

Monitoring Results of Natural Gas Wells near the Rulison, Colorado, Site September 2021 Monitoring Event

U.S. Department of Energy Office of Legacy Management Grand Junction, Colorado

Date Sampled: September 8, 2021

Background

The Rulison, Colorado, Site is in the Piceance Basin of western Colorado, 40 miles northeast of Grand Junction. The U.S. Atomic Energy Commission (a predecessor agency to the U.S. Department of Energy [DOE]), in partnership with Austral Oil Company Inc. and the nuclear engineering firm CER Geonuclear Corporation, conducted an underground nuclear test at the site on September 10, 1969. The Rulison site is identified as Lot 11 on the site map (Figure 1). The test, known as Project Rulison, was designed to evaluate the feasibility of using a nuclear detonation to fracture low-permeability gas-bearing sandstone reservoirs to improve gas production. This was the second natural gas stimulation experiment in the Plowshare Program, a program initiated to develop peaceful uses for nuclear energy. The exploratory well (R-Ex) was drilled at the site to determine the optimum depth for the test within the targeted formation. The device was detonated in the emplacement well (R-E) at a depth of 8425 feet (ft) and had a reported yield of 40 kilotons (DOE 2015). The surface location of the R-E emplacement well is identified as surface ground zero (SGZ) on the site map (Figure 1). The detonation created a temporary cavity, a subsequent collapse chimney, and a fractured zone surrounding the cavity (collectively known as the detonation zone).

In October 1970, a year after the detonation, a reentry well was drilled into the upper part of the chimney to evaluate the test. The reentry well (R-En) was a sidetrack hole drilled directionally from the nearby exploratory well, which is about 300 ft northwest of the emplacement well. Production testing on the reentry well produced 455 million cubic feet (MMCF) of gas in 107 days from October 1970 through April 1971 (Reynolds 1971). Analysis of data collected during production testing indicated that essentially all tritium present as tritiated methane was removed from the detonation zone, but that tritium likely remained in the detonation zone as tritiated water (liquid and vapor), and some remained in minerals that make up the melt rock (Smith 1971). In 1976, the participating parties agreed that there would be no future gas production at the site, the reentry well was abandoned, and a deed restriction was established for Lot 11. The deed restriction prohibits penetration or withdrawal of any material below 6000 ft within the boundary of Lot 11 unless authorized by the U.S. government. A more detailed description of the production testing is provided in the *Modeling of Flow and Transport Induced by Gas Production Wells near the Project Rulison Site, Piceance Basin, Colorado* (DOE 2013).

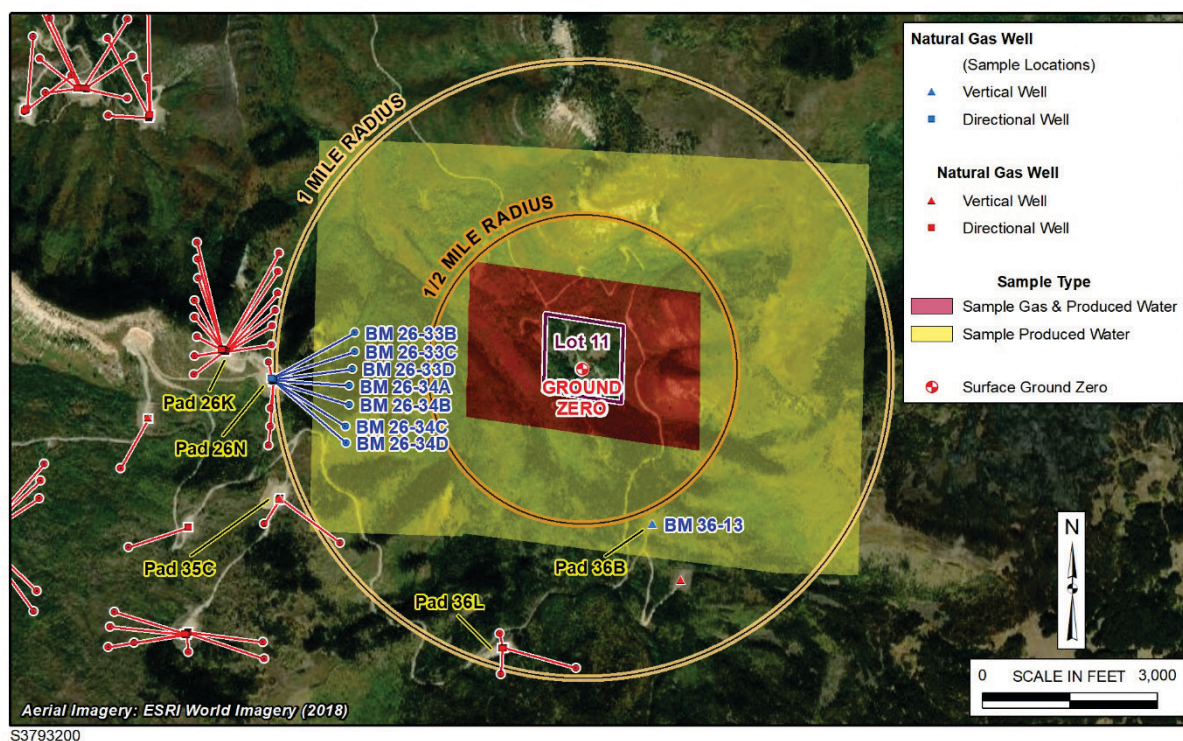


Figure 1. Rulison, Colorado, Site and Well Location Map

Purpose

DOE's Office of Legacy Management (LM) collects samples (natural gas and produced water) from producing natural gas wells near the site to confirm that detonation-related radionuclides are not migrating from the detonation zone to these wells. Tritium is the most abundant radionuclide remaining in the detonation zone that can be present in the gas and aqueous phases. This is based on estimated inventories of radionuclides produced by the detonation and the amounts removed by production testing. Tritium's presence in water vapor (a minor constituent of natural gas) is the primary concern because gas is much more mobile than liquid in a gas reservoir.

Most natural gas wells produce some liquids (produced water and hydrocarbon condensate) along with natural gas; these liquids are brought to the surface with the natural gas and are mechanically separated at the wellhead. Produced water is a mixture of water vapor in the natural gas that condenses at the surface, formation water, and remnant water introduced during the hydrofracturing process. Natural gas and produced water samples are collected from the producing wells near the Rulison site for analysis (Figure 1).

The Colorado Oil and Gas Conservation Commission (COGCC) requires that operators with gas wells within approximately 2 miles of the Rulison site adhere to COGCC's *Rulison Sampling and Analysis Plan for Operational and Environmental Radiological Monitoring Near Project Rulison, Revision 4* (COGCC 2017). LM, in a separate effort, implemented the *Rulison Monitoring Plan, Revision 1* (DOE 2019), also called the Monitoring Plan, which outlines a strategy for sampling gas wells within 1 mile of the detonation zone. The Monitoring Plan and

laboratory results from past monitoring activities are available on the LM public website at <https://www.energy.gov/lm/rulison-colorado-site>. Laboratory results obtained from LM's September 2021 monitoring event are summarized in the following sections.

Monitoring Protocol

The Monitoring Plan provides guidance on the type of samples collected (natural gas or produced water), the laboratory analyses performed, and the frequency of sample collection. The sampling frequency is based on the amount of gas produced and the distance and direction of the well from the site. It also establishes screening levels or concentrations (Table 1) that, if exceeded in the sample results, require that samples be reanalyzed or additional sampling be done (DOE 2019). The samples are analyzed for tritium, which is the most mobile contaminant remaining in significant quantities in the detonation zone. Samples are submitted to a commercial environmental laboratory that provides analytical services in accordance with the *Department of Defense (DoD) Department of Energy (DOE) Consolidated Quality Systems Manual (QSM) for Environmental Laboratories* (DOD and DOE 2021) to ensure data are of known, documented quality. The laboratory results are validated according to Section 5.0, "Validation of Environmental Data," of the *Environmental Data Validation Procedure* (LMS/PRO/S15870). Table 1 provides the sample screening levels (concentrations).

Table 1. Rulison Area Sample Screening Levels

Analyte	Sample Matrix	Laboratory Detection Limit	Screening Concentration	Action Concentration
Tritium	Natural gas	10 TU ^a	100 TU ^a	200 TU ^a
		32 pCi/L	320 pCi/L	640 pCi/L
	Produced water	400 pCi/L	1000 pCi/L	15,000 pCi/L ^b

Notes:

The laboratory detection limits are an estimate of the laboratory's capability of a given analytical procedure; they are reported by the laboratory as a minimum detectable concentration that is often lower than the detection limit. The screening activities (concentrations) were obtained from the *Rulison Monitoring Plan, Revision 1* (DOE 2019).

^a A tritium unit (TU) is equal to 3.19 pCi/L in water at a standard temperature (0 °C) and pressure (1 atmosphere).

^b The U.S. Environmental Protection Agency standard for tritium in drinking water is 20,000 pCi/L.

Abbreviations:

pCi/L = picocuries per liter

TU = tritium unit (1 tritium atom in 1×10^{18} hydrogen atoms)

Sample Collection

Samples of the produced water were collected from eight natural gas wells operating near the site on September 8, 2021 (Figure 1 and Table 2). The wells were selected based on their proximity to the site (Figure 1) and the amount of natural gas produced in accordance with the Monitoring Plan (DOE 2019). Samples are generally collected from a well after 50 to 100 MMCF of natural gas has been produced. The last sampling event was conducted on September 24, 2019 (DOE 2020), and since that sampling event, the sampled wells produced between 3 to 61 MMCF of natural gas (Table 2). No wells are currently within 0.5 mile of the site or within the designated area for natural gas samples to be collected, so only produced water samples were collected. The produced water samples were obtained from a tap on the dump line connecting the

gas-liquid separators and the accumulation tank. Before sample collection, the gas-liquid separators that share a dump line were isolated using valves and then purged of produced water and condensate. The samples were contained in plastic bottles provided by the laboratory and submitted to the ALS Laboratory in Fort Collins, Colorado, for tritium analysis. Appendix A includes a chart for each well showing the monthly and cumulative gas production volumes in MMCF with the sampling events.

Table 2. Rulison Area Natural Gas Well Sample Locations for September 2021

Well ID	Well Pad	API No.	Natural Gas Produced Since Last Sampling Event (MMCF)	Sample Type	
				Natural Gas	Produced Water
BM 26-33B	26N	05-045-15743	61	NS	Sampled
BM 26-33C	26N	05-045-15742	50	NS	Sampled
BM 26-33D	26N	05-045-15739	61	NS	Sampled
BM 26-34A	26N	05-045-15744	53	NS	Sampled
BM 26-34B	26N	05-045-15745	48	NS	Sampled
BM 26-34C	26N	05-045-15741	61	NS	Sampled
BM 26-34D	26N	05-045-15748	45	NS	Sampled
BM 36-13	36B	05-045-10840	3	NS	Sampled

Abbreviations:

API = American Petroleum Institute

NS = not sampled

Sample Results

The produced water samples had no detections of tritium above the laboratory minimum detectable concentrations (MDCs) (Table 3). The laboratory results were validated in accordance with Section 5.0, "Validation of Laboratory Data," of the *Environmental Data Validation Procedure*. All analyses were completed, and the samples were prepared and analyzed in accordance with accepted procedures for the specified methods. The laboratory radiochemical MDC reported with these data is an a priori estimate of the detection capability of a given analytical procedure; it is not an absolute concentration that can or cannot be detected. Laboratory results for produced water samples collected in September 2021 are provided in Table 3. A copy of the Data Validation Memo is available upon request.

Conclusion

Natural gas wells near the Rulison site have not been impacted by detonation-related contaminants. Tritium was not detected above the laboratory MDC in any of the produced water samples collected during this sampling event (September 2021) or above screening levels in any of the produced water and natural gas samples collected during previous sampling events dating back to the first sampling event in 2007. Data collected during this and previous sampling events are available on the Geospatial Environmental Mapping System (GEMS) website at <https://gems.lm.doe.gov/#site=RUL>. This report is available on the LM public website at <https://www.energy.gov/lm/rulison-colorado-site>.

Table 3. Produced Water Sample Results for September 2021

Well ID	Well Pad	API No.	Tritium in Natural Gas (TU) ^a	Tritium in Produced Water (pCi/L)
BM 26-33B	26N	05-045-15743	NS	<221
BM 26-33C	26N	05-045-15742	NS	<222
BM 26-33D	26N	05-045-15739	NS	<222
BM 26-34A	26N	05-045-15744	NS	<223
BM 26-34B	26N	05-045-15745	NS	<222
BM 26-34C	26N	05-045-15741	NS	<222
BM 26-34D	26N	05-045-15748	NS	<222
BM 36-13	36B	05-045-10840	NS	<222
Screening Concentrations			100	1000

Note:

^a A tritium unit (TU) is equal to 3.19 pCi/L in water at a standard temperature (0 °C) and pressure (1 atmosphere).

Abbreviations:

API = American Petroleum Institute

NS = not sampled

pCi/L = picocuries per liter

TU = tritium unit (1 tritium atom in 1×10^{18} hydrogen atoms)

References

COGCC (Colorado Oil and Gas Conservation Commission), 2017. *Rulison Sampling and Analysis Plan for Operational and Environmental Radiological Monitoring Near Project Rulison, Revision 4*, July.

DOD and DOE (U.S. Department of Defense and U.S. Department of Energy), 2021. *Department of Defense (DoD) Department of Energy (DOE) Consolidated Quality Systems Manual (QSM) for Environmental Laboratories*, Version 5.4.

DOE (U.S. Department of Energy), 2013. *Modeling of Flow and Transport Induced by Gas Production Wells near the Project Rulison Site, Piceance Basin, Colorado*, LMS/RUL/S08716, Office of Legacy Management, June.

DOE (U.S. Department of Energy), 2015. *United States Nuclear Tests, July 1945 through September 1992*, DOE/NV-209-Rev 16, National Nuclear Security Administration, September.

DOE (U.S. Department of Energy), 2019. *Rulison Monitoring Plan, Revision 1*, LMS/RUL/S06178, Office of Legacy Management, December.

DOE (U.S. Department of Energy), 2020. *Monitoring Results of Natural Gas Wells near the Rulison, Colorado, Site, September 2019 Monitoring Event*, LMS/RUL/S29387, Office of Legacy Management, August.

Environmental Data Validation Procedure, LMS/PRO/S15870, continually updated, prepared by the LMS contractor for the U.S. Department of Energy Office of Legacy Management.

Reynolds, M., 1971. "Project Rulison—Summary of Results and Analyses," at American Nuclear Technology Winter Meeting, October 1971.

Smith, C.F., Jr., 1971. *Gas Analysis Results for Project Rulison Production Testing Samples*, UCRL-51153, Lawrence Livermore National Laboratory, Livermore, California, November 29.

Appendix A

Gas Well Production Data

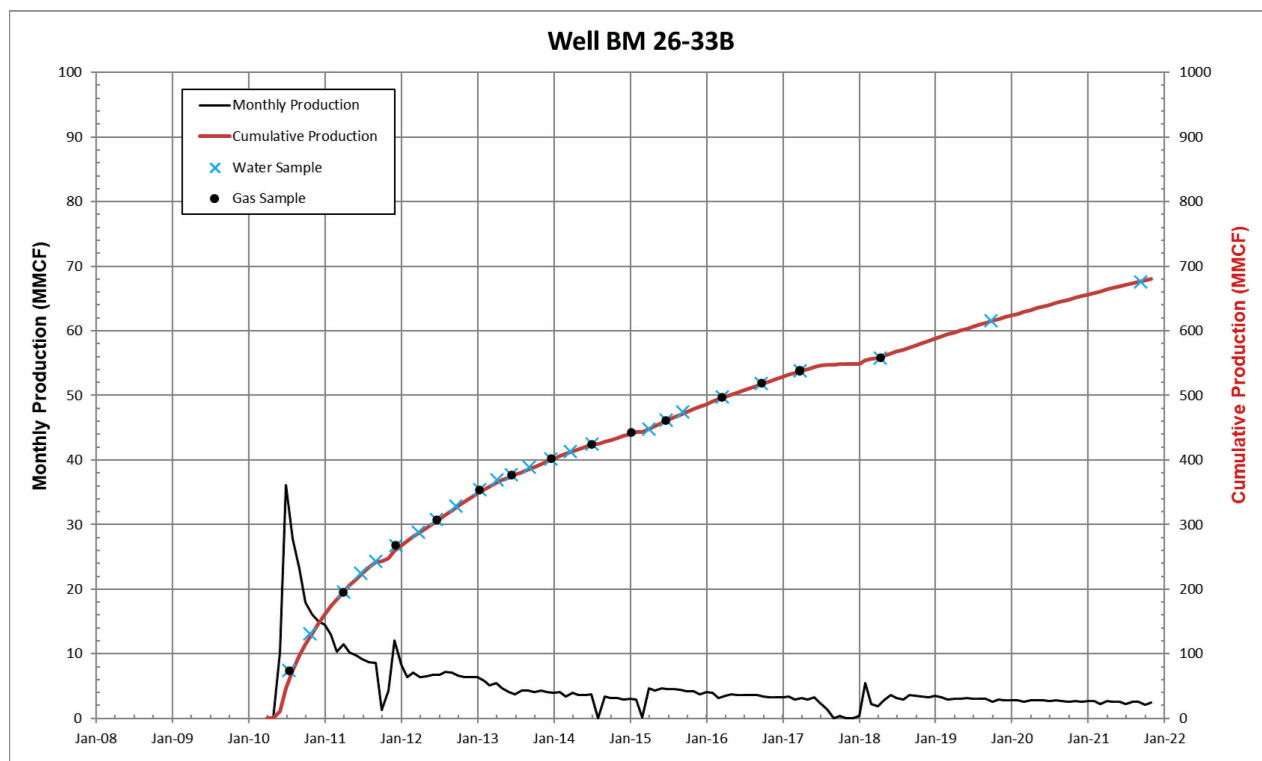


Figure A-1. Frequency of Sampling with Gas Production Data for Well BM 26-33B

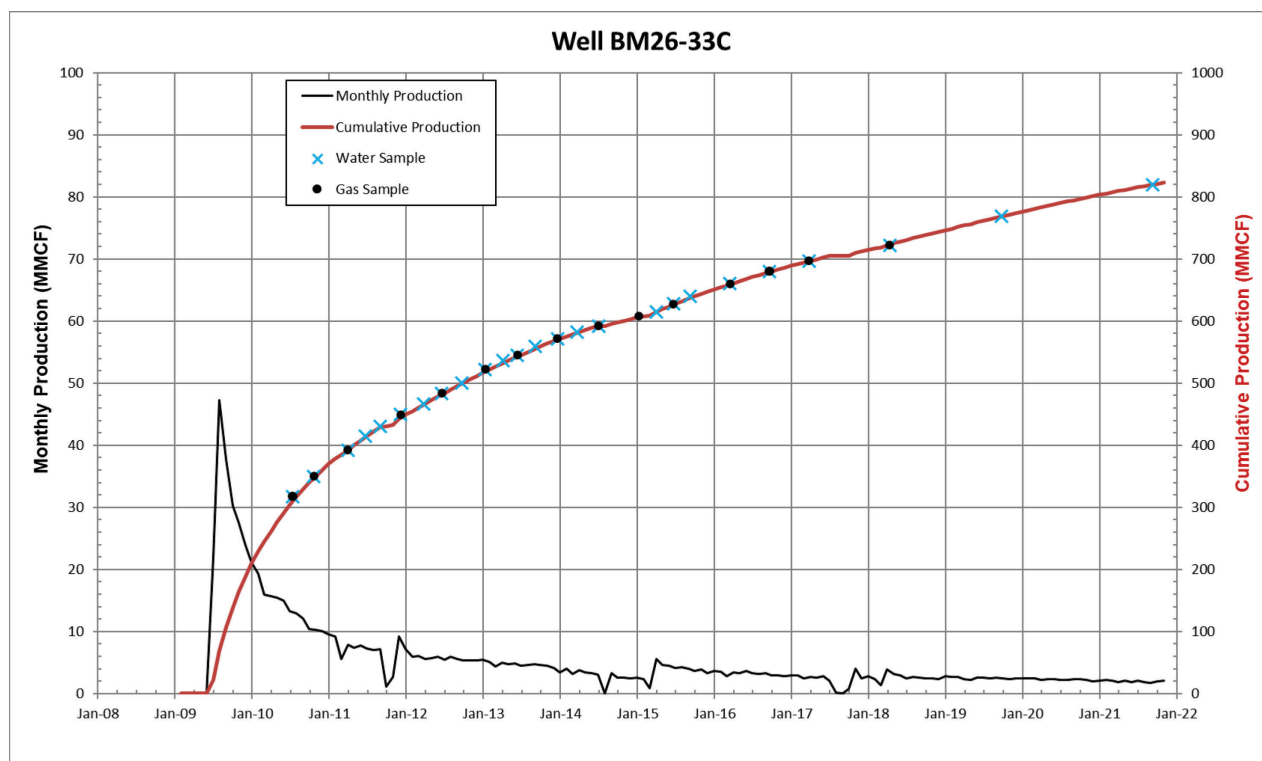


Figure A-2. Frequency of Sampling with Gas Production Data for Well BM 26-33C

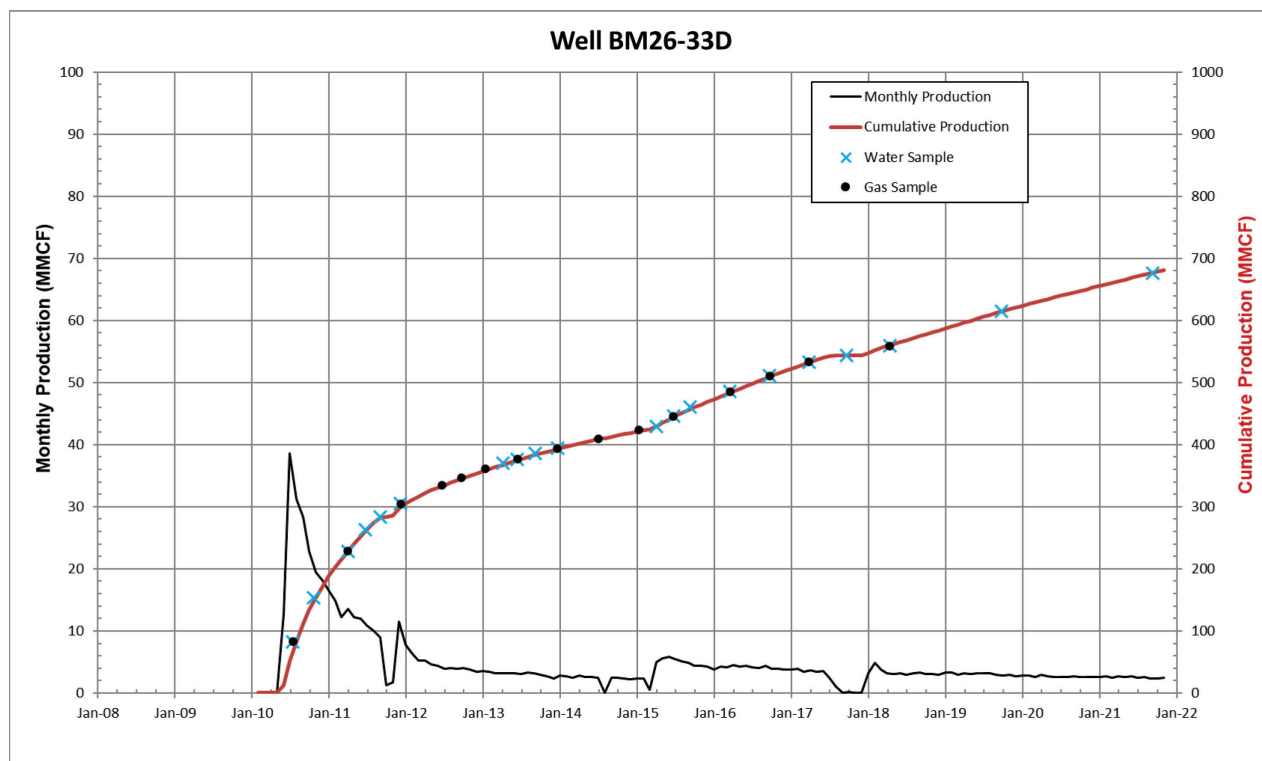


Figure A-3. Frequency of Sampling with Gas Production Data for Well BM 26-33D

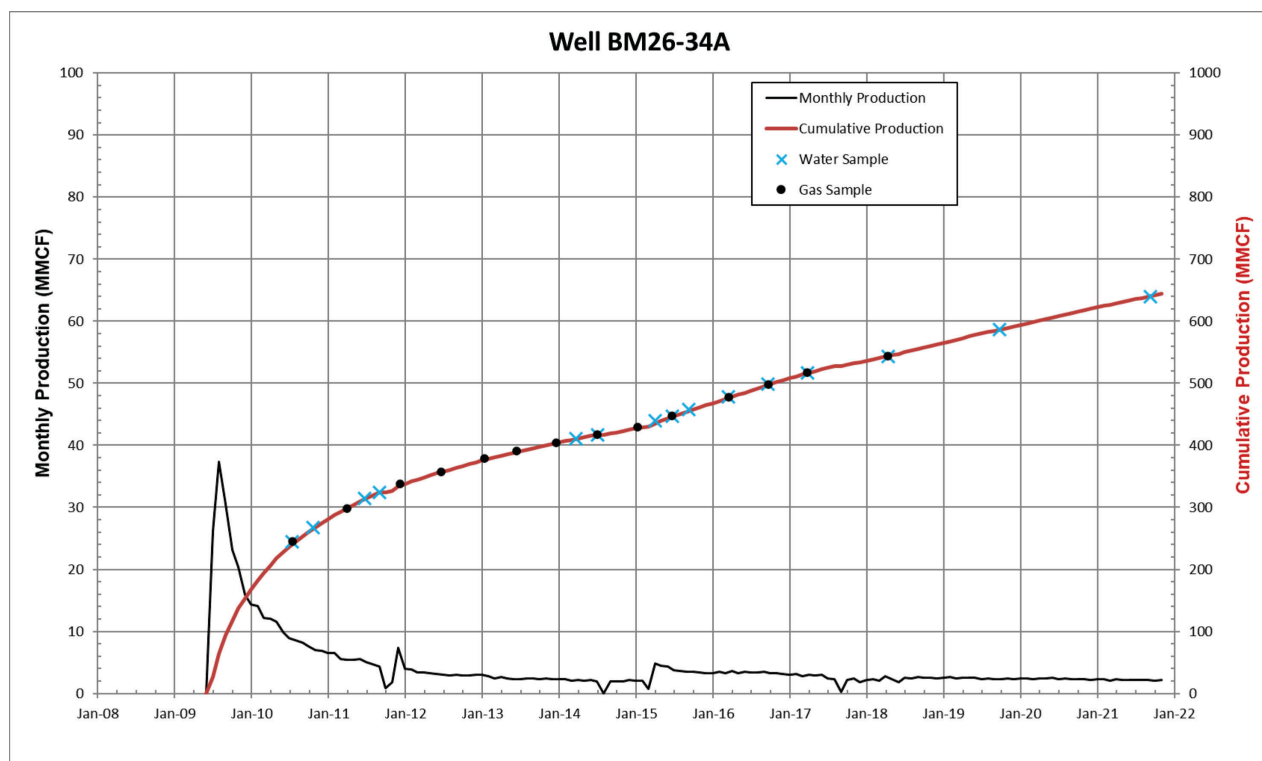


Figure A-4. Frequency of Sampling with Gas Production Data for Well BM 26-34A

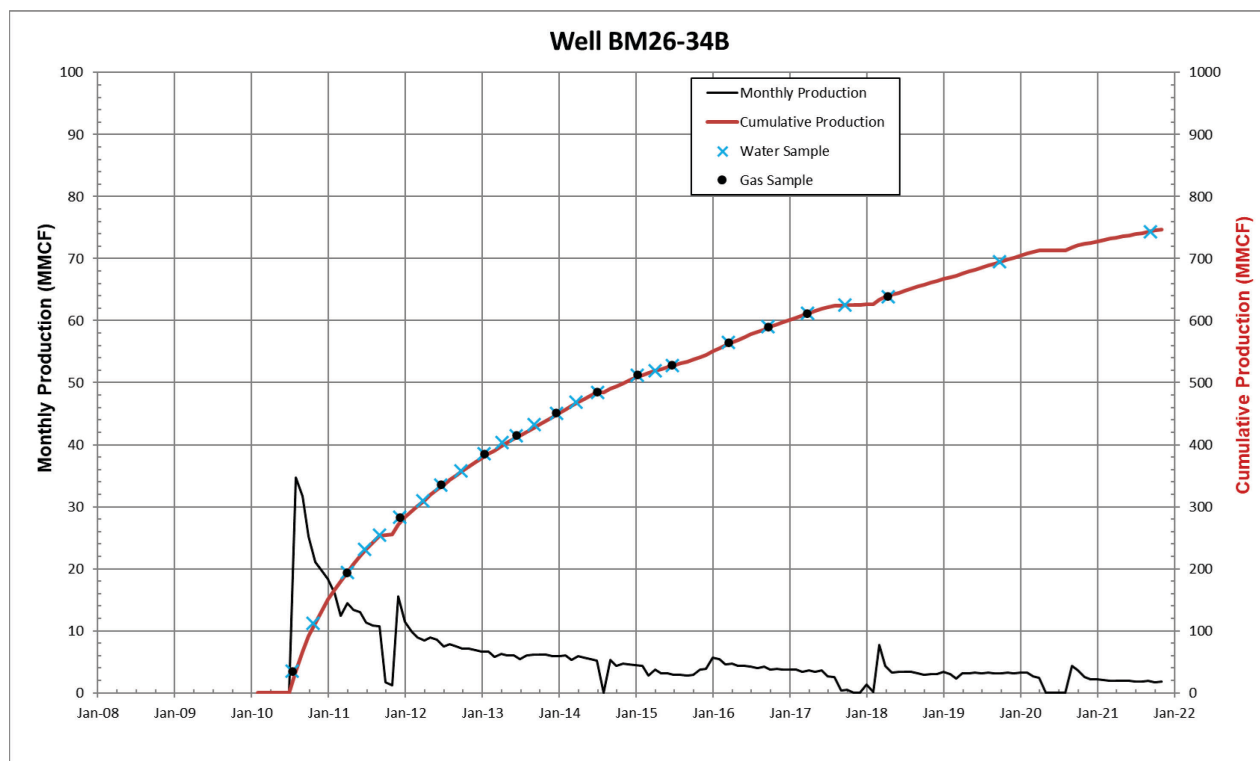


Figure A-5. Frequency of Sampling with Gas Production Data for Well BM 26-34B

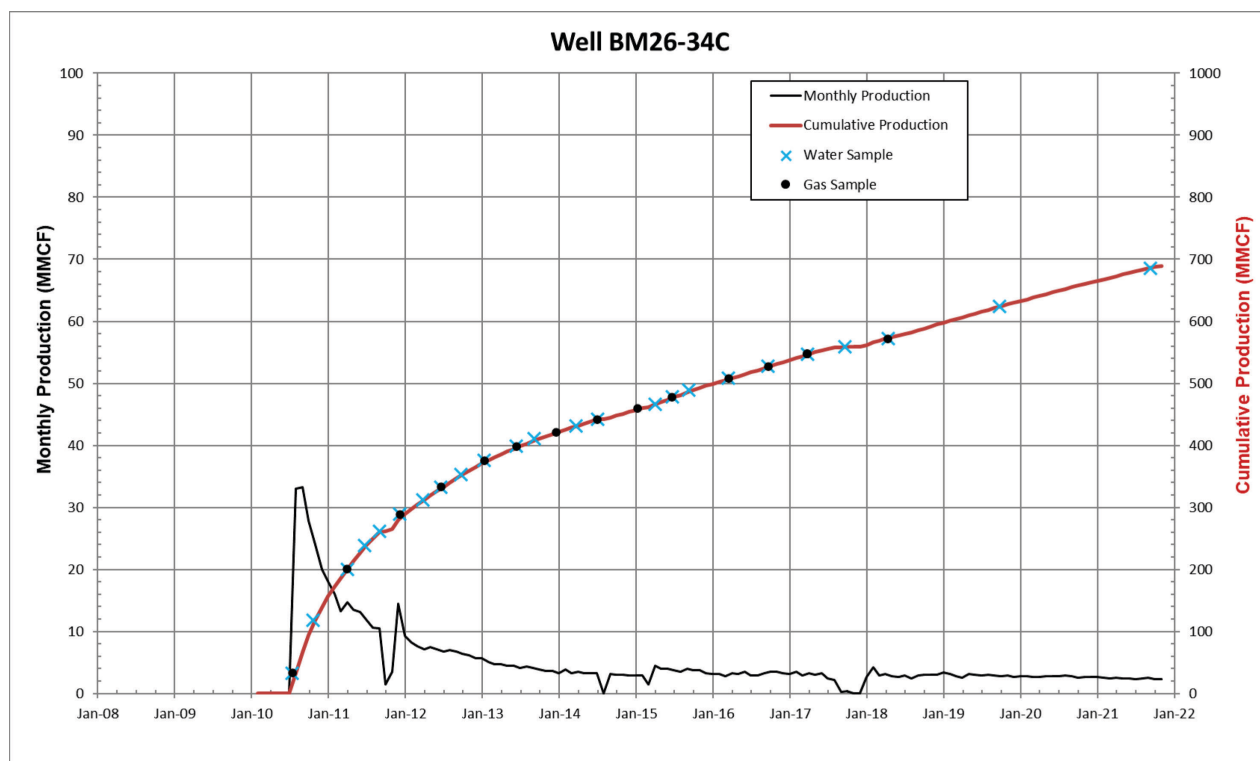


Figure A-6. Frequency of Sampling with Gas Production Data for Well BM 26-34C

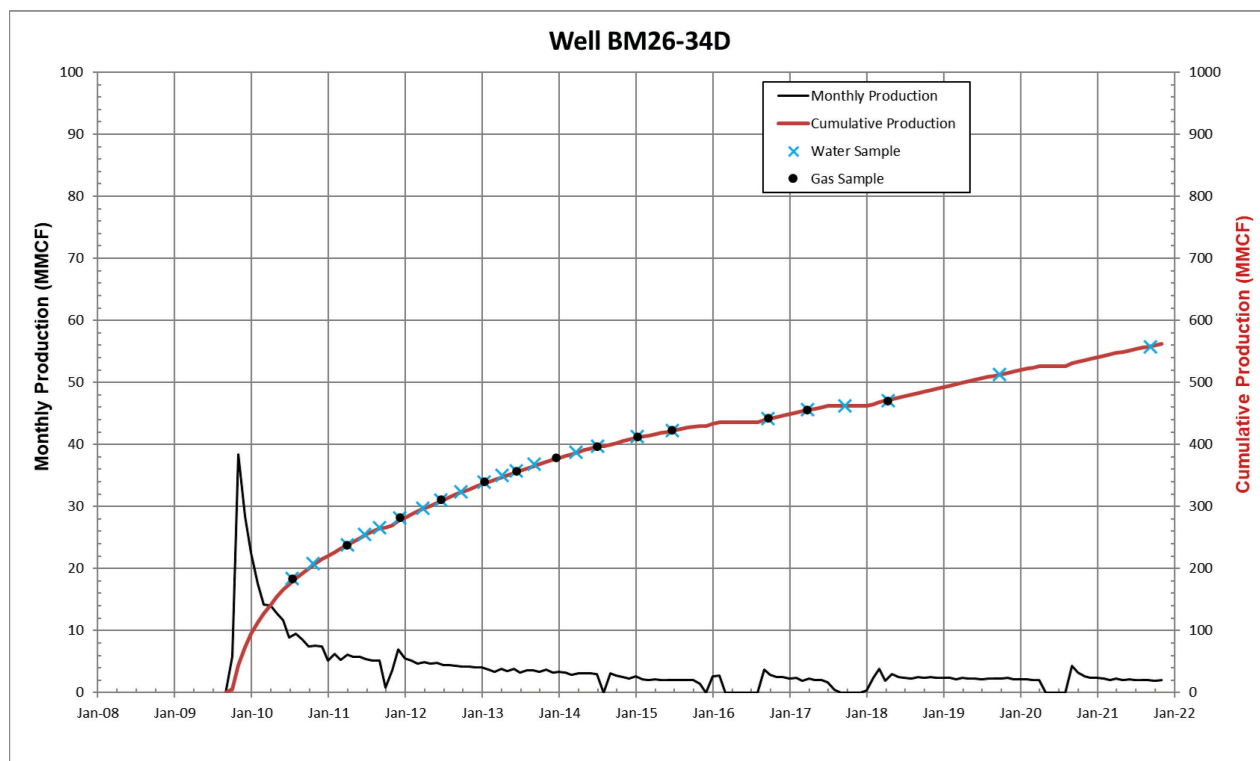


Figure A-7. Frequency of Sampling with Gas Production Data for Well BM 26-34D

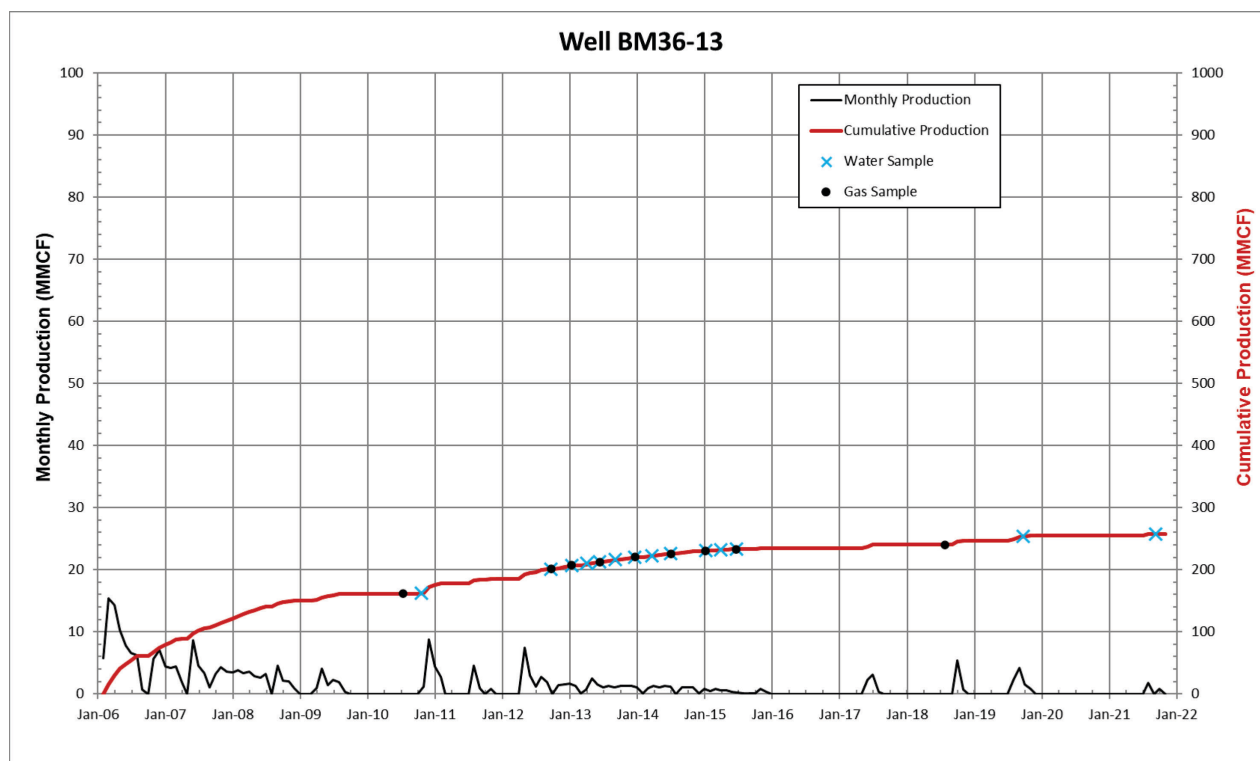


Figure A-8. Frequency of Sampling with Gas Production Data for Well BM 36-13