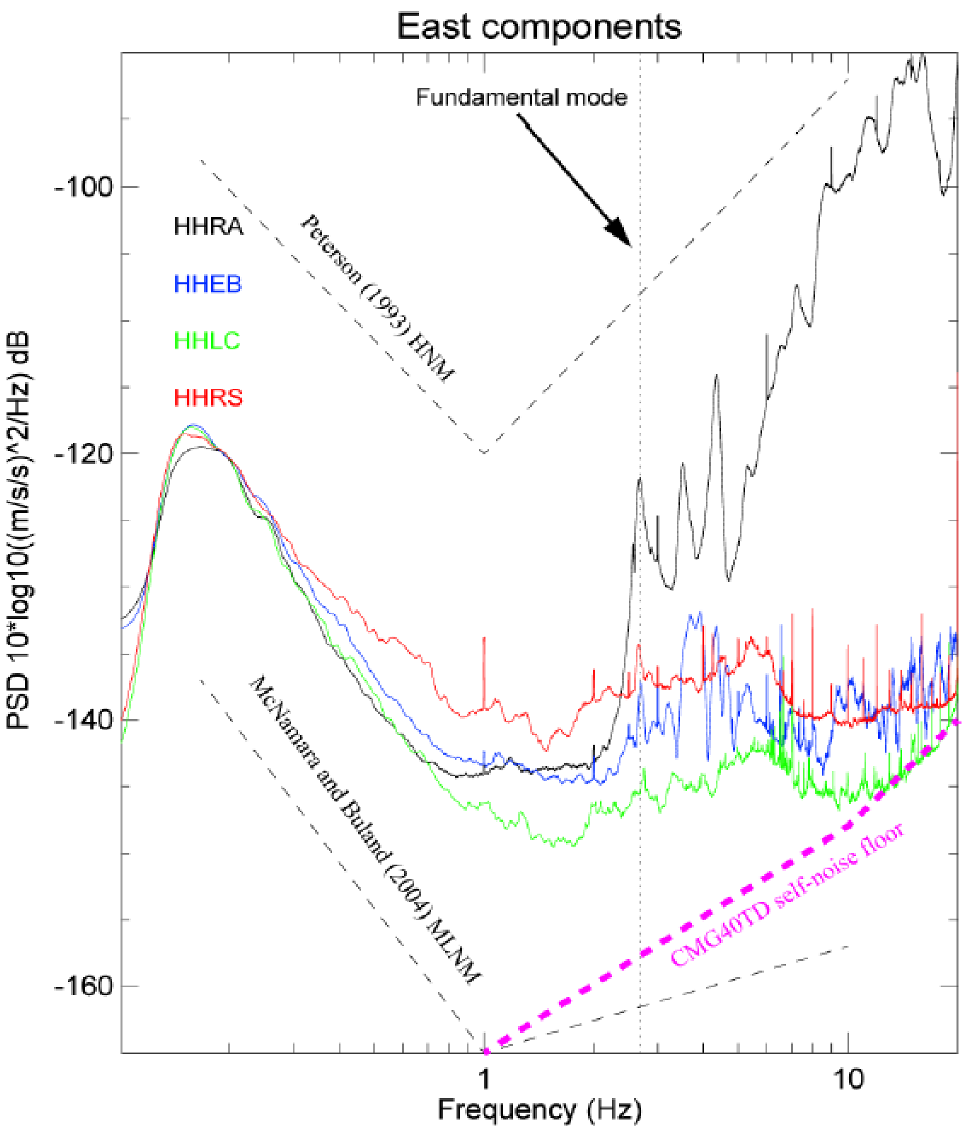

Figure 7.—Stacked multi-taper acceleration power spectra from the east-west components of Guralp model CMG40TD seismometers installed at four first-generation stations (HHRA, HHEB, HHLC, and HHRS) near Hungry Horse Dam, Montana. Windows were 400 seconds in length and represented ambient conditions. (Station HHRA was located close to the power generation plant at the dam and therefore exhibited much higher ambient noise levels at frequencies above 2 Hz.) The obvious spikes in the spectra at frequencies of 1 Hz and higher were caused by GPS antenna crosstalk problems inherent in the first-generation stations. A new station design was developed and implemented at PVSN to substantially reduce these crosstalk problems. Figure from O'Connell (2008).

The original instruments at PVPP and PVEF consisted of 12-bit data loggers (Kinemetrics model SSA-2 and Syscom model MR2002) and three-component force-balance accelerometers, with the digitizers only approximately synchronized to Coordinated Universal Time (UTC). In November 1999, station PVEF was upgraded to use an 18-bit digitizer (Kinemetrics model K2), which was synchronized to UTC using a GPS receiver. Station PVPP was similarly upgraded in October 2003. Station PVCC had used a K2 data logger since its original installation in 2005.

On February 28, 2019, the K2 was removed from station PVEF, and three different data loggers and accelerometers were installed for a temporary side-by-side comparison study. These included the following instruments: (1) Reftek model RT130 data logger with Silicon Audio model 203V accelerometer, (2) Reftek RT130 data logger with Nanometrics model Titan accelerometer, and (3) Guralp model Minimus data logger with Guralp model Fortis accelerometer. A wireless TCP/IP bridge was installed to provide continuous real-time radio telemetry. In May 2019, the Silicon Audio sensor and Reftek digitizer were removed, and the Titan sensor was replaced with a similar unit with an internal digitizer. From May 2019 to October 2020, the Guralp instruments and the Nanometrics Titan with internal digitizer were run side-by-side at PVEF with continuous telemetry.

Following the testing of strong motion sensors and digitizers in 2019–2020, the decision was made to upgrade all strong motion sites using a Silicon Audio model 203V accelerometer and a Guralp Minimus digitizer. These upgrades were implemented in October 2020. At the same time, real-time radio telemetry was established for stations PVPP and PVCC. The real-time data from all three strong motion sites are integrated with the data from the high-gain broadband sites at the PVSN communication center at Hopkins Field in Nucla, Colorado.

2.3.2 Induced Seismicity

Approximately 11,570 relatively shallow (≤ 10 km deep) earthquakes have been recorded in the vicinity of Paradox Valley since injection began in 1991. No natural earthquakes were detected near the well-head in six years of seismic monitoring prior to the start of injection operations. Most of the induced events have focal depth estimates between approximately 2.5 and 6.5 km (relative to the ground surface elevation at the PVU injection wellhead), close to the depth of the injection interval (4.3 to 4.8 km). The seismicity has been observed at increasing distance from the injection well over time (figure 8). Initial earthquakes were detected just four days after the start of the first injection test in July 1991 and occurred very close to the injection well. As injection continued, earthquakes occurred at progressively increasing distances from the well. By 2002, earthquakes were occurring as far as 16 km away. The lack of shallow seismicity detected during six years of pre-injection seismic monitoring, the general correlation of the depths of the earthquakes and the depth of injection, and the spatiotemporal evolution of the seismicity since the start of injection demonstrated in figure 8 indicate that these earthquakes have been induced by PVU fluid injection.

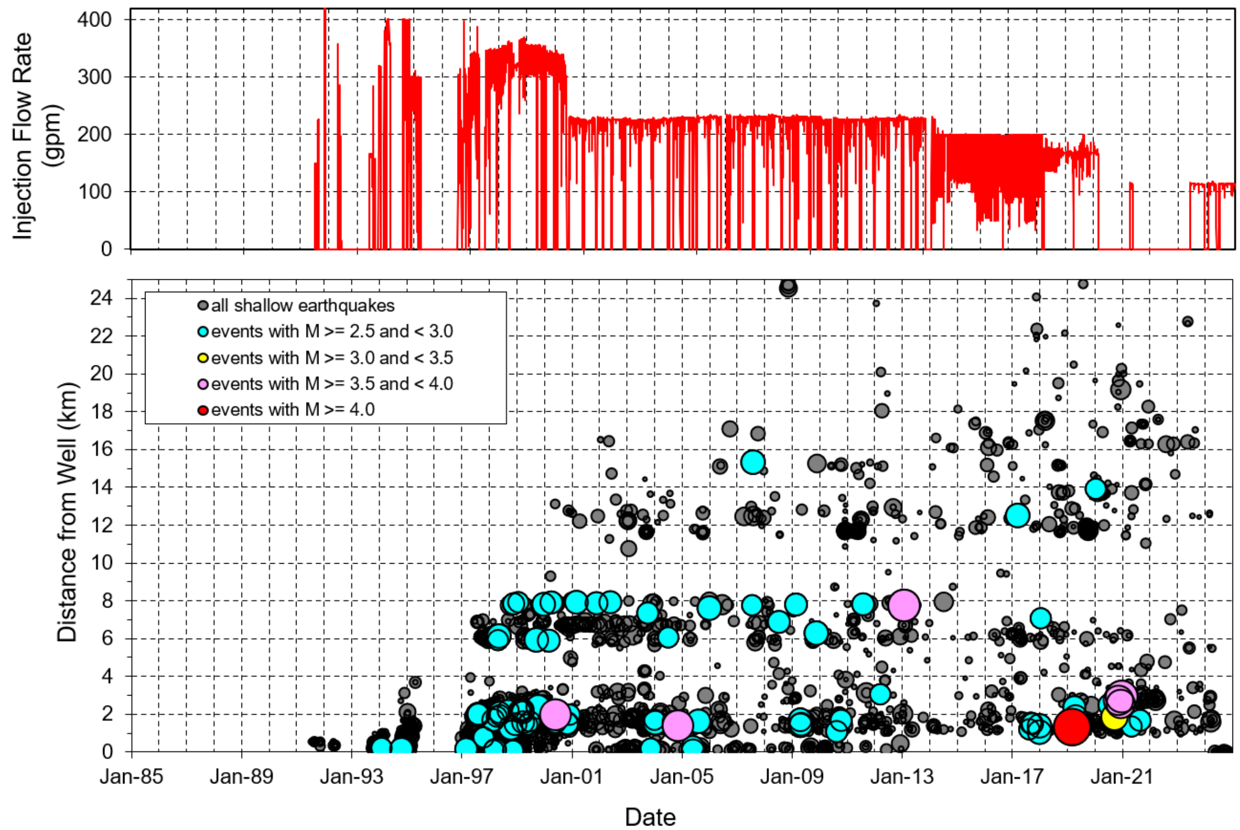

Figure 8.—Lower plot: scatter plot of earthquakes having magnitude ≥ 0.5 and depth ≤ 10 km (relative to the ground surface elevation at the injection wellhead), plotted as a function of date and distance from the PVU injection well. Each circle represents a single earthquake, with the width of the circle scaled by the event magnitude. The magnitudes shown are duration magnitudes for earthquakes with M_D < 3.0 and moment magnitudes for larger events. Upper plot: daily average injection flow rate.

Several distinct groups, or clusters, of induced seismicity have developed over the history of PVU injection operations. By the end of the injection tests in 1995, earthquakes were occurring to radial distances of roughly 4 km from the well (figure 9a). This area of induced seismicity immediately surrounding the injection well is referred to as the “near-well” region. In 1997, about one year after the start of continuous injection, earthquakes began occurring 6 to 8 km northwest of the injection well (figure 9b). This group of induced seismicity is called the “northwest cluster”. In mid-2000, earthquakes were first detected 12 to 14 km from the injection well, along the northern edge of Paradox Valley (figure 9b). Several distinct clusters of earthquakes soon formed along the northern edges of the valley (figure 9c). The earthquakes occurring in all these groups are referred to as “northern valley events”. Following the formation of these clusters (and a 32% decrease in the injection rate in mid-2000), the geographical expansion of induced seismicity greatly slowed for nearly a decade (figures 9c, d) but was renewed in 2010. For example, a single earthquake was first detected about 6 km southeast (SE) of the injection well in 2004 (figure 9c), but the seismicity rate in this area markedly increased beginning in 2010 (figure 9e). This tight group of earthquakes is referred to as the “SE cluster”.

Earthquakes also began occurring in north-central Paradox Valley in 2010. (figure 9e). In the last several years, the rate of induced seismicity at the northern end of Paradox Valley has increased, and its geographical extent has expanded (figures 9e, f, g, and h). Earthquakes likely related to PVU brine injection are now occurring at distances up to approx. 27 km northwest of the injection well and up to approx. 7 km outside the northwest perimeter of the seismic network (figure 9g). In addition, seismicity potentially related to PVU brine injection has occurred in several previously aseismic areas, including: toward the SE to a distance of approx. 37 km from the injection well, east to a distance of approx. 24 km from the well, and west to a distance of approx. 14 km from the well (figures 9f, g, h).

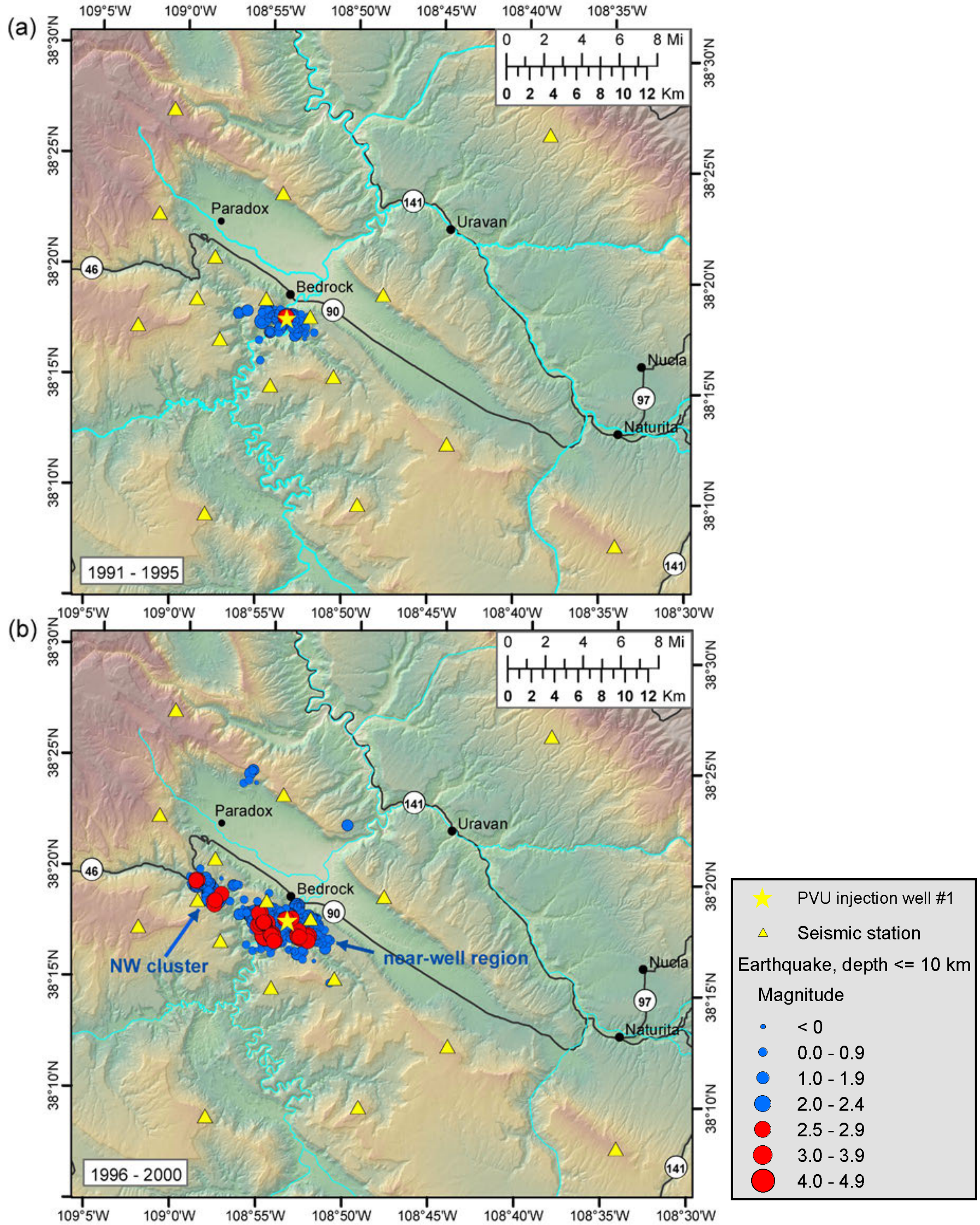

Figure 9.—Maps showing the spatial distribution of shallow seismicity (depth ≤ 10 km) over time: (a) 1991–1995 (b) 1996–2000 (c) 2001–2004 (d) 2005–2008 (e) 2009–2012 (f) 2013–2016 (g) 2017–2020 (h) 2021–2024. Earthquake symbols (filled circles) are sized and color-coded according to magnitude: earthquakes with magnitudes < 2.5 are in blue while those with magnitude ≥ 2.5 are shown in red.

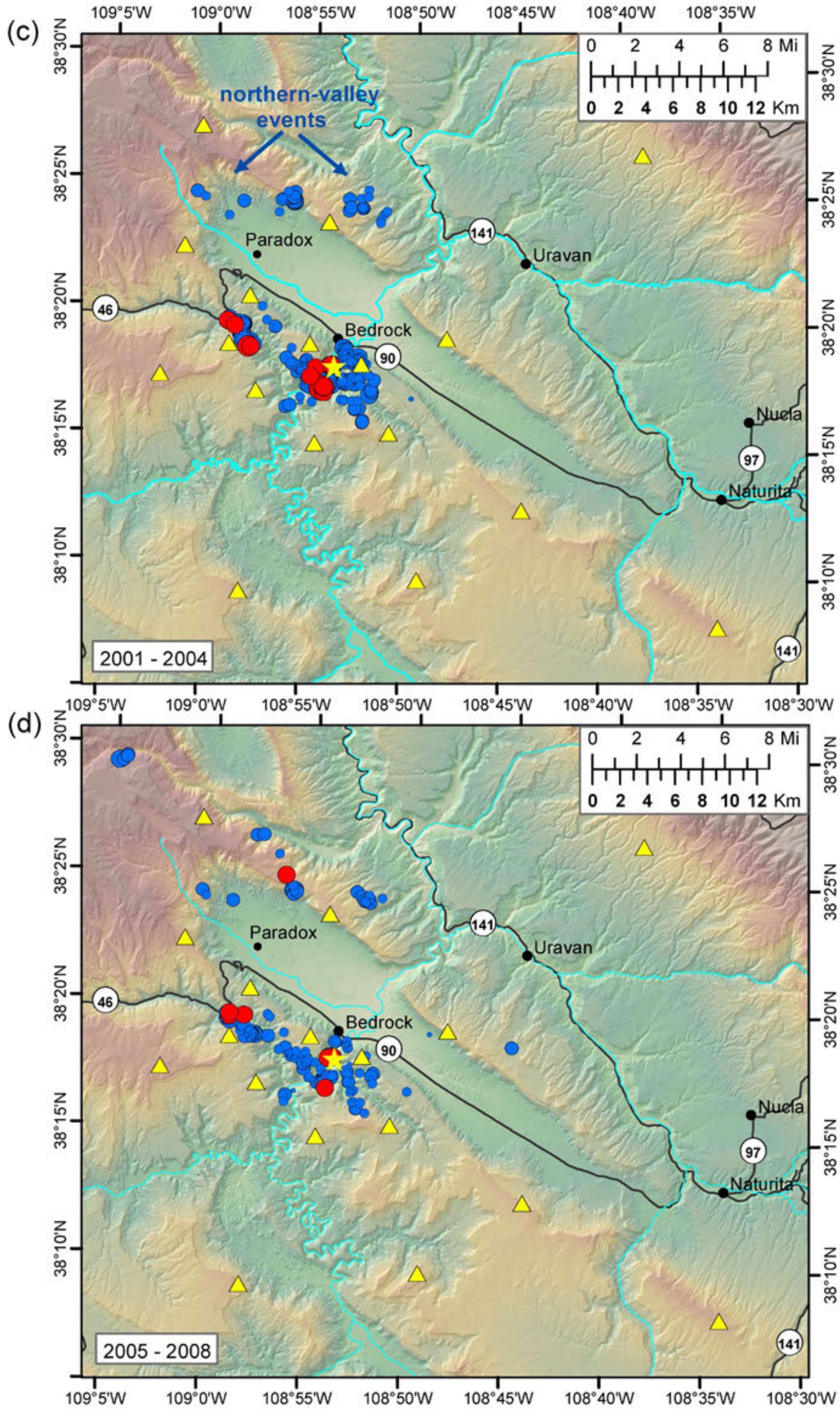

Figure 9, continued.

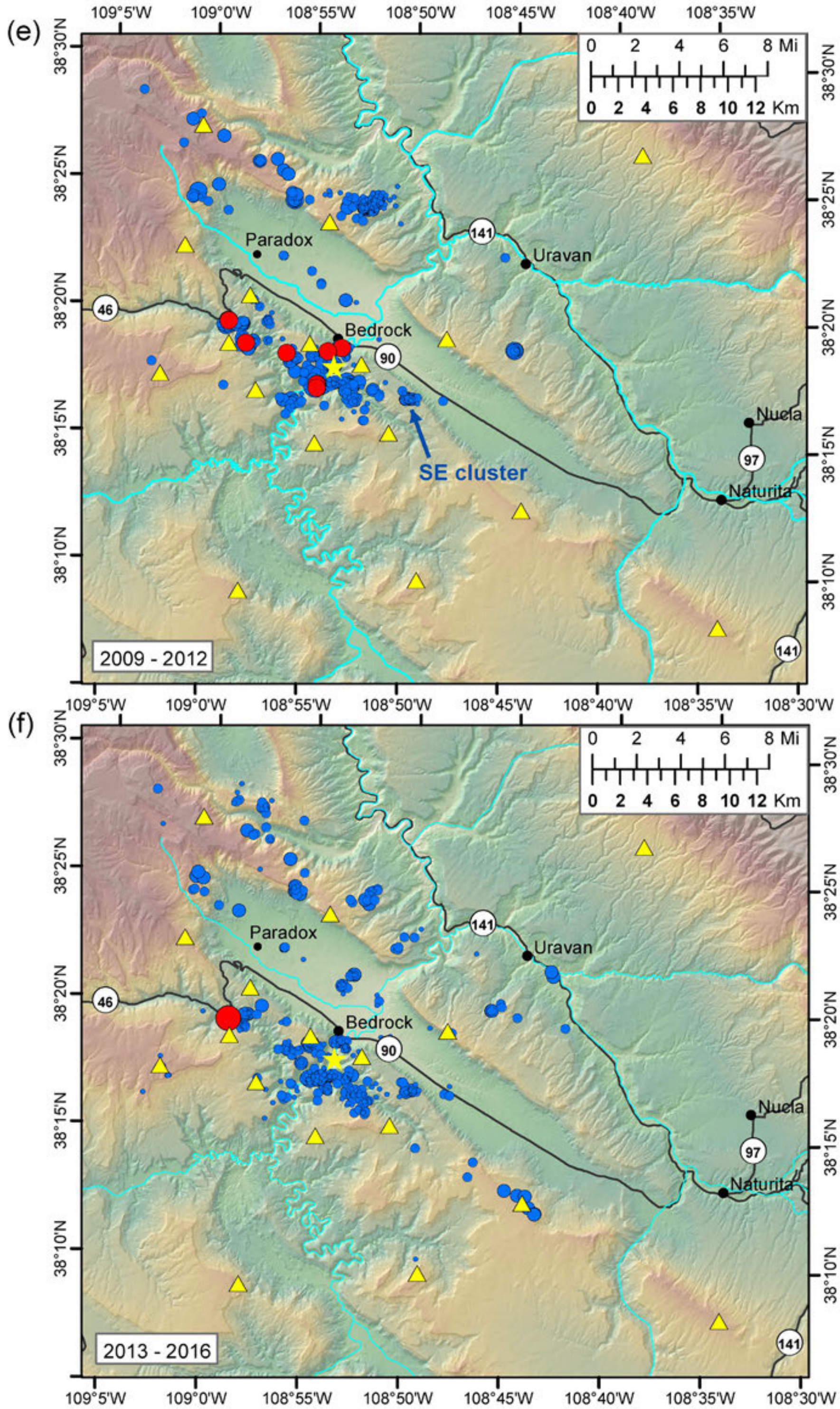

Figure 9, continued.

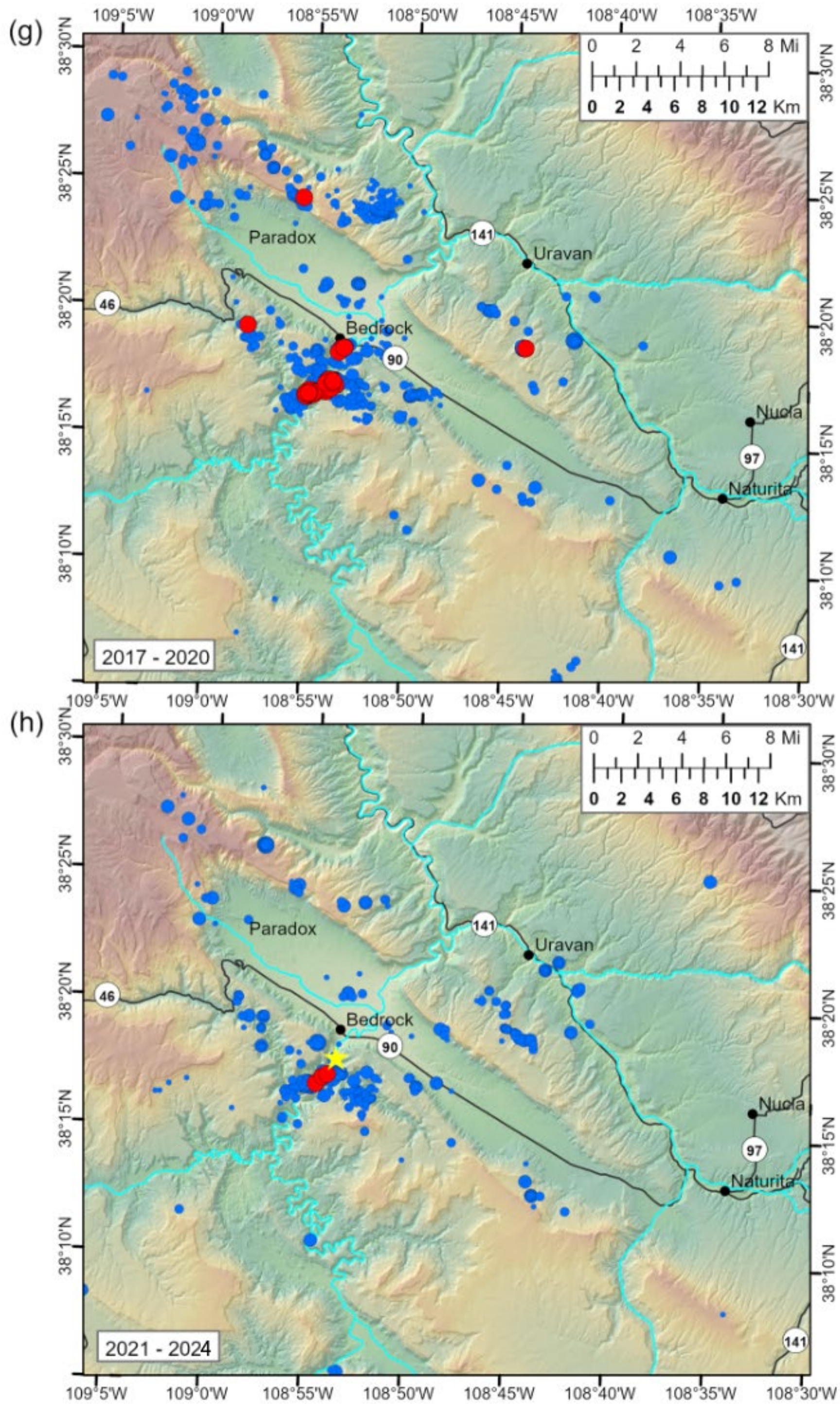

Figure 9, continued.

3.0 Network Operations during 2024

3.1 Network Maintenance and Upgrades

Two site visits were conducted in 2024. During these site visits, preventive and remedial maintenance was performed at the remote broadband seismic stations, strong motion sites, and the data communication center at Hopkins Field in Nucla, CO. A summary of the activities performed at the sites during 2024 is provided below. Additional details of the work performed at each site are included in the site visit reports in appendix A.

The preventive maintenance performed at the seismic stations included: checking station power systems, replacing aging batteries, testing cables and antennas and replacing degraded components, and inspecting seismometer vaults. Remedial maintenance required during 2024 to repair seismic stations was limited and included replacing drained batteries, repairing and replacing WAGO™ blocks, and power-cycling equipment.

A logger was replaced at one of the strong motion sites (PVEF) due to a faulty Ethernet connection during the first visit. In the second visit, radio tests proved difficult at Hopkins due to receiver interference. Radio tests at site PV20 showed unusual interference that was not related to faulty equipment; further tests are needed to determine what might be causing the interference.

3.2 Network Performance

The PVSN network performance depends on the hardware at individual seismic stations, the robustness of the radio data communication between the stations and the communication center at Hopkins Field, and the reliability of the data acquisition computer systems. The performance of each of these components during 2024 is discussed below.

Table 3.—Performance of PVSN Seismic Stations in 2024

Station	Performance
PV01	Some drops in server performance but mostly online and functioning normally throughout the year.
PV02	Some network outages but mostly online and functioning normally throughout the year.
PV03	Some network outages but mostly online and functioning normally throughout the year.
PV04	Some network outages but mostly online and functioning normally throughout the year.
PV05	Some network outages but mostly online and functioning normally throughout the year.
PV07	Some network outages but mostly online and functioning normally throughout the year.
PV10	Some network outages but mostly online and functioning normally throughout the year.
PV11	Some network outages but mostly online and functioning normally throughout the year.
PV12	Some network outages but mostly online and functioning normally throughout the year.

Station	Performance
PV13	Some network outages but mostly online and functioning normally throughout the year.
PV14	Some network outages but mostly online and functioning normally throughout the year.
PV15	Some network outages but mostly online and functioning normally throughout the year.
PV16	Some network outages but mostly online and functioning normally throughout the year.
PV17	Some network outages but mostly online and functioning normally throughout the year.
PV18	Some network outages but mostly online and functioning normally throughout the year.
PV19	Some network outages but mostly online and functioning normally throughout the year.
PV20	Some network outages but mostly online and functioning normally throughout the year.
PV21	Some network outages but mostly online and functioning normally throughout the year.
PV22	Some network outages but mostly online and functioning normally throughout the year.
PV23	Some network outages but mostly online and functioning normally throughout the year.
PVEF	Server issues and went offline for part of the year due to an unresponsive digitizer.
PVPP	Drops for parts of the year due to server issues.
PVCC	Server issues and went offline for part of the year due to a faulty datalogger.

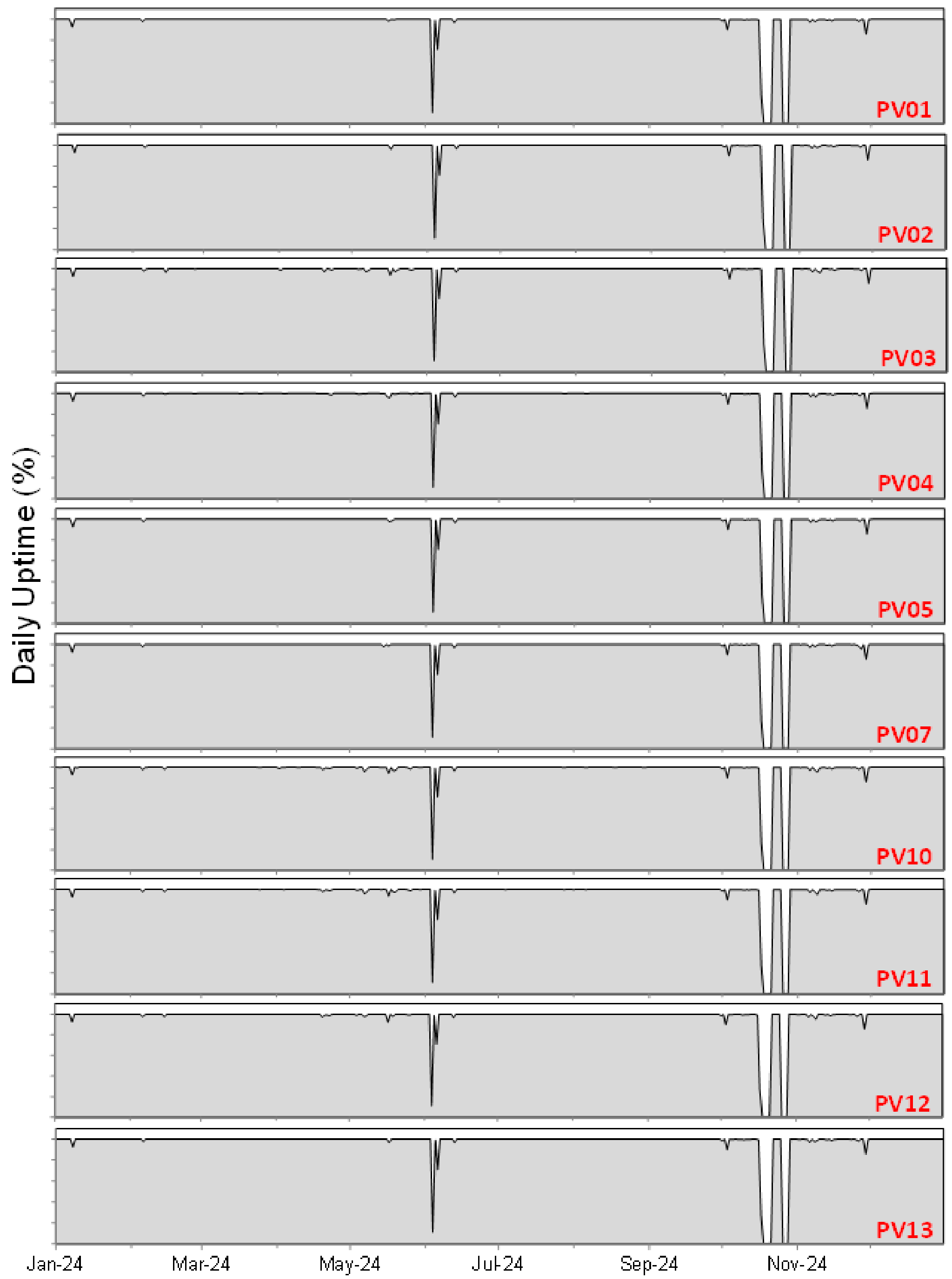

Figure 10.—Daily uptime (%) for the PVSN seismic stations during 2024. The uptime values represent the percent of the day for which data from a given station were recorded. The vertical axes on the plots are scaled from 0 to 110%. Filled gray areas represent daily uptime, while dips in the filled volume show decreases in uptime (lack of data).

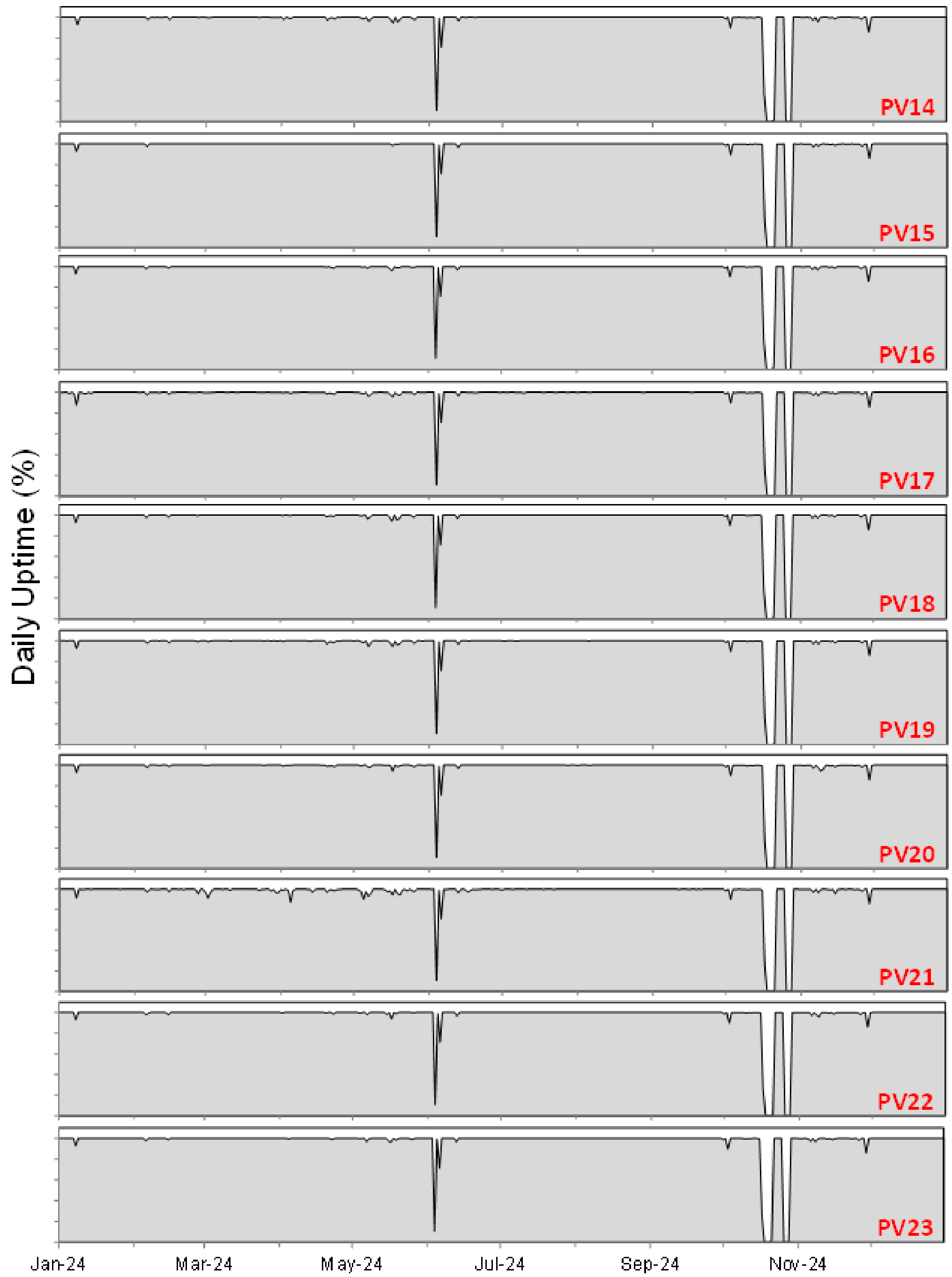

Figure 10 continued.

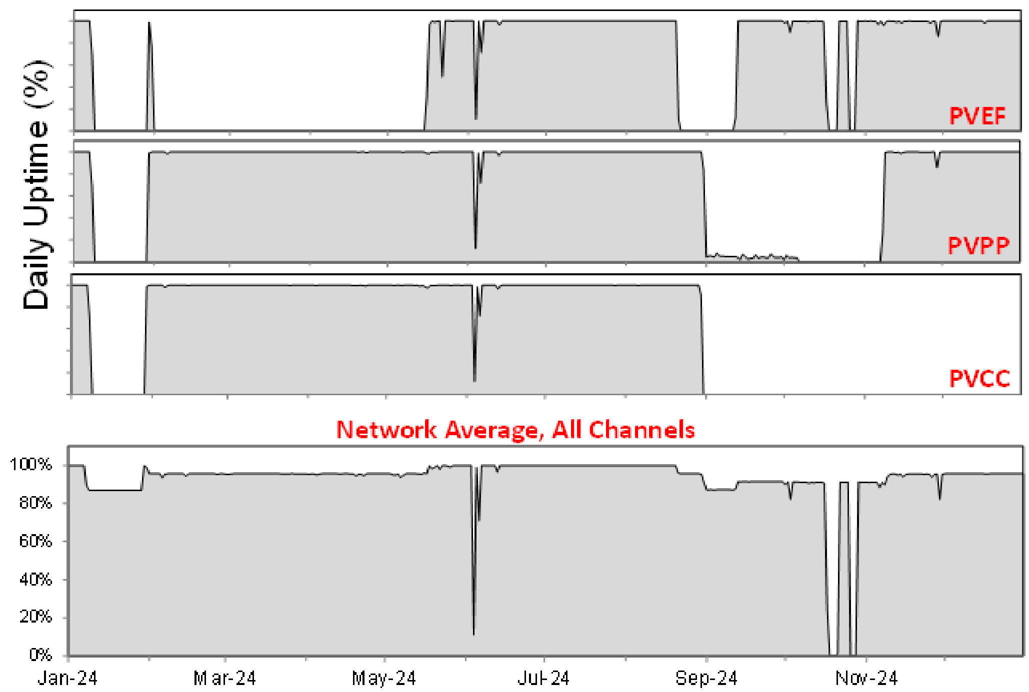

Figure 10, continued. The bottom plot shows the daily average performance for all PVSN channels.

Instances where performance across all PVSN channels was affected occurred in both June and October. In June, an undetermined processing failure occurred on the server running the *Scream* data acquisition software in Nucla, Colorado. This led to network outages on June 4, June 5, and again on June 13, 2024. The system was brought back online on June 6 and June 13, 2024.

In October, another undetermined processing failure resulted in lost connections from October 18 to 20 and again from October 26 to 28, 2024. Before the issue was resolved, uptime data was lost, resulting in an artificially low uptime calculation for the month.

The seismic instrumentation at the three strong-motion sites operated normally throughout 2024. However, the real-time data streams from these sites were intermittently disconnected from the data acquisition systems at the Hopkins Field communication center several times during the year. During routine server updates and reboots in January, the initialization file used by the *Scream* data acquisition software was not properly configured to reconnect the data streams from the three strong-motion stations. This issue went unrecognized until January 30, 2024, when it was identified and corrected.

Additionally, strong-motion station PVEF went offline on January 31, 2024. Although radio communication with the site was available, the digitizer was unresponsive. A site visit on May 16, 2024, restored the station to operational status. On August 13, 2024, station PVEF experienced a power surge caused by lightning. Surge protection equipment was replaced, and the station was brought back online.

Station PVCC went offline on August 31, 2024, due to a faulty datalogger and remained offline for the rest of the year. A future site visit is planned to restore the station to service.

Nearly all stations experienced robust radio communications during 2024, which maintained the network's ability to continuously transmit the seismic data. No other hardware problems with the radios or their antenna systems developed during the year. Received signal strength indicator (RSSI) and signal-to-noise values remained good for all radio links throughout the year (figure 11, figure 12). Radio response times for strong motion station PVCC were extremely large (> 800 milliseconds) from August to September. This issue may have been caused by a loose connector; response times decreased to normal values in late September (figure 13).

The only other times when PVSN was offline during the year were for very short periods (< 2 hours each) to accommodate routine equipment testing at Hopkins Field or computer system operating system updates.

Considering data loss from hardware failures at individual seismic stations, radio communication data dropouts, and PVSN system downtimes, the 2024 annual uptimes for the PVSN broadband and strong motion seismic stations ranged from 60.2% to 97.4%, with 20 of the 23 stations having uptimes ≥ 97% (figure 5; table 5). These uptimes represent the percentage of the year for which data from a given station were recorded by the PVSN data acquisition computer systems.

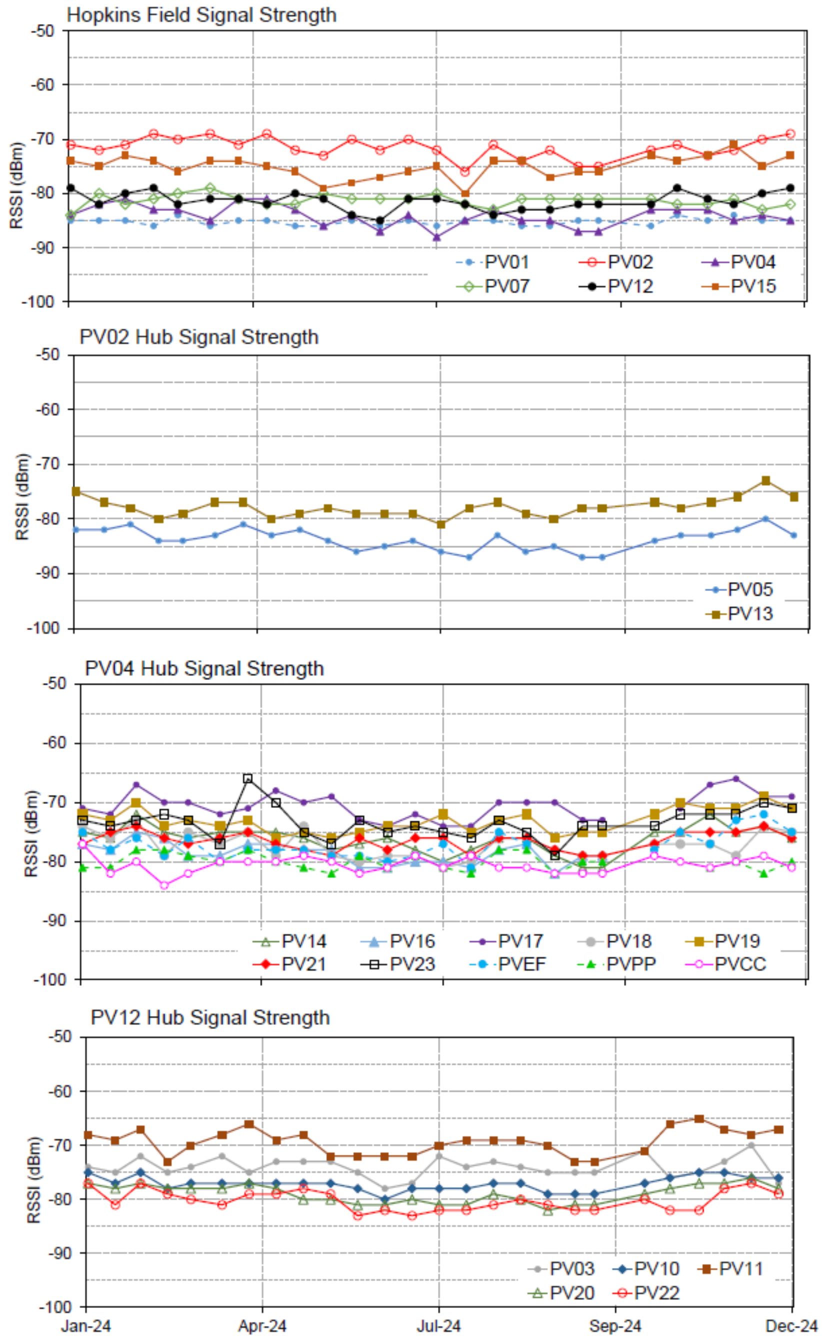

Figure 11.—PVSN received signal strength indicator (RSSI) values recorded approximately every two weeks during 2024. Higher values represent better signal quality. The measurements represent radio signal quality between the Hopkins Field communication center and the stations listed. The top plots show the measurements for stations that send data directly to Hopkins Field, whereas the other plots show measurements for stations that send data through the radio repeater (hub) sites PV02, PV04, and PV12.

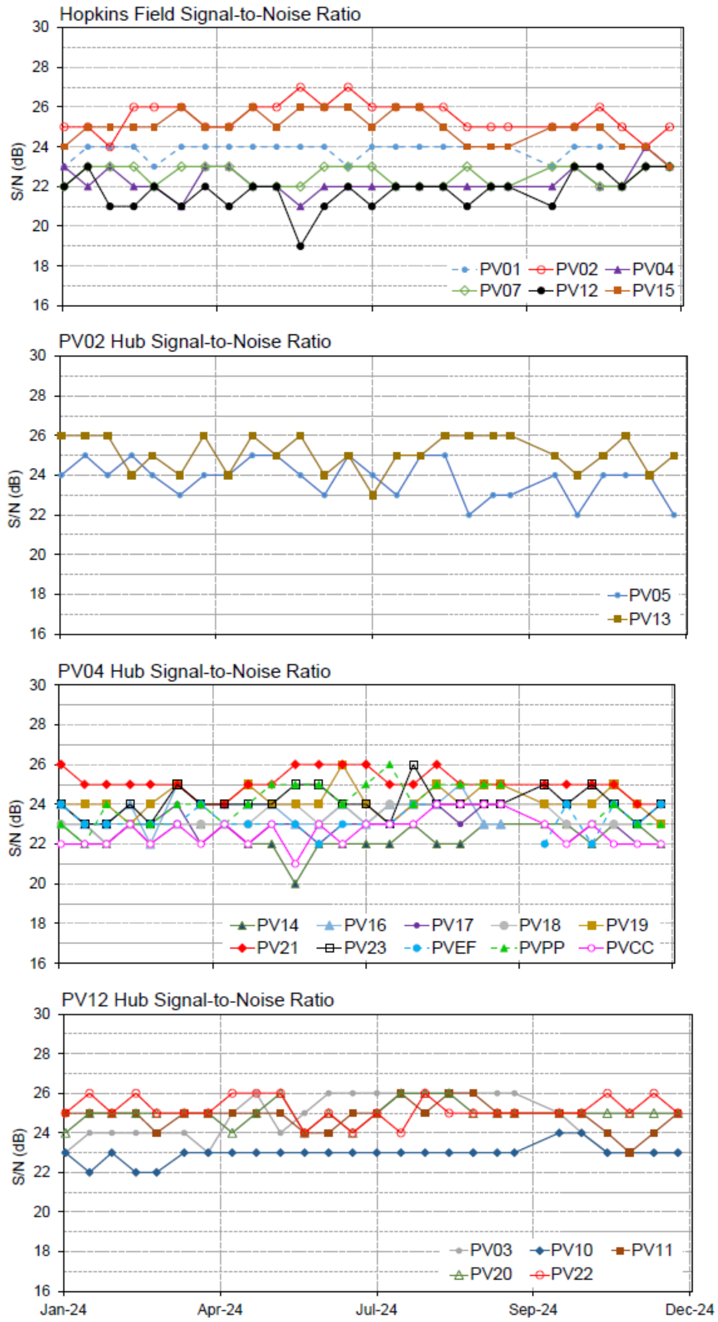

Figure 12.—PVSN radio signal-to-noise values recorded approximately every two weeks during 2024. Higher values represent better signal quality. The measurements represent radio signal quality between the Hopkins Field communication center and the stations listed. The top plots show the measurements for stations that send data directly to Hopkins Field, whereas the other plots show measurements for stations that send data through the radio repeater (hub) sites PV02, PV04, and PV12.

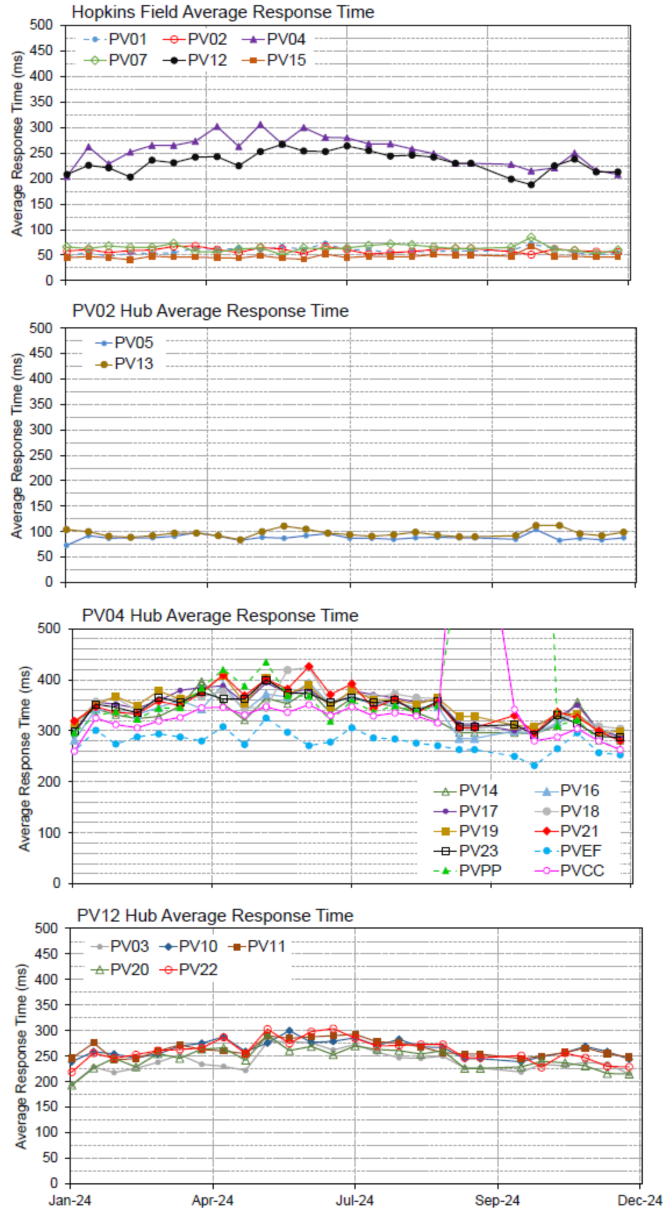

Figure 13.—PVSN radio response times recorded approximately every two weeks during 2024. Higher values represent better signal quality. The measurements represent radio signal quality between the Hopkins Field communication center and the stations listed. The top plots show the measurements for stations that send data directly to Hopkins Field, whereas the other plots show measurements for stations that send data through the radio repeater (hub) sites PV02, PV04, and PV12. Response times for station PVCC from August to September exceeded 800 milliseconds and are clipped in the third plot (magenta line).

Table 4.—Annual PVSN Uptimes Since 2000

Year	Annual Number of Days with Monitoring Absent or Substantially Degraded	Percent Uptime
2000	24	93.4%
2001**	**	**
2002	5	98.6%
2003	14.5	96.0%
2004	16	95.6%
2005	34	90.7%
2006	47	87.1%
2007	37	89.9%
2008	10	97.2%
2009	6.5	98.2%
2010	0	100.0%
2011	12.2	96.7%
2012	2.2	99.4%
2013	4.6	98.8%
2014[1]	10.3	97.2%
2015[2]	8.7	97.6%
2016[3]	17.3	95.3%
2017[4]	1.2	99.7%
2018	2.4	99.3%
2019	0.03	100.0%
2020	2.3	99.4%
2021	0.1	100.0%
2022	0.03	100.0%
2023	0.7	99.8%
2024	6	93%

** not tabulated in 2001

[1] includes 40.5 hours of downtime in September 2014 when the network was operating, but event detection was severely degraded due to malfunctioning of the data acquisition software

[2] includes a 50% rating for 12 days in February and 5 days in December when the network was operating but monitoring was substantially degraded due to the absence of data from 8–12 stations simultaneously.

[3] includes a 50% rating for 9 days in August and 22 days in September when network was operating but monitoring was substantially degraded due to absence of data from 14 stations simultaneously.

[4] includes 50% rating for 31 hours in January when network was operating but monitoring was substantially degraded due to absence of data from ≥ 5 stations simultaneously.

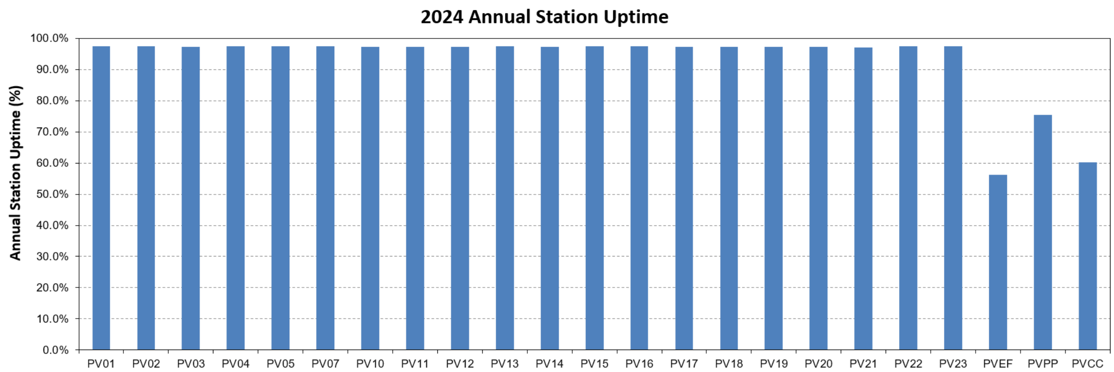

Figure 14.—Graph of annual (2024) uptime for each PVSN seismic station.

Table 5.—Annual PVSN Station Uptimes in 2024

Station	Annual Station Uptime
PV01	97.4%
PV02	97.4%
PV03	97.3%
PV04	97.4%
PV05	97.4%
PV07	97.4%
PV10	97.3%
PV11	97.3%
PV12	97.3%
PV13	97.4%
PV14	97.3%
PV15	97.4%
PV16	97.3%
PV17	97.3%
PV18	97.3%
PV19	97.3%
PV20	97.3%
PV21	97.0%
PV22	97.3%
PV23	97.3%
PVEF	56.3%
PVPP	75.4%
PVCC	60.2%

4.0 Seismic Data Recorded in 2024

4.1 Annual Summary

This annual report includes the highest-quality earthquake locations only through the end of April. These events are determined using a relative earthquake location method, which relies on precise arrival time differences between pairs of earthquakes, calculated via waveform cross-correlation. Lower quality "absolute" locations are computed separately using manually determined absolute arrival times. Each class of earthquake locations has a letter quality indicator A-D depending on the number of stations recording the earthquake, coverage, and other factors. Relative relocations have not yet been performed for the last 9 months of 2024 due to staffing shortages within the Bureau of Reclamation. As a result, events occurring after April 2024 are represented by lower-quality absolute locations. The combined catalog of relative and absolute locations was used to generate the figures and tables presented in this report.

It is also important to note that only induced earthquakes occurring within a specific geographic threshold were included in the catalog. These additional processing steps are not applied to the monthly status reports, which may lead to minor discrepancies between the monthly status report data and the final 2024 earthquake summary in this report.

In 2024, 269 earthquakes were recorded within or near the perimeter of PVSN. The map in figure 15 shows the epicenters of these events (colored circles), as well as the epicenters of all earthquakes recorded in previous years (gray and white circles). The local earthquakes are classified into four categories based on their depths (relative to the ground surface elevation of 1.524 km above MSL at the PVU injection well) and distances from the injection well:

1. Shallow near-well: depth ≤ 10 km, distance from the injection well ≤ 5 km
2. Shallow intermediate: depth ≤ 10 km, distance from the injection well > 5 km and ≤ 10 km
3. Shallow distant: depth ≤ 10 km, distance from the injection well >10 km
4. Deep: depth > 10 km, any distance from the injection well

The earthquakes recorded during 2024 are color-coded according to these categories in the map presented in figure 15, and the numbers and magnitudes of the earthquakes in each category are summarized in table 6. The 2024 local earthquake catalog is included in appendix B.

Table 6.—Summary of Earthquakes Recorded During 2024 by Location Category

Location Category	Depth	Distance from well	Number of Earthquakes	Number of Earthquakes with $M_D \geq 0.5$	Min. Magnitude[1]	Max. Magnitude[1]
shallow near-well	≤ 10 km	0 to 5 km	212	23	-1.7	2.4
shallow intermediate	≤ 10 km	> 5 to 10 km	29	10	-0.7	1.8
shallow distant	≤ 10 km	> 10 km	25	8	-0.7	1.5
Deep	> 10 km	all distances, within or near the perimeter of PVSN	3	1	0.1	0.9
TOTAL SHALLOW	**≤ 10 km**	**all**	266	41	-1.7	2.4
TOTAL	**all**	**all**	269	42	-1.7	2.4

[1] Duration magnitudes (M_D) are used for events with M_D < 3.0, and moment magnitudes (M_W) are used for larger events.

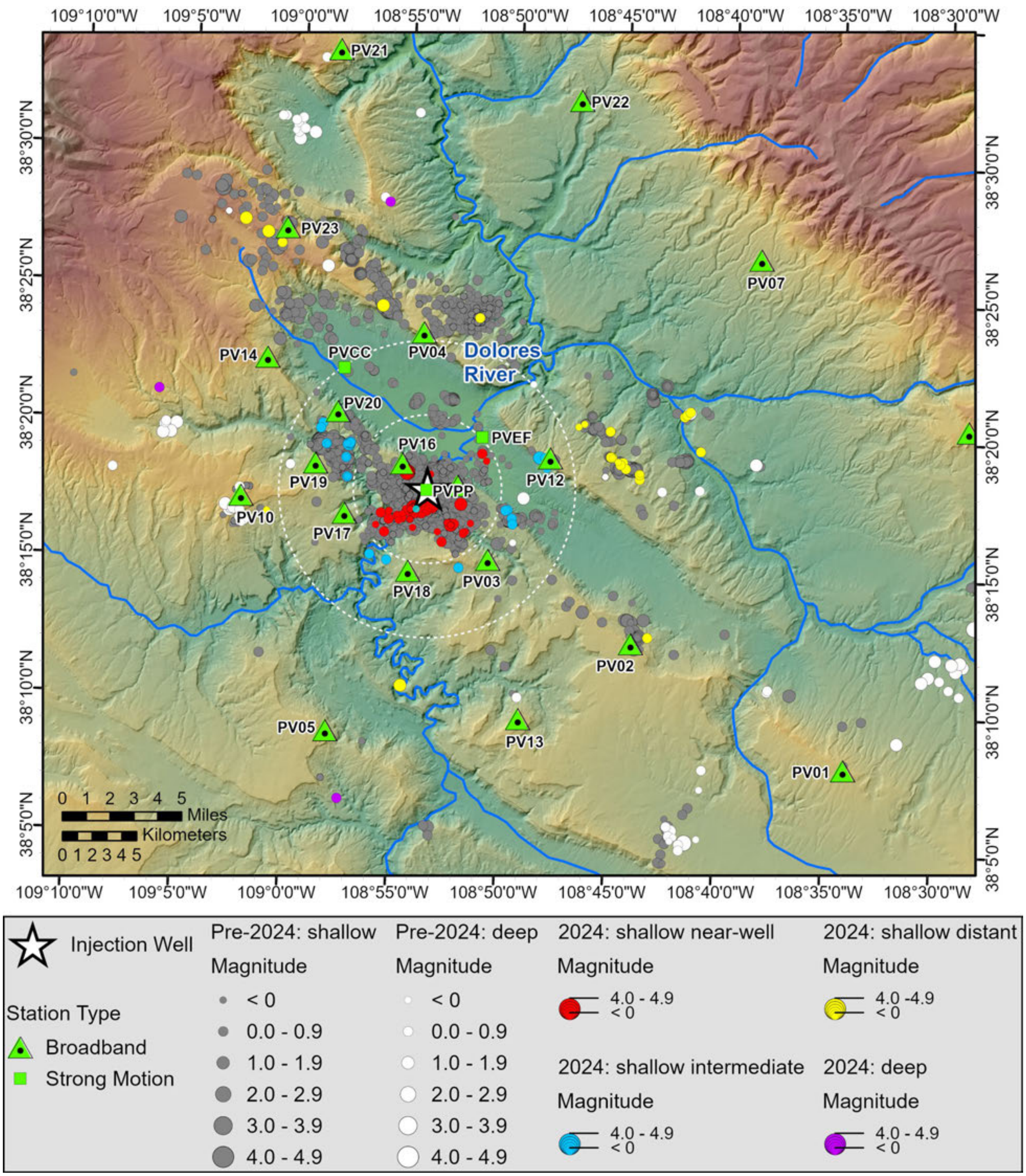

Figure 15.—Locations of local earthquakes recorded by PVSN during 2024 (colored circles) and previous years (gray and white circles). The events that occurred during 2024 are color-coded using the event location categories described in the text. Events identified as "shallow" have depths ≤ 10 km (relative to the ground surface elevation at the injection well); those identified as "deep" have depths > 10 km. The white dashed circles represent radial distances of 5 and 10 km from the injection well.

All but three of the 269 local earthquakes recorded during 2024 have depths ≤ 10 km. Of these relatively shallow earthquakes, 212 occurred within 5 km of the injection well, 29 occurred at distances between 5 and 10 km from the well, and 25 occurred > 10 km from the well. Based on the relatively shallow depths of these earthquakes and the geographical expansion of the seismicity since injection began, we interpret these earthquakes as being induced by PVU brine injection.

Throughout the year, we recorded and located other earthquakes that do not fit the spatiotemporal evolution of the PVU-induced seismicity and that occurred several km outside the perimeter of PVSN. Since the hypocenters of these events do not fit the spatiotemporal evolution of the PVU-induced seismicity and are distant from historical PVU-induced earthquakes, we interpret these earthquakes as either naturally occurring or induced by other human activities. These earthquakes are not included in our analyses.

No local earthquakes with a duration magnitude (M_D) ≥ 2.5 occurred during 2024. This magnitude threshold is significant because it is the approximate minimum magnitude for ground shaking to be felt in the Paradox Valley area. 2024 marks the second consecutive year for which no such local earthquakes have been reported.

The local earthquakes recorded by PVSN during 2024 are plotted as a function of date, earthquake magnitude, and location category in figure 16. Scattered events of low-magnitude, shallow distant seismicity occurred throughout the year. Earthquake rates were higher than last year but not substantially. So, annual seismicity rates have generally increased.

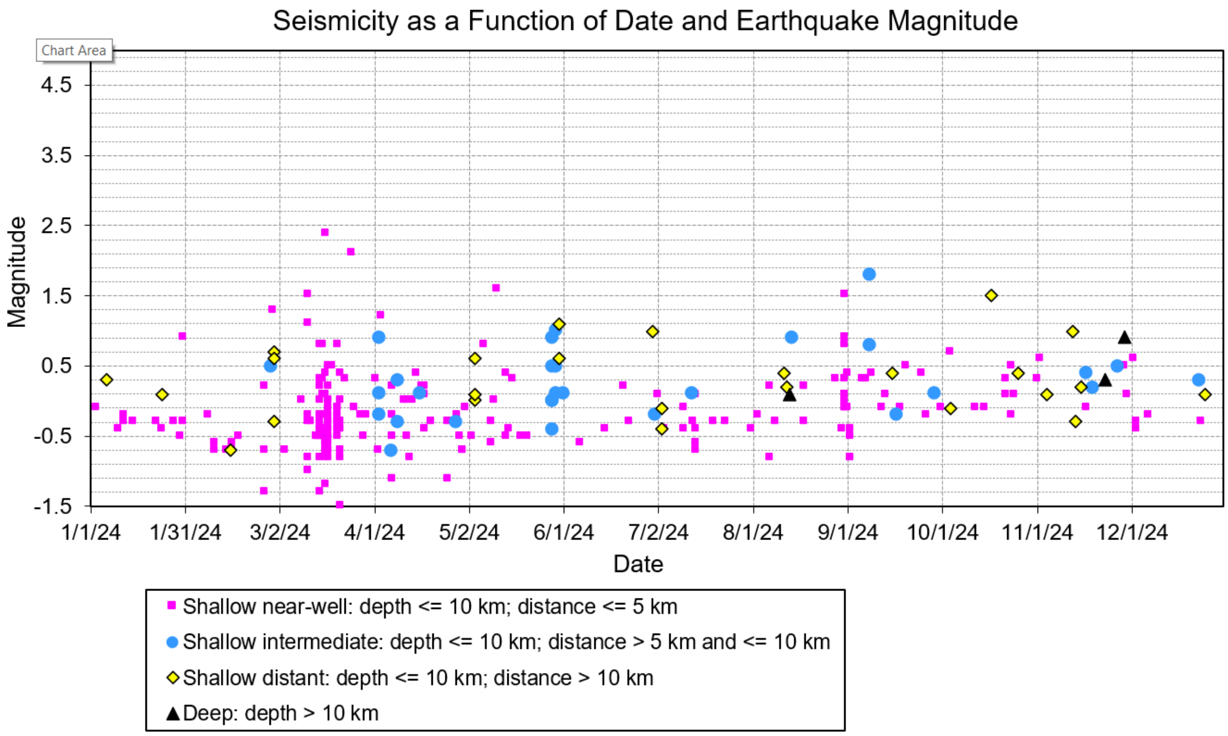

Figure 16.—Earthquakes recorded by PVSN during 2024 plotted as a function of date, magnitude, and event location category. Duration magnitudes are used for events with M_D < 3.0, and moment magnitudes are used for larger events.

4.2 Distant Earthquakes

In 2024, 28 local earthquakes were detected at distances greater than 10 km from the injection well. Of these, 25 earthquakes with depths ≤ 10 km (relative to the ground surface at the injection well) and 3 earthquakes with depths greater than 10 km are interpreted as induced by PVU injection (section 4.1). These 28 distant induced earthquakes are discussed below.

Five of the distant induced earthquakes occurred at or near the northern end of Paradox Valley (figure 15, yellow circles), where seismicity has been detected every year since 2000. For comparison, 8 events occurred in this northern-valley region in 2022, and 20 events occurred here in 2021. Historically, the annual number of northern-valley events has varied widely, ranging from 2 to 725 events per year from 2000 to 2022. The northern-valley earthquakes recorded during 2024 range in magnitude from M_D 0.1 to M_D 1.5. Their depth estimates range from 5.34 km to 8.27 km (relative to the ground surface at the PVU injection well), consistent with depth estimates of previous northern-valley events.

The seismicity in the northern-valley area is expanding to the northwest, beyond the northwestern perimeter of the Paradox Valley Seismic Network (figure 15). Uncertainties in the computed locations and depths of earthquakes increase when they occur outside the perimeter of the seismic monitoring network. Earthquakes are already occurring up to roughly 7 km outside the northwestern perimeter of PVSN. Hence, it will be difficult to monitor the further expansion of the seismicity to the northwest with the current network configuration.

In 2024, 18 induced earthquakes occurred east of Paradox Valley and south of the Dolores River, at distances of approx. 11 km to approx. 17 km from the well (figure 15, yellow and purple circles east of seismic station PV12). The magnitudes of these events range from M_D -0.7 to M_D 1.0, and their depth estimates range from 5.54 to 9.78 km (relative to the ground surface at the PVU injection well). Earthquakes have occurred in this area since 2007, and the seismicity rates have generally increased over time.

Two distant earthquakes recorded in 2024 occurred approx. 6–8 km south-southeast of the injection well, near seismic stations PV05 and PV02 (figure 15). These events have magnitudes of M_D 0.4 and M_D 1.0, with estimated depths of 6.36 km and 8.25 km, respectively. A small number of shallow earthquakes have been recorded in this Southeastern area since 2018, which may indicate a continued expansion of PVU-induced seismicity in that direction.

One distant earthquake recorded in 2024 occurred 11 km west of the injection well, near seismic station PV10 (figure 15). This event has a magnitude of M_D -0.1, with an estimated depth of 1.83 km. Earthquakes have occurred in this area and have generally increased over time,

Three distant earthquakes were recorded at depths greater than 10 km. The first event occurred 19.5 km north of the well, with an estimated depth of 14.85 km—nearly 5 km deeper than the 10-km threshold used for event classification. The second event was located 19.8 km southwest of the well, with a depth of 12.69 km, approximately 3 km deeper than the classification criterion. The third event occurred 19.3 km west of the well, with a depth of 10.24 km—just slightly deeper than the 10-km threshold. Seismicity has been detected in these areas in the past.

4.3 Seismicity Trends

Compared to the previous year, the number of earthquakes interpreted as induced by PVU injection increased near the PVU injection well and decreased at distances >10 km (table 7). During 2024, 212 earthquakes were detected within 5 km of the injection well, compared to 118 events in 2023, an increase of 80%. The largest percent change in annual seismicity rate occurred for earthquakes at distances of 5 to 10 km from the well. The number of these distant earthquakes increased by 123% from 2023 to 2024 (table 7).

Table 7.—Number of Induced Earthquakes of All Magnitudes in 2023 and 2024

Distance Range (km)	Number of Events Recorded in 2023	Number of Events Recorded in 2024	Percent Change
0 to 5	118	212	80%
> 5 to 10	13	29	123%
> 10	44	25	-43%

Because the ability to detect very small earthquakes can vary over time, depending on both the operating status of the seismic network and background seismic noise levels, more robust estimates of the variation in seismicity rate are determined by comparing the occurrence of earthquakes with magnitude ≥ M_D 0.5 (PVSN's approximate magnitude completeness threshold). These values for the last two years are presented in table 8. (Earthquakes interpreted as unrelated to PVU injection are excluded; see section 4.1.) Considering only earthquakes with $M_D \geq 0.5$, a 15% change in seismicity rate is observed within 5 km of the well. This table indicates a 150% increase in seismicity rate in the 5-to-10-km distance range, but this statistic is not very meaningful because of the small number of events in the data sets. At distances greater than 10 km from the well, the rate of earthquakes with magnitude ≥ M_D 0.5 increased by 100% in 2024 compared to 2023. This is the opposite trend compared to the counts that consider events of all magnitudes (table 7). Hence, the number of distant earthquakes of small magnitude (≤ M_D 0.5) decreased in 2023 compared to 2024, but the number of larger earthquakes increased.

Table 8.—Number of Induced Earthquakes with Magnitude ≥ M_D 0.5 in 2022 and 2024

Distance Range (km)	Number of Events Recorded in 2023	Number of Events Recorded in 2024	Percent Change
0 to 5	20	23	15%
> 5 to 10	4	10	150%
> 10	4	8	100%

The maximum earthquake magnitudes observed in each distance range for the previous two years are compared in table 9. In the near-well area, the maximum earthquake magnitude increased from M_D 1.7 in 2023 to M_D 2.4 in 2024. The maximum magnitudes for earthquakes in the intermediate distance range (5 to 10 km from the injection well), did increase, but not by much, from M_D 1.4 in 2023 to M_D 1.8 in 2024. The maximum observed magnitude in the largest distance range (>10 km from the well) decreased from M_D 1.7 in 2023 to M_D 1.5 in 2024.

Table 9.—Maximum Earthquake Magnitudes in 2022 and 2024

Distance Range (km)	Mmax in 2023	Mmax in 2024
0 to 5	M_D 1.7	M_D 2.4
> 5 to 10	M_D 1.4	M_D 1.8
> 10	M_D 1.7	M_D 1.5

Longer-term trends of earthquake rates and magnitudes are presented in three plots described below. Events with $M_D \geq 0.5$ and depth ≤ 12 km are included in these plots. First, the bubble plots in figure 17 show the historical occurrence of seismicity as a function of date and earthquake magnitude during long-term injection at PVU (since 1996). The area of each circle in these plots is scaled by the number of earthquakes in a given quarter-year and magnitude range. Individual bubble plots are included for earthquakes occurring within 5 km of the injection well, between 5 and 10 km from the well, and more than 10 km from the well. The daily average injection rates are included in figure 17 for reference. In order to better observe the trends in recent years, similar plots that only include data from 2013 to 2024 are presented in figure 18. Lastly, we show the annual seismicity rates for the last 15 years at different distances from the well, in figure 19.

These plots show that the seismicity rates and maximum magnitudes for the near-well area (within 5 km of the well) in 2024 were consistent compared to the general historical trends (figure 17b and figure 18b). The annual rate of near-well seismicity decreased every year from 2019 (when the M_W 4.5 near-well induced earthquake occurred) to 2023. In 2024, the near-well seismicity rate did not continue to decrease but has remained rather consistent. (figure 19a).

The seismicity rates in 2024 at distances of 5 to 10 km from the injection well were consistent in comparison to historical trends, and no events at or above the magnitude threshold of M_D 0.5 occurred here during the second half of 2024 (figure 17c and figure 18c). Annual seismicity rates in this distance range have been relatively low for the last five years, since the injection well was shut down in early 2019 (figure 19b). The rates were also low in 2014–2015, following a 3-month injection well shut-in in early to mid-2013 (figure 19b). This pattern suggests that earthquakes at these distances may be more sensitive to injection operations than a simple pore pressure diffusion model would predict.

The rate of distant M 0.5+ events, those occurring more than 10 km from the injection well, has historically been highly variable (figure 17d). The annual rate observed in 2024 was relatively low (figure 19c).

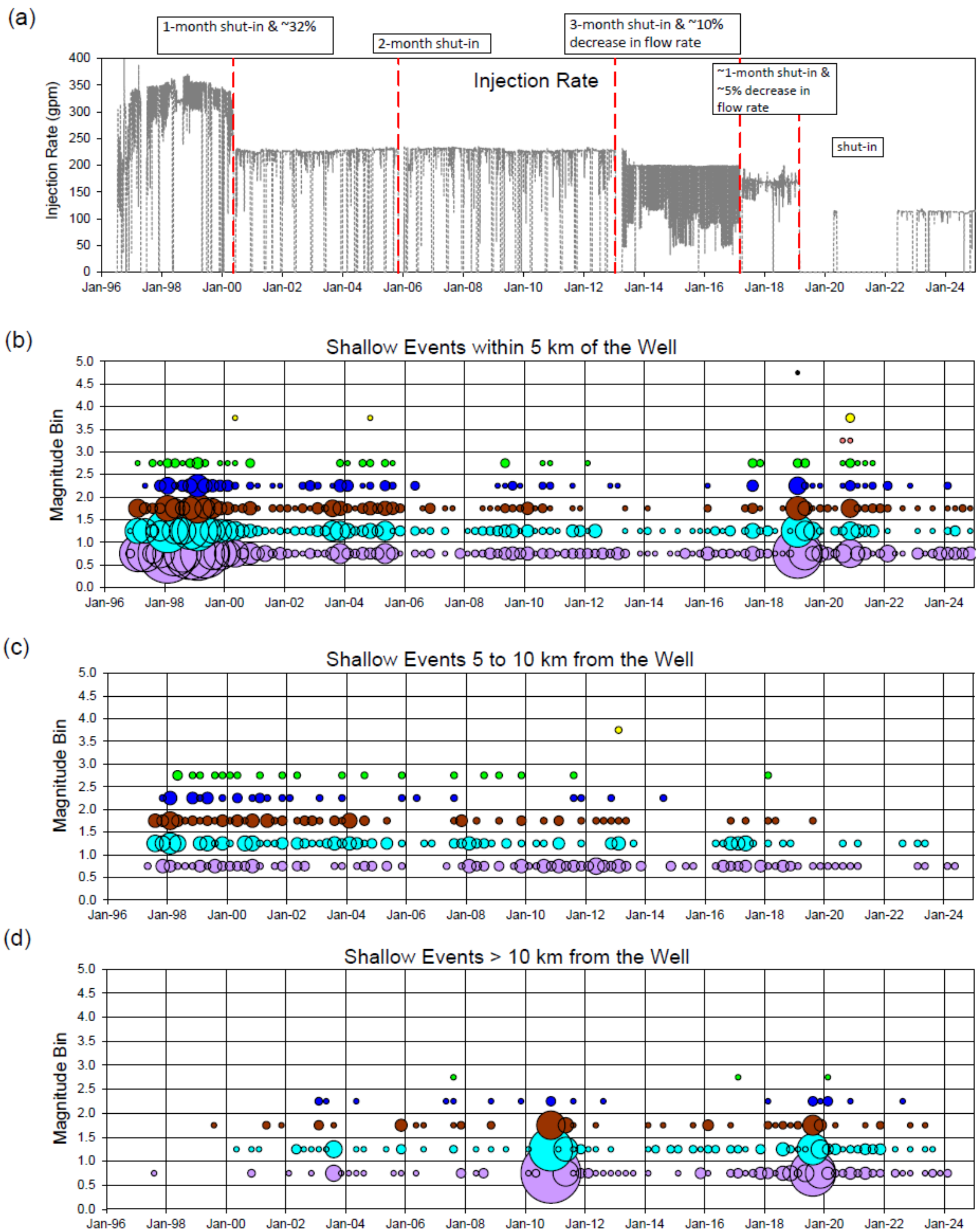

Figure 17.—Injection flow rates (a) and occurrence of seismicity with $M_D \geq 0.5$ and depth ≤ 12 km as a function of date and magnitude: (b) within 5 km of the injection well, (c) at distances of 5 to 10 km from the well, and (d) more than 10 km from the well. In the seismicity plots, the area of each circle is scaled by the number of earthquakes in a given quarter-year and magnitude range; each plot is scaled independently. Duration magnitudes are used for events with $M_D < 3.0$, and moment magnitudes are used for larger events.

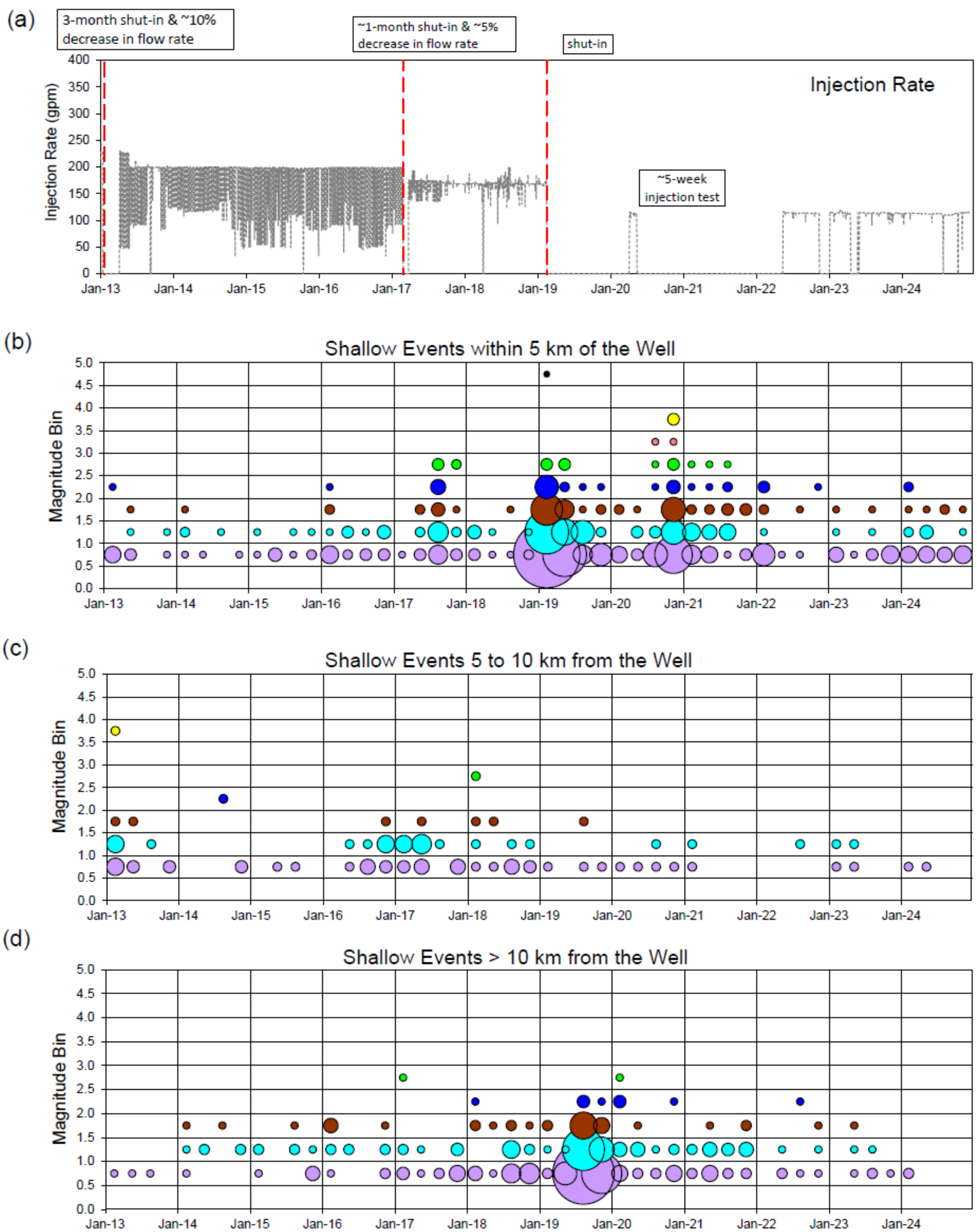

Figure 18.—Same as figure 17, but only showing data from 2013–2024.

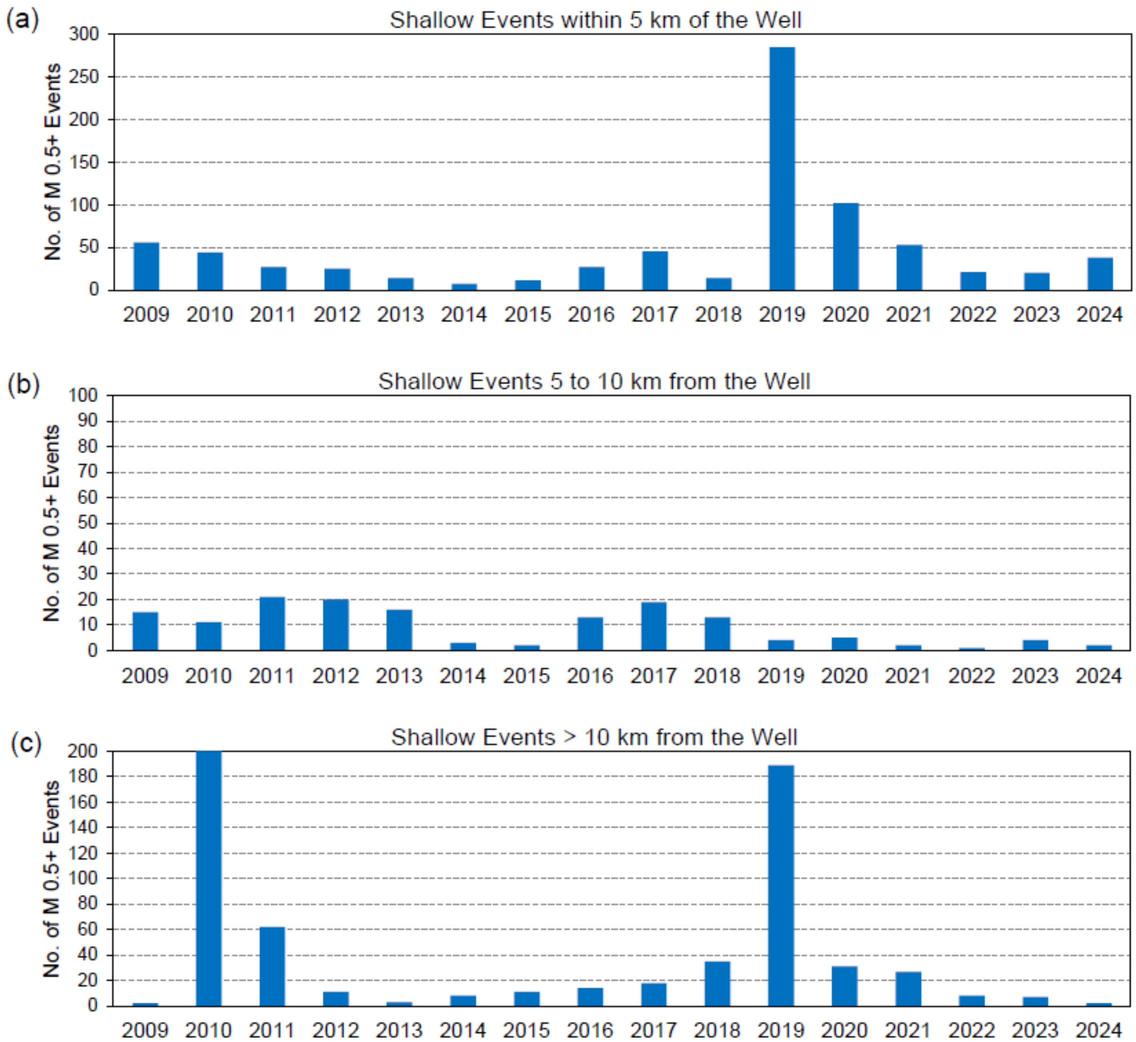

Figure 19.—Annual numbers of earthquakes with $M_D \geq 0.5$ and depth ≤ 12 km: (a) within 5 km of the injection well, (b) 5 to 10 km from the well, and (c) more than 10 km from the well. Data for the last 15 years are shown.

5.0 Conclusions

The PVSN performed well in 2024, and 269 local earthquakes were recorded. The seismic network had an annual uptime of 93%. Uptimes of individual seismic stations varied from 56% to 97%, with 20 of the 23 stations having uptimes ≥ 97%. The spatiotemporal seismicity trends observed since 1985 indicate that all the local earthquakes recorded in 2024 were induced by PVU brine injection.

No induced earthquakes with magnitude ≥ M_D 2.5 occurred in 2024. This magnitude threshold is significant because it is the approximate minimum magnitude for ground shaking to be felt in the Paradox Valley area. This marks the third consecutive calendar year in which no such earthquakes were recorded.

Changes in induced seismicity rates compared to the previous year vary by distance from the PVU injection well. Rates of M_D 0.5+ events within 5 km of the injection well were about the same in 2024 (23 events) as in 2023 (20 events). This marks the second consecutive since 2019, when the near-well M_W 4.5 earthquake occurred, that near-well seismicity rates did not decline. The M_D 0.5+ seismicity rate at distances of 5 to 10 km from the PVU injection well decreased in 2024 compared to the previous year, however quantitative statistics are not robust due to the small numbers of events in the data sets. At distances > 10 km from the well, the rate of M_D 0.5+ events increased 100% compared to the previous year. Conversely, the rate of earthquakes with magnitude < M_D 0.5 decreased in this distance range, but not significantly, Events in this range are driven by increased rates of low-magnitude seismicity east of Paradox Valley and south of the Dolores River, at distances of approx. 11 km to approx. 17 km from the injection well.

Induced seismicity is occurring several km outside the perimeter of PVSN, reducing the ability of the seismic network to detect and provide accurate locations for all induced earthquakes.

In 2024, general maintenance of stations was conducted, along with improvements at some seismic stations. The strong motion stations experienced difficulties throughout the year that were not resolved until the scheduled network maintenance trips. Server maintenance continued as usual with no detrimental failures reported. Personnel turn over at the Bureau of Reclamation has slowed progress in meeting goals within the PVSN and has prompted changes in the annual report. With the ongoing training of new personnel, innovations within the network will be implemented gradually.

6.0 References

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Appendix A

2024 Site Visit Reports

Paradox Valley Seismic Network
Site Visit Report

Site Visit Number: PVSN-2024-01
Prepared by: Justin Schwarzer
Departure Date: 5/14/2024
Return Date: 5/21/2024
Personnel: Justin Schwarzer, David Heeszel

Primary Purpose: General maintenance and diagnosing communication problems at PVEF.

Details:
Power and antenna testing were performed at PV01, 02, 03, 03, 04, 05, 07, 10, 11, 12, 13, 15, 18, 19, 21, 23, PVEF, PVPP, and PVCC. All tests came back within an acceptable range at all locations.

Vaults were dug up and inspected at PV02, 04, 05, 07, 12, 21, and 22. A small amount of condensation was found and cleaned up in all vaults. At PV02, 05, 07, and 21 the vault glass plate had cracking. PV04 had no plate. All sensors were level.

Hog wire was added at PV10, 13, and 05.

Water was added to the chemical grounding rod at PV02.

Radio tests at Hopkins were all within acceptable ranges. There is a clicking sound coming from server rack approx. 2.5 seconds; the exact location of the sound could not be determined. Dust and debris were swept from the building. The lock on the door is not activating with the correct code and may need servicing. The outdoor fiber optic run has a loose fiber jumper.

At PVEF it was found that the installed Minimus logger was not responding to Ethernet connections. The Minimus was replaced with a new system and communication to the site was reestablished. The removed Minimus will require in-lab testing and shipping back to Guralp for repair. The Nanometrics Titan installed at the site was also removed.

Table A-1.—Summary of work by site

Site	Checked Power System	Replaced Batteries	Performed Antenna Test	Performed Wattmeter Test	Inspected Vault	Comments
Hopkins	x		x			Lock on door is sticking, clicking coming from server rack approx. 2.5 seconds. Outdoor fiber is still a jumper.
PV01	x		x			
PV02	x		x		x	Vault plate broken; water added to ground rod.
PV03	x		x			Grounding is not completed.
PV04	x		x		x	No plate in vault.
PV05	x		x		x	Vault plate broken, added hog wire.
PV07	x		x		x	Vault plate broken
PV10	x		x			Grounding not completed, added hog wire.
PV11	x		x			
PV12	x		x		x	
PV13	x		x			Hog wire added
PV15	x		x			Grounding not completed
PV18	x		x			Grounding not completed
PV19	x		x			
PV21	x		x		x	Vault plate broken.
PV22	x		x		x	
PV23	x		x			
PVEF	x		x			Minimus replaced.
PVPP	x		x			
PVCC	x		x			

Abbreviations:

AP-1 – access point #1 antenna on the tower at the Hopkin's Field data communications center; receives radio data communications from individual stations PV01, PV07, and PV15

AP-2 – access point #2 antenna on the tower at the Hopkin's Field data communications center; receives radio data communications from radio repeater station PV02

AP-3 – access point #3 antenna on the tower at the Hopkin's Field data communications center; receives radio data communications from radio repeater stations PV04 and PV12

Chem rod – chemical ground rod that is part of the lightning protection grounding system at station PV02

DM24-BOB - seismic station electronics break-out-box located in enclosure; conditions power supply for the DM24 seismometer digitizer

GPS – refers to antenna that receives Global Positioning System satellite data to provide station timing

GPS-BOB - seismic station electronics break-out-box located in enclosure; serves as junction for dirty and clean power supplies and data communications

LVD - low-voltage disconnect

SPM – station power monitor

WAGO – refers to special tool needed for engaging (or disengaging) some electronics connections within station enclosure; manufactured by WAGO Corporation

Paradox Valley Seismic Network
Site Visit Report

Site Visit Number: PVSN-2024-02
Prepared by: Vivian Rosas and Justin Schwarzer
Departure Date: 11/06/2024
Return Date: 11/10/2024
Personnel: Field- Justin Schwarzer, Vivian Rosas **Office-** Justin Ball, Elize Chaves

Primary Purpose: General maintenance on stations & bringing station PVPP back online.

Details:

Radio tests at Hopkins were difficult to record due to the Federal Aviation Administration (FAA) Network Operations Center (NOC) not being able to turn off their receivers fully. Further research and discussion with NOC needed before spring testing. Dust and debris were swept from the building. The lock on the door works with the correct code but is difficult to open; it may need to be serviced or replaced.

Batteries for stations PVPP, PVEF, and PVCC were replaced. The breaker for PVPP's AC power was tripped, but once it was reset, AC power was restored to the site.

Power and antenna testing were performed at PVEF, PVPP, PVCC, 04, 14, 12, 02, and 10. All tests returned results within an acceptable range. Site access was limited by snowy and muddy road conditions.

Radio tests at PV20 showed unusual interference. Testing was done by replacing the antenna cables, polyphaser, and the Yagi antenna, but no improvement was noted. Therefore, the original equipment was left at the station, and further research will be conducted to isolate the cause of the interference.

Table A-2.—Summary of work by site

Site	Checked Power System	Replaced Batteries	Performed Antenna Test	Performed Wattmeter Test	Inspected Vault	Comments
Hopkins	X		X			Lock on the door is sticking. Problems with the airport turning off receivers (?)
PVPP	X	X	X			AC power breaker was reset
PVEF	X	X	X			
PVCC	X	X	X			
PV04	X		X			
PV14	X		X			
PV12	X		X			
PV02	X		X			
PV10	X		X			
PV20	X		X			Radio testing showed interference

Abbreviations:

AP-1 – access point #1 antenna on the tower at the Hopkin's Field data communications center; receives radio data communications from individual stations PV01, PV07, and PV15

AP-2 – access point #2 antenna on the tower at the Hopkin's Field data communications center; receives radio data communications from radio repeater station PV02

AP-3 – access point #3 antenna on the tower at the Hopkin's Field data communications center; receives radio data communications from radio repeater stations PV04 and PV12

Chem rod – chemical ground rod that is part of the lightning protection grounding system at station PV02

DM24-BOB - seismic station electronics break-out-box located in enclosure; conditions power supply for the DM24 seismometer digitizer

GPS – refers to antenna that receives Global Positioning System satellite data to provide station timing

GPS-BOB - seismic station electronics break-out-box located in enclosure; serves as junction for dirty and clean power supplies and data communications

LVD - low-voltage disconnect
SPM – station power monitor

WAGO – refers to special tool needed for engaging (or disengaging) some electronics connections within station enclosure; manufactured by WAGO Corporation

Appendix B

PVSN 2024 Local Earthquake Catalog

Table B-1.—Local Earthquakes Recorded by PVSN During 2024

Date	Time[1]	Latitude (degree)	Longitude (degree)	Elevation[2] (km)	Depth[3] (km)	M_D[4]	M_W[5]	Horizontal Distance from Injection Well (km)
1/3/24	14:20:39	38.2824	-108.9242	-0.1230	1.6	-0.1		3.0
1/6/24	13:10:56	38.3351	-108.7555	-4.7490	6.3	0.3		12.9
1/10/24	8:20:36	38.2839	-108.9056	-1.7600	3.3	-0.4		1.7
1/12/24	16:31:21	38.2855	-108.9045	-1.6740	3.2	-0.3		1.5
1/12/24	16:33:07	38.2855	-108.9044	-1.6810	3.2	-0.2		1.5
1/15/24	18:11:03	38.2874	-108.8976	-1.7240	3.2	-0.3	1.1	1.0
1/22/24	8:36:25	38.2844	-108.8990	-2.2850	3.8	-0.3		1.4
1/24/24	8:02:23	38.4012	-108.8592	-3.8160	5.3	0.1	0.9	12.0
1/24/24	8:03:47	38.2860	-108.9019	-1.6610	3.2	-0.4		1.3
1/28/24	23:51:45	38.2795	-108.9173	-2.0370	3.6	-0.3	0.5	2.7
1/30/24	8:53:40	38.2856	-108.9031	-1.6940	3.2	-0.5		1.4
1/31/24	2:09:04	38.2794	-108.9174	-2.0380	3.6	0.9	1.2	2.7
1/31/24	5:02:04	38.2795	-108.9172	-2.0300	3.6	-0.3		2.7
2/8/24	18:28:49	38.2735	-108.9340	-0.2620	1.8	-0.2		4.3
2/10/24	20:45:37	38.3054	-108.8931	-1.7540	3.3	-0.6		1.0
2/10/24	21:49:55	38.2985	-108.8974	-2.5950	4.1	-0.7		0.3
2/14/24	9:43:48	38.2839	-108.9063	-1.7070	3.2	-0.7		1.7
2/15/24	5:43:35	38.3191	-108.7533	-6.2020	7.7	-0.7		12.6
2/16/24	10:01:32	38.2824	-108.9242	-0.1210	1.6	-0.6		3.0
2/16/24	10:02:14	38.2824	-108.9243	-0.1220	1.6	-0.7		3.0
2/18/24	15:36:43	38.2847	-108.9053	-1.9280	3.5	-0.5	0.8	1.6
2/26/24	8:02:08	38.2871	-108.8990	-1.6800	3.2	0.2	0.7	1.1
2/26/24	8:04:43	38.2870	-108.8990	-1.6570	3.2	-0.7		1.1
2/26/24	19:10:04	38.2775	-108.9078	-3.3090	4.8	-1.3		2.4
2/28/24	7:00:02	38.2853	-108.8329	-2.2080	3.7	0.5	1.1	5.6
2/29/24	4:41:28	38.2877	-108.8690	-3.4000	4.9	1.3	1.3	2.5
2/29/24	23:46:35	38.3192	-108.7535	-6.2230	7.7	0.7		12.6
2/29/24	23:47:04	38.3167	-108.7487	-7.7910	9.3	-0.3		13.0
2/29/24	23:59:38	38.3195	-108.7546	-6.1580	7.7	0.6	1.5	12.5
3/4/24	0:54:09	38.2870	-108.8991	-1.6480	3.2	-0.7		1.1
3/9/24	13:02:22	38.2773	-108.9243	-1.3950	2.9	0.0		3.3
3/11/24	1:13:57	38.2749	-108.8760	-0.6350	2.2	-0.2		2.9
3/11/24	1:51:07	38.2749	-108.8760	-0.6310	2.2	-0.3		2.9
3/11/24	1:51:22	38.2762	-108.8789	-1.1800	2.7	-1.7		2.7
3/11/24	1:51:27	38.2748	-108.8759	-0.6330	2.2	-0.8		2.9
3/11/24	2:13:49	38.2748	-108.8760	-0.6410	2.2	1.5	1.6	2.9
3/11/24	4:40:25	38.2749	-108.8763	-0.6450	2.2	1.1	1.3	2.9
3/11/24	12:41:00	38.2749	-108.8758	-0.5670	2.1	-1.0		2.9
3/12/24	11:14:27	38.2844	-108.9055	-1.7560	3.3	-0.3		1.6

Date	Time[1]	Latitude (degree)	Longitude (degree)	Elevation[2] (km)	Depth[3] (km)	M_D[4]	M_W[5]	Horizontal Distance from Injection Well (km)
3/14/24	9:04:51	38.2846	-108.9051	-1.7610	3.3	-0.5		1.6
3/14/24	23:48:32	38.2843	-108.9065	-1.7150	3.2	-0.5		1.7
3/15/24	6:37:44	38.2850	-108.9043	-1.6370	3.2	-0.5		1.5
3/15/24	12:27:33	38.2847	-108.9047	-1.7830	3.3	-0.3		1.6
3/15/24	19:30:31	38.2843	-108.9063	-1.7390	3.3	-0.4		1.7
3/15/24	19:38:48	38.2844	-108.9062	-1.7480	3.3	-0.5	0.7	1.7
3/15/24	20:01:15	38.2845	-108.9052	-1.7640	3.3	0.0		1.6
3/15/24	20:03:45	38.2847	-108.9065	-1.9150	3.4	-1.3	1.1	1.7
3/15/24	20:03:45	38.2844	-108.9063	-1.7370	3.3	0.8	1.2	1.7
3/15/24	20:59:14	38.2845	-108.9060	-1.7320	3.3	0.2	0.8	1.7
3/15/24	21:18:03	38.2843	-108.9061	-1.7390	3.3	-0.8		1.7
3/15/24	21:19:12	38.2846	-108.9052	-1.7560	3.3	-0.2		1.6
3/15/24	23:48:07	38.2842	-108.9067	-1.6940	3.2	0.3	0.9	1.7
3/16/24	0:22:17	38.2844	-108.9063	-1.7060	3.2	0.3	0.9	1.7
3/16/24	2:10:10	38.2844	-108.9056	-1.7660	3.3	-0.2		1.6
3/16/24	2:39:11	38.2847	-108.9049	-1.7600	3.3	0.1		1.6
3/16/24	2:51:07	38.2844	-108.9065	-1.7280	3.3	0.8	1.2	1.7
3/16/24	2:58:14	38.2846	-108.9054	-1.7250	3.2	-0.5		1.6
3/16/24	16:39:07	38.2842	-108.9069	-1.7230	3.2	-0.4		1.7
3/17/24	18:29:05	38.2845	-108.9051	-1.7830	3.3	2.4	2.1	1.6
3/17/24	18:41:45	38.2844	-108.9056	-1.7720	3.3	0.4		1.6
3/17/24	18:42:36	38.2845	-108.9051	-1.8430	3.4	-0.7		1.6
3/17/24	18:42:44	38.2844	-108.9054	-1.7550	3.3	-1.2		1.6
3/17/24	18:44:24	38.2844	-108.9060	-1.7090	3.2	-0.8		1.7
3/17/24	19:44:02	38.2845	-108.9058	-1.7440	3.3	0.1		1.6
3/17/24	19:58:51	38.2844	-108.9057	-1.7530	3.3	-0.4		1.6
3/17/24	20:00:19	38.2845	-108.9052	-1.7670	3.3	-0.4		1.6
3/17/24	20:16:23	38.2845	-108.9053	-1.7660	3.3	-0.6		1.6
3/17/24	20:27:41	38.2846	-108.9052	-1.8120	3.3	-0.4	1.1	1.6
3/17/24	20:31:57	38.2848	-108.9041	-1.7460	3.3	-0.5		1.5
3/18/24	1:00:03	38.2848	-108.9028	-1.8590	3.4	-0.7		1.5
3/18/24	1:45:40	38.2844	-108.9055	-1.7820	3.3	-0.5		1.6
3/18/24	2:32:45	38.2845	-108.9051	-1.8280	3.4	-0.4		1.6
3/18/24	5:49:34	38.2844	-108.9053	-1.8040	3.3	0.0		1.6
3/18/24	6:26:51	38.2844	-108.9059	-1.6730	3.2	-0.3		1.7
3/18/24	8:45:41	38.2850	-108.9037	-1.7830	3.3	0.2	0.9	1.5
3/18/24	8:45:54	38.2849	-108.9038	-1.7480	3.3	-0.2		1.5
3/18/24	8:49:00	38.2850	-108.9038	-1.7870	3.3	0.5		1.5
3/18/24	9:24:59	38.2851	-108.9035	-1.7900	3.3	-0.1		1.5
3/18/24	14:10:02	38.2845	-108.9054	-1.7020	3.2	-0.3		1.6

Date	Time[1]	Latitude (degree)	Longitude (degree)	Elevation[2] (km)	Depth[3] (km)	M_D[4]	M_W[5]	Horizontal Distance from Injection Well (km)
3/18/24	16:26:29	38.2844	-108.9064	-1.6840	3.2	0.0		1.7
3/18/24	16:27:28	38.2844	-108.9063	-1.6680	3.2	-0.6		1.7
3/18/24	16:28:58	38.2844	-108.9062	-1.6830	3.2	-0.5		1.7
3/18/24	16:29:48	38.2844	-108.9063	-1.6740	3.2	-0.8		1.7
3/18/24	16:30:39	38.2844	-108.9063	-1.6500	3.2	-0.7		1.7
3/18/24	22:34:49	38.2844	-108.9057	-1.7620	3.3	-0.4	0.8	1.6
3/19/24	6:09:56	38.2845	-108.9050	-1.8410	3.4	0.5	0.9	1.6
3/21/24	2:20:53	38.2850	-108.9041	-1.7840	3.3	-0.4	0.7	1.5
3/21/24	3:02:21	38.2851	-108.9040	-1.7890	3.3	-0.1		1.5
3/21/24	3:35:39	38.2850	-108.9038	-1.8490	3.4	-0.1		1.5
3/21/24	4:21:24	38.2847	-108.9045	-1.7520	3.3	-0.3		1.6
3/21/24	4:47:47	38.2850	-108.9040	-1.7900	3.3	-0.3		1.5
3/21/24	5:46:34	38.2849	-108.9044	-1.7350	3.3	0.8	1.1	1.5
3/21/24	6:24:14	38.2849	-108.9043	-1.7320	3.3	-0.2		1.5
3/21/24	18:21:12	38.2871	-108.8988	-1.7760	3.3	-0.5		1.1
3/21/24	23:50:17	38.2850	-108.9040	-1.7890	3.3	-0.1		1.5
3/22/24	0:55:52	38.2844	-108.9056	-1.7870	3.3	0.0	1.1	1.6
3/22/24	0:56:04	38.2844	-108.9056	-1.7960	3.3	-1.5		1.6
3/22/24	0:56:08	38.2844	-108.9055	-1.7940	3.3	-0.8		1.6
3/22/24	0:57:37	38.2844	-108.9055	-1.7950	3.3	-0.3	0.8	1.6
3/22/24	0:59:08	38.2844	-108.9057	-1.7940	3.3	-0.7		1.6
3/22/24	1:14:39	38.2844	-108.9054	-1.7960	3.3	-0.4	1.0	1.6
3/22/24	6:05:05	38.2843	-108.9066	-1.6520	3.2	-0.4		1.7
3/22/24	18:38:58	38.3049	-108.9109	-2.4190	3.9	0.4	1.0	1.7
3/23/24	5:49:26	38.2831	-108.9073	-1.3630	2.9	0.3	1.0	1.8
3/25/24	7:14:48	38.3060	-108.9110	-2.6240	4.1	2.1	2.0	1.8
3/26/24	1:19:39	38.2726	-108.9054	1.4290	0.1	-0.1		2.8
3/28/24	4:47:20	38.2845	-108.9052	-1.8960	3.4	-0.2		1.6
3/29/24	22:28:27	38.2985	-108.8975	-2.6010	4.1	-0.5		0.3
3/30/24	10:42:31	38.2860	-108.8894	-1.9460	3.5	-0.2	1.2	1.3
4/2/24	17:37:46	38.2843	-108.9067	-1.7160	3.2	0.3	1.0	1.7
4/3/24	12:15:58	38.3022	-108.9573	-1.5120	3.0	0.9	1.2	5.5
4/3/24	12:57:57	38.2849	-108.8344	-2.0900	3.6	0.1	0.7	5.5
4/3/24	20:27:14	38.3022	-108.9573	-1.5070	3.0	-0.2		5.5
4/3/24	20:28:14	38.3073	-108.9131	-2.6580	4.2	-0.7		2.0
4/4/24	2:16:41	38.3059	-108.9105	-2.3770	3.9	1.2	1.2	1.7
4/7/24	4:53:53	38.2832	-108.9073	-1.9570	3.5	-0.2		1.8
4/7/24	5:47:02	38.3021	-108.9573	-1.4990	3.0	-0.7		5.5
4/7/24	6:38:34	38.2830	-108.9072	-1.9600	3.5	0.2		1.8
4/7/24	18:43:39	38.2839	-108.9076	-1.3360	2.9	-1.1		1.8

Date	Time[1]	Latitude (degree)	Longitude (degree)	Elevation[2] (km)	Depth[3] (km)	M_D[4]	M_W[5]	Horizontal Distance from Injection Well (km)
4/7/24	18:43:49	38.2842	-108.9066	-1.8380	3.4	-0.7		1.7
4/7/24	21:32:40	38.2843	-108.9060	-1.7980	3.3	-0.5	0.9	1.7
4/7/24	23:08:09	38.2854	-108.9051	-2.0150	3.5	-0.2		1.5
4/9/24	4:51:14	38.3021	-108.9573	-1.5070	3.0	-0.3		5.5
4/9/24	9:34:53	38.3343	-108.9771	-0.8160	2.3	0.3	0.6	8.3
4/11/24	2:01:55	38.2844	-108.9062	-1.7460	3.3	0.0	0.8	1.7
4/12/24	1:43:39	38.2844	-108.9060	-1.7070	3.2	-0.5		1.7
4/12/24	8:27:45	38.2875	-108.8977	-1.7480	3.3	0.0		1.0
4/13/24	21:49:20	38.2847	-108.9048	-1.7770	3.3	-0.8		1.6
4/14/24	7:50:29	38.2847	-108.9048	-1.7580	3.3	0.0	0.7	1.6
4/15/24	19:35:41	38.2844	-108.9058	-1.7600	3.3	0.4	1.1	1.6
4/16/24	16:40:23	38.3139	-108.9586	-1.1100	2.6	0.1	1.0	5.9
4/17/24	6:19:20	38.2856	-108.9025	-1.7520	3.3	0.2	0.9	1.4
4/18/24	0:21:05	38.2711	-108.8647	-1.1350	2.7	-0.4	0.8	3.9
4/18/24	10:27:11	38.2842	-108.9066	-1.8030	3.3	0.2	0.7	1.7
4/18/24	20:35:50	38.2810	-108.9303	0.1970	1.3	0.1	0.6	3.5
4/20/24	19:17:52	38.2711	-108.8649	-1.1100	2.6	-0.3		3.9
4/25/24	18:53:01	38.2873	-108.8983	-1.7740	3.3	-0.3		1.1
4/25/24	18:53:06	38.2874	-108.8985	-1.8400	3.4	-1.1		1.1
4/28/24	2:57:40	38.2823	-108.9110	-1.3880	2.9	-0.2	0.6	2.1
4/28/24	21:09:00	38.3139	-108.9585	-1.1170	2.6	-0.3		5.9
4/29/24	18:59:00	38.2845	-108.9053	-1.8960	3.4	-0.5		1.6
4/30/24	3:42:38	38.2849	-108.9051	-1.6290	3.2	-0.7		1.6
4/30/24	10:31:49	38.2858	-108.9020	-1.7400	3.3	-0.7		1.3
5/1/24	10:57:03	38.2695	-108.8660	-1.4700	3.0	-0.1	1.0	4.1
5/3/24	1:00:13	38.2833	-108.9073	-1.5100	3.0	-0.5		2.0
5/4/24	6:43:49	38.3150	-108.7470	-7.5200	9.0	0.0		13.3
5/4/24	6:44:08	38.3127	-108.7427	-8.2300	9.8	0.1		13.9
5/4/24	12:06:49	38.3163	-108.7450	-6.9900	8.5	0.6	0.8	13.5
5/7/24	14:02:37	38.2855	-108.8978	-2.2700	3.8	0.8	1.2	1.4
5/9/24	1:20:49	38.2848	-108.9068	-1.9600	3.5	-0.6	0.4	1.9
5/9/24	9:07:40	38.2767	-108.9165	-2.7800	4.3	-0.3	0.6	3.2
5/10/24	14:27:10	38.2852	-108.9030	-1.9200	3.4	0.0	0.9	1.4
5/11/24	6:44:56	38.2838	-108.9045	-2.1400	3.7	1.6	1.4	1.7
5/14/24	4:37:55	38.2838	-108.9042	-1.8400	3.4	-0.5		1.9
5/14/24	13:13:53	38.2848	-108.9050	-1.8500	3.4	0.4		1.6
5/15/24	12:10:01	38.2847	-108.8930	-2.7700	4.3	-0.4		1.5
5/16/24	4:27:34	38.2645	-108.8827	2.1900	-0.7	0.3	1.0	3.8
5/19/24	2:45:59	38.2815	-108.9245	0.1300	1.4	-0.5	0.6	3.2
5/21/24	5:31:21	38.2838	-108.9112	-1.9000	3.4	-0.5		2.1

Date	Time[1]	Latitude (degree)	Longitude (degree)	Elevation[2] (km)	Depth[3] (km)	M_D[4]	M_W[5]	Horizontal Distance from Injection Well (km)
5/29/24	14:55:29	38.3232	-108.9553	-2.2100	3.7	0.0		6.5
5/29/24	15:05:45	38.3220	-108.9558	-2.3300	3.9	0.5	1.0	6.5
5/29/24	15:31:22	38.3227	-108.9558	-2.5200	4.0	0.0	0.5	6.5
5/29/24	15:56:02	38.3222	-108.9580	-2.5500	4.1	-0.4		6.6
5/29/24	23:32:46	38.3223	-108.9567	-2.5700	4.1	0.9	1.4	6.6
5/30/24	7:55:26	38.3220	-108.9560	-2.3300	3.9	0.5	0.9	6.6
5/30/24	8:19:26	38.3228	-108.9557	-2.1900	3.7	0.1	0.7	6.5
5/30/24	11:50:38	38.3218	-108.9567	-2.6800	4.2	1.0	1.2	6.6
5/31/24	3:58:45	38.4492	-109.0250	-6.5600	8.1	1.1	1.1	19.1
5/31/24	17:50:58	38.4427	-109.0140	-4.1100	5.6	0.6		19.7
6/1/24	4:22:42	38.3225	-108.9562	-2.4400	4.0	0.1	0.5	6.1
6/7/24	13:56:03	38.2857	-108.9028	-1.9400	3.5	-0.6		1.4
6/15/24	0:43:26	38.2857	-108.8957	-1.7800	3.3	-0.4		1.2
6/21/24	3:46:14	38.2695	-108.9273	-0.4100	1.9	0.2	0.6	4.1
6/23/24	9:47:47	38.2828	-108.9043	-1.6200	3.1	-0.3	0.7	1.7
6/30/24	14:11:03	38.4067	-108.9343	-4.0200	5.5	1.0	1.3	12.7
7/1/24	1:12:09	38.3215	-108.9732	-2.3200	3.8	-0.2	0.7	7.4
7/2/24	8:30:38	38.2860	-108.8980	-2.5400	4.1	0.1	1.0	1.2
7/3/24	16:43:36	38.3390	-108.7757	-4.0900	5.6	-0.1		11.5
7/3/24	16:46:14	38.3372	-108.7800	-3.6100	5.1	-0.4		11.0
7/4/24	13:24:52	38.2862	-108.8910	-1.9700	3.5	-0.4		1.2
7/10/24	2:17:38	38.2808	-108.9135	-1.6100	3.1	-0.4		2.4
7/10/24	20:46:29	38.2862	-108.9003	-2.0200	3.5	-0.1	0.8	1.2
7/13/24	15:05:13	38.3217	-108.9740	-2.3300	3.9	0.1	0.9	7.5
7/13/24	15:38:54	38.2838	-108.9047	-1.8700	3.4	-0.3		1.6
7/14/24	0:49:06	38.2833	-108.9097	-2.0100	3.5	-0.7		1.9
7/14/24	3:14:14	38.2708	-108.8668	-0.7300	2.3	-0.6		3.8
7/14/24	6:22:28	38.2695	-108.8667	-1.2400	2.8	-0.4	0.7	3.9
7/14/24	22:16:06	38.3188	-108.8537	-3.5000	5.0	0.1	1.1	4.4
7/20/24	5:10:46	38.2868	-108.9023	-1.8900	3.4	-0.3		1.3
7/24/24	6:45:29	38.3145	-108.8502	-2.6300	4.2	-0.3		4.4
8/1/24	0:19:19	38.2878	-108.8958	-1.7700	3.3	-0.4		1.0
8/3/24	16:16:38	38.2872	-108.8977	-1.6700	3.2	-0.2		1.1
8/7/24	17:59:42	38.2873	-108.8937	-1.6700	3.2	0.2		1.0
8/7/24	18:00:12	38.2858	-108.8977	-1.8500	3.4	-0.8		1.2
8/9/24	21:03:57	38.2833	-108.8953	-1.0800	2.6	-0.3		1.5
8/11/24	22:07:01	38.3453	-108.6985	-6.4300	8.0	0.4		18.0
8/12/24	5:40:56	38.3483	-108.6942	-6.4000	7.9	0.2		18.5
8/13/24	2:57:16	38.4698	-108.9318	-13.3300	14.9	0.1		19.5
8/14/24	21:38:36	38.2802	-108.8292	-2.2600	3.8	0.9		6.0

Date	Time[1]	Latitude (degree)	Longitude (degree)	Elevation[2] (km)	Depth[3] (km)	M_D[4]	M_W[5]	Horizontal Distance from Injection Well (km)
8/18/24	8:11:04	38.2882	-108.8973	-0.9900	2.5	0.2		1.0
8/18/24	8:15:54	38.2833	-108.9007	-1.7800	3.3	-0.3		1.5
8/18/24	12:19:22	38.2807	-108.9068	-1.3100	2.8	0.2		2.0
8/28/24	11:02:46	38.2840	-108.9020	-1.4500	3.0	0.3		1.5
8/30/24	10:46:13	38.2840	-108.9005	-1.3200	2.8	-0.4		1.5
8/31/24	13:15:14	38.2837	-108.9048	-1.3000	2.8	0.1		1.7
8/31/24	13:29:58	38.2843	-108.9055	-2.3300	3.9	0.0		1.6
8/31/24	13:44:32	38.2842	-108.9042	-1.9300	3.5	0.9		1.6
8/31/24	14:09:17	38.2832	-108.9048	-0.8500	2.4	-0.1		1.7
8/31/24	14:30:18	38.2815	-108.9027	-1.5700	3.1	0.8		1.8
8/31/24	15:28:01	38.2833	-108.9038	-1.6200	3.1	1.5		1.7
8/31/24	16:03:21	38.2855	-108.9035	-1.7800	3.3	-0.1		1.4
8/31/24	16:51:39	38.2840	-108.9027	-1.4400	3.0	0.3		1.5
8/31/24	17:29:22	38.2843	-108.9028	-1.7900	3.3	-0.1		1.5
8/31/24	17:59:28	38.2805	-108.9043	-1.0700	2.6	-0.1		2.0
8/31/24	18:09:27	38.2833	-108.9062	-1.0400	2.6	0.1		1.8
9/1/24	11:45:29	38.2833	-108.9038	-1.6900	3.2	-0.1		1.7
9/1/24	12:45:52	38.2843	-108.9032	-1.5000	3.0	0.4		1.5
9/2/24	3:02:00	38.2842	-108.9048	-2.1900	3.7	-0.8		1.6
9/2/24	5:31:41	38.2853	-108.9045	-2.0000	3.5	-0.5		1.5
9/2/24	6:11:03	38.2838	-108.9032	-1.6900	3.2	-0.8		1.6
9/2/24	6:13:01	38.2852	-108.9033	-1.4400	3.0	-0.4		1.5
9/6/24	13:41:22	38.2883	-108.8965	-2.4700	4.0	0.3		0.9
9/7/24	3:20:14	38.2825	-108.9055	-2.1100	3.6	0.3		1.8
9/8/24	20:24:58	38.3177	-108.8095	-3.2700	4.8	1.8		7.8
9/8/24	22:24:15	38.3177	-108.8052	-3.0900	4.6	0.8		8.2
9/9/24	15:34:33	38.2855	-108.9018	-1.8200	3.3	0.4		1.4
9/12/24	2:01:16	38.2705	-108.8862	-1.6300	3.2	-0.1		3.0
9/13/24	3:05:45	38.2832	-108.9058	-1.4900	3.0	0.1		1.8
9/15/24	14:56:28	38.2108	-108.7218	-4.8400	6.4	0.4		17.9
9/17/24	5:58:28	38.3108	-108.8035	-2.5400	4.1	-0.2		8.2
9/18/24	13:24:59	38.2763	-108.8610	-3.1800	4.7	-0.1		3.7
9/20/24	9:49:35	38.2828	-108.9048	-1.2700	2.8	0.5		1.7
9/25/24	5:29:28	38.2757	-108.8737	0.5900	0.9	0.4		3.0
9/26/24	8:19:35	38.2825	-108.9047	-1.2800	2.8	-0.2		1.8
9/29/24	6:03:54	38.2492	-108.8690	-5.6900	7.2	0.1		5.7
10/1/24	11:43:54	38.2845	-108.9038	-1.8400	3.4	-0.1		1.5
10/4/24	3:36:10	38.2847	-108.8908	-2.2300	3.8	0.7		1.4
10/4/24	14:16:47	38.2798	-109.0185	-0.3100	1.8	-0.1		11.0
10/12/24	11:13:18	38.2810	-108.8988	-2.5800	4.1	-0.1		1.8

Date	Time[1]	Latitude (degree)	Longitude (degree)	Elevation[2] (km)	Depth[3] (km)	M_D[4]	M_W[5]	Horizontal Distance from Injection Well (km)
10/15/24	17:36:35	38.2853	-108.9077	-2.0600	3.6	-0.1		1.7
10/17/24	5:47:59	38.4567	-109.0427	-6.7500	8.3	1.5		22.0
10/22/24	0:19:48	38.2830	-108.8950	-2.1700	3.7	0.3		1.5
10/22/24	14:27:51	38.2840	-108.9038	-1.2200	2.7	0.1		1.6
10/22/24	23:24:49	38.2845	-108.9027	0.3600	1.2	0.1		1.5
10/24/24	5:31:09	38.2825	-108.9087	-1.9600	3.5	0.5		2.0
10/24/24	21:11:34	38.2952	-108.8948	-1.6600	3.2	-0.2		0.2
10/25/24	0:42:14	38.2948	-108.8980	-1.7500	3.3	0.1		0.3
10/26/24	21:29:02	38.3465	-108.6967	-8.2600	9.8	0.4		18.2
11/1/24	23:52:02	38.2848	-108.9053	-1.7500	3.3	0.3		1.6
11/2/24	5:56:48	38.2813	-108.8990	-2.4300	4.0	0.6		1.7
11/4/24	2:06:35	38.3095	-108.7320	-7.8700	9.4	0.1		14.3
11/12/24	14:54:20	38.1768	-108.9107	-6.7300	8.3	1.0		13.4
11/13/24	12:51:45	38.3100	-108.7315	-7.5000	9.0	-0.3		14.4
11/15/24	1:05:11	38.3065	-108.7317	-7.4400	9.0	0.2		14.3
11/17/24	2:16:58	38.2833	-108.8938	-0.9100	2.4	-0.1		1.5
11/17/24	3:42:36	38.2767	-108.8287	-1.9000	3.4	0.4		6.2
11/19/24	5:02:37	38.3312	-108.9788	0.1300	1.4	0.2		8.3
11/23/24	17:47:14	38.1070	-108.9563	-11.1700	12.7	0.3		19.8
11/27/24	19:59:46	38.2557	-108.9380	-5.1500	6.7	0.5		5.9
11/29/24	7:58:19	38.3518	-109.1047	-8.7200	10.2	0.9		19.3
11/29/24	10:48:00	38.2853	-108.9045	-1.6700	3.2	0.5		1.5
11/30/24	6:36:47	38.2857	-108.8897	-1.8600	3.4	0.1		1.3
12/2/24	8:11:53	38.2785	-108.9142	-0.4300	2.0	0.6		2.6
12/3/24	6:26:05	38.2838	-108.9032	-1.0800	2.6	-0.3		1.6
12/3/24	6:34:53	38.2838	-108.9030	-1.1600	2.7	-0.4		1.6
12/7/24	1:32:46	38.2853	-108.8993	-1.4500	3.0	-0.2		1.3
12/23/24	23:13:55	38.2525	-108.9250	-2.1600	3.7	0.3		5.5
12/24/24	2:11:29	38.2848	-108.9015	-2.3600	3.9	-0.3		1.4
12/25/24	8:50:52	38.3245	-108.6853	-4.1600	5.7	0.1		18.6

[1] Time listed is Coordinated Universal Time, UTC (Mountain Standard Time = UTC – 7 hours; Mountain Daylight Savings Time = UTC – 6 hours)
[2] Elevation is given with respect to mean sea level.
[3] Depth is referenced to the surveyed ground elevation at the injection wellhead, 1.524 km.
[4] Reclamation-computed duration magnitude
[5] Reclamation-computed moment magnitude