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to: WIPP Records Center

from: Dale O. Bowman III & Amelia Hayes Shelly R. Nelson for AH

subject: Milestone HYDRO 20-02: Progress Report that Documents CY19 Fluctuations in the WIPP Monitoring Well Network

1.0 Purpose

The Sandia National Laboratories (SNL) long-term, high-frequency monitoring program collects pressure transducer data in the Culebra and Magenta Members of the Rustler Formation, the Bell Canyon Formation, and shallow subsurface wells across the Waste Isolation Pilot Plant (WIPP) facility. Programmatic groundwater measurements focus primarily on the Culebra Member of the Rustler Formation because it is the most transmissive and laterally extensive water-bearing stratigraphic unit in proximity to the WIPP repository. Therefore, the Culebra water level fluctuations are the focus of this progress report.

The Culebra Dolomite has been identified as the most likely groundwater release pathway for potential future inadvertent human intrusion of the repository (Wagner and Hayes, 2019). Monitoring of Culebra groundwater composition, change in flow, and well water levels are to be conducted both during the pre-closure and post-closure phases of the repository (DOE, 2003). The Dewey Lake, Magenta, and Bell Canyon Members are not currently monitored as Compliance Monitoring Parameters (COMPs) and do not have Performance Assessment (PA) flow models (Wagner and Hayes, 2019). The objective of this milestone report is to present and summarize the pressure transducer data collected in Culebra wells for calendar year (CY) 2019.

2.0 Introduction

In CY2019, SNL recorded pressure data across 39 Culebra wells using calibrated pressure transducers. The transducers, which are generally installed at mid-formation depths, record water pressure at 15-minute intervals during routine monitoring. Pressure transducers provide a more complete record of the changes in hydraulic head occurring in the wells than is provided by monthly water-level measurements alone.

For the purposes of this report, these pressure data are reported in equivalent feet of fresh water (1 psi = 2.309 ft H_2O) and the first yearly value is normalized to zero. The data were also corrected for barometric and earth-tide effects using nSIGHTS v.2.5 in accordance with SP 9-13 Rev 0. Data for each well are plotted individually and are also plotted in groups based on similarly sourced hydraulic

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head changes. A reference map of the Culebra monitoring well locations is shown in Figure 1. For completeness, Figure 1 also shows Magenta locations.

Table 1 contains a list of all monitored Culebra wells in CY2019, as shown in Figure 1, and an abbreviated description of the dominant influence(s) (the most prevalent cause(s) of change) on each well's hydraulic head. A more precise description and broader context for each of the wells and the associated influences are provided in Section 3. Table 2 contains the delta hydraulic head (Δ) change and net change of hydraulic head (both in feet of fresh water) for CY2019. Delta hydraulic head is calculated per well as the difference between the minimum and maximum recorded heads, and net change of hydraulic head is calculated as the difference between the first and last recorded head for CY2019. In circumstances where transducers were placed at different depths during CY2019 (i.e. AEC-7R in Figure 5) or head attenuation to reinstallation occurred, heads were adjusted to compensate for the artificial change in pressure value. This compensation was made by aligning the last head value preceding the transducer adjustment with the first unaffected head value after the transducer adjustment. These compensations have been made for Table 2 in this report, however their methodology will be applied as part of a future data correction procedure.

Table 1. Culebra Wells with Pressure Transducer Data for CY2019

Well	Dominant Influences
AEC-7R	Gravity Flow
C-2737	Recovery, Industrial Pumping
ERDA-9	Recovery; Gravity Flow
H-2b2	Gravity Flow
H-4bR	Recovery; Industrial Pumping
H-5b	Gravity flow; Well Replacement
H-6bR	Precipitation events
H-7b1	H-7 Pad Pumping; Precipitation Events
H-9bR	Recovery; Gravity Flow
H-10cR	Long-Term Recovery
H-11b4R	Long-Term Recovery
H-12R	Recovery; Industrial Pumping
H-15R	Recovery; Industrial Pumping
H-16	Recovery; Precipitation events
H-17	Recovery; Industrial Pumping
H-19b0	Recovery; Industrial Pumping
IMC-461	Precipitation Events
SNL-01	Precipitation Events
SNL-02	Precipitation Events
SNL-03	Precipitation Events; Well Development
SNL-05	Precipitation Events; Well Development
SNL-06	Long-Term Recovery
SNL-08	Gravity Flow
SNL-09	Precipitation Events, Industrial Drilling
SNL-10	Gravity Flow
SNL-12	Recovery; Industrial Pumping
SNL-13	Recovery; Industrial Pumping
SNL-14	Recovery; Industrial Pumping
SNL-15	Long-Term Recovery
SNL-16	Precipitation Events
SNL-17	Recovery; Industrial Pumping
SNL-18	Precipitation Events
SNL-19	Precipitation Events
WIPP-11	Precipitation Events; Well Replacement
WIPP-13	Precipitation Events; Well Development
WIPP-19	Gravity Flow; Well Development
WQSP-1	Water Quality Sampling
WQSP-2	Water Quality Sampling; Well Development
WQSP-3	Water Quality Sampling

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Table 2. Culebra Hydraulic Head Fluctuations

Well	Δ Hydraulic Head (ft fresh water)	Net Change (ft fresh water)
AEC-7R*	0.48	0.07
C-2737	2.15	1.49
ERDA-9	3.51	-0.73
H-2b2*	1.13	1.00
H-4bR	6.00	-2.01
H-5b	1.65	1.00
H-6bR*	2.46	-2.05
H-7b1*	0.93	0.42
H-9bR	10.80	10.73
H-10cR*	3.80	2.37
H-11b4R	4.26	2.47
H-12R*	5.00	0.75
H-15R*	2.93	0.87
H-16	1.13	-0.41
H-17	7.49	-0.36
H-19b0	4.06	1.07
IMC-461	3.82	-3.01
SNL-01	1.56	-1.51
SNL-02	3.93	-3.70
SNL-03	2.32	-1.37
SNL-05*	3.17	-1.96
SNL-06*	23.82	23.13
SNL-08*	0.78	-0.20
SNL-09	2.25	-2.17
SNL-10	2.02	-1.84
SNL-12*	14.20	5.05
SNL-13	1.91	1.79
SNL-14	22.88	3.70
SNL-15	11.00	11.00
SNL-16*	2.03	-1.88
SNL-17	1.81	0.25
SNL-18	2.85	-2.12
SNL-19	3.96	-3.84
WIPP-11*	2.09	-1.97
WIPP-13	5.50	-1.90
WIPP-19	1.22	-1.09
WQSP-1	5.51	-1.12
WQSP-2	5.46	-1.89
WQSP-3	296.70	-2.26

*Period(s) of data were adjusted for calculations due to artificial changes (changes in transducer depth)

All files associated with this analysis stored in the software configuration versioning system: /cvs/CVSLIB/WIPP_EXTERNAL/SP913_CY19. The Software Configuration Management (SCM) Coordinator, the person responsible for overseeing the operation of the SCM system, will ensure that the source code, input and output files, scripts and any other information needed to re-run the calculation are stored onto the centralized storage system (e.g., UNIX/Linux/CVS) (Kirchner 2012).

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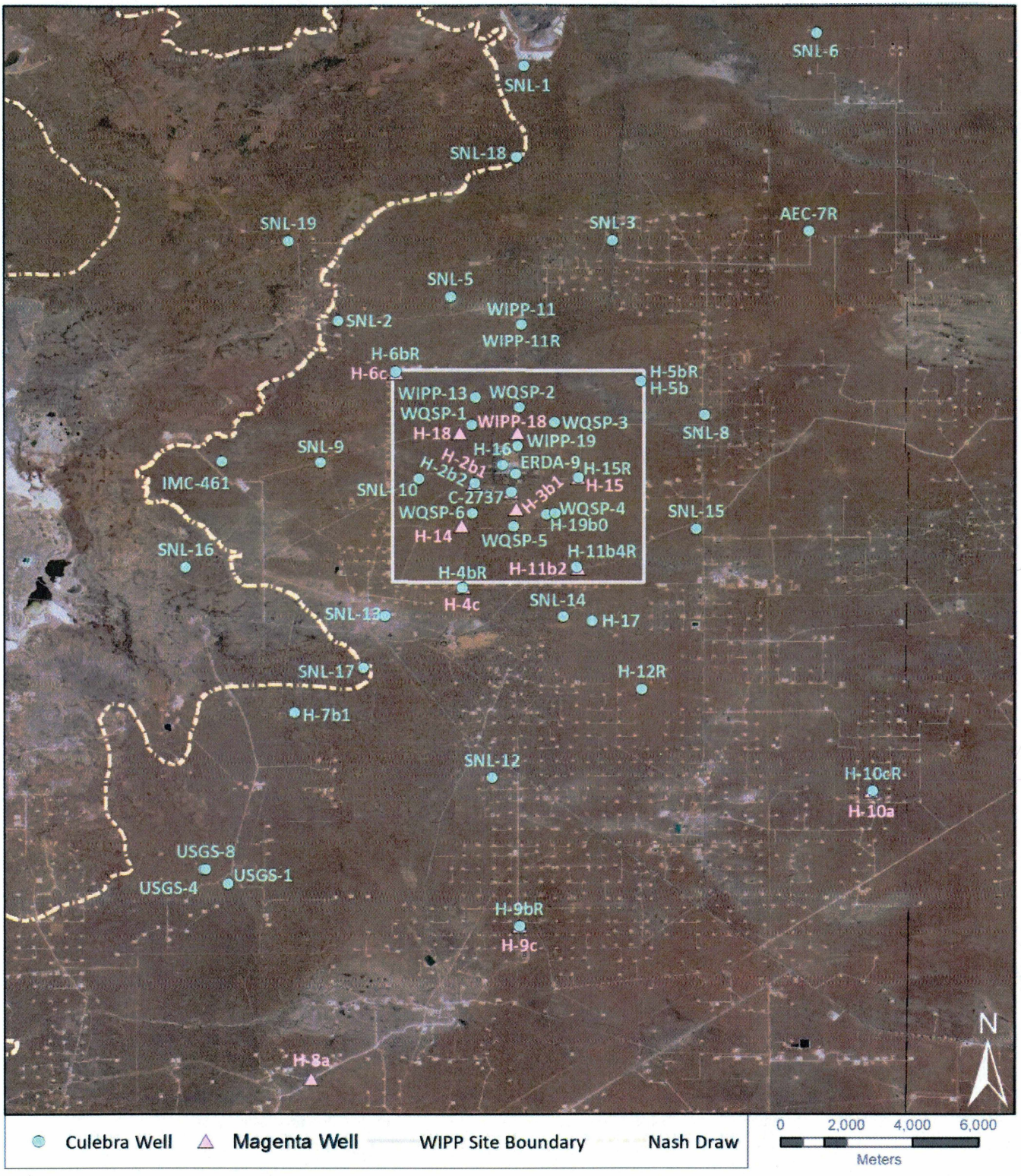

Figure 1. Locations of Culebra (blue circles) and Magenta (pink triangles) wells in the WIPP Groundwater Monitoring Network. Well C-2737 is a dual completion in both the Culebra and Magenta. The Land Withdrawal Area is outlined in grey and the approximate boundary of Nash Draw is outlined in a tan dashed line.

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3.0 Dominant Influences Affecting Wells

3.1 Anthropogenic Influences

The anthropogenic impacts on the Culebra monitoring wells include:
- Pumping at H-7 well pad: pumping from a livestock watering well located on the H-7 well pad,
- WQSP water quality sampling: pumping for water quality sampling at WQSP wells,
- Well maintenance, development and replacement activities,
- Recovery: hydraulic head returning to equilibrium after testing/purging/pumping,
- Long-term recovery: recovery from past well development and/or nearby testing/purging/pumping that has been consistent for more than 12 months and uninterrupted in CY2019, and
- Industrial, Non-WIPP related (NWR) pumping and drilling: pumping and drilling associated with the oil and gas industry.

These human-driven impacts are discussed further in the following sections.

3.1.1 Pumping at H-7 Well Pad

The H-7b1 well shares the H-7 well pad with one plugged and abandoned Culebra well (H-7b2) one plugged and abandoned Magenta well (H-7a), and a livestock watering well (formerly H-7c). Water levels in H-7b1 subsequently respond to intermittent pumping by the livestock well. Well H-7b1 is on the edge of Nash Draw and also responds to precipitation with relatively immediate changes in hydraulic head. In CY2019, intermittent livestock well pumping induced H-7b1 drawdown throughout the year. Though the nearby livestock well lowered H-7b1 hydraulic head, there was a net increase of 0.42 feet fresh water with a fresh water hydraulic head range of 0.93 ft in CY2019 (see Figure 12).

3.1.2 WQSP Water Quality Sampling

Wells WQSP 1-3 were integrated into the high-frequency monitoring network and pressure data collection began in March 2019. These wells are designated as water quality compliance wells and undergo annual pumping for sampling purposes. In 2019, this sampling occurred in March for WQSP-1 and WQSP-2. WQSP-3 was sampled in April and was also pumped intermittently by the Management and Operations Contractor (MOC) from June through August. The net hydraulic head changes in these wells ranged from -2.26 to -1.12 ft fresh water (see Figures 41, 43, and 44).

3.1.3 Well Maintenance, Development and Replacement Activities

Wells H-5b and WIPP-11 were plugged and replaced with wells H-5bR and WIPP-11R, respectively, in September 2019 (see Figures 10 and 38). Well H-9bR was also scheduled for maintenance in CY2019 and the transducer was pulled from the well in August 2019 (Figure 13).

Development activities at WIPP-11R affected several wells in its vicinity. Wells SNL-3, SNL-5, WIPP-13, WIPP-19, and WQSP-2 experienced drawdown from pumping at WIPP-11R in September 2019 (Figure 2). These responses were expected due to their proximity to WIPP-11R.

3.1.4 Recovery

There were thirteen wells undergoing recovery that was interrupted or completed in CY2019. Recovery interruptions in wells C-2737, H-4bR, H-12R, H-15R, H-17, H-19b0, SNL-12, SNL-13, SNL-14, and SNL-17 was caused by NWR pumping and are discussed in section 3.1.6. Wells

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ERDA-9 and H-16 completed recovery in CY2019 and began to react to natural processes. Well ERDA-9 is discussed in section 3.2.2 and well H-16 is discussed in section 3.2.1. Well H-9bR was dominated by recovery for the first six month of CY2019 and appeared to be approaching a state of gravity flow, but well maintenance activities interrupted monitoring at H-9bR in the latter half of the year as discussed in section 3.1.3.

3.1.5 Long-Term Recovery

Wells SNL-6 and SNL-15 were drilled in areas where the Culebra contains halite cements, and the wells are still recovering from well-development activities that occurred before 2009 (DOE, 2019). H-10cR is recovering from testing in 2017, but at a less pronounced magnitude. Wells H-9bR and H-11b4R were dominated by recovery from pumping at an industrial well at Mills Ranch that ceased pumping activities in Fall 2017. The SNL-6 net recovery is 23.13 ft fresh water head (Figure 26), SNL-15 net recovery is 11.00 ft fresh water head (Figure 33), H-10cR net recovery is 2.37 ft fresh water head (Figure 14), H-9bR net recovery is 10.73 ft fresh water (Figure 13), and H-11b4R net recovery is 2.47 ft fresh water (Figure 15).

3.1.6 Industrial, NWR Pumping and Drilling

Beginning in June of 2018, several wells experienced intermittent drawdown from NWR pumping. These are pressure changes that are characteristic of a pumping event, but the source well and operators are many times unknown. In CY2019, there was a discrete pumping event in October (Figure 3). The wells affected by the unknown pumping source were C-2737, H-4bR, H-12R, H-15R, H-17, H-19b0, SNL-12, SNL-13, SNL-14, and SNL-17. All of these wells were recovering from drawdown events that occurred in either CY2017 or CY2018 (Bowman and Hayes, 2019) before recovery was interrupted in CY2019. Well SNL-14 was the first well to respond to the October pumping and also had the largest drawdown as a result with a pressure change equivalent to 22.88 ft fresh water. The net change during CY2019 in the Culebra hydraulic heads affected by NWR pumping ranged from -2.01 ft fresh water to 5.05 ft fresh water (see Figures 6, 9, 17, 19, 20, 25, 30, 31, 32 and 35). Based on manual depth to water measurements, wells ERDA-9, H-9bR, and H-11b4R were also affected by the unknown pumping source; however, these wells do not have pressure data from the time of the pumping event.

In December 2019, well SNL-9 experienced a pressure change consistent with an aquifer injection (Figure 28). This was likely caused by nearby oil and gas industry drilling when the Culebra was penetrated; however, the exact source is unconfirmed.

3.2 Natural Processes

The main natural processes that impact Culebra monitoring wells are precipitation events in Nash Draw and gravity-driven flow. We acknowledge that these processes also exist in our previously described anthropogenically affected wells; however, natural processes tend to be muted under human-driven or anthropogenic hydraulic head responses. In the following sections, we discuss wells with responses dominated by natural processes.

3.2.1 Precipitation

Several wells in the vicinity of Nash Draw show relatively immediate hydraulic head responses to precipitation events. Figure 4 correlates precipitation data collected from rain gauges on well pads SNL-16, H-9, and WIPP-30 to show hydraulic head responses to precipitation events. Some wells show a minimal delay between precipitation events and pressure changes (H-6bR, IMC-461, SNL-2,

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SNL-9, SNL-16, and SNL-19). Other wells (H-16, SNL-1, SNL-3, SNL-5, SNL-18, WIPP-11, and WIPP-13) have delayed pressure responses to precipitation. The hydraulic head fluctuations for all thirteen wells mentioned are consistent with precipitation fluctuations seen in previous years (Hayes & Kuhlman, 2018, Bowman & Hayes, 2019). The net hydraulic head change in these wells ranged from -3.84 ft fresh water to -0.41 ft fresh water (see Figures 11, 18, 21, 22, 23, 24, 25, 28, 34, 36, 37, 38, and 39). Many of the wells affected by precipitation events may also respond to longer drought cycles. A water level rise in these wells in 2010 was followed by general decline until the end of 2014, when water levels rose, but did not return to previously observed peak levels (DOE, 2019). Water levels in these wells continued to decline in CY2019. As mentioned in section 3.1.1, well H-7b1 also responds to precipitation events; however, it follows different trends than the other wells affected by precipitation because of its response to the livestock well pumping on the H-7 well pad.

3.2.2 Gravity Flow

Certain wells experience little or no pronounced pressure data affects from precipitation or other anthropogenic events (AEC-7R, ERDA-9, H-2b2, H-5b, SNL-8, and SNL-10). These wells are located in areas of the Culebra with the largest distance from recharge, relatively low transmissivity, and other geologic factors that mute or prevent hydraulic responses observed in other wells. The net change in hydraulic heads for these wells ranged between -1.84 ft fresh water to 1.00 ft fresh water (see Figures 5, 7, 8, 10, 27, and 29).

4.0 Summary

Wells within the Culebra Groundwater Monitoring Network are affected by both anthropogenic influences and natural processes. The largest hydraulic head changes for CY2019 were in wells undergoing long-term recovery followed by wells affected by pumping events. Those wells that have been predominantly affected by natural processes continue to behave consistent with previous years' precipitation responses. Many of the pressure responses described herein that are important to our understanding of the Culebra in the WIPP vicinity would not have been identifiable using only monthly water level data. The monitoring of Culebra wells using pressure transducers continues to enhance monthly water level measurements by recording high-resolution changes in hydraulic heads.

5.0 Graphs

The following section contains both composite and individual graphs of hydraulic head data from Culebra monitoring wells. Gaps and/or inconsistencies that exist in the data caused by transducer failure are described in individual well graphs, were evaluated under NP 16-1, Rev 7, and were addressed in a Corrective Action Request (CAR) and Corrective Action Plan (CAP) as needed. Other gaps and inconsistencies caused by routine activities are also described in individual graphs.

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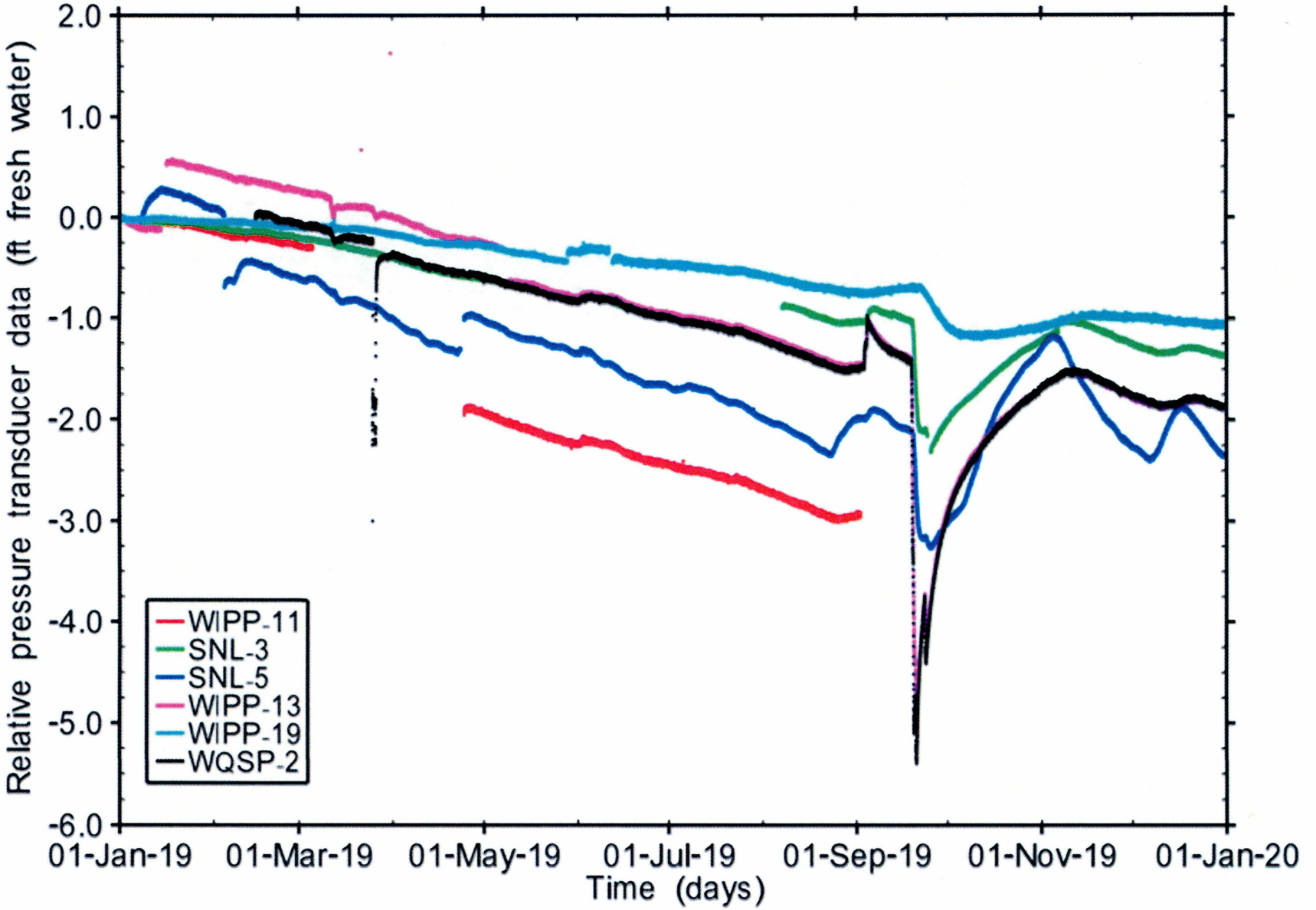

Figure 2. Five wells were affected by WIPP-11R development. WIPP-11 (red) is also included for reference when monitoring in the old well ended. Note: Data gaps in CY2019 are identified in individual well graphs.

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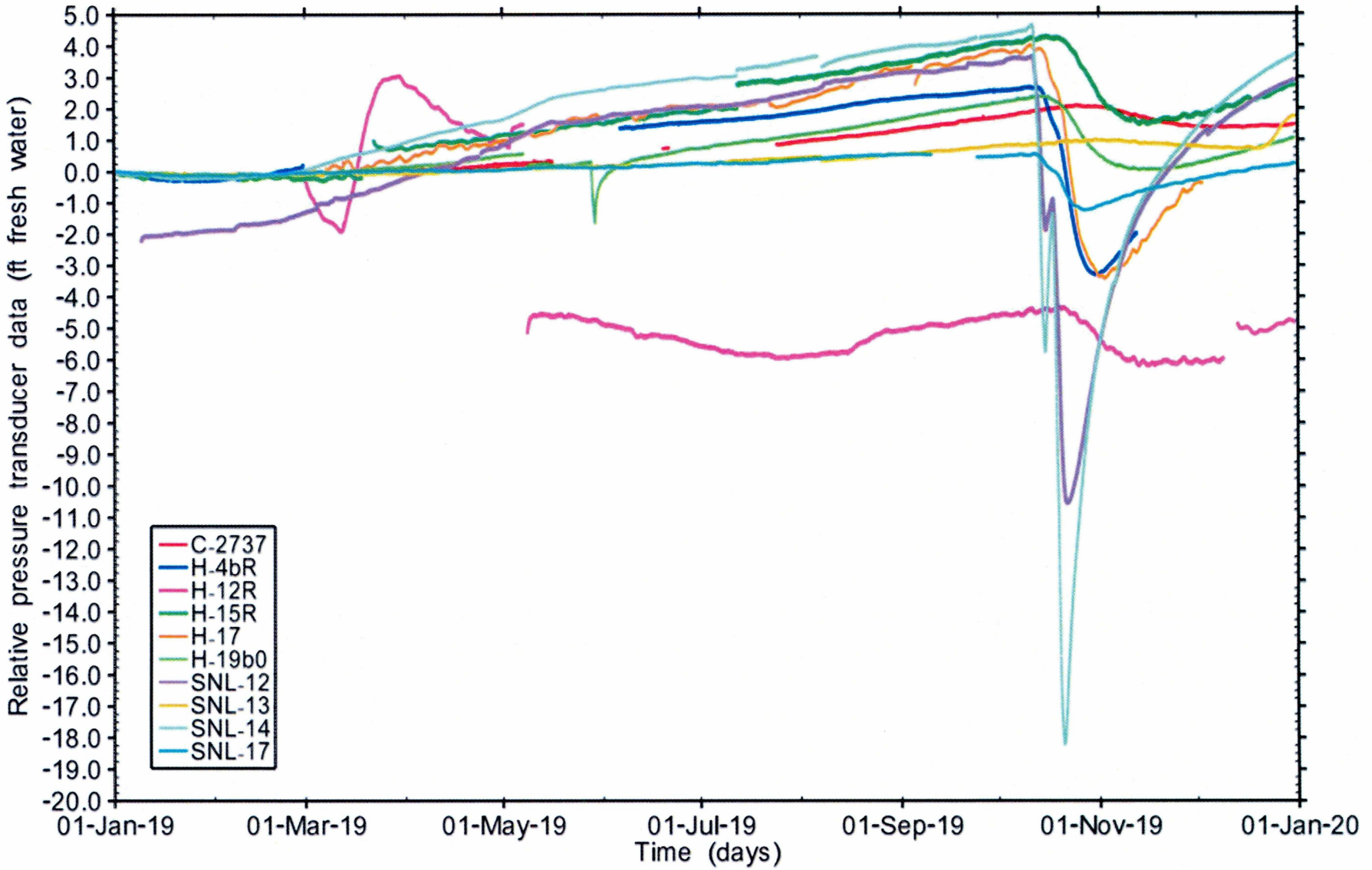

Figure 3. Ten wells affected by NWR industrial pumping are shown above. Wells ERDA-9, H-9bR and H-11b4R were not included because transducer failures during the pumping event erased the pressure data. Note: Data gaps in CY2019 are identified in individual well graphs.

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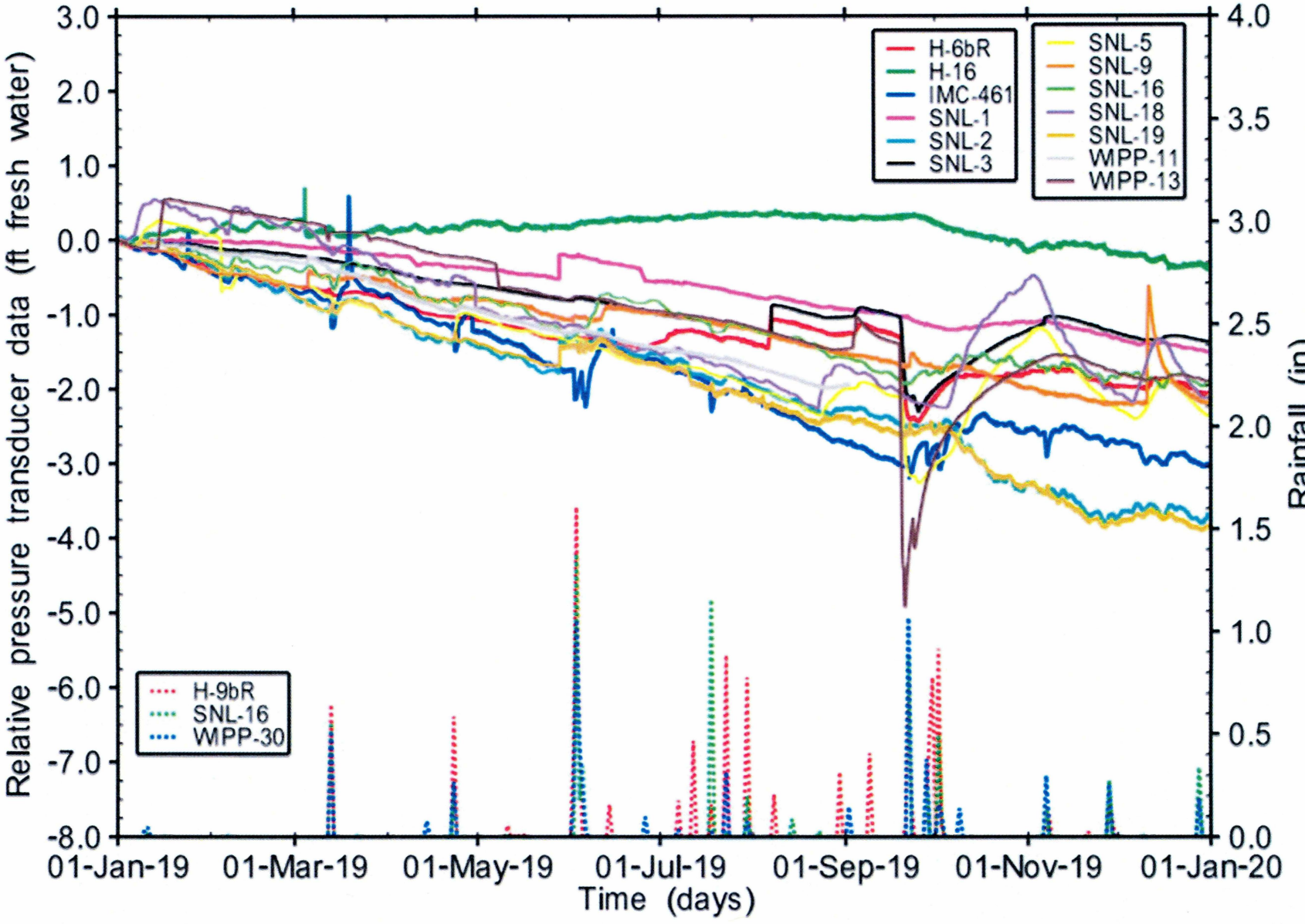

Figure 4. A group of thirteen Culebra wells (H-6bR, H-16, IMC-461, SNL-01, SNL-02, SNL-03, SNL-05, SNL-09, SNL-16, SNL-18, SNL-19, WIPP-11, and WIPP-13) demonstrate the range of responses to precipitation events. Daily precipitation totals from three rain gauge sites are plotted as dotted lines.

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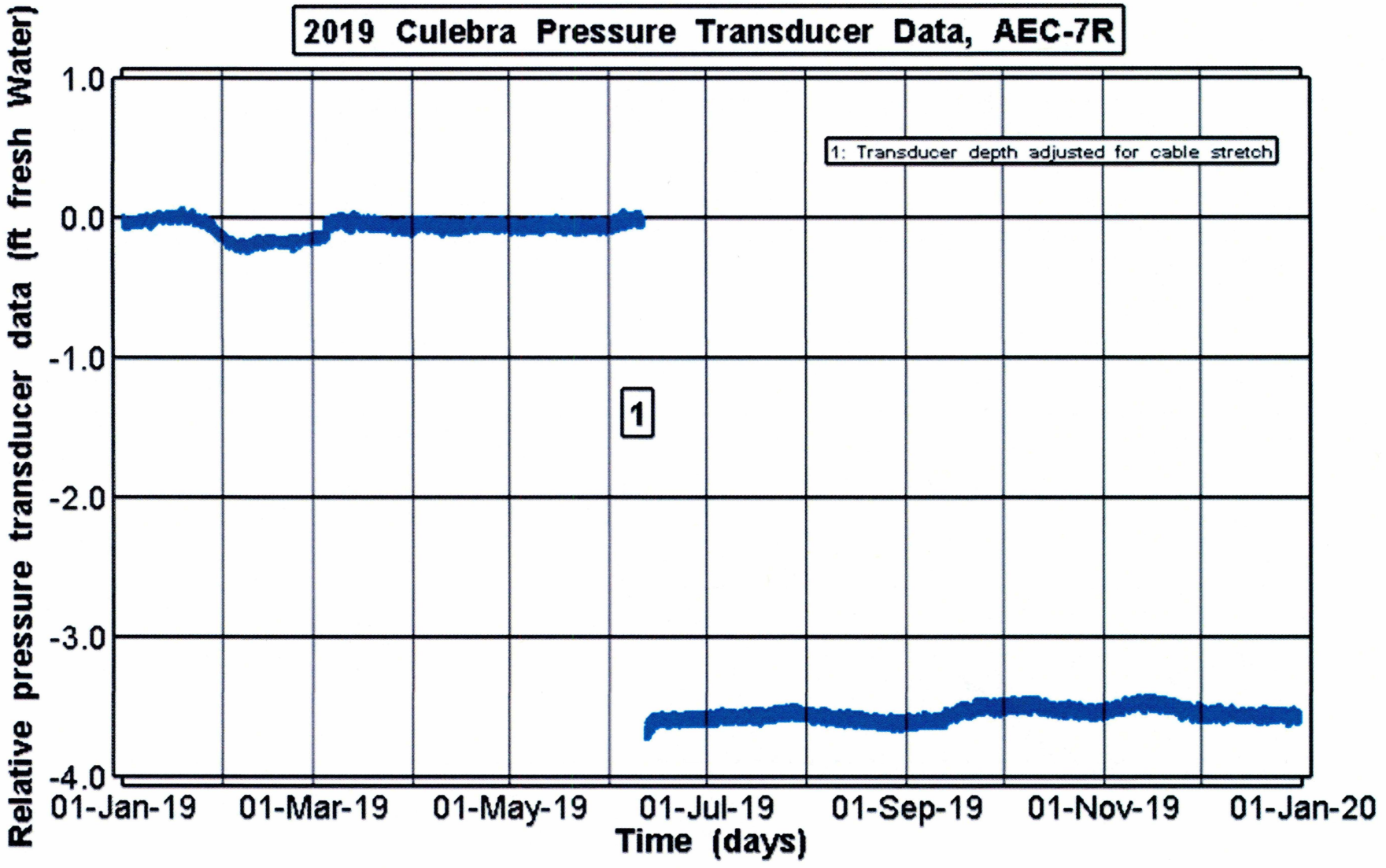

Figure 5. Well AEC-7R experienced a net change in hydraulic head of 0.07 ft fresh water in 2019.

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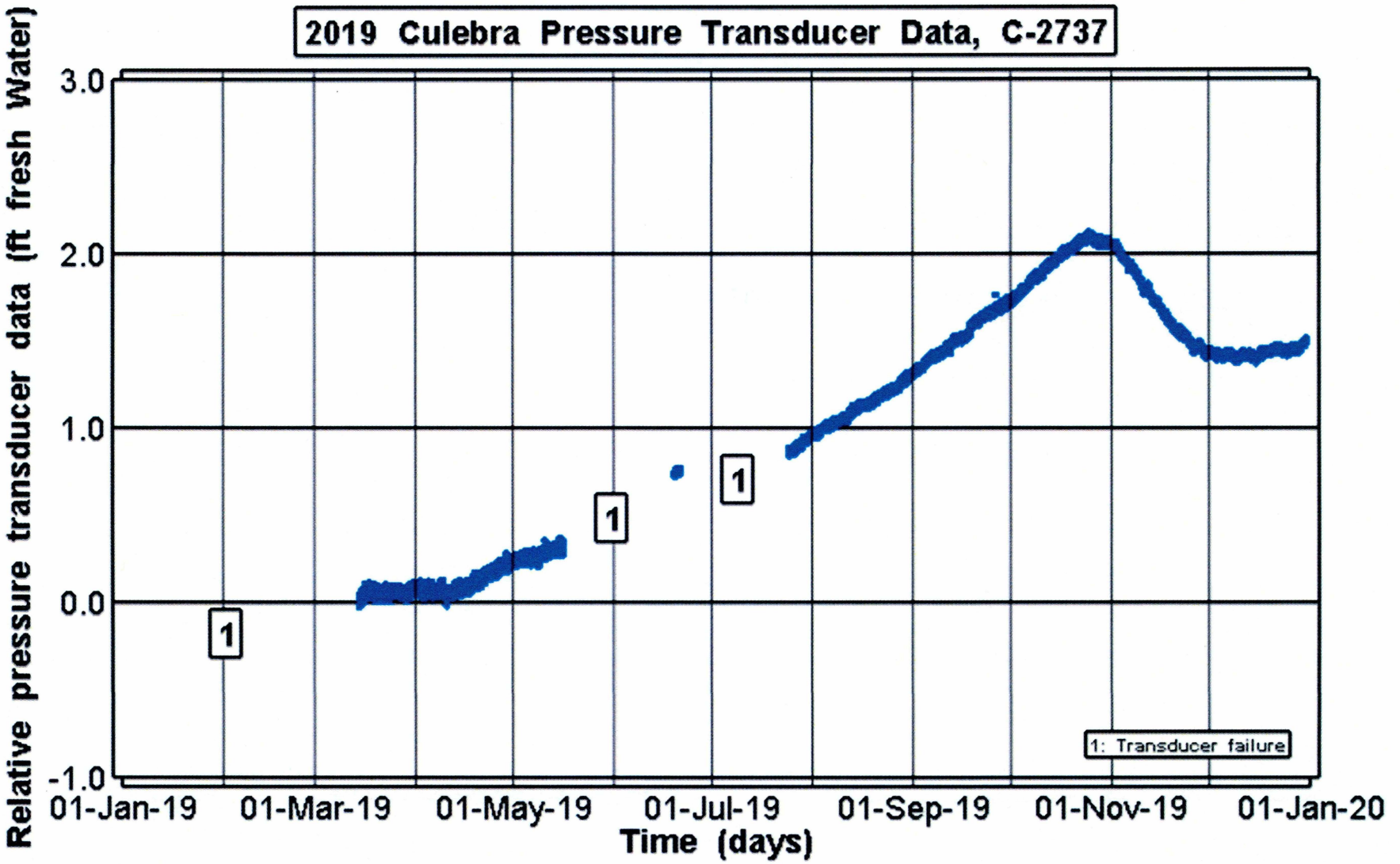

Figure 6. Well C-2737 experienced a net change in hydraulic head of 1.49 ft fresh water in 2019. The well was recovering from previous years' pumping before being affected by NWR pumping. Transducer failures are documented in CAR W-19-07 and CAR W-20-03

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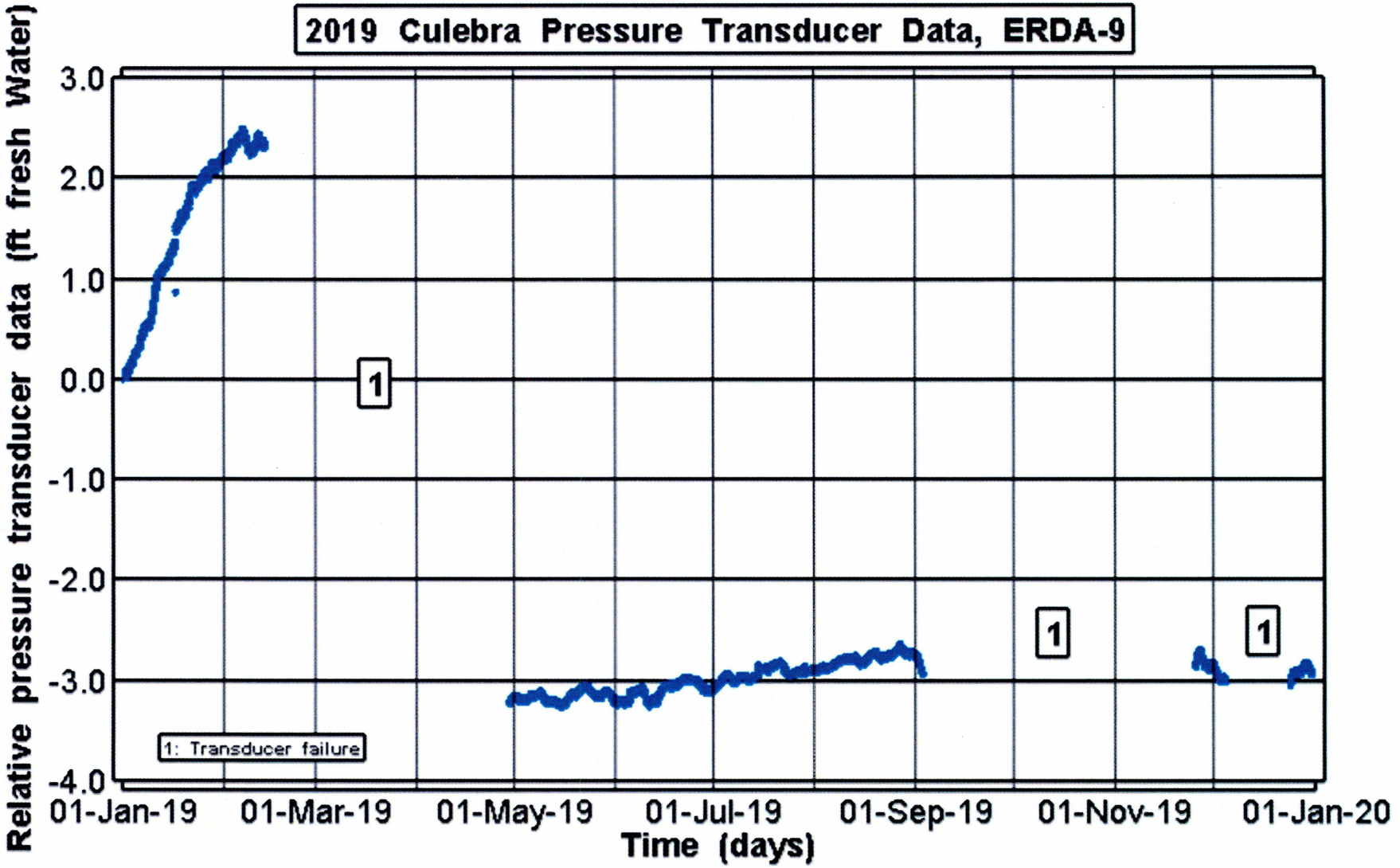

Figure 7. Well ERDA-9 experienced a net change in hydraulic head of -0.73ft fresh water in 2019. At the beginning of the year, the well was recovering from previous years' pumping. Transducer failures are documented in CAR W-19-12 and CAR W-20-03

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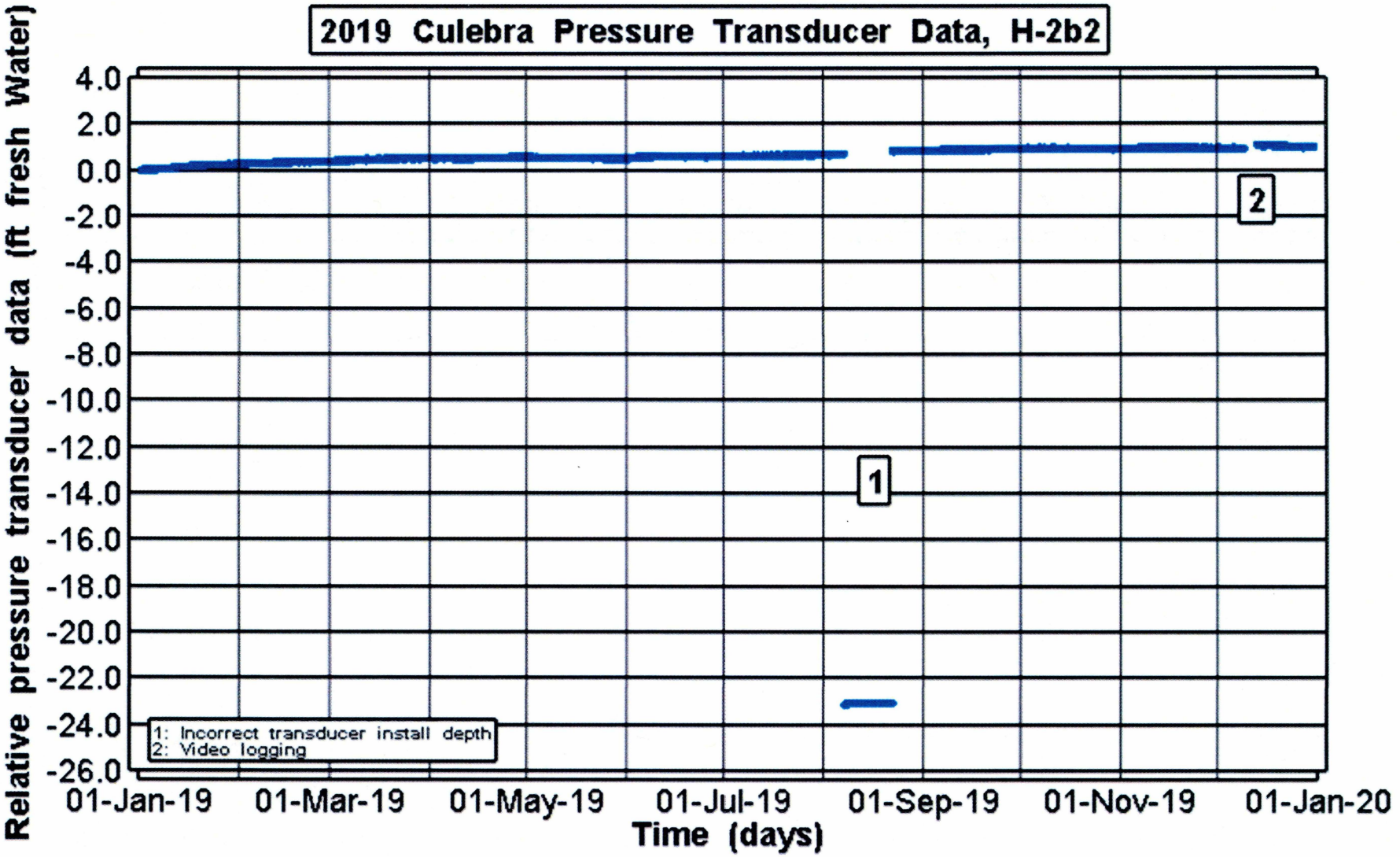

Figure 8. Well H-2b2 experienced a net change in hydraulic head of 1.00 ft fresh water in 2019.

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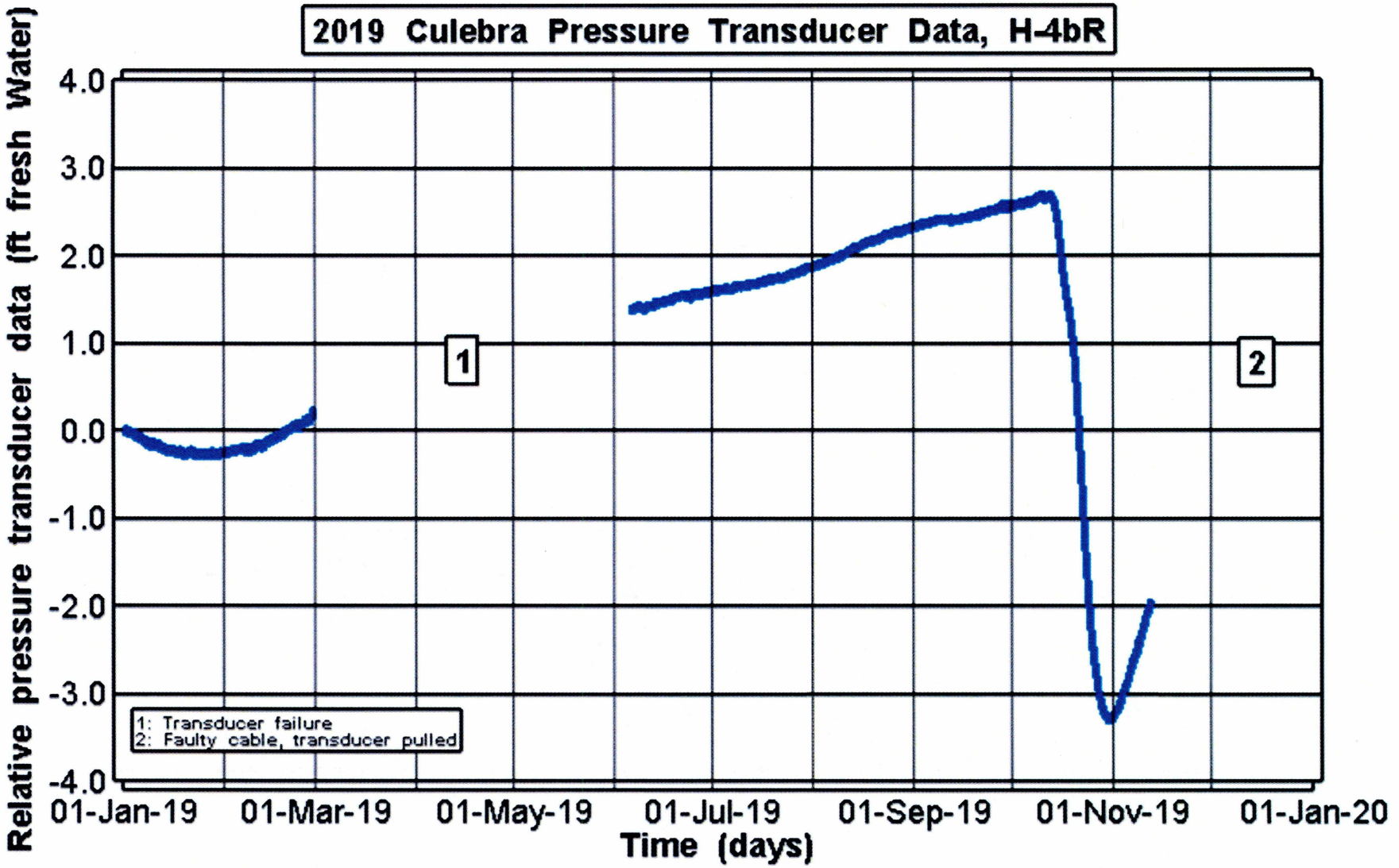

Figure 9. Well H-4bR experienced a net change in hydraulic head of -2.01 ft fresh water in 2019. The well was recovering from previous years' pumping before being affected by NWR pumping. Transducer failure is documented in CAR W-19-12.

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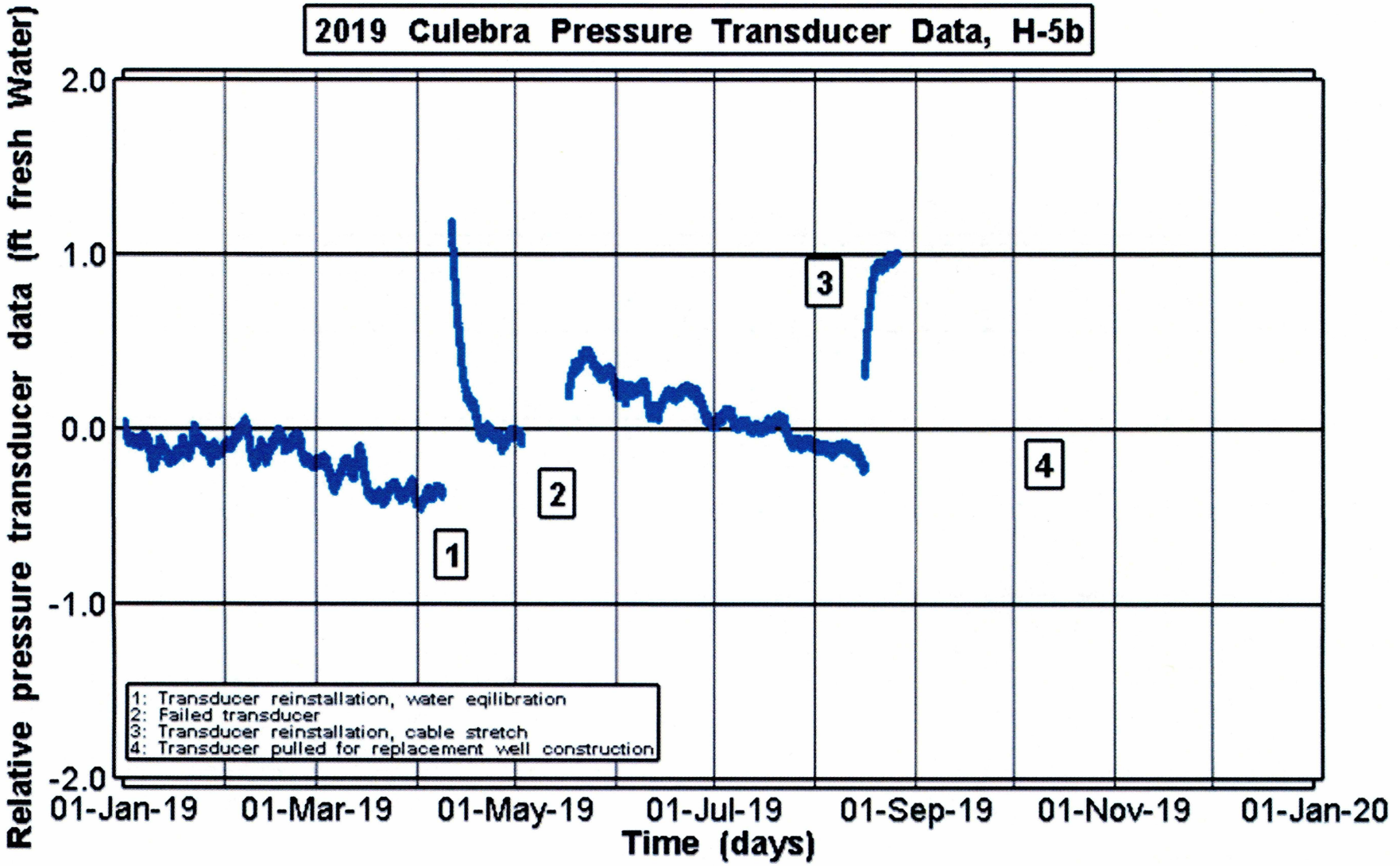

Figure 10. Well H-5b experienced a net change in hydraulic head of 1.00 ft fresh water in 2019. Transducer failure is documented in CAR W-19-12

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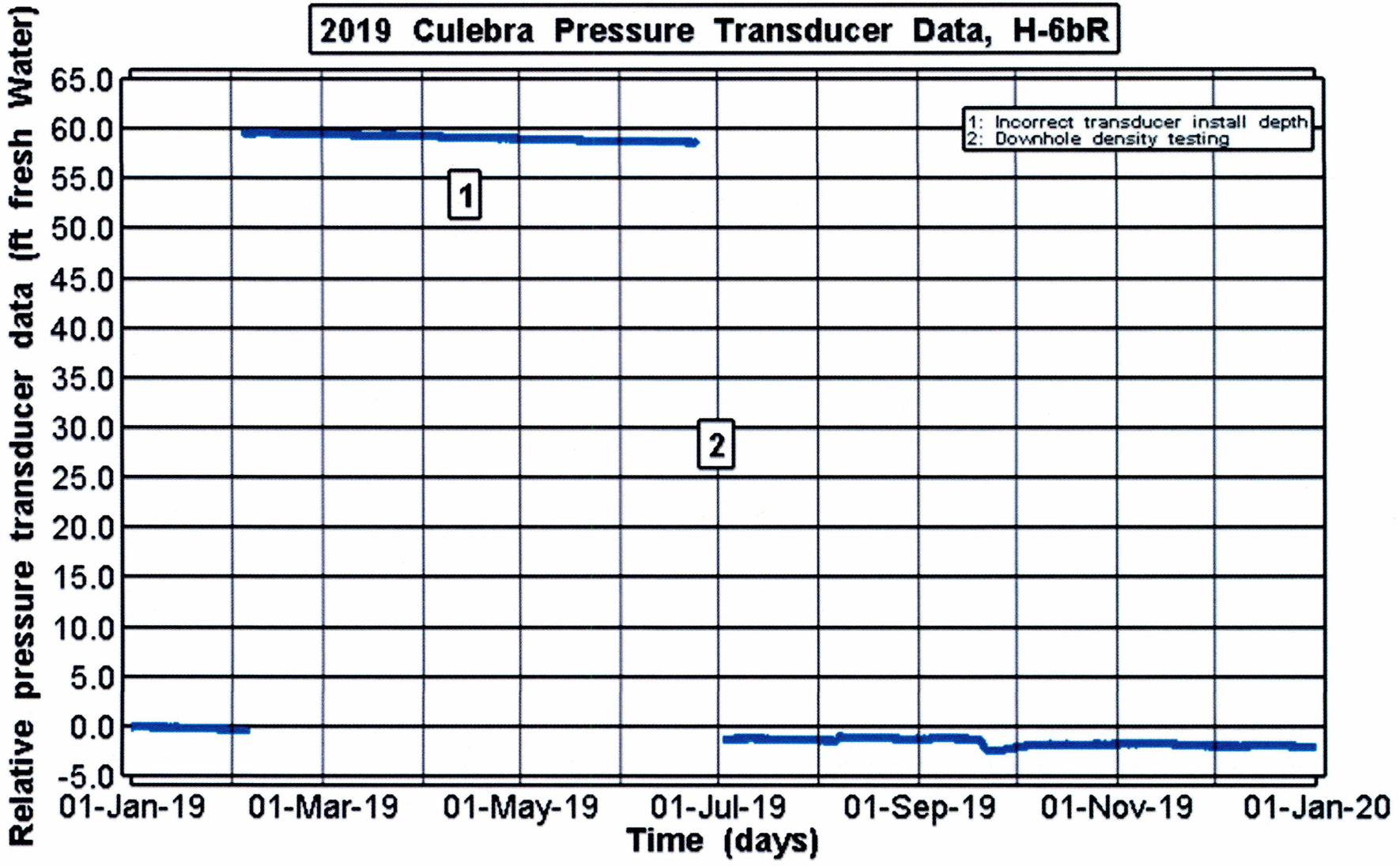

Figure 11. Well H-6bR experienced a net change in hydraulic head of -2.05 ft fresh water in 2019. This well responds to precipitation events.

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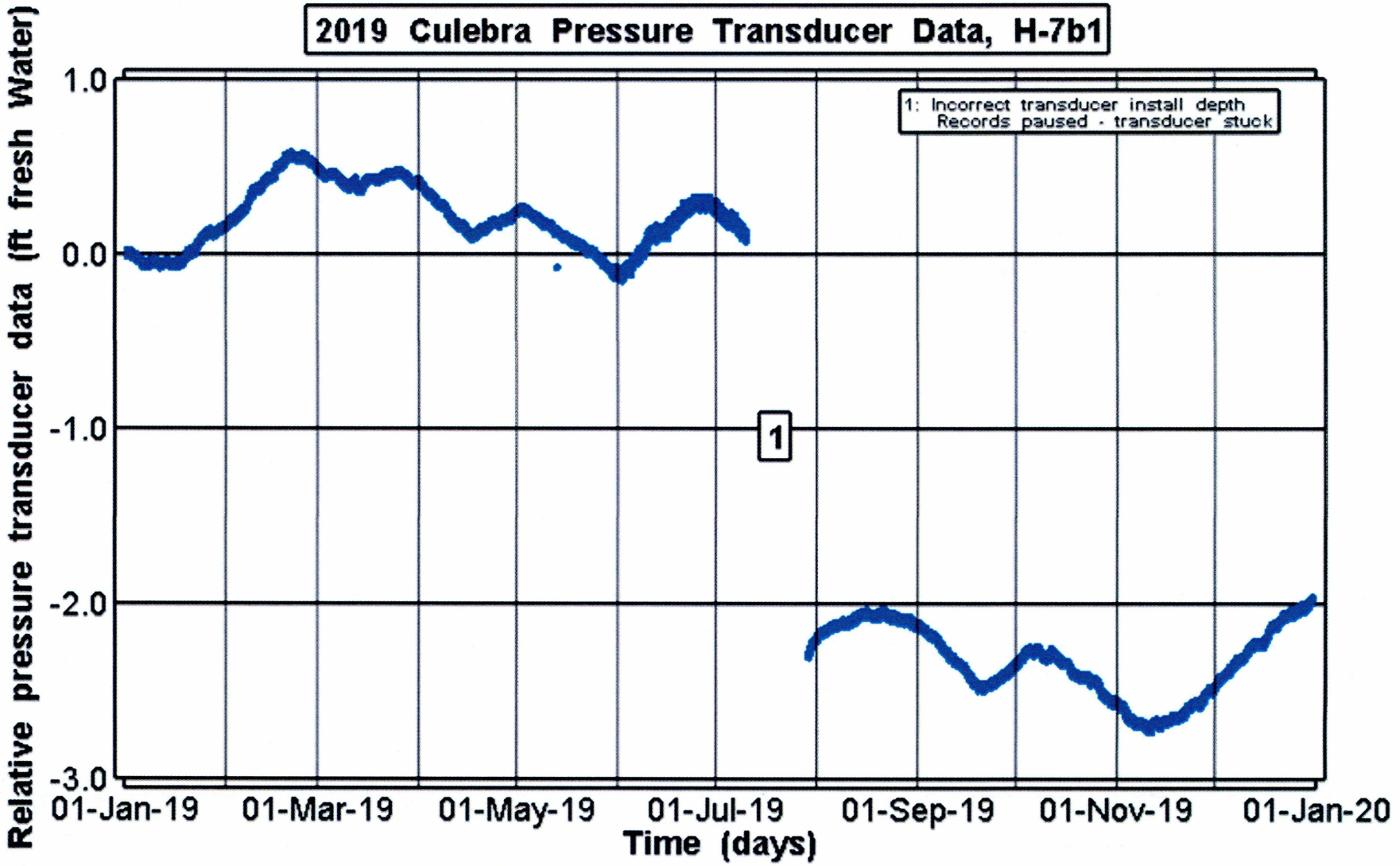

Figure 12. Well H-7b1 experienced a net change in hydraulic head of 0.42 ft fresh water in 2019. The well responds to pumping from a livestock well on the same pad and precipitation events.

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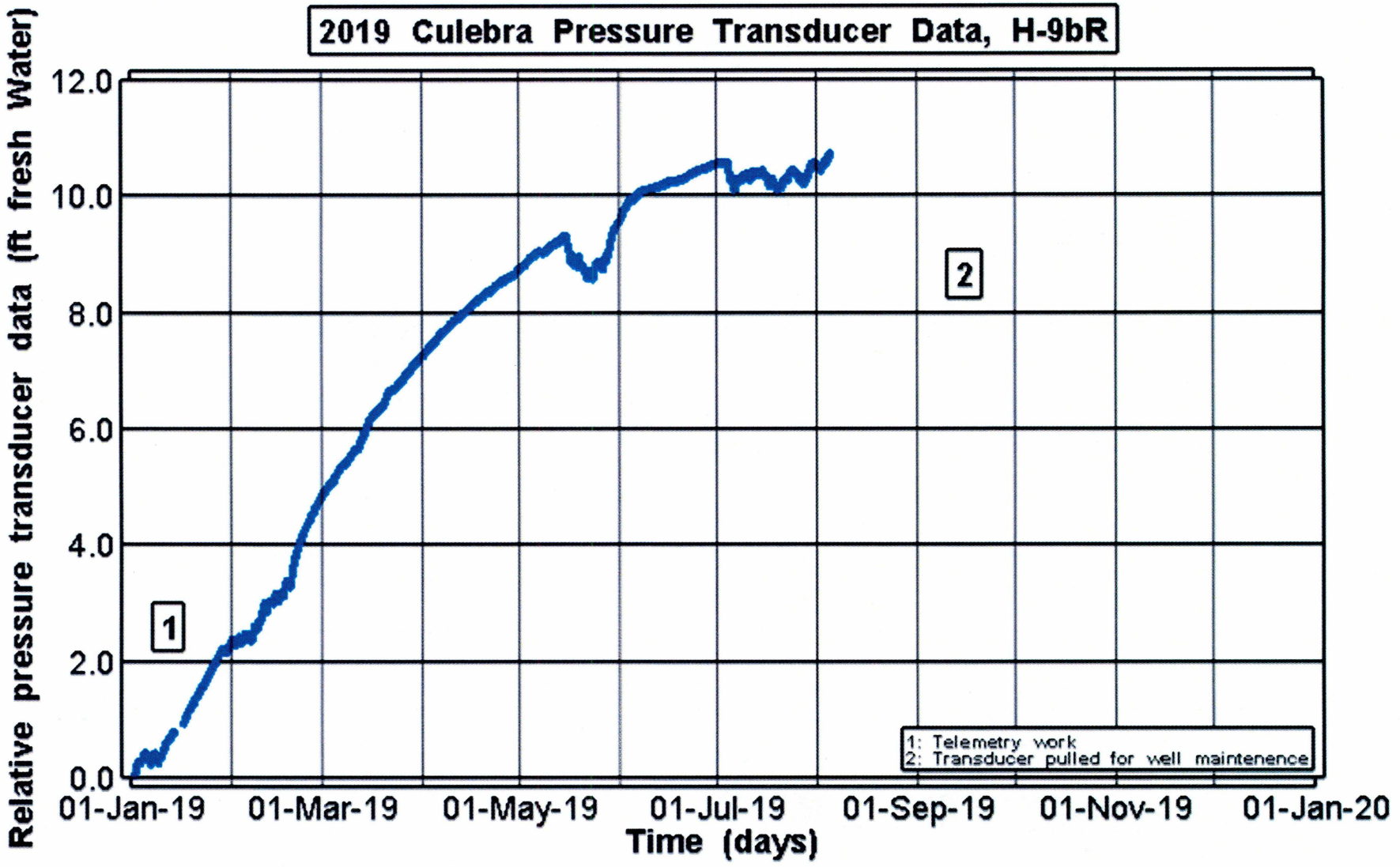

Figure 13. Well H-9bR experienced a net change in hydraulic head of 10.73 ft fresh water in 2019. The well was recovering from previous years' pumping before monitoring was paused for maintenance activities.

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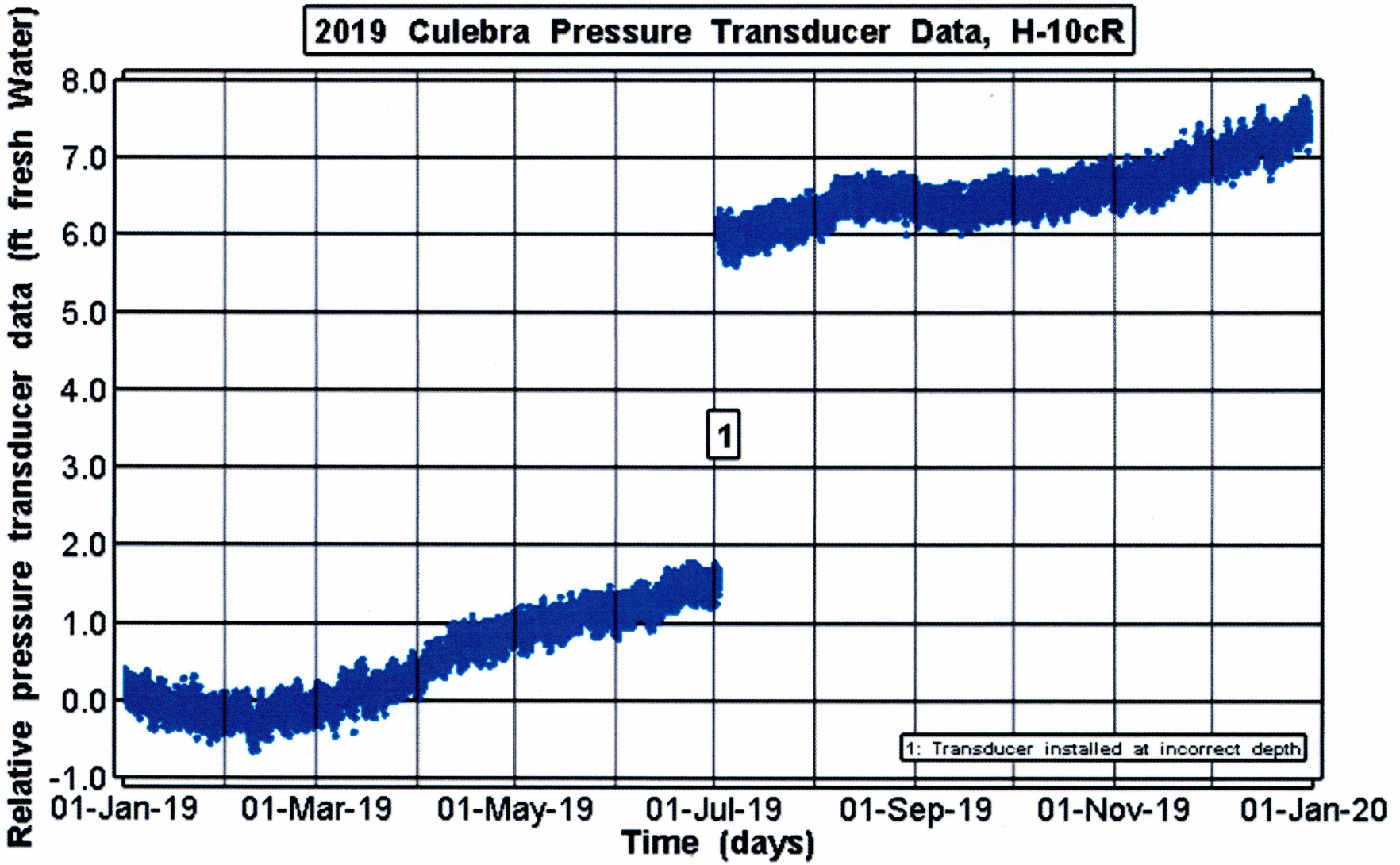

Figure 14. Well H-10cR experienced a net change in hydraulic head of 2.37 ft fresh water in 2019. The well is in long-term recovery from well development.

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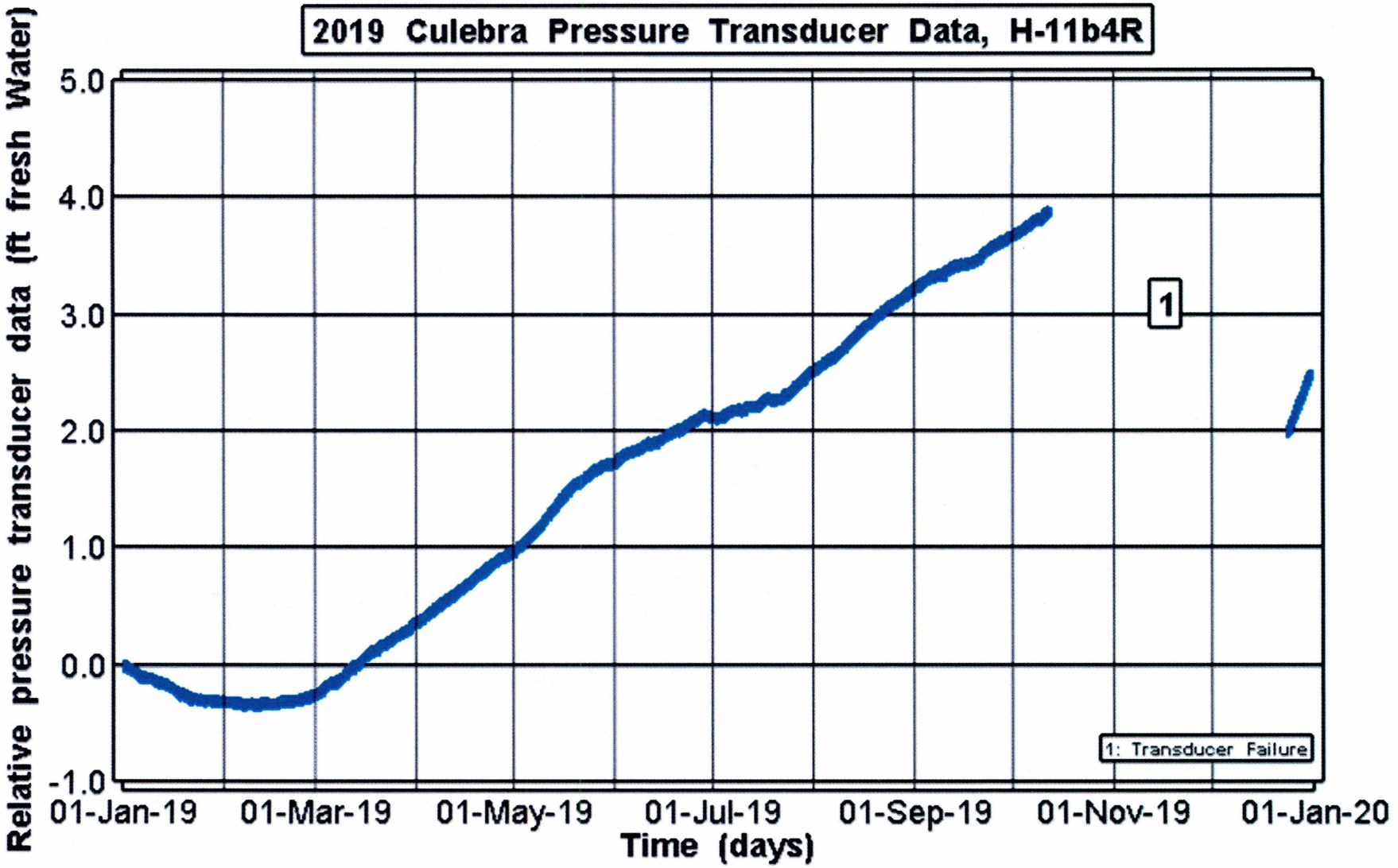

Figure 15. Well H-11b4R experienced a net change in hydraulic head of 2.47 ft fresh water in 2019. The well was recovering from previous years' pumping. Transducer failure is documented in CAR W-20-03.

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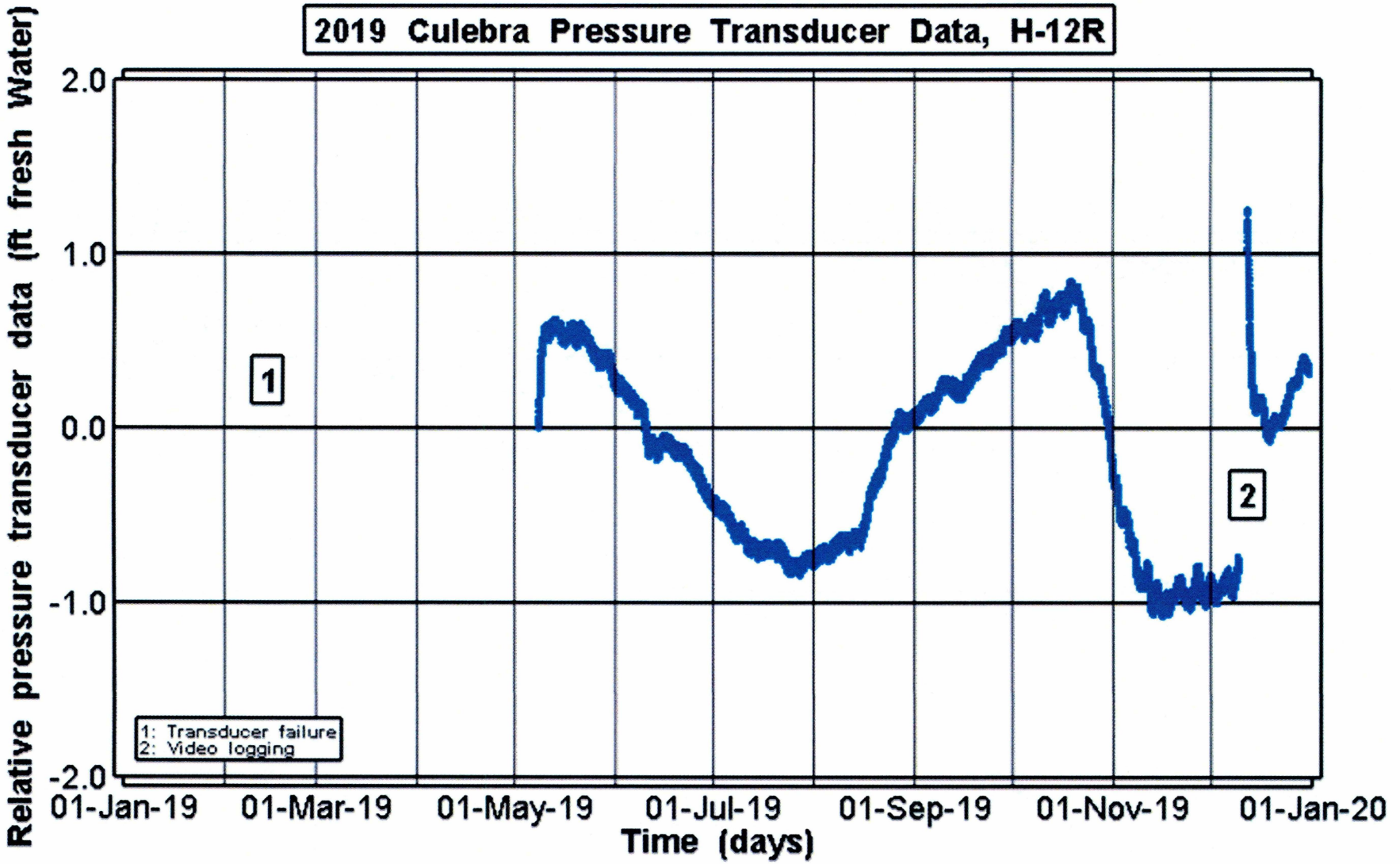

Figure 16. Well H-12R experienced a net change in hydraulic head of 0.75 ft fresh water in 2019. The well was recovering from previous years' pumping before being affected by development at WIPP-11R. Transducer failures are documented in CAR W-19-07 and CAR W-19-12.

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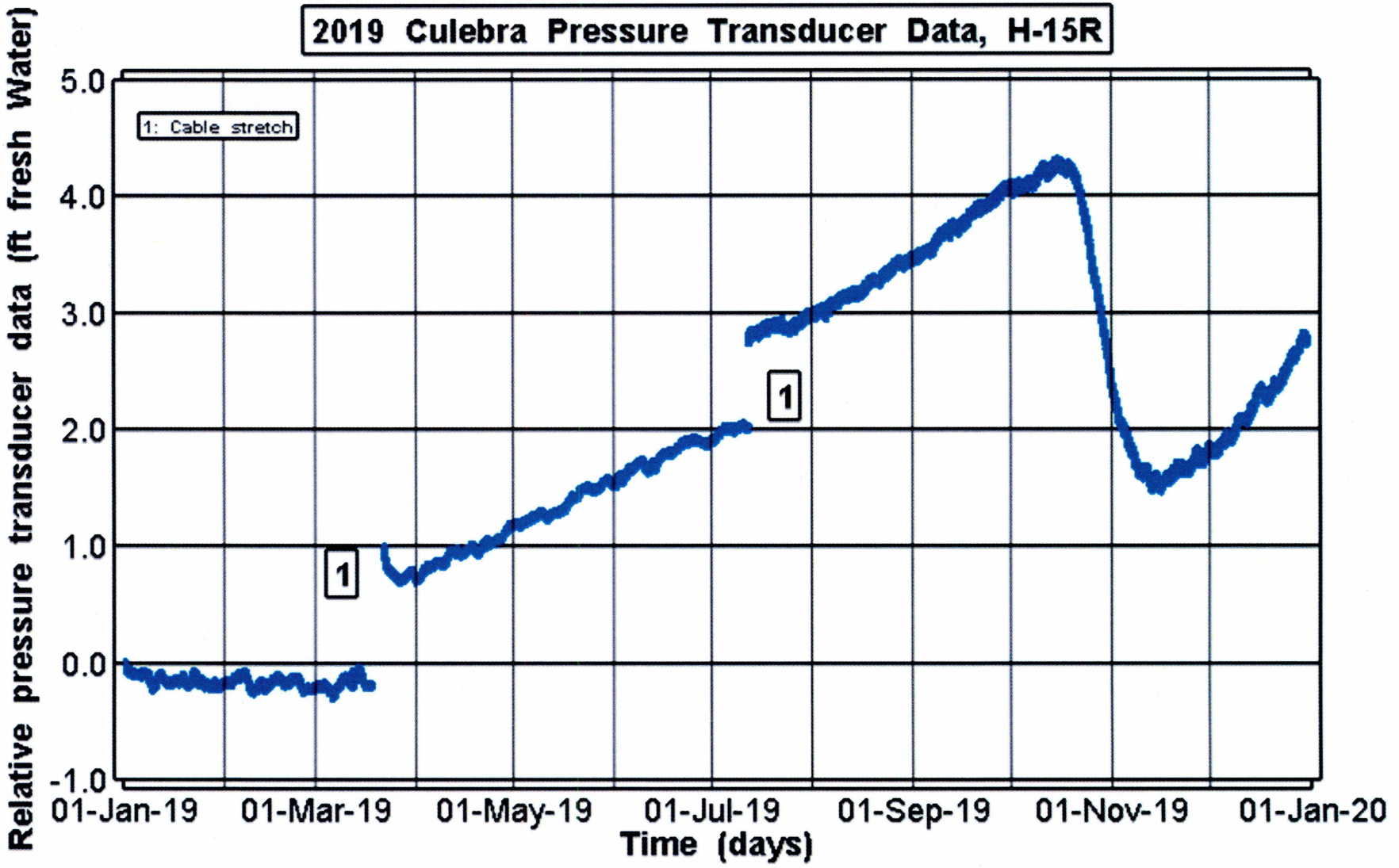

Figure 17. Well H-15R experienced a net change in hydraulic head of 0.87 ft fresh water in 2019. The well was recovering from previous years' pumping before being affected by development at WIPP-11R.

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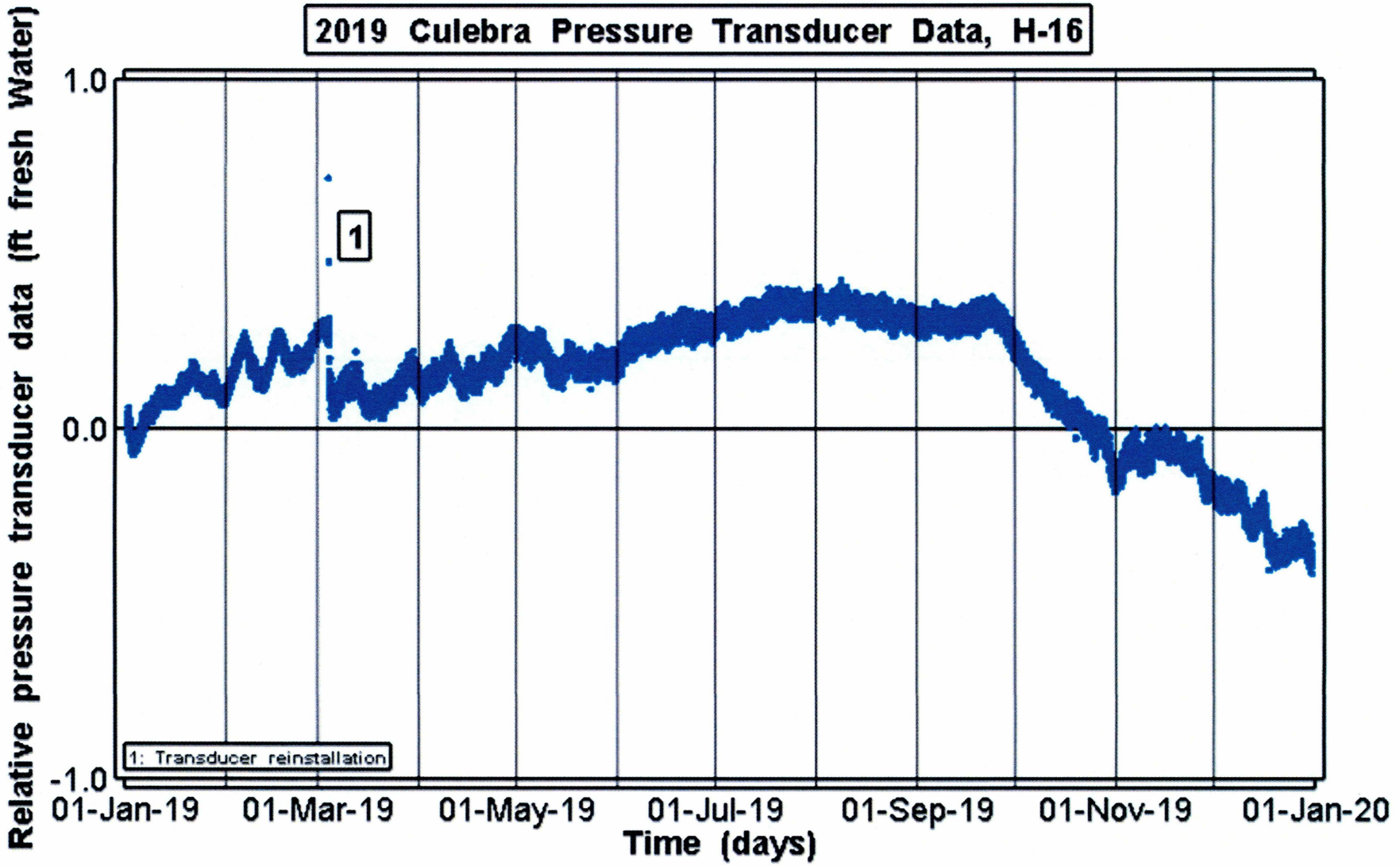

Figure 18. H-16 experienced a net change in hydraulic head of -0.41 ft fresh water in 2019. The well was recovering from previous years' pumping, which overrode the signal from precipitation effects until recovery was complete.

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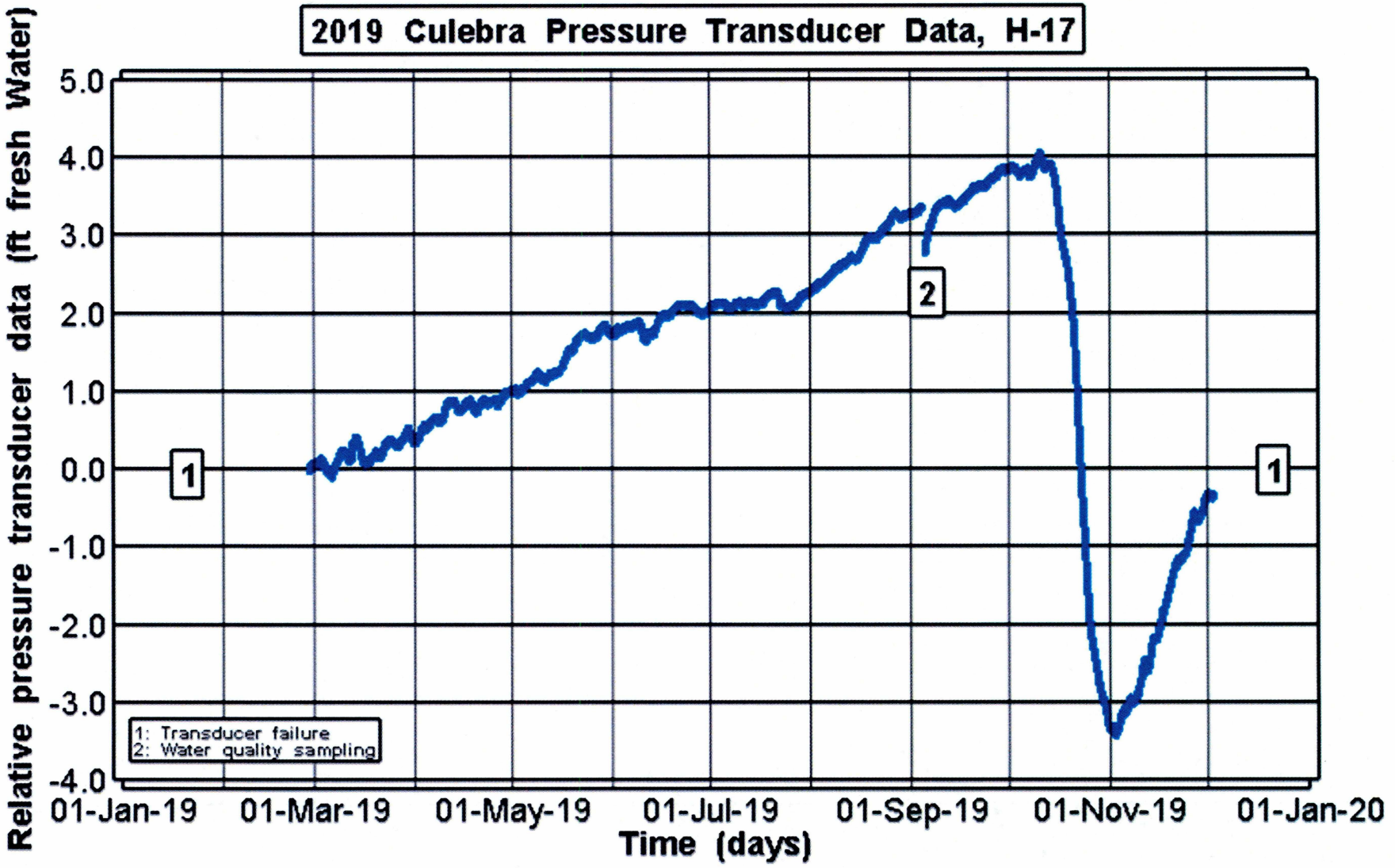

Figure 19. Well H-17 experienced a net change in hydraulic head of -0.36 ft fresh water in 2019. The well was recovering from previous years' pumping before being affected by NWR pumping. Transducer failures are documented in CAR W-19-07 and CAR W-20-03.

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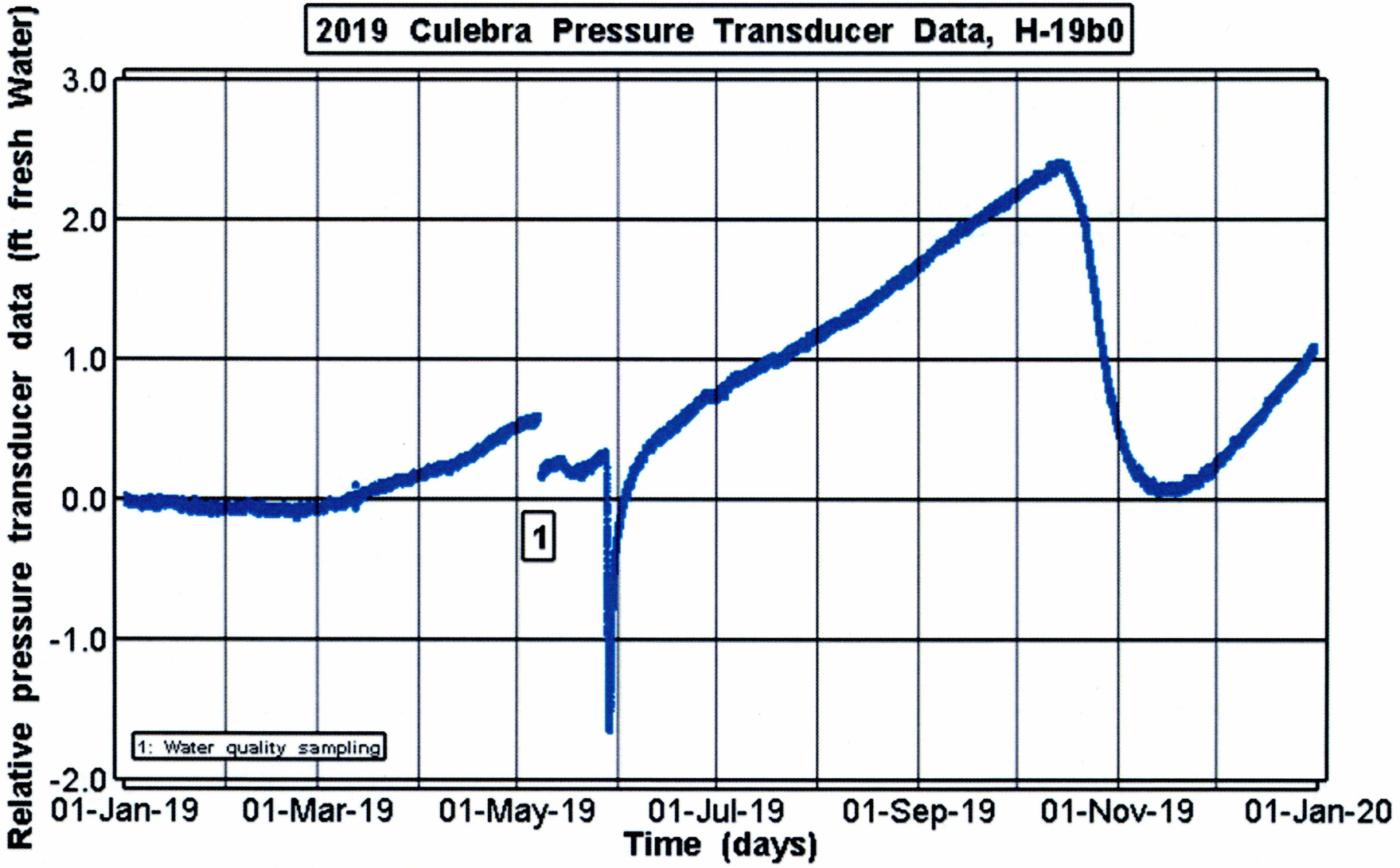

Figure 20. Well H-19b0 experienced a net change in hydraulic head of 1.07 ft fresh water in 2019. The well was recovering from previous years' pumping before being affected by NWR pumping.

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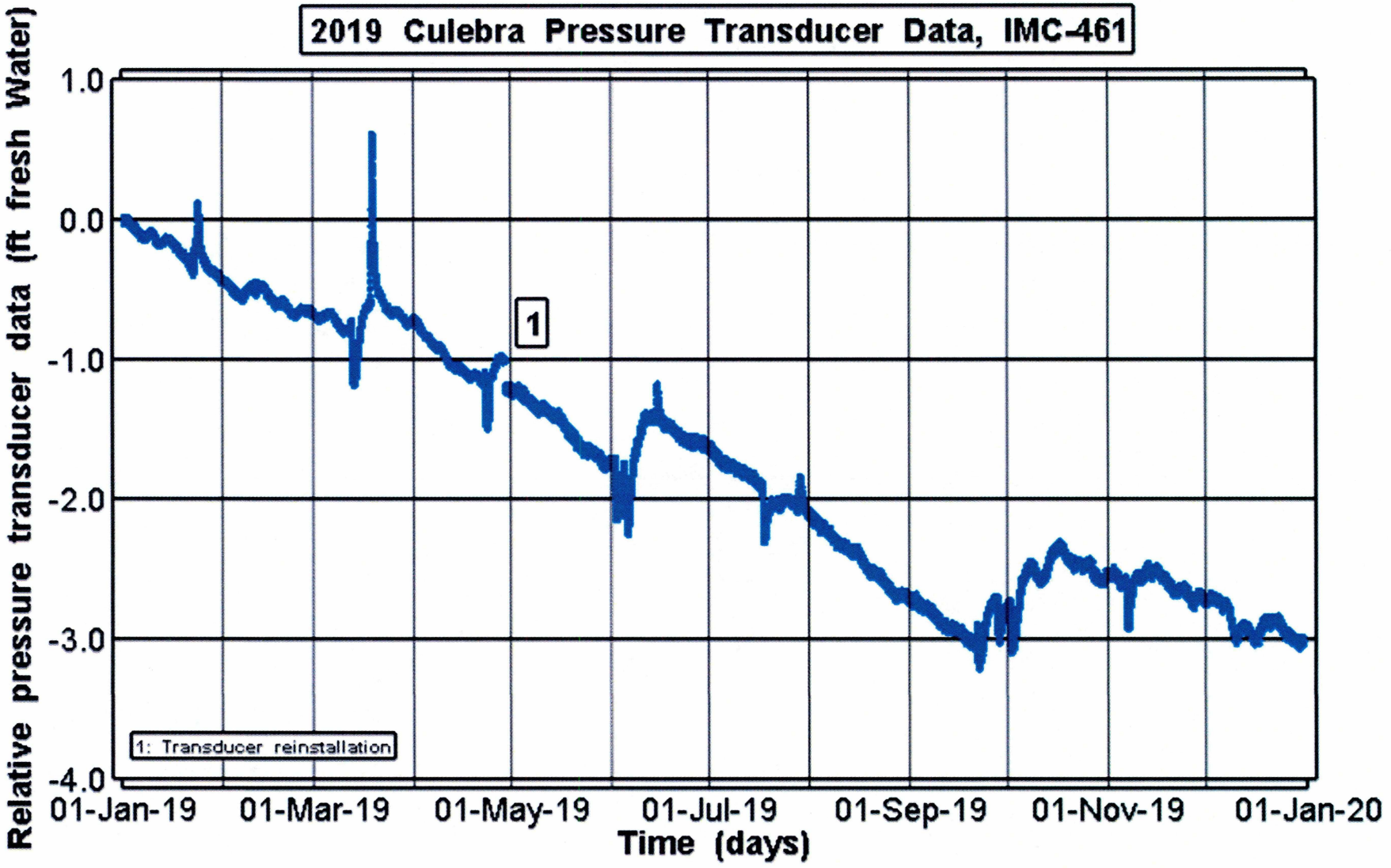

Figure 21. Well IMC-461 experienced a net change in hydraulic head of -3.01 ft fresh water in 2019. The well is affected by precipitation events.

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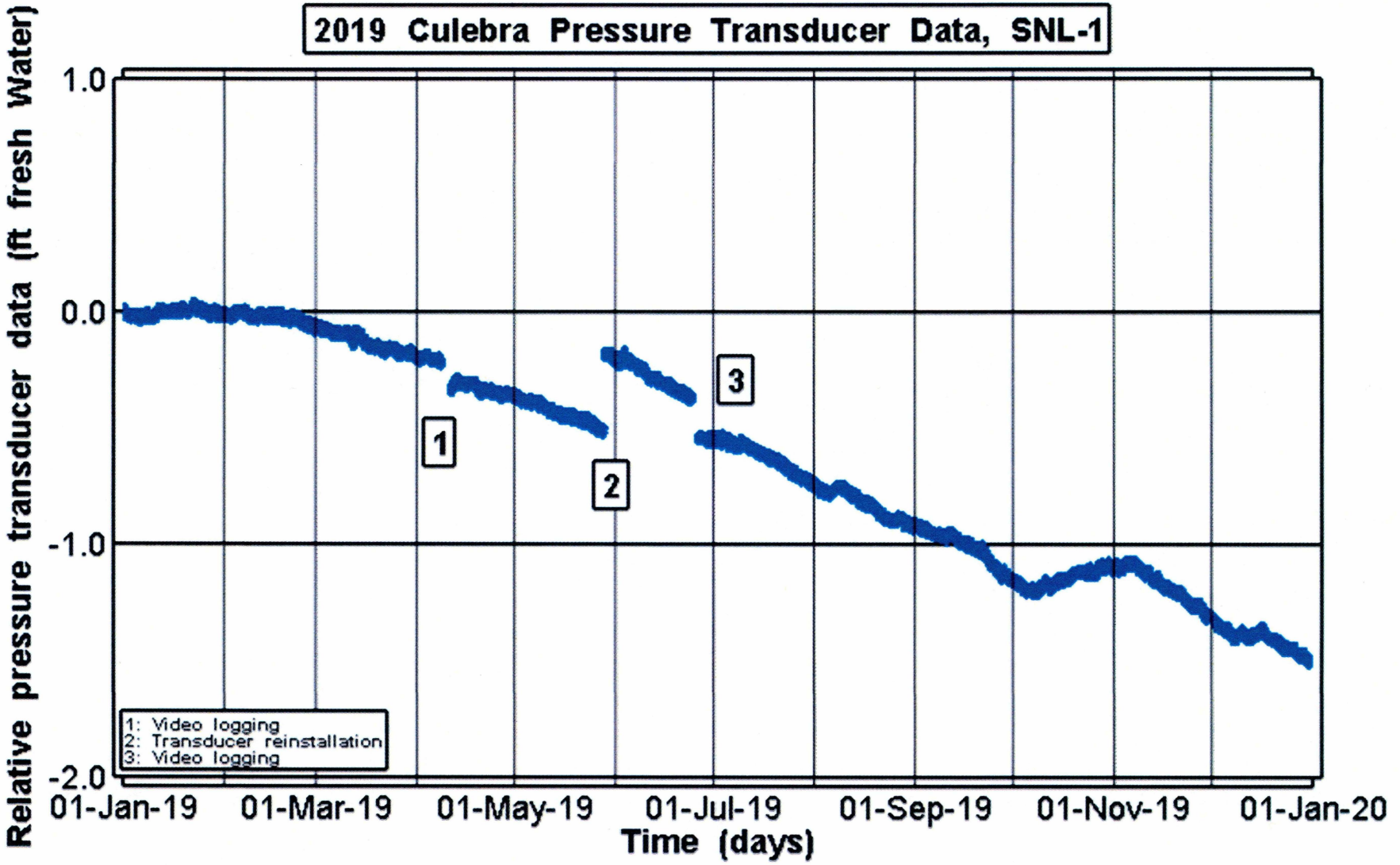

Figure 22. Well SNL-1 experienced a net change in hydraulic head of -1.51 ft fresh water in 2019. The well is affected by precipitation events.

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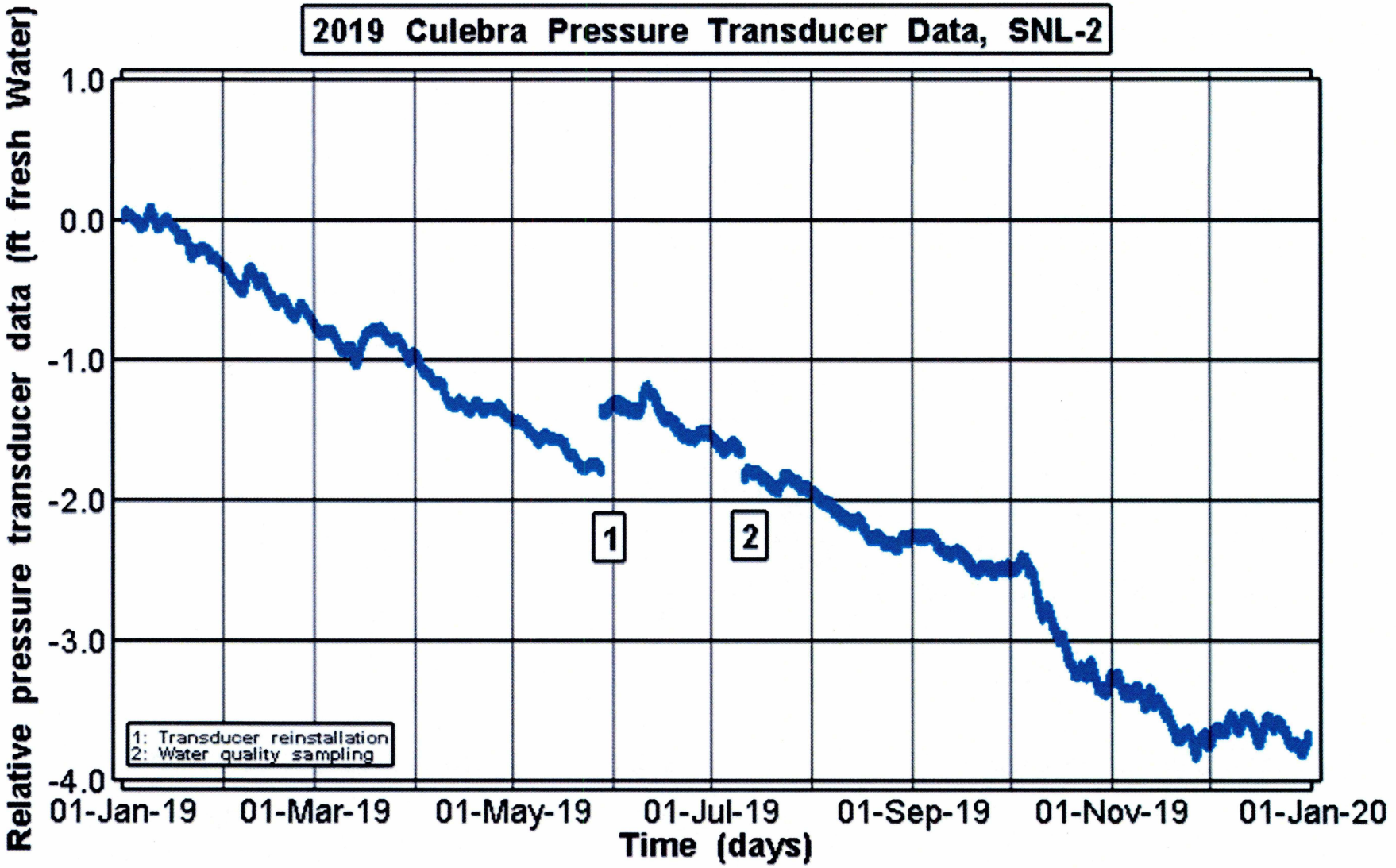

Figure 23. Well SNL-2 experienced a net change in hydraulic head of -3.70 ft fresh water in 2019. The well is affected by precipitation events.

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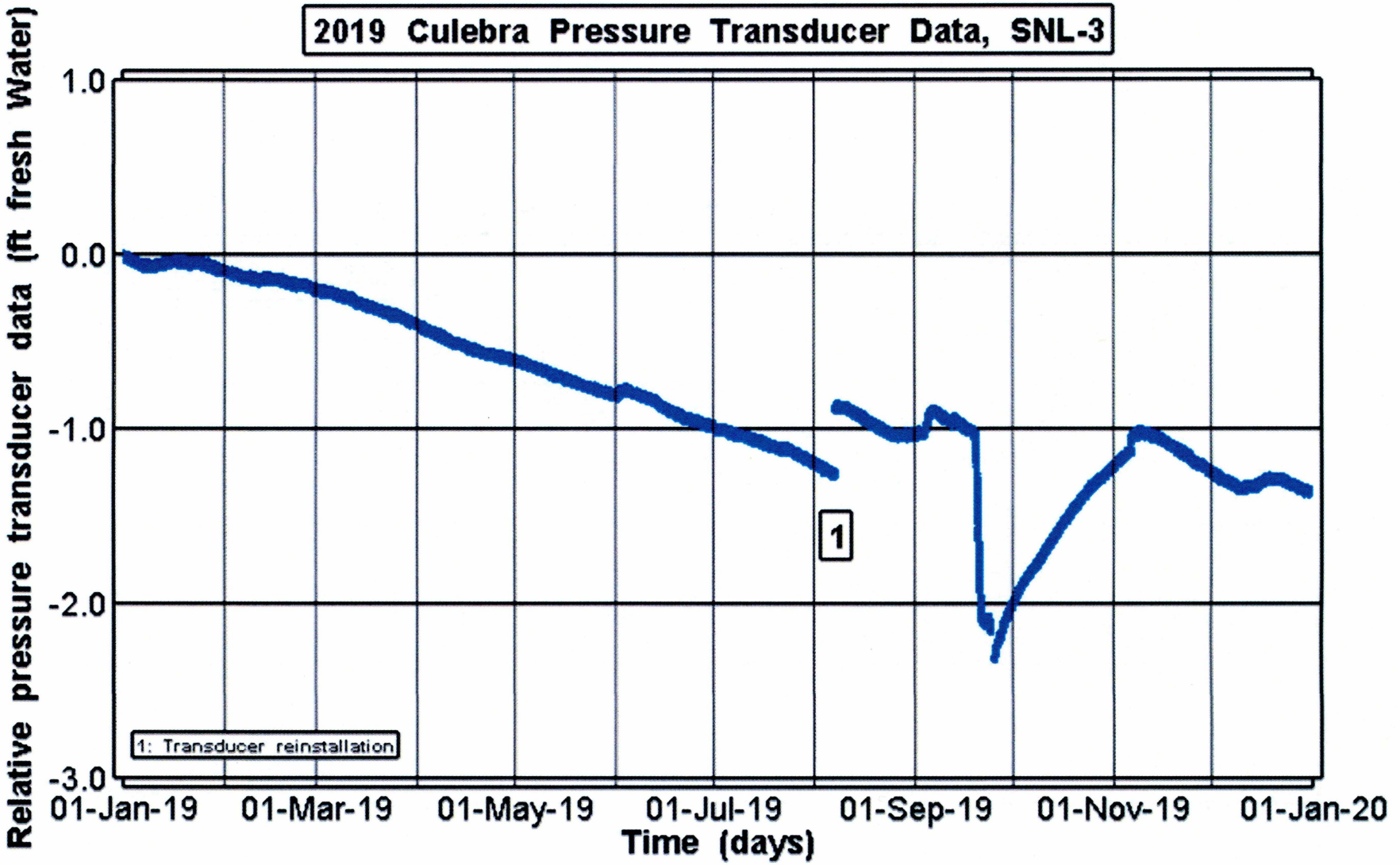

Figure 24. Well SNL-3 experienced a net change in hydraulic head of -1.37 ft fresh water in 2019. The well is affected by precipitation events and well development at WIPP-11R.

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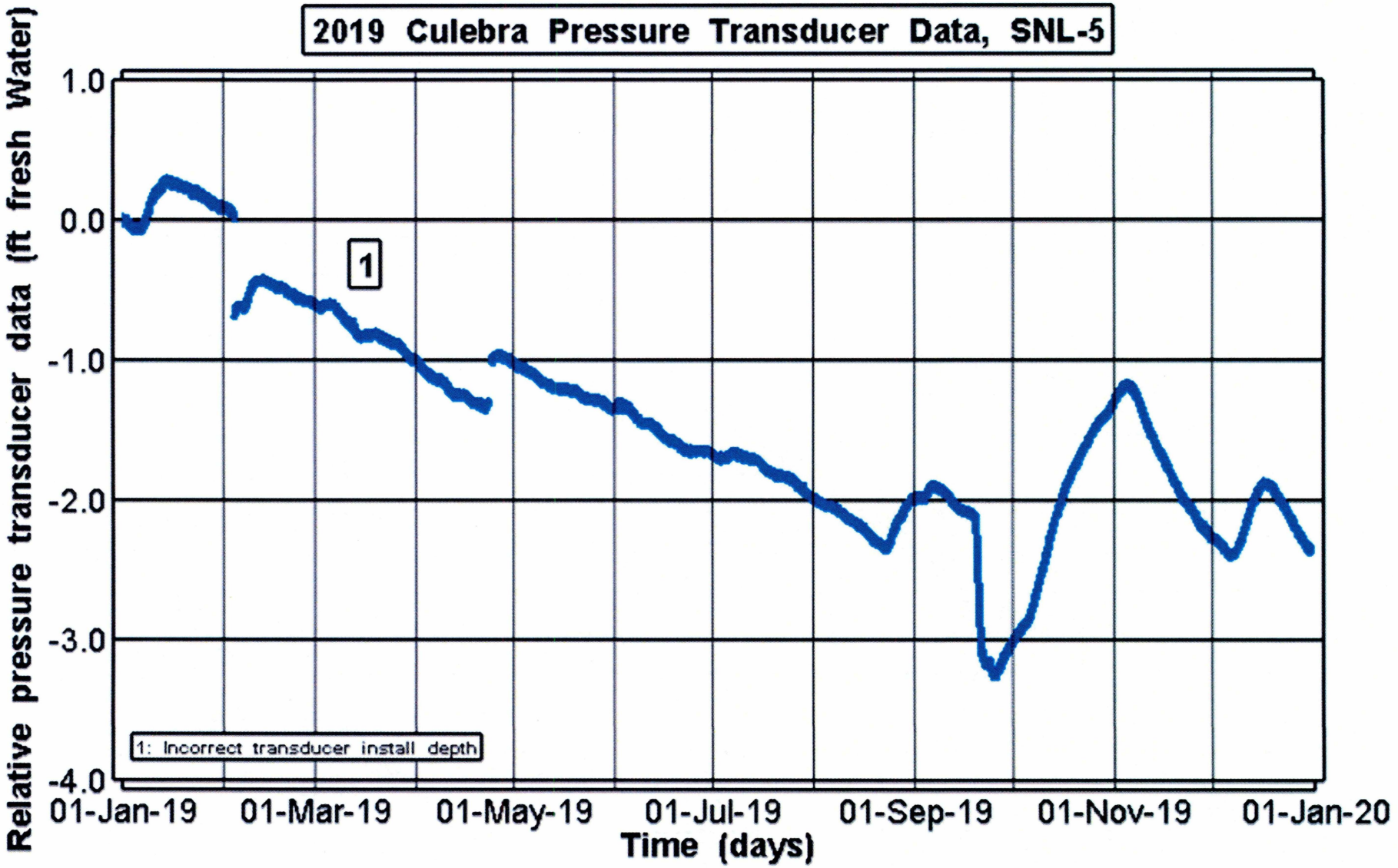

Figure 25. Well SNL-5 experienced a net change in hydraulic head of -1.96 ft fresh water in 2019. The well is affected by precipitation events and well development at WIPP-11R.

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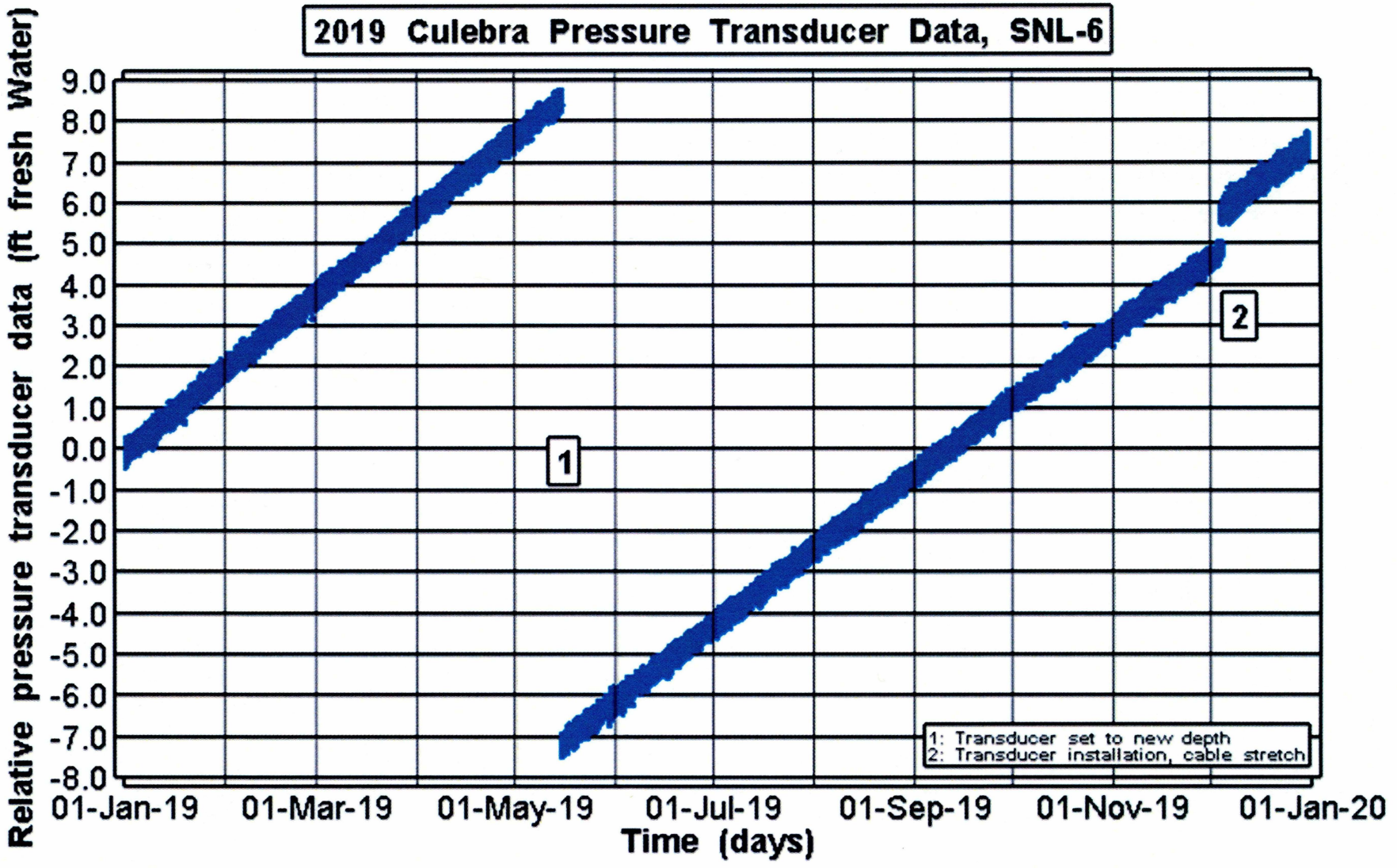

Figure 26. Well SNL-6 experienced a net change in hydraulic head of 23.13 ft fresh water in 2019. The well is in long-term recovery from well development.

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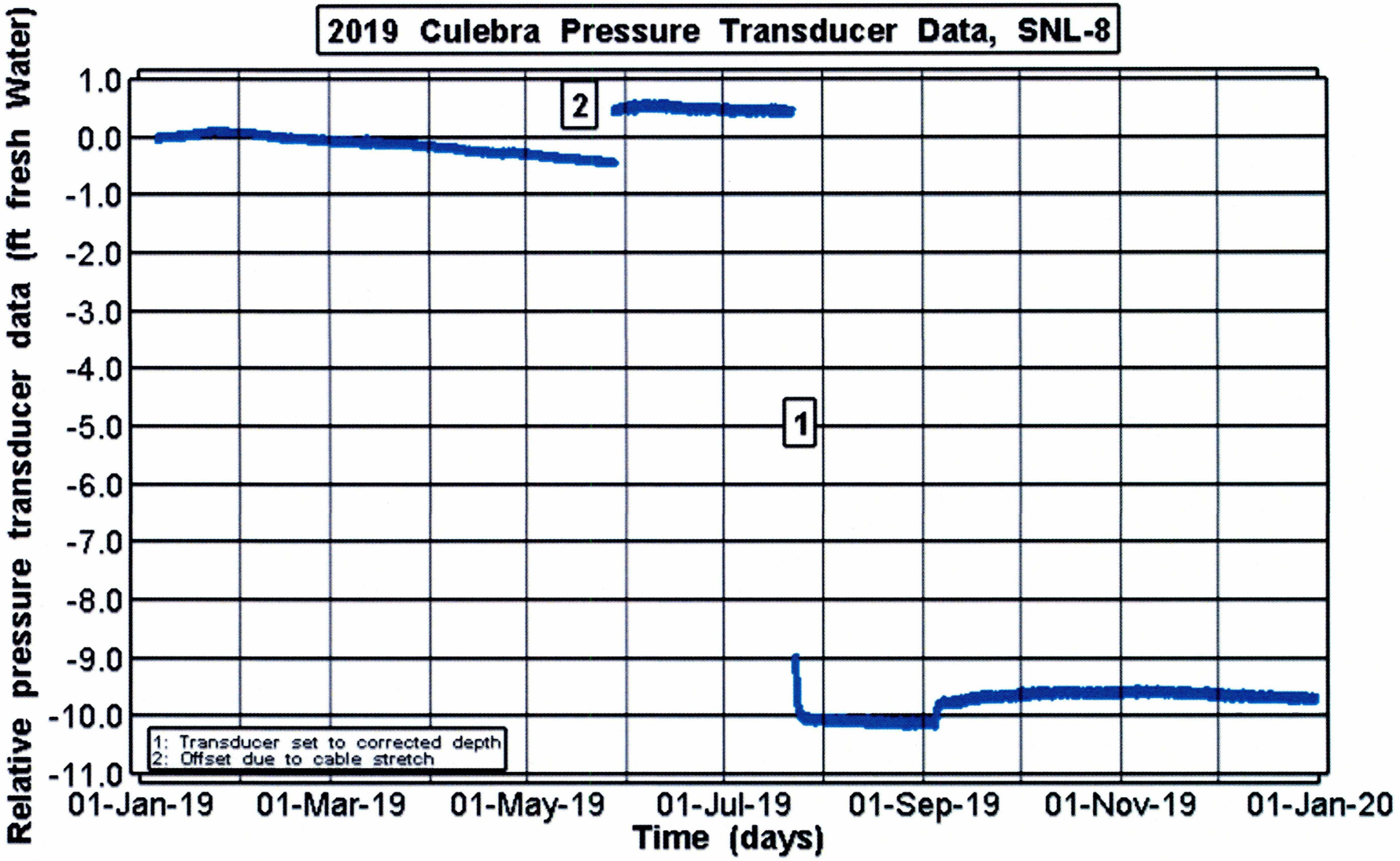

Figure 27. Well SNL-8 experienced a net change in hydraulic head of -0.20 ft fresh water in 2019.

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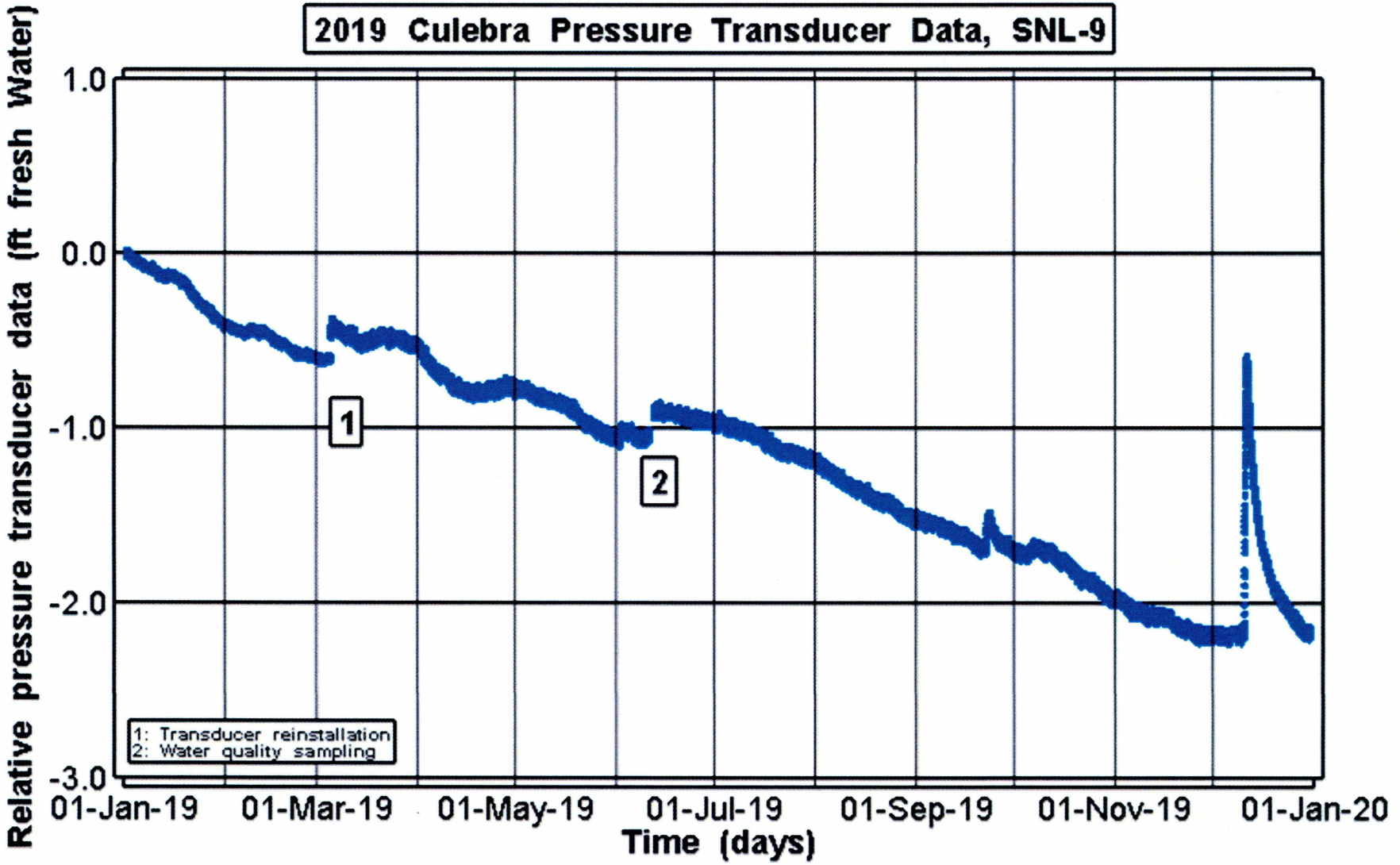

Figure 28. Well SNL-9 experienced a net change in hydraulic head of -2.17 ft fresh water in 2019. The well is affected by precipitation events Additionally, the well was likely affected by oil industry drilling in December 2019.

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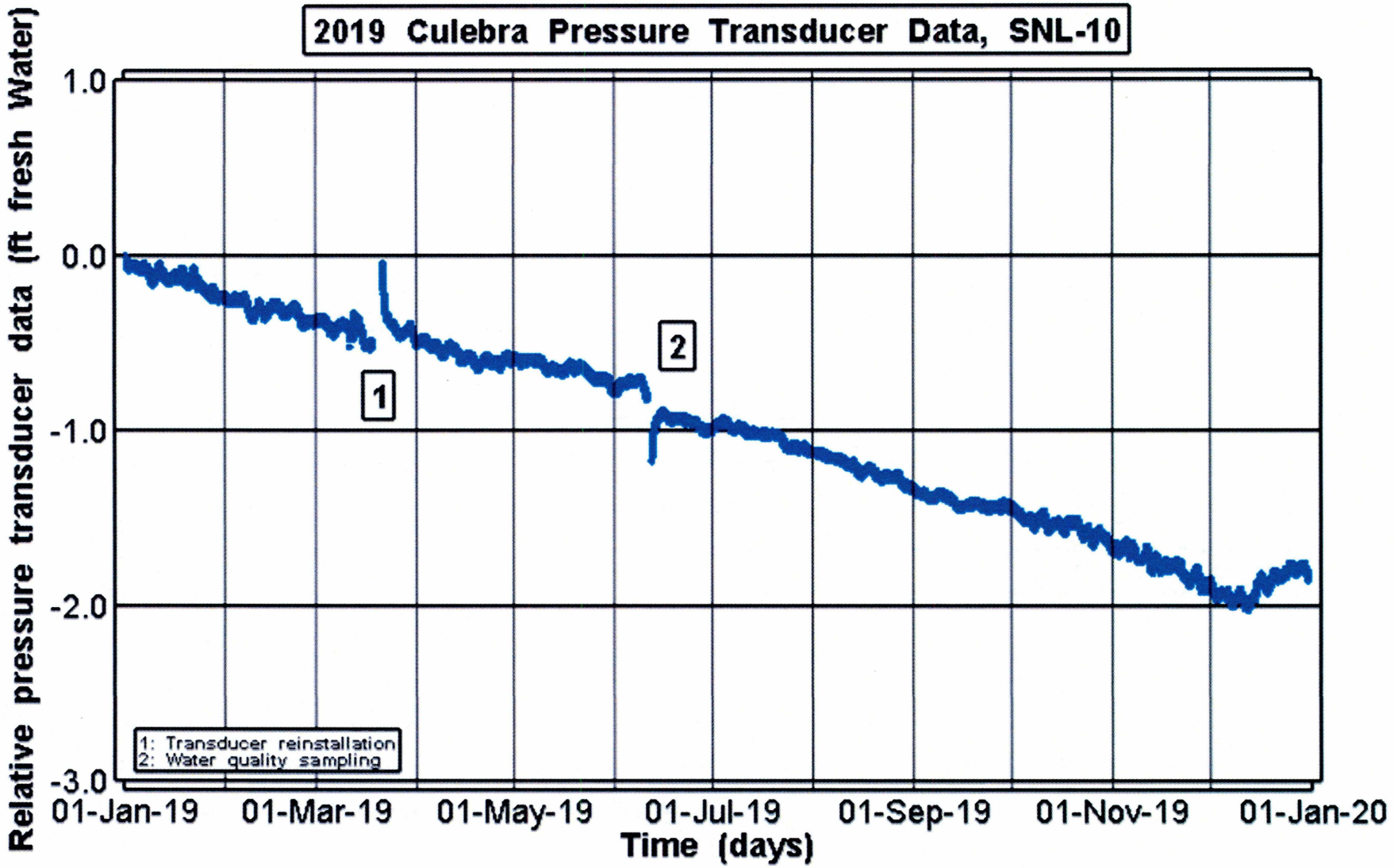

Figure 29. Well SNL-10 experienced a net change in hydraulic head of -1.84 ft fresh water in 2019. The well is affected by gravity flow.

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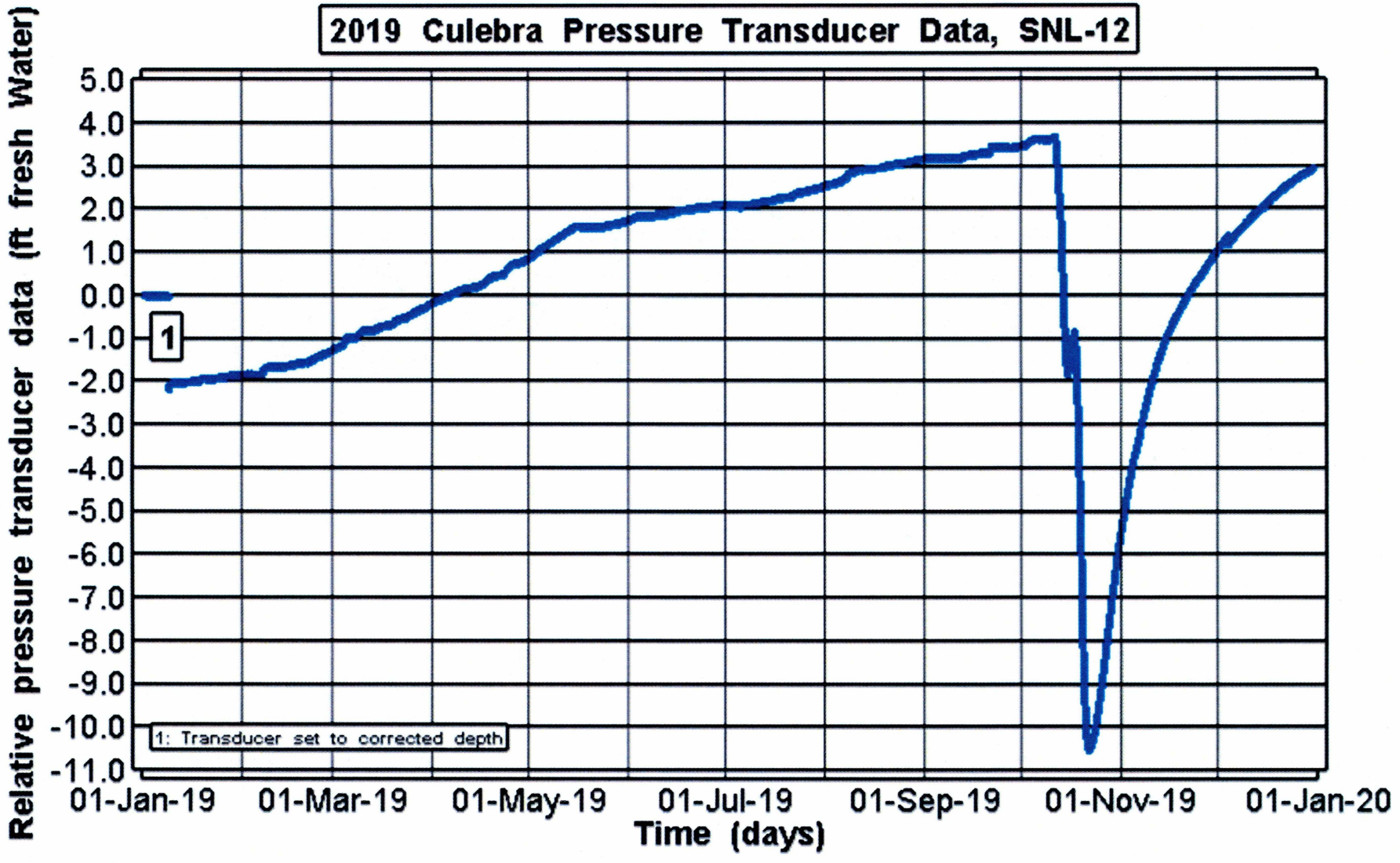

Figure 30. Well SNL-12 experienced a net change in hydraulic head of 5.05 ft fresh water in 2019. The well was recovering from previous years' pumping before being affected by NWR pumping.

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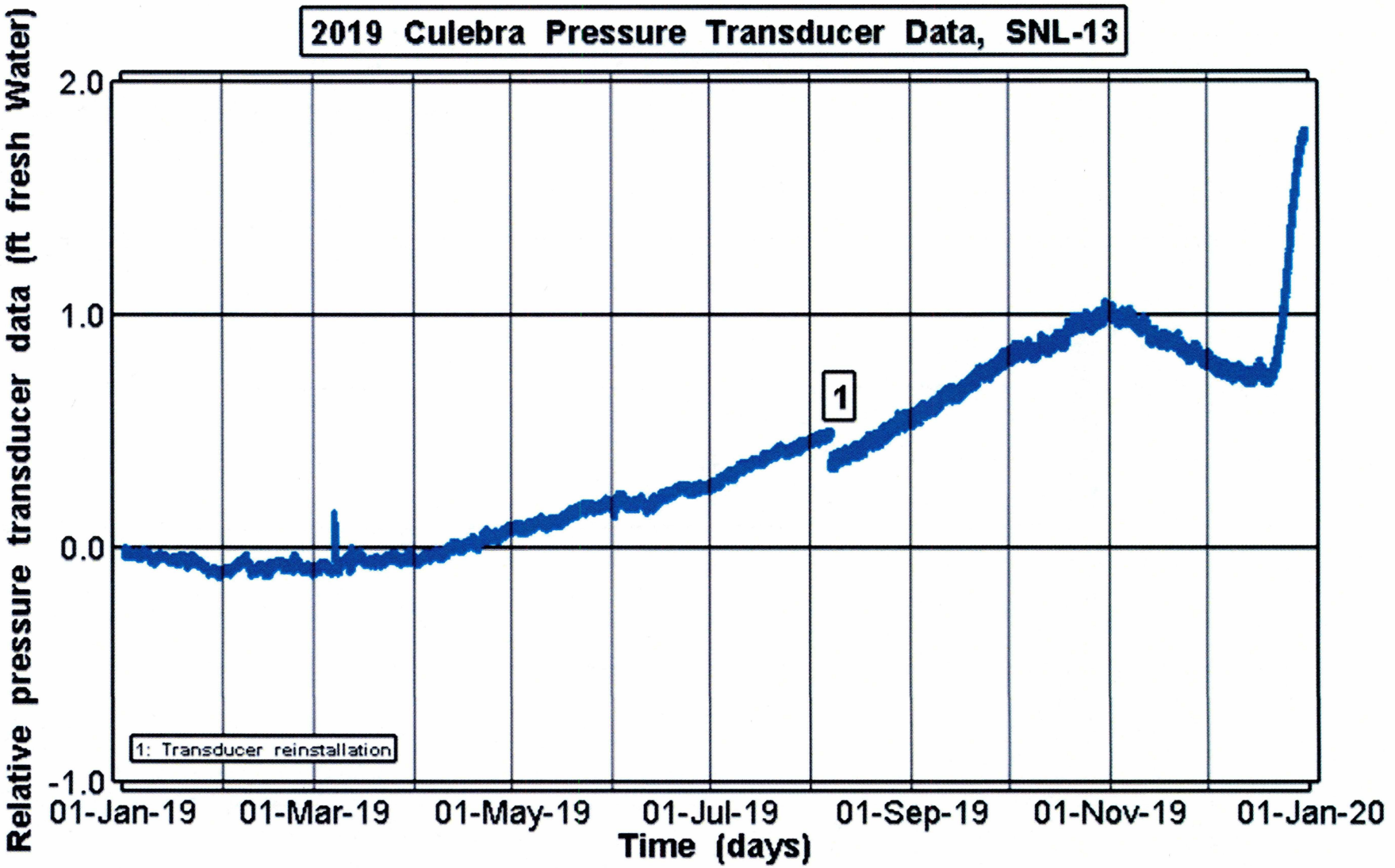

Figure 31. Well SNL-13 experienced a net change in hydraulic head of 1.79 ft fresh water in 2019. The well was recovering from previous years' pumping before being affected by NWR pumping.

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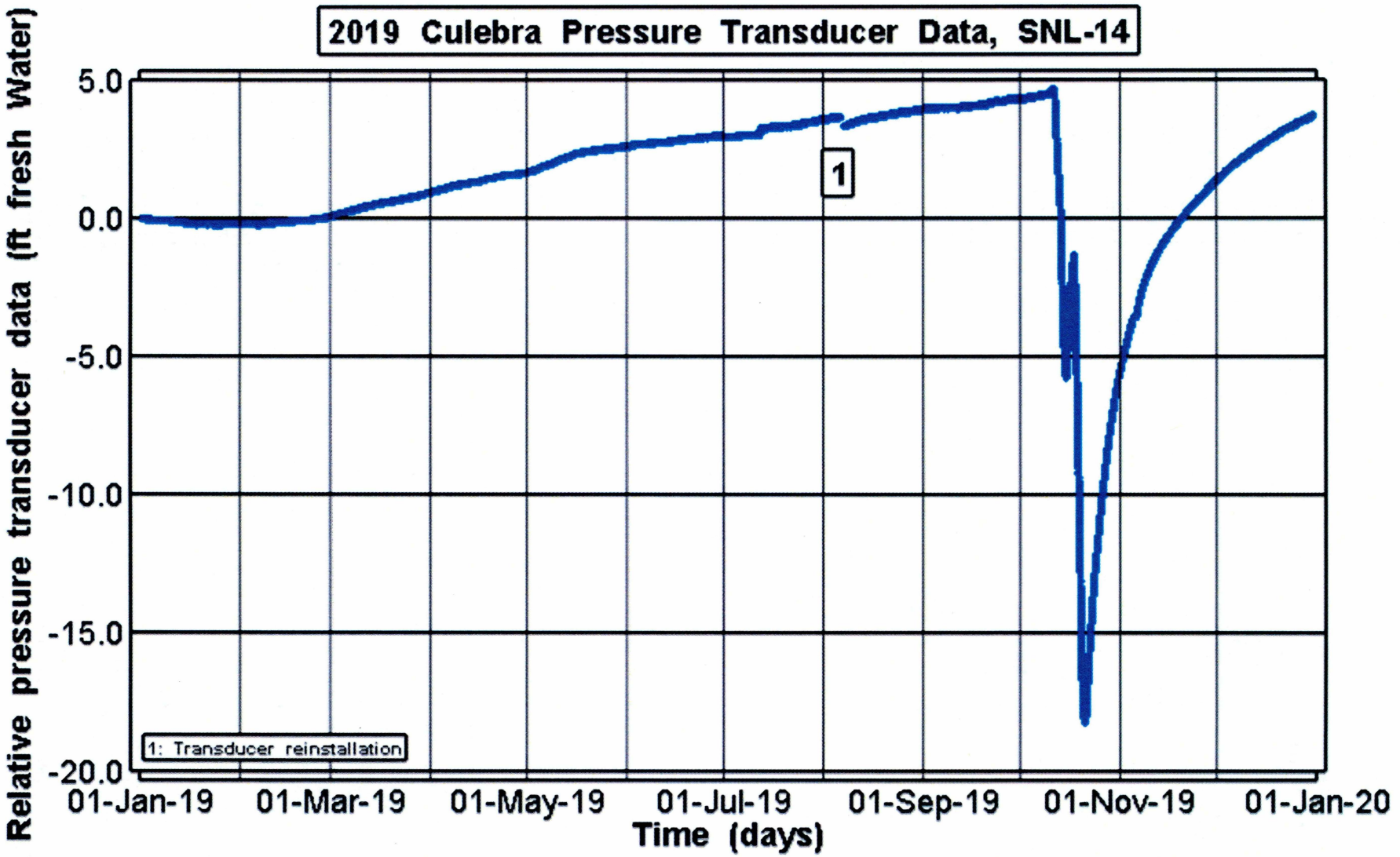

Figure 32. Well SNL-14 experienced a net change in hydraulic head of 3.70 ft fresh water in 2019. The well was recovering from previous years' pumping before being affected by NWR pumping.

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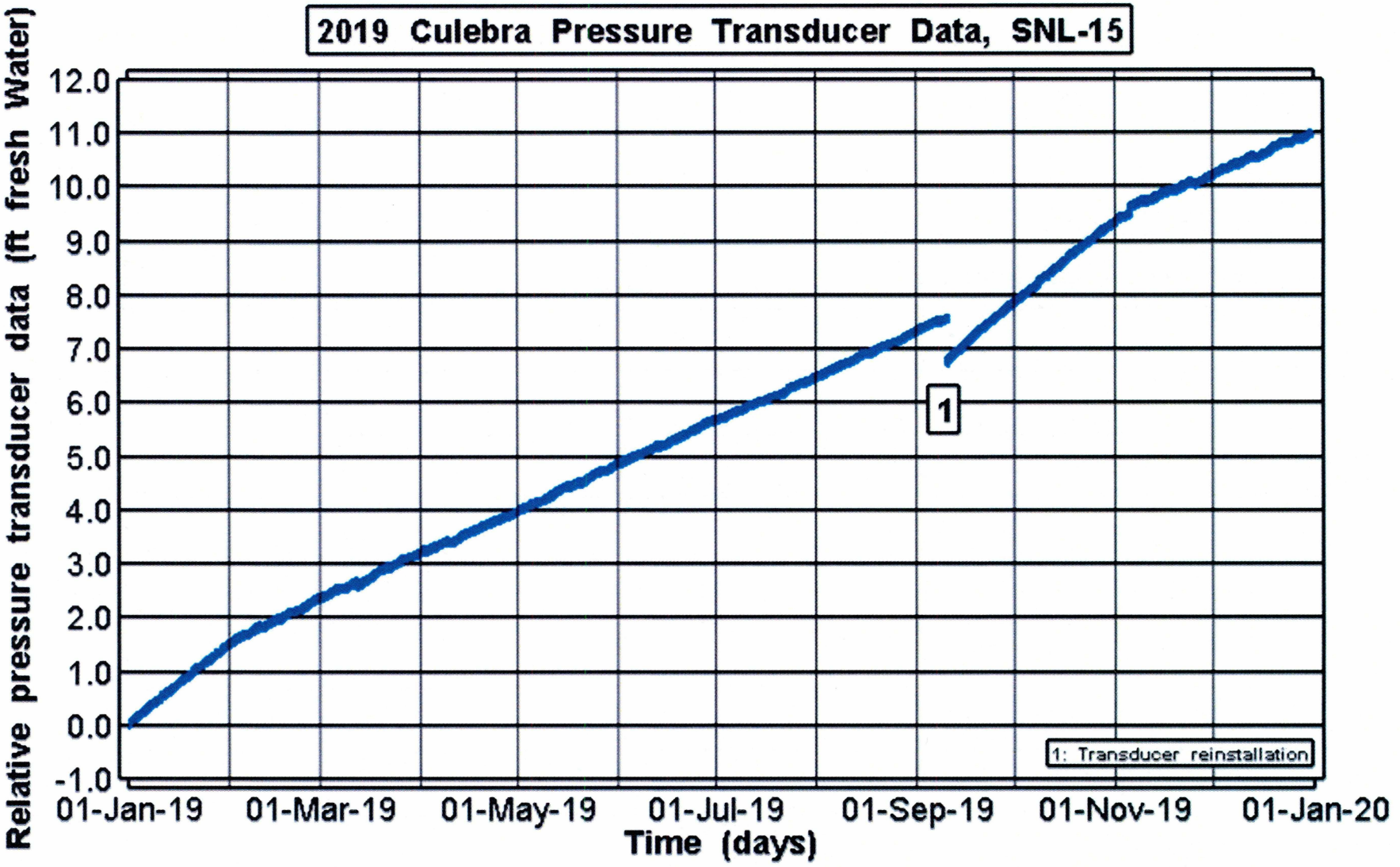

Figure 33. Well SNL-6 experienced a net change in hydraulic head of 11.00 ft fresh water in 2019. The well is in long-term recovery from well development.

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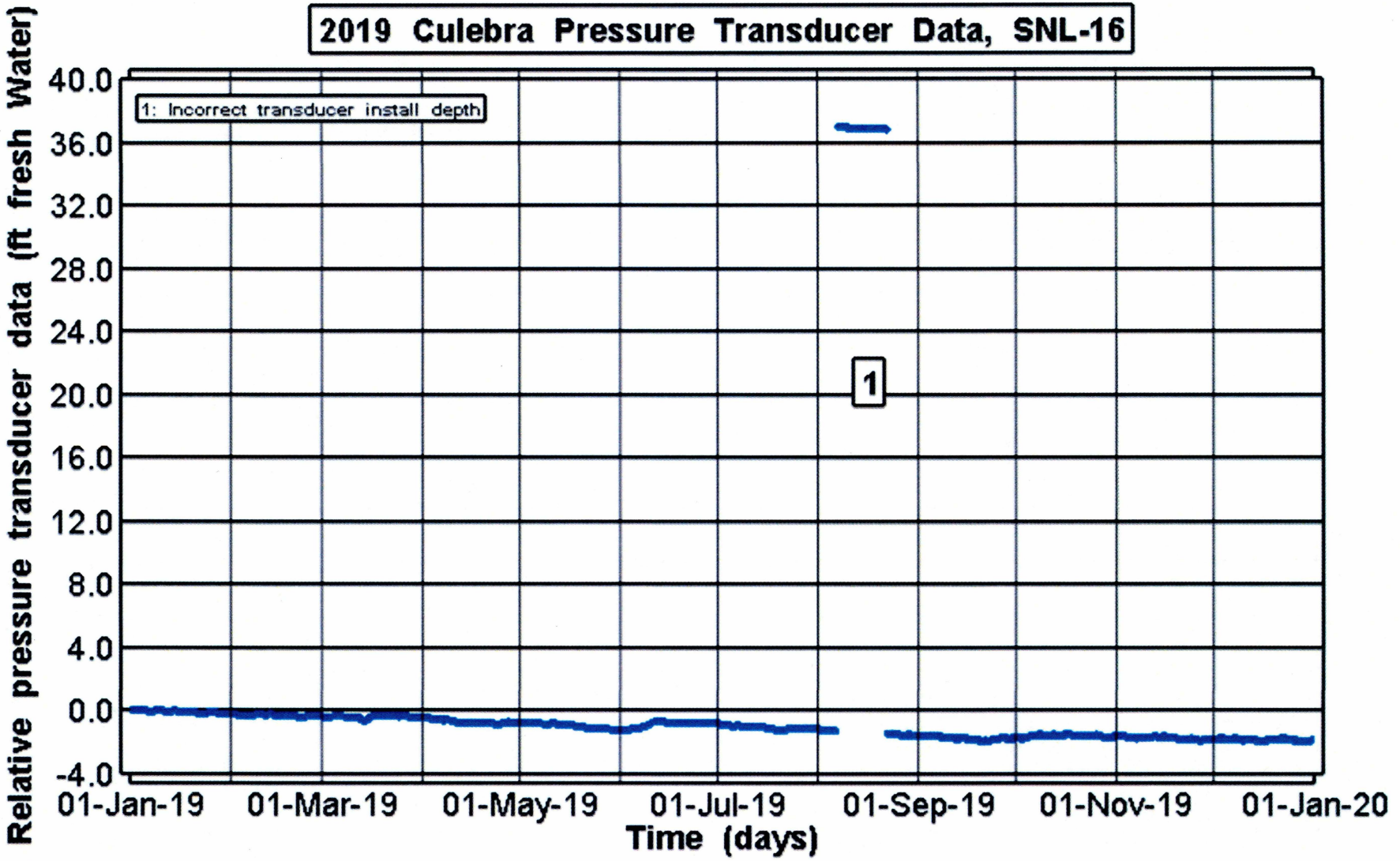

Figure 34. Well SNL-16 experienced a net change in hydraulic head of -1.88 ft fresh water in 2019. The well is affected by precipitation events.

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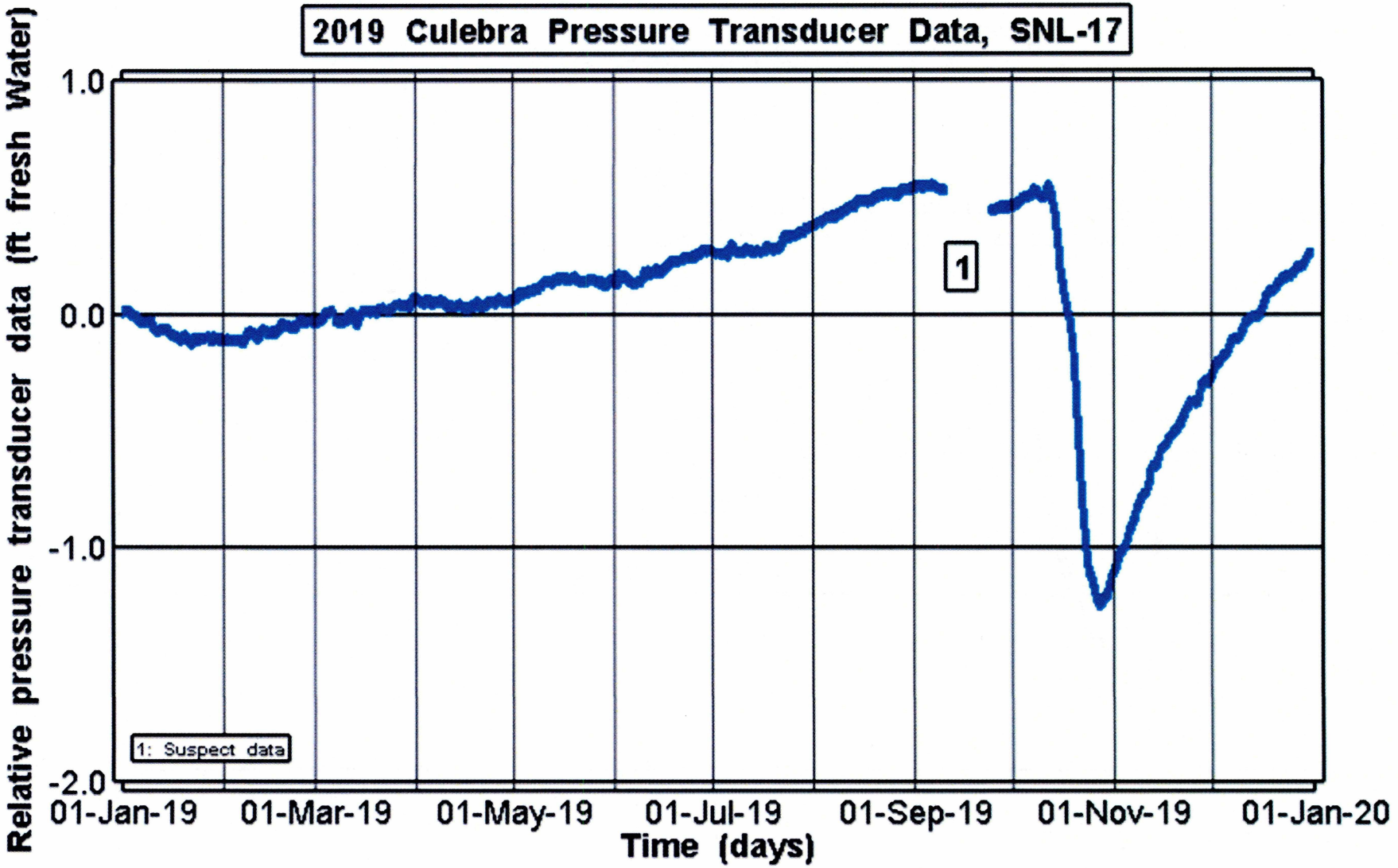

Figure 35. Well SNL-17 experienced a net change in hydraulic head of 0.25 ft fresh water in 2019. The well was recovering from previous years' pumping before being affected by NWR pumping. The suspect data is addressed CAR W-20-08.

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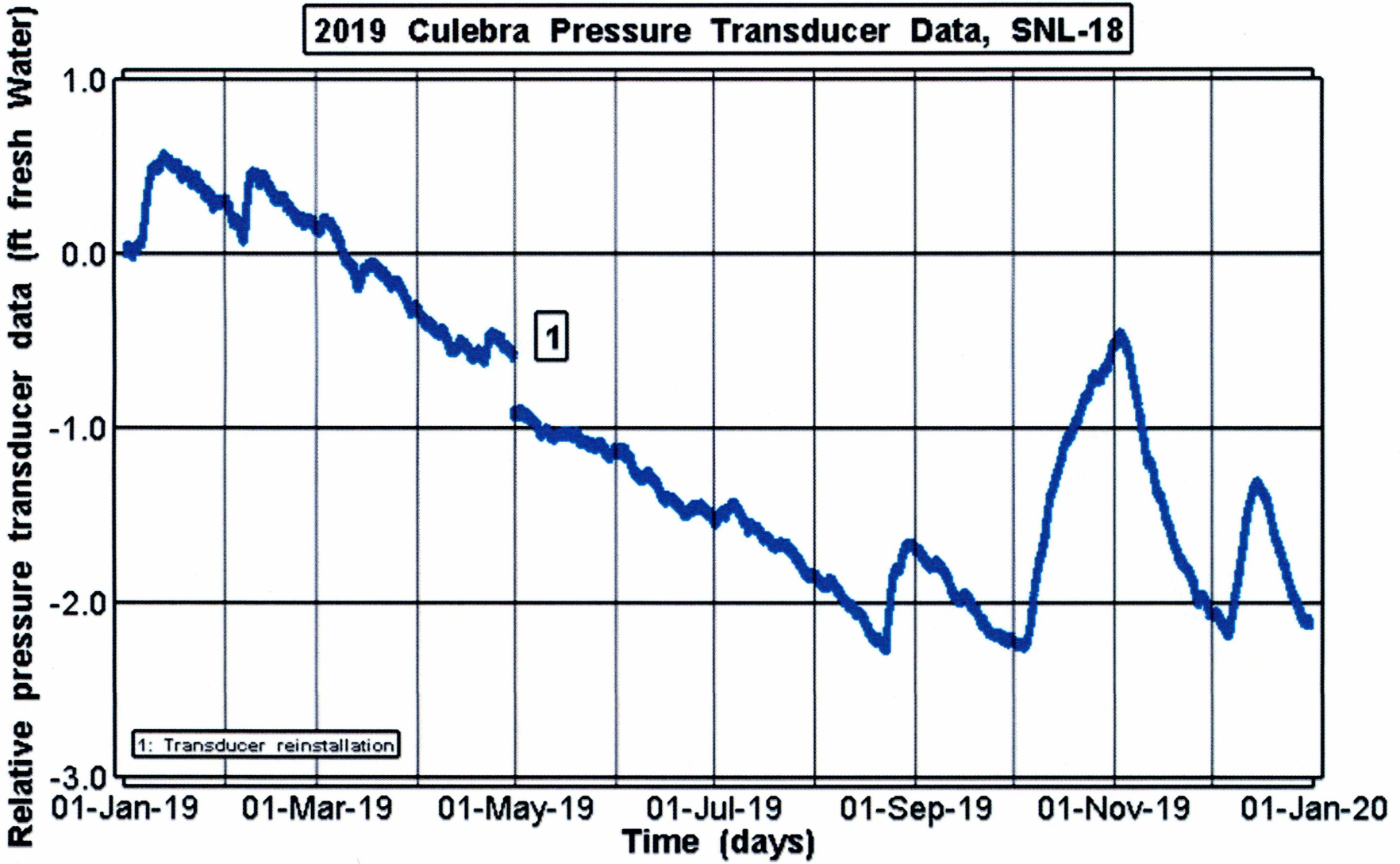

Figure 36. Well SNL-18 experienced a net change in hydraulic head of -2.12 ft fresh water in 2019. The well is affected by precipitation events.

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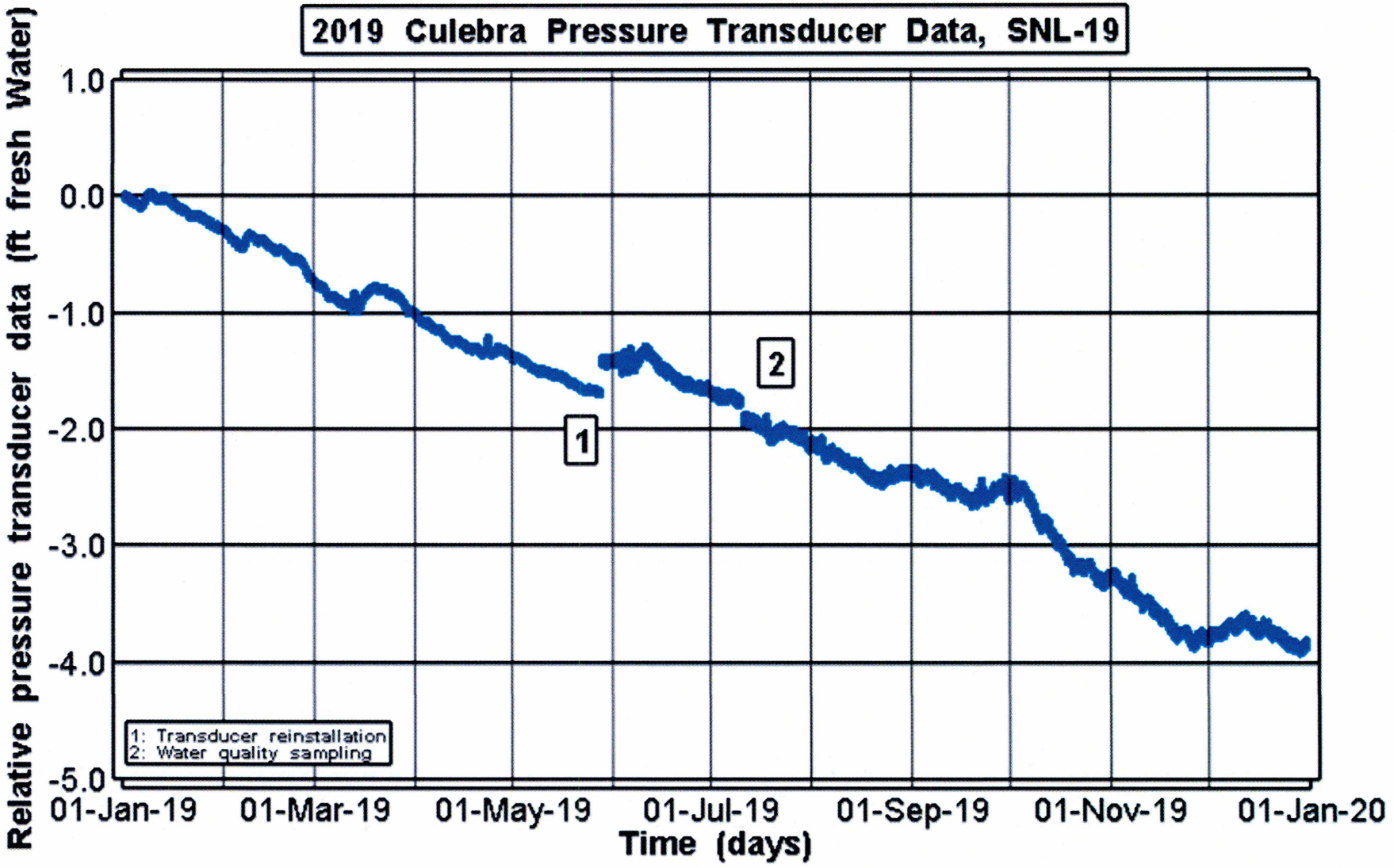

Figure 37. Well SNL-19 experienced a net change in hydraulic head of -3.84 ft fresh water in 2019. The well is affected by precipitation events.

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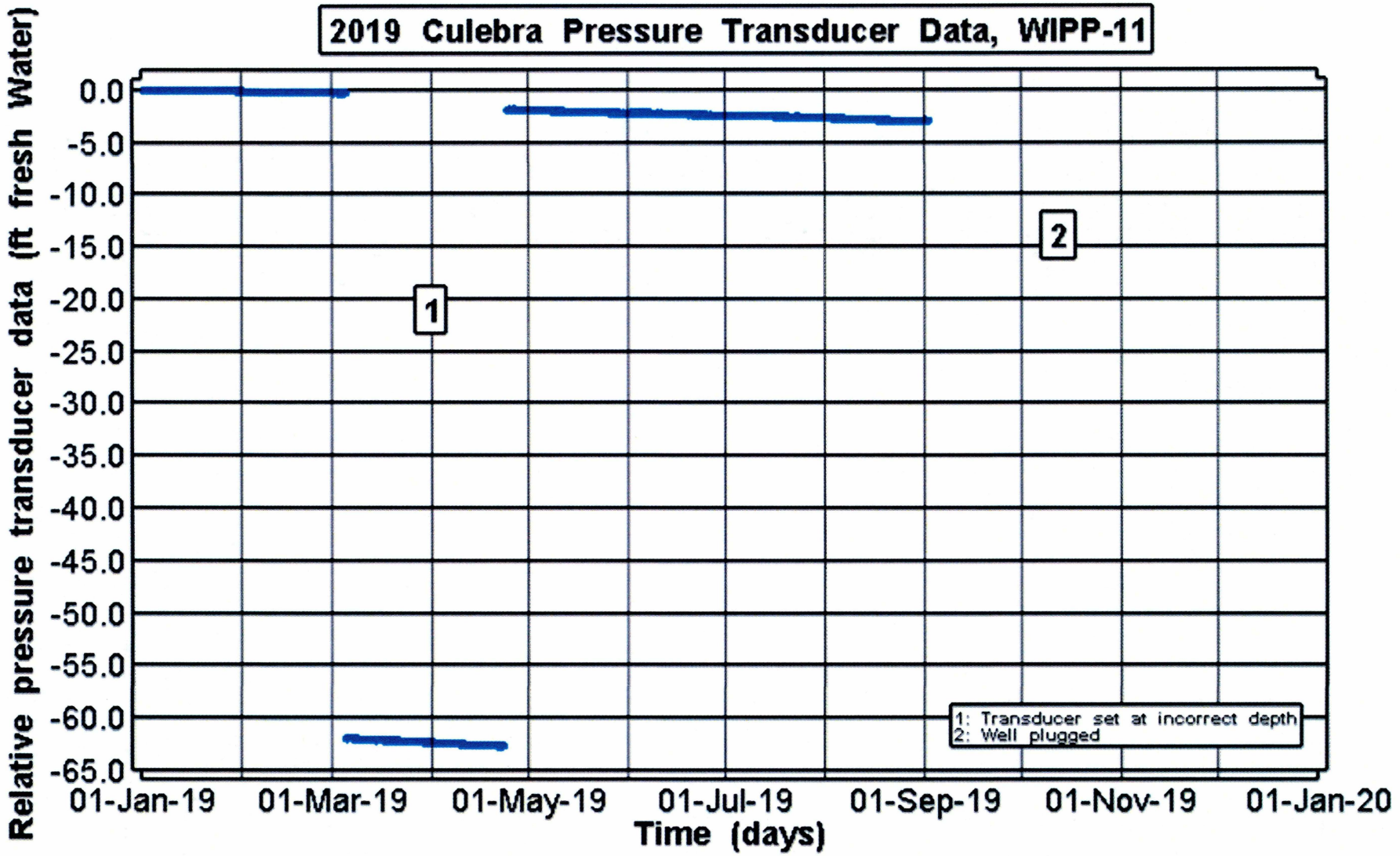

Figure 38. Well WIPP-11 experienced a net change in hydraulic head of -1.97 ft fresh water in 2019. The well is affected by precipitation events. The well was plugged in October 2019.

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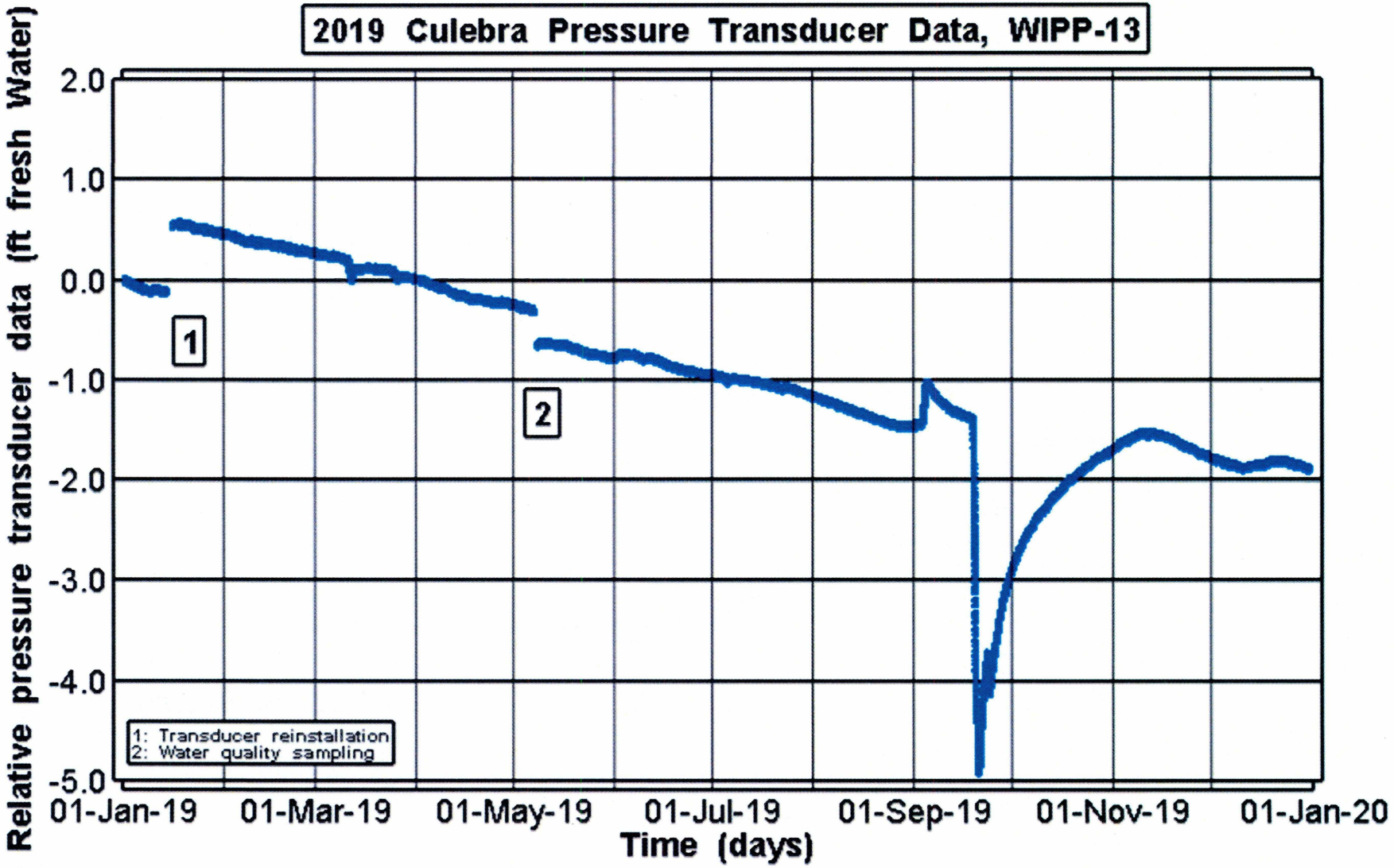

Figure 39. Well WIPP-13 experienced a net change in hydraulic head of -1.90 ft fresh water in 2019. The well is affected by precipitation events and well development at WIPP-11R.

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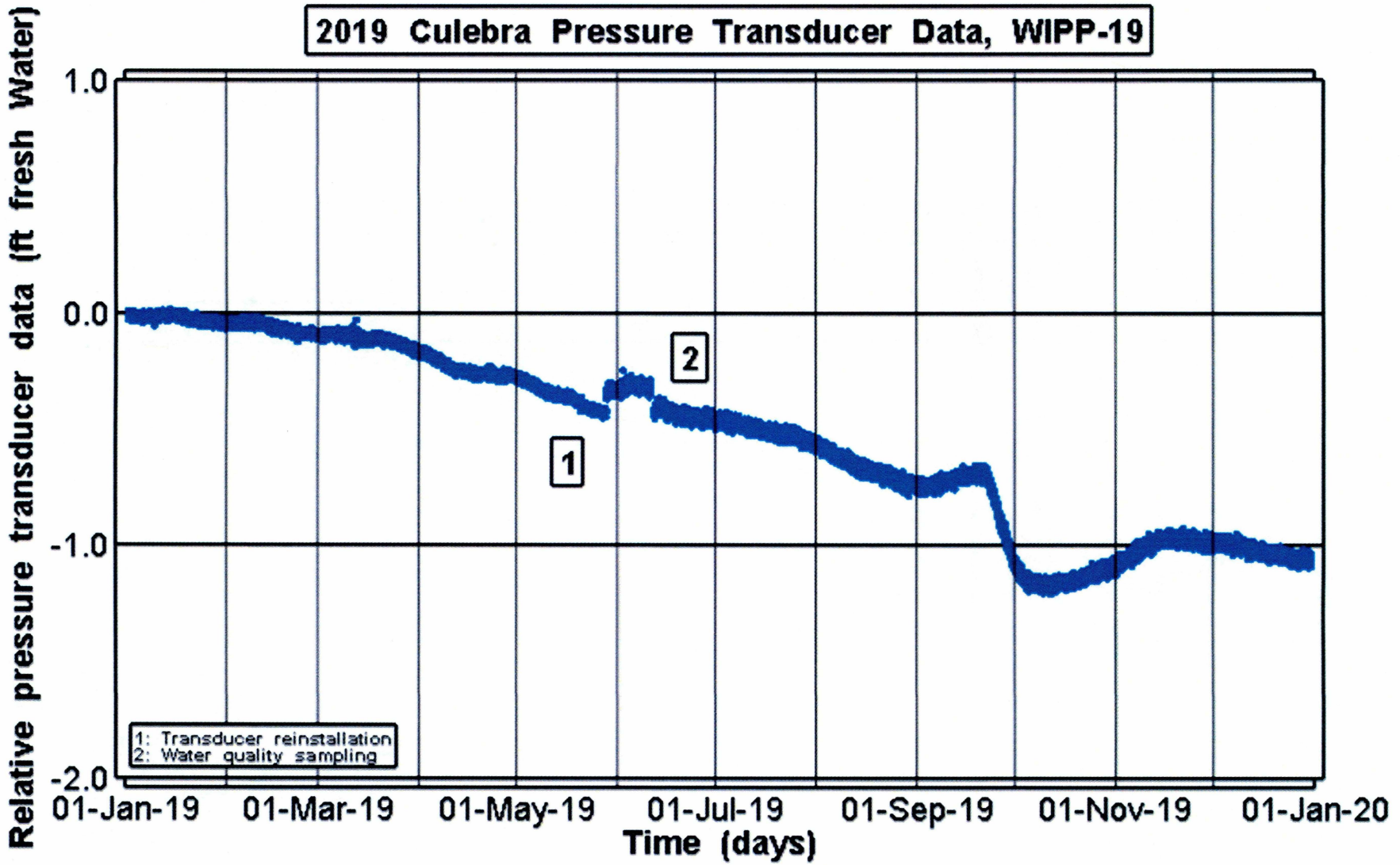

Figure 40. Well WIPP-19 experienced a net change in hydraulic head of -1.09 ft fresh water in 2019. The well is affected by gravity flow and well development at WIPP-11R.

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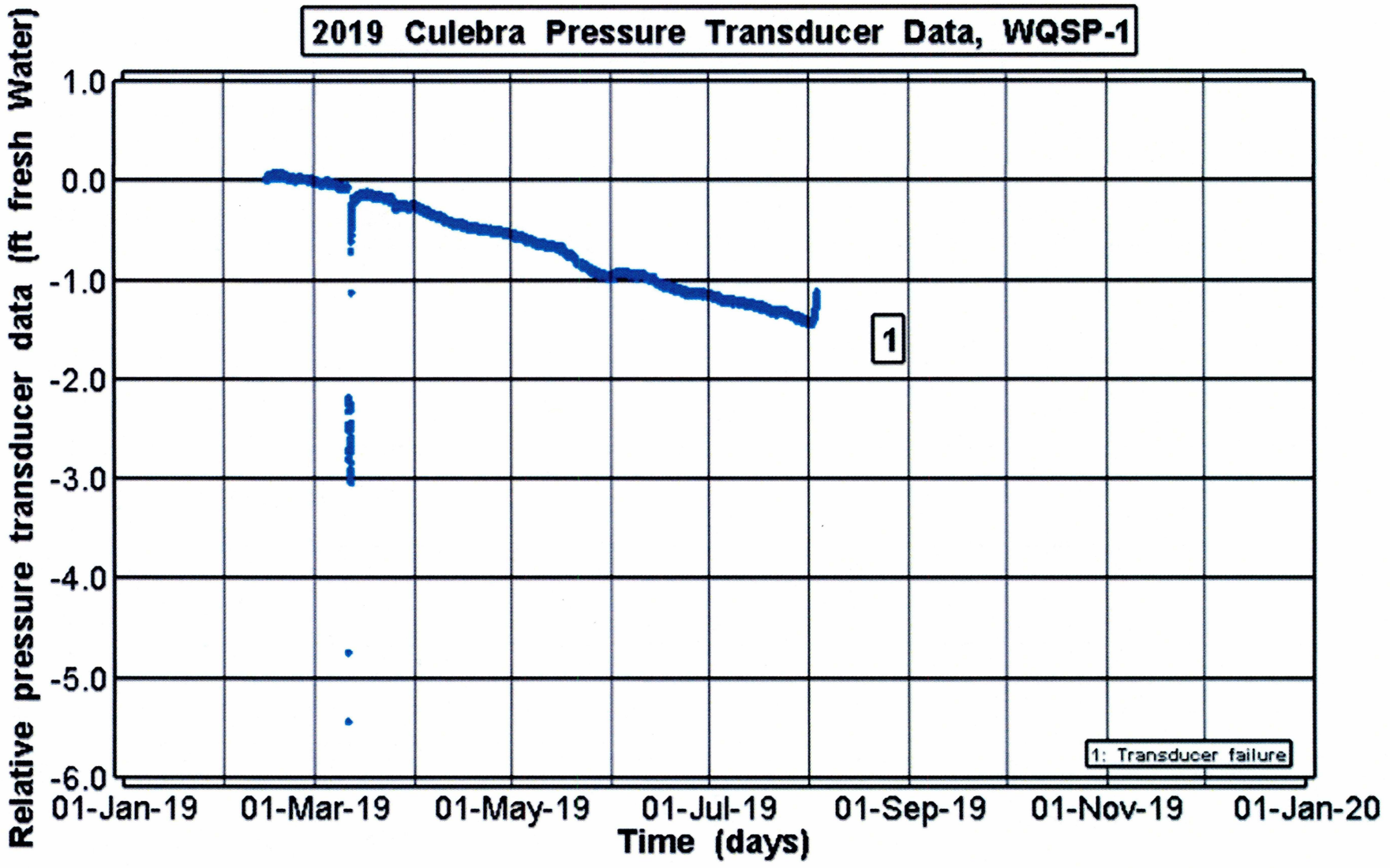

Figure 41. Well WQSP-1 experienced a net change in hydraulic head of -1.12 ft fresh water in 2019. The well was sampled in March 2019. Transducer failure is documented in CAR W-20-08.

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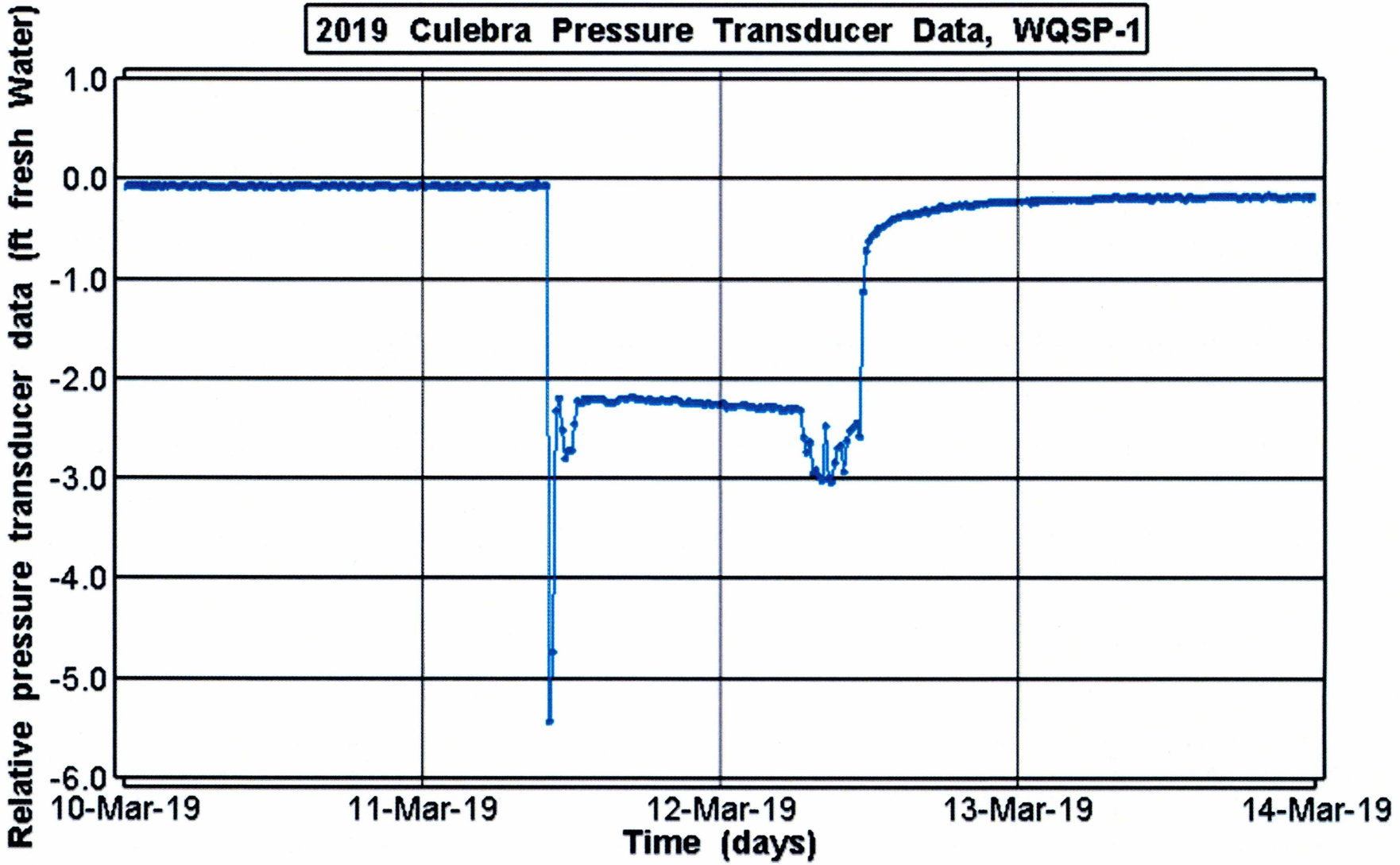

Figure 42. Head data for WQSP-1 over the time span of 3/10/19 to 3/14/19. The decrease in head is the result of pumping and water sampling by Regulatory and Environmental Services (RES).

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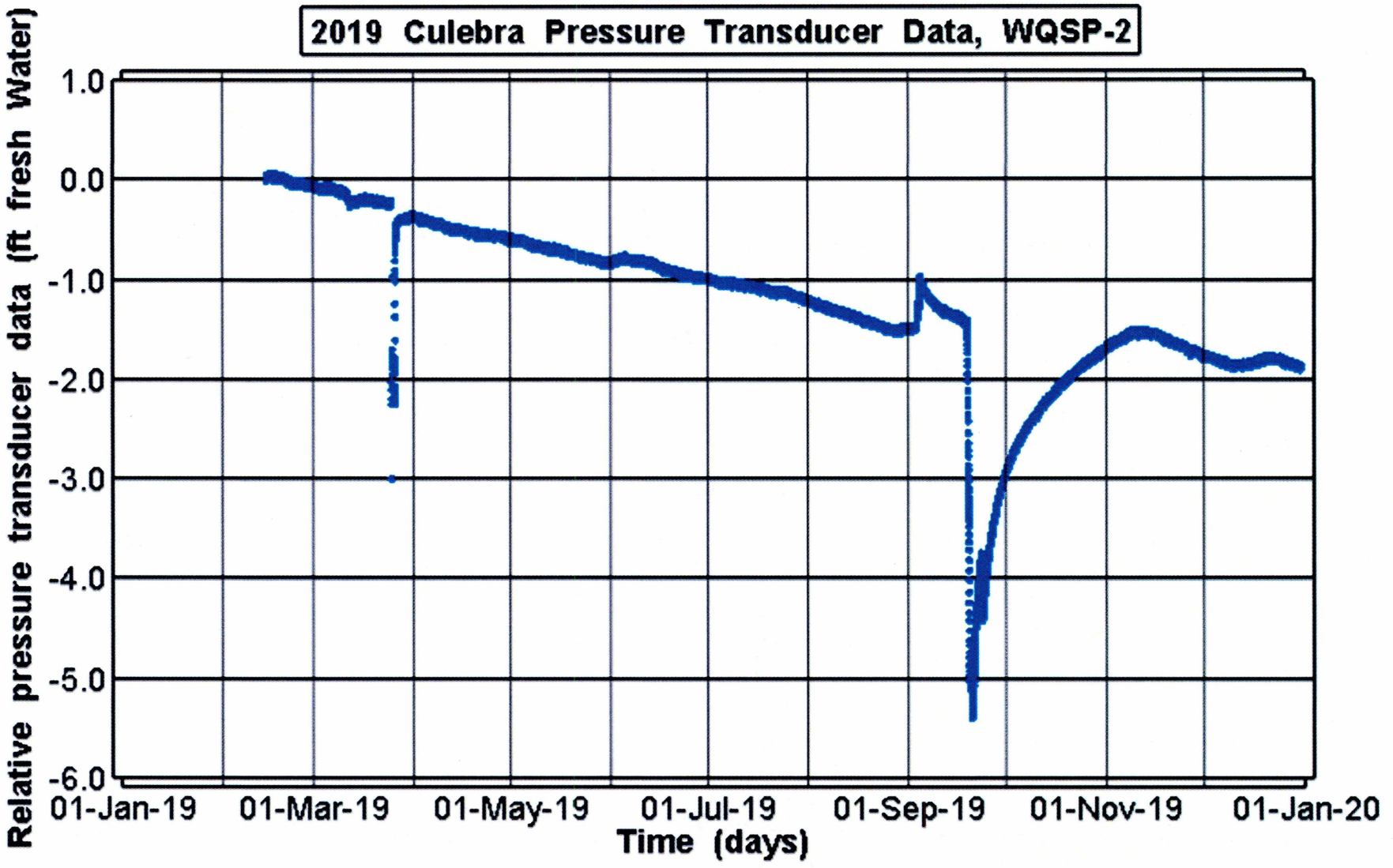

Figure 43. Well WQSP-2 experienced a net change in hydraulic head of -1.89 ft fresh water in 2019. The well was sampled in March 2019 and was affected by well development at WIPP-11R.

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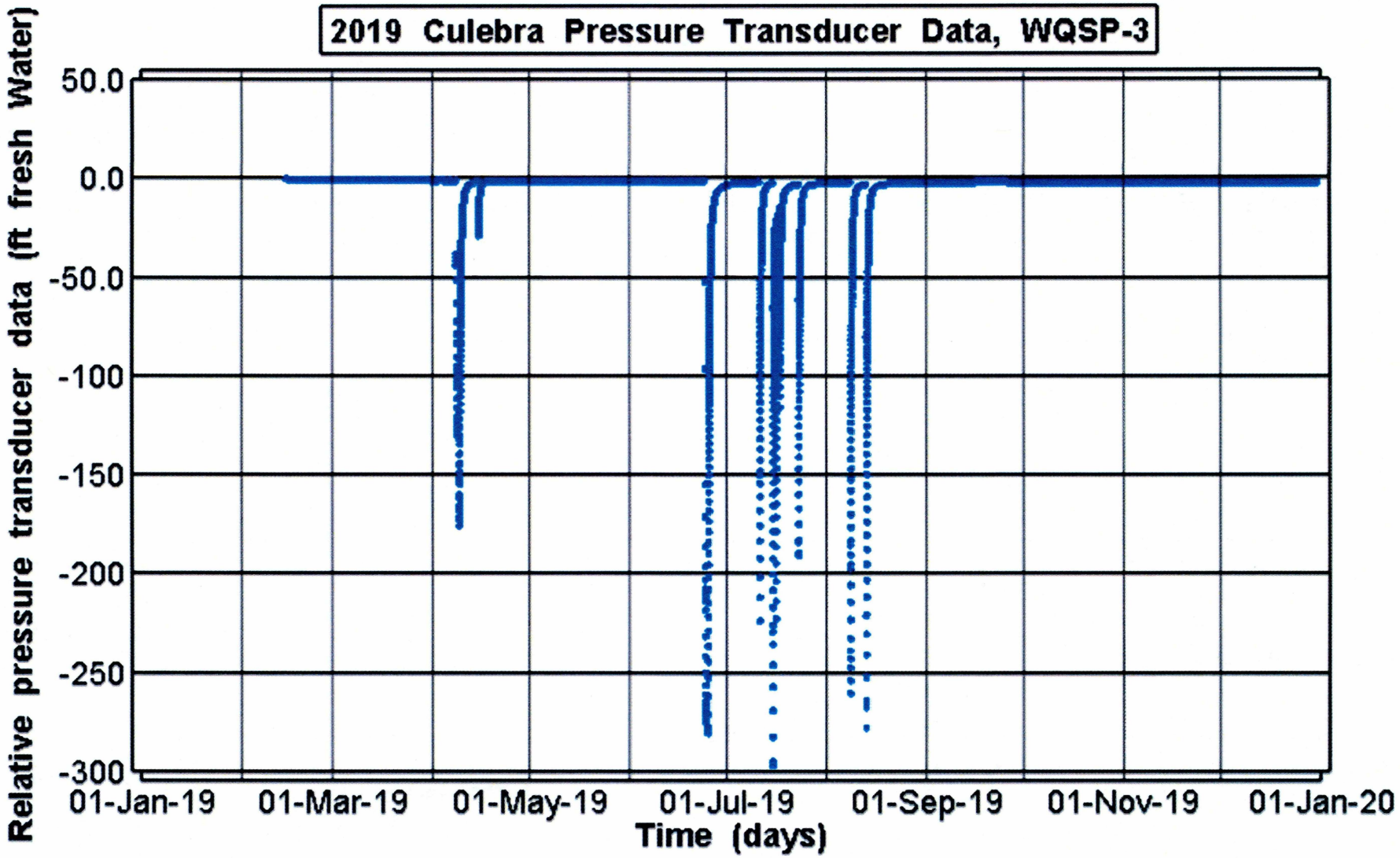

Figure 44. WQSP-3 experienced a net change in hydraulic head of -2.26 ft fresh water in 2019. The well was sampled in April 2019 and was pumped intermittently from June to August 2019.

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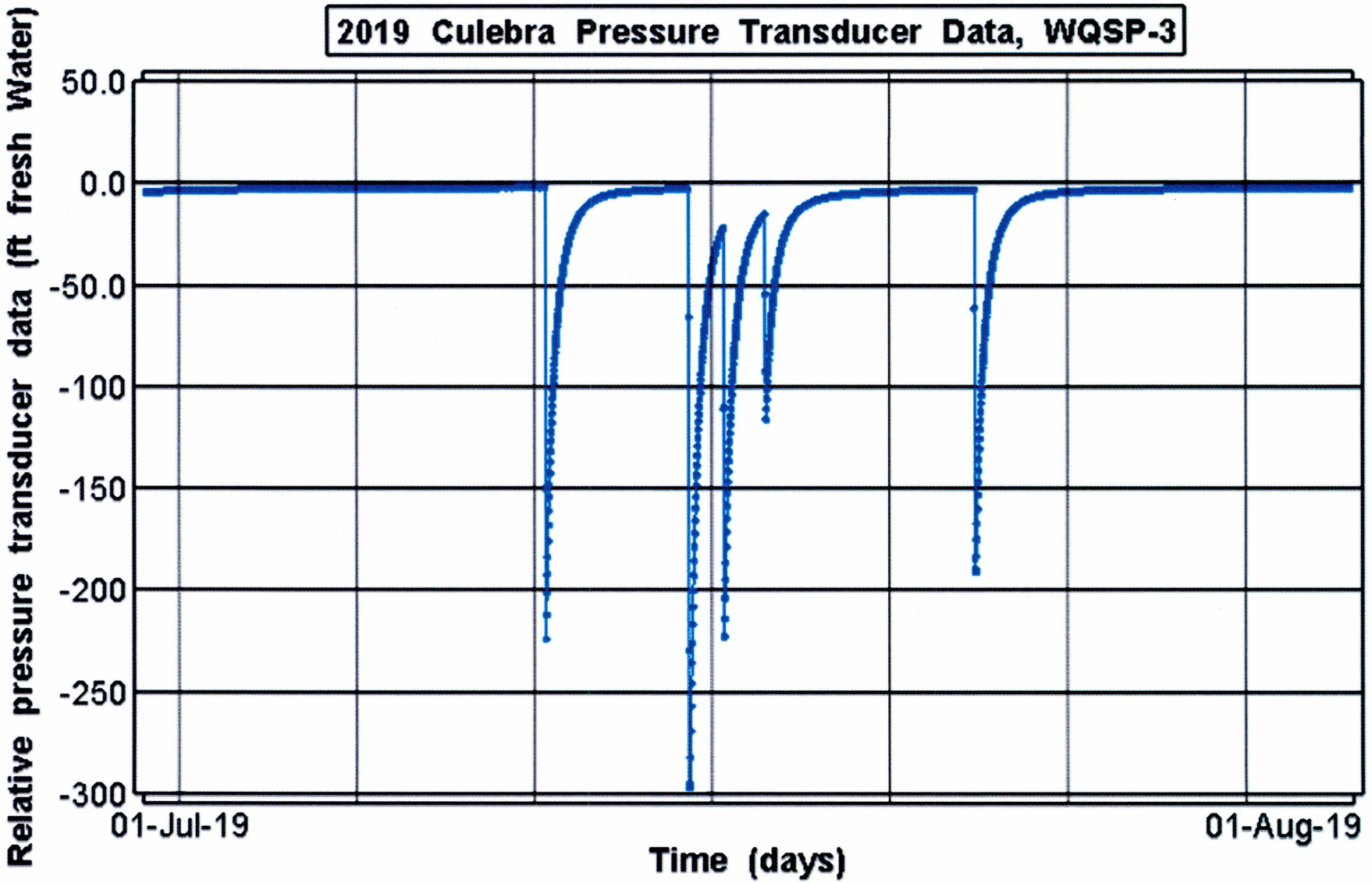

Figure 45. Head data for WQSP-3 for the month of July 2019. The decrease in head is the result of pumping and water sampling by RES. The other drawdown events throughout 2019 for this well are similar in nature.

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