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date: July 7, 2023

to: WIPP Records Center

from: Dale O. Bowman II.
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subject: Milestone HYDRO 23-02: Progress Report that Documents CY22 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 Dewey Lake shallow subsurface wells across the Waste Isolation Pilot Plant (WIPP) facility. Programmatic groundwater measurements focus primarily on the Culebra Member of the Rustler Formation, as 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 monitoring 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) 2022.

2.0 Introduction

In CY2022, SNL recorded pressure data across 37 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.2.41a (nSIGHTS 2013) in accordance with SP 9-

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13 Rev 1 (Bowman 2021). Data for each well are plotted individually and are also plotted in groups based on similarly sourced hydraulic head changes. A reference map of the Culebra monitoring well locations is shown in Figure 1. For completeness, Figure 1 also shows the Magenta monitoring well locations.

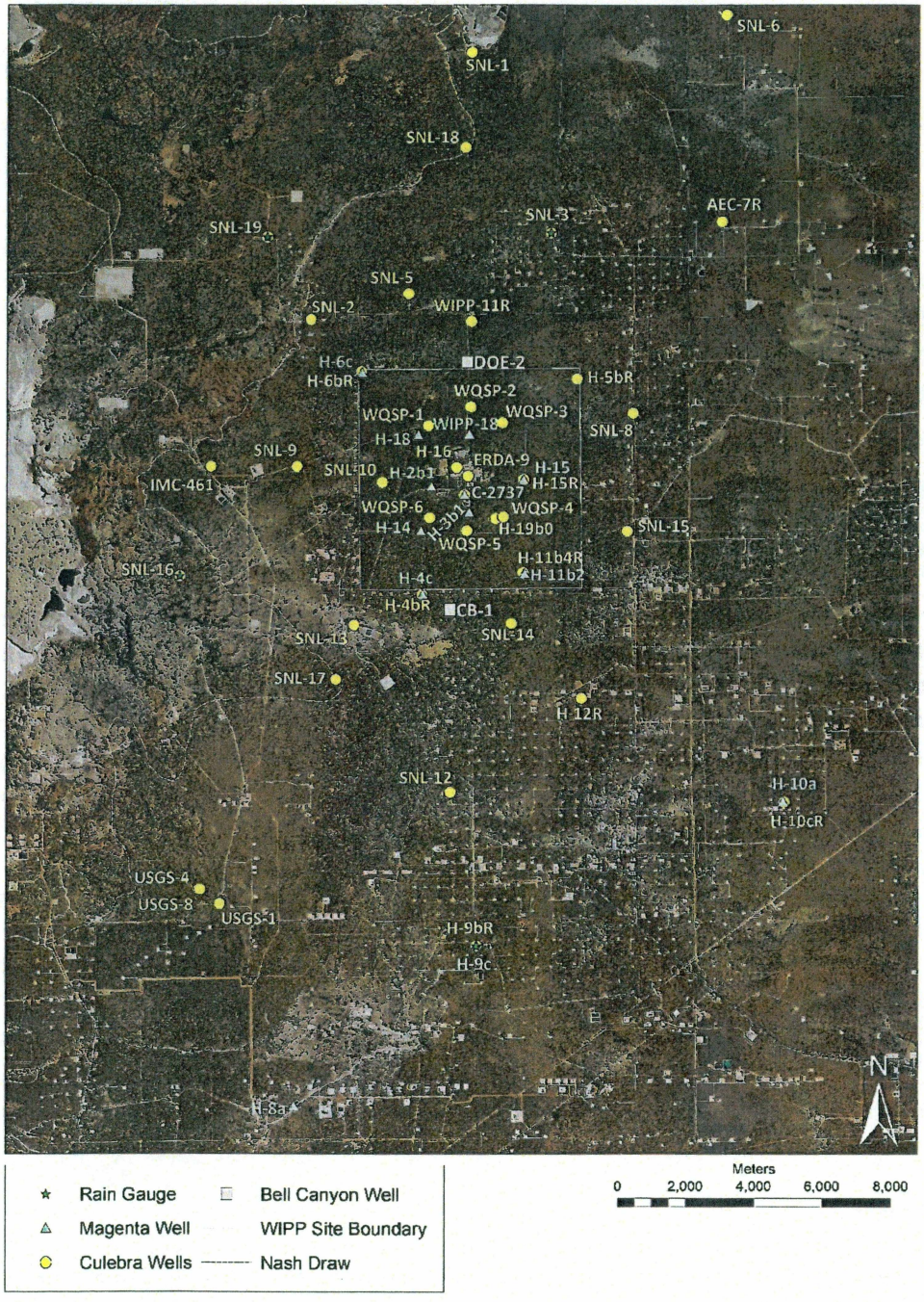

Figure 1. Locations of Culebra (yellow circles) and Magenta (blue triangles) wells in the WIPP Groundwater Monitoring Network. Well C-2737 is a dual completion in both the Culebra and Magenta. The Land Withdrawal Boundary (LWB) is outlined in grey, and the approximate boundary of Nash Draw is outlined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

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Hydraulic head fluctuations for several wells include shifts, spikes, or incongruities. These fluctuations are due to various causes including adjustments to transducer depths, displacement of water during removal and replacement of transducers, transducer failures, cable stretch, or the operation of other equipment in the well. Small-scale instances of this type are not discussed in this report. Specific large-scale comments about breaks in the data or anomalous data are given on individual plots, as appropriate.

Table 1 contains a list of all monitored Culebra wells in CY2022, as shown in Figure 1, and an abbreviated description of the dominant influence(s) (the most prevalent cause(s) of pressure 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 3.0. Table 2 contains the delta hydraulic head (Δ) and net change of hydraulic head (both in feet of fresh water) for CY2022. 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 CY2022. In circumstances where transducers were placed at different depths during CY2022 (i.e., SNL-6 in Figure 25), 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 head value after the transducer adjustment. These compensations are made solely for the calculations presented in Table 2.

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Table 1. Culebra Wells with Pressure Transducer Data for CY2022

Well	Precipitation	Leakage	NWRA	Water Quality Sampling	Gravity Flow	Long-Term Recovery	Well	Precipitation	Leakage	NWRA	Water Quality Sampling	Gravity Flow	Long-Term Recovery
AEC-7R					X		SNL-8					X	
C-2737	X	X					SNL-9	X				X	
ERDA-9		X					SNL-10					X	
H-4bR			X				SNL-12			X			
H-5bR					X		SNL-13					X	
H-6bR	X				X		SNL-14			X			
H-9bR					X		SNL-15						X
H-10cR					X		SNL-16	X		X			
H-11b4R			X				SNL-17A	X		X			
H-12R			X				SNL-18	X				X	
H-15R		X			X		SNL-19	X					
H-16		X					WIPP-11R					X	
H-19b0			X				WQSP-1				X		
IMC-461	X		X				WQSP-2				X		
SNL-1	X				X		WQSP-3				X		
SNL-2	X		X				WQSP-4				X		
SNL-3	X				X		WQSP-5				X		
SNL-5					X		WQSP-6				X		
SNL-6						X							

NWRA = Non-WIPP Related Anthropogenics

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Table 2. Culebra Hydraulic Head Fluctuations

Well	Δ Hydraulic Head (ft fresh water)	Net Change (ft fresh water)	Well	Δ Hydraulic Head (ft fresh water)	Net Change (ft fresh water)
AEC-7R	2.04	1.11	SNL-8	1.98	-0.70
C-2737	13.77	-13.19	SNL-9	1.64	0.44
ERDA-9	21.92	-19.85	SNL-10	2.44	-1.68
H-4bR	6.44	-3.99	SNL-12	9.56	-6.60
H-5bR	12.57	-1.56	SNL-13	2.17	-0.90
H-6bR	1.06	-0.25	SNL-14	7.68	-6.05
H-9bR	16.05	-13.07	SNL-15	7.57	6.92
H-10cR	3.18	1.34	SNL-16	3.49	1.86
H-11b4R	6.98	-5.87	SNL-17A	3.13	-0.05
H-12R	19.48	-1.30	SNL-18	1.84	-1.61
H-15R	6.13	-4.58	SNL-19	1.35	-0.19
H-16	52.99	-52.56	WIPP-11R	1.98	-1.42
H-19b0	6.39	-5.42	WQSP-1	21.52	-0.70
IMC-461	3.01	0.73	WQSP-2	5.16	-1.08
SNL-1	1.18	-0.77	WQSP-3	219.83	-1.84
SNL-2	1.20	0.05	WQSP-4	36.81	-5.71
SNL-3	1.01	-0.49	WQSP-5	62.47	-5.19
SNL-5	1.77	-1.25	WQSP-6	135.69	-3.96
SNL-6	13.66	13.66			

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

All files associated with this analysis are stored on Sandia's Concurrent Versioning System in location: /cvs/CVSLIB/WIPP_EXTERNAL/SP913_CY22.

3.0 Dominant Influences Affecting Wells

3.1 Anthropogenic Influences

The anthropogenic impacts on the Culebra monitoring wells include:
- WQSP water quality sampling: pumping for water quality sampling at WQSP wells,
- Well maintenance activities: including development, replacement, and pumping activities,
- 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 CY2022, and
- Non-WIPP related anthropogenic affects.

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

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3.1.1 WQSP Water Quality Sampling

Sampling occurred between March and June 2022 for wells WQSP-1 through WQSP-6.

3.1.2 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). The SNL-6 net recovery is 13.66 ft freshwater head (Figure 25), the SNL-15 net recovery is 6.92 ft freshwater head (Figure 32).

3.1.3 Non-WIPP-Related Anthropogenic (NWRA) Affects

Six wells out of ten that responded to NWRA affects in CY2022 are displayed in Figures 2 and 3. Graphically, the events are separated into those that are associated with a singular large-scale NWRA event that began in April 2022 and those that are independent of that singular event. In April, there was a negative pressure event near well SNL-12 that lasted approximately two weeks followed by recovery for the rest of the calendar year. Two water wells presently located near this grouping of monitoring wells are the possible source of drawdown (NMOSE 2022). Well C-2258 (production) is located approximately 2 miles east of SNL-12 and it is owned by Devon Energy. Well C-2258 is the likely source of drawdown. The second well, BLM livestock well C-03351, is co-located on the same well pad as SNL-14, but as the drawdown is of greater magnitude at SNL-12, Well C-2258 is the more likely source of drawdown.

Well H-12R was subject to the most prominent positive pressure events in May and July of 2022, which did not largely affect other wells. Two oil wells (BELLOQ 11 2 FEDERAL STATE COM #611H, and ALEUTIAN 10 3 FEDERAL COM #814) were drilled in 2022 in proximity to the H-12 well pad in a similar time frame (EMNRD 2022). The remaining NWRA wells experience smaller, isolated effects.

3.1.4 Shaft Leakage Event

Four wells that responded to shaft leakage that began in January 2023 are displayed in Figure 4. ERDA-9 was plugged and abandoned after a net hydraulic head response of -19.85 ft fresh water. Well H-16 showed a hydraulic head response of -52.56 ft fresh water while wells C-2737, and H-15R showed less of a response as they are farther away from the shaft leakage event.

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 anthropogenic hydraulic head responses. The following sections discuss wells with responses dominated by natural processes.

3.2.1 General Water Level Decline

In 2021, water levels in most wells (26) had a net negative head change, and most wells that had a positive net head change for the year still had declining water levels. The net hydraulic head change in 2021 ranged from -16.72 to 9.38 ft fresh water. The decrease in water levels correlated with the

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drought status of Eddy County but also had possible contributions from far-field aquifer use. In 2022, we still see a decline in water levels, but in greater magnitude than in 2021. The net hydraulic head change in 2022 ranged from -52.56 to 13.66 ft fresh water. The data show a decrease in measured precipitation with an average inches of rain in 2022 of 9.07 inches of rain compared to 10.89 inches in 2021. The average precipitation in 2022 was largely due to an absence of recorded rain at SNL-19 until mid-November of 2022. Cumulative change in head in 2021 (excluding test/developed wells and wells that were plugged and abandoned) was -11.53 ft while in 2022 cumulative head change was -50.12 ft.

3.2.2 Precipitation

Eleven wells in the vicinity of Nash Draw show relatively immediate hydraulic head responses to precipitation events. Figure 6 correlates precipitation data collected from rain gauges on well pads, SNL-3, H-9bR, SNL-16, and SNL-19, to show hydraulic head responses to those precipitation events. The hydraulic head fluctuations for all eleven wells mentioned (C-2737, H-6bR, IMC-461, SNL-1, SNL-2, SNL-3, SNL-9, SNL-16, SNL-17A, SNL-18, and SNL-19) are consistent with precipitation fluctuations seen in previous years (Bowman & Hayes, 2019 and 2020).

3.2.3 Gravity Flow

Sixteen wells experienced minimal pronounced pressure data affects from precipitation or anthropogenic events (AEC-7R, H-5bR, H-6bR, H-9bR, H-10cR, H-15R, WIPP-11R, SNL-1, SNL-3, SNL-5, SNL-8, SNL-9, SNL-10, SNL-13, SNL-14, SNL-18). AEC-7R and SNL-8 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. Wells C-2737, H-6bR, SNL-1, SNL-2, SNL-3, SNL-9, and SNL-18 were all slightly affected by rain events in the region. Wells AEC-7R, H-5bR, H-10cR, WIPP-11R, SNL-1, SNL-2, SNL-3, SNL-5, SNL-8, SNL-9, SNL-10, SNL-13, SNL-17A, SNL-18, and SNL-19 all experienced net hydraulic head pressure changes that were less than +/- 2 ft of fresh water.

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 CY2022 were in wells being developed and sampled, followed by those affected by the July NWRA event. Most wells that have been predominantly affected by natural processes in past years continue to behave consistent with previous years' precipitation responses. CY2022 was a wetter year than 2021 in regard to precipitation, the water levels in a majority of the observation wells are still in decline.

Many of the pressure responses described in this report 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.

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Appendix 1

Appendix 1 contains both composite and individual graphs of hydraulic head data from Culebra monitoring wells. Gaps and/or inconsistencies that exist in the data are described in individual well graphs, and they were evaluated under NP 16-1, Rev 7, and addressed in a Corrective Action Requests (CARs) and Corrective Action Plans (CAPs), as needed.

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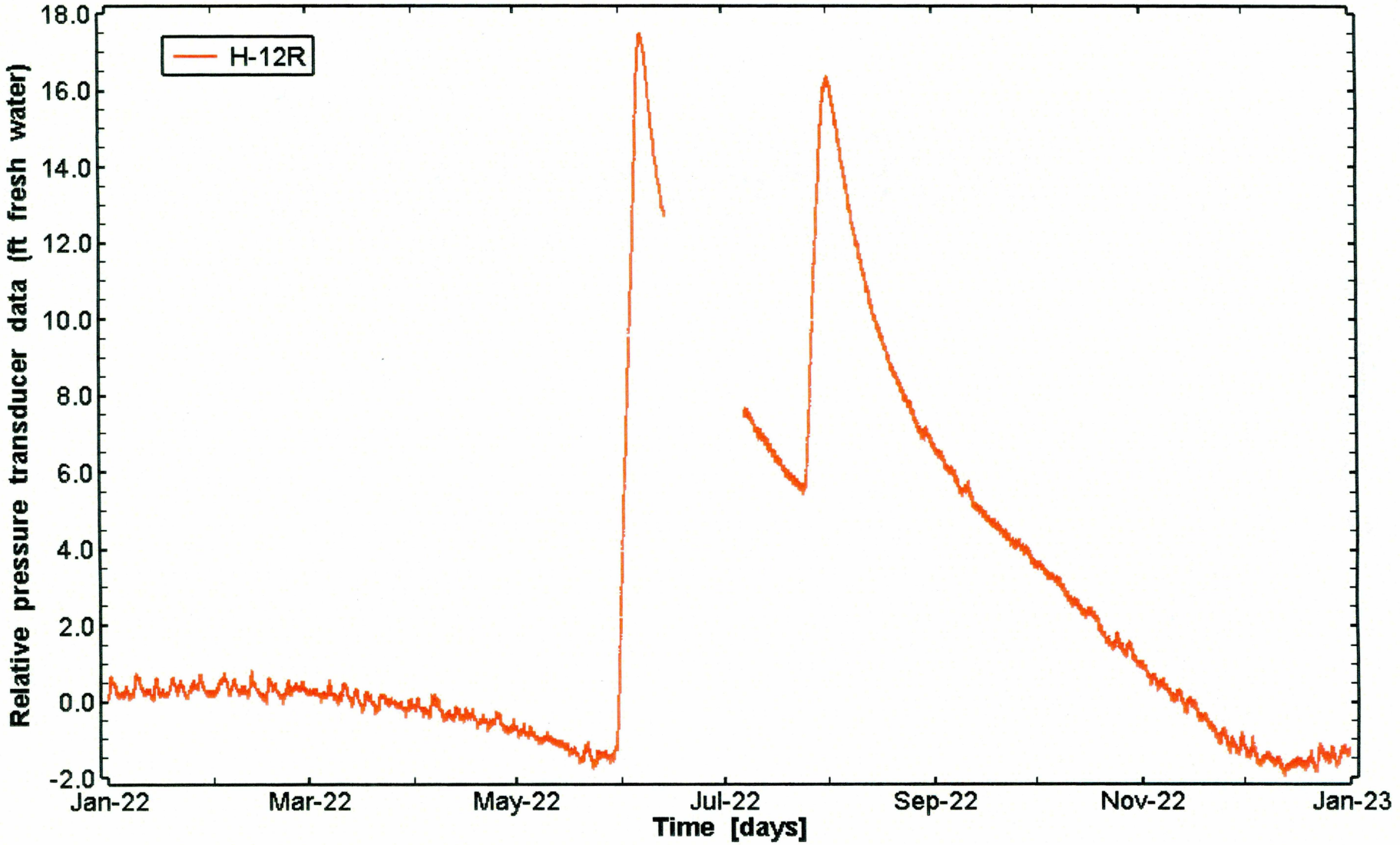

Figure 2. One well was affected by NWRA effects. Note: Data gap is identified in individual well graphs.

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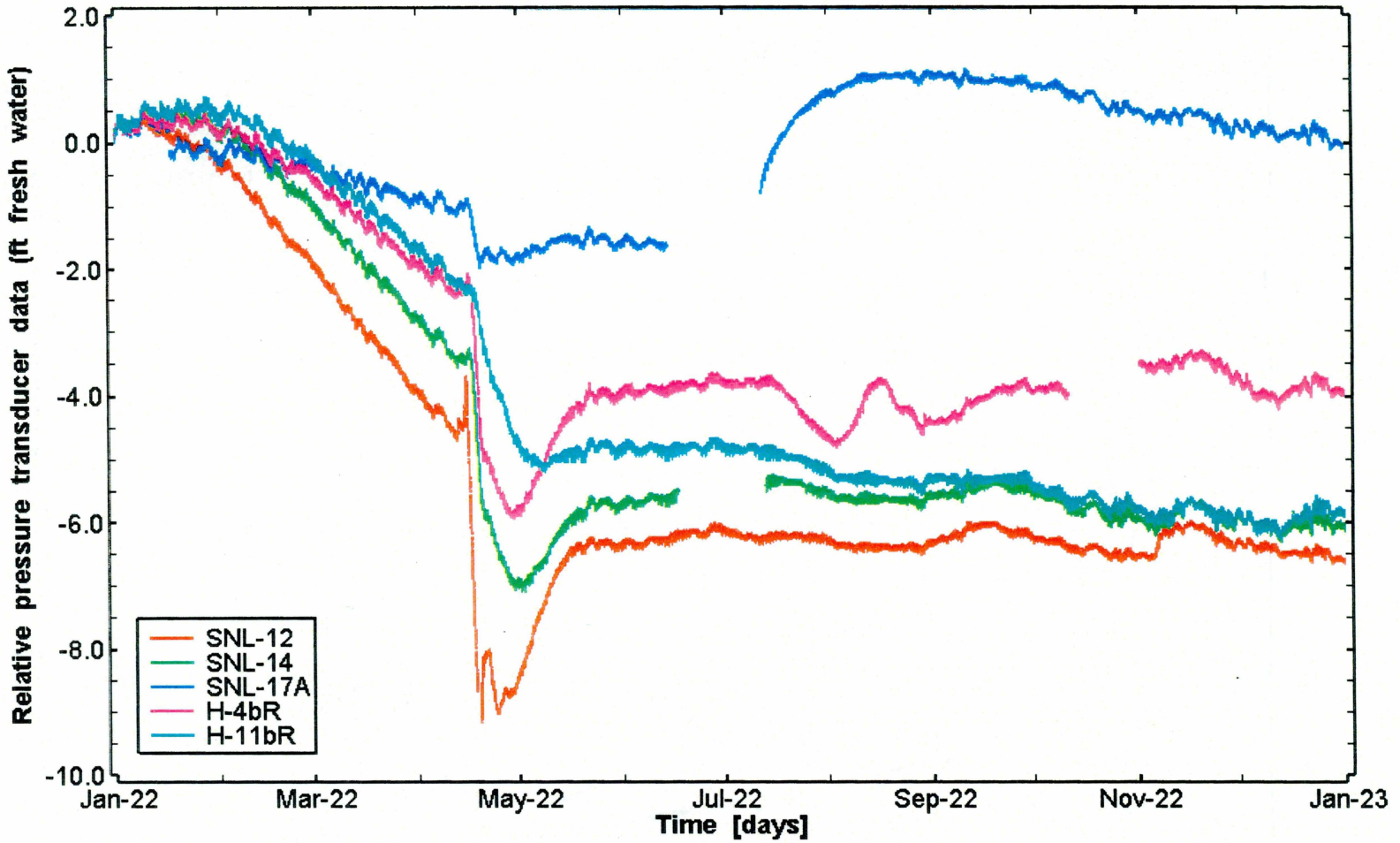

Figure 3. Five wells affected by a single NWRA event beginning in mid-April 2022. Data gaps are identified in individual well graphs.

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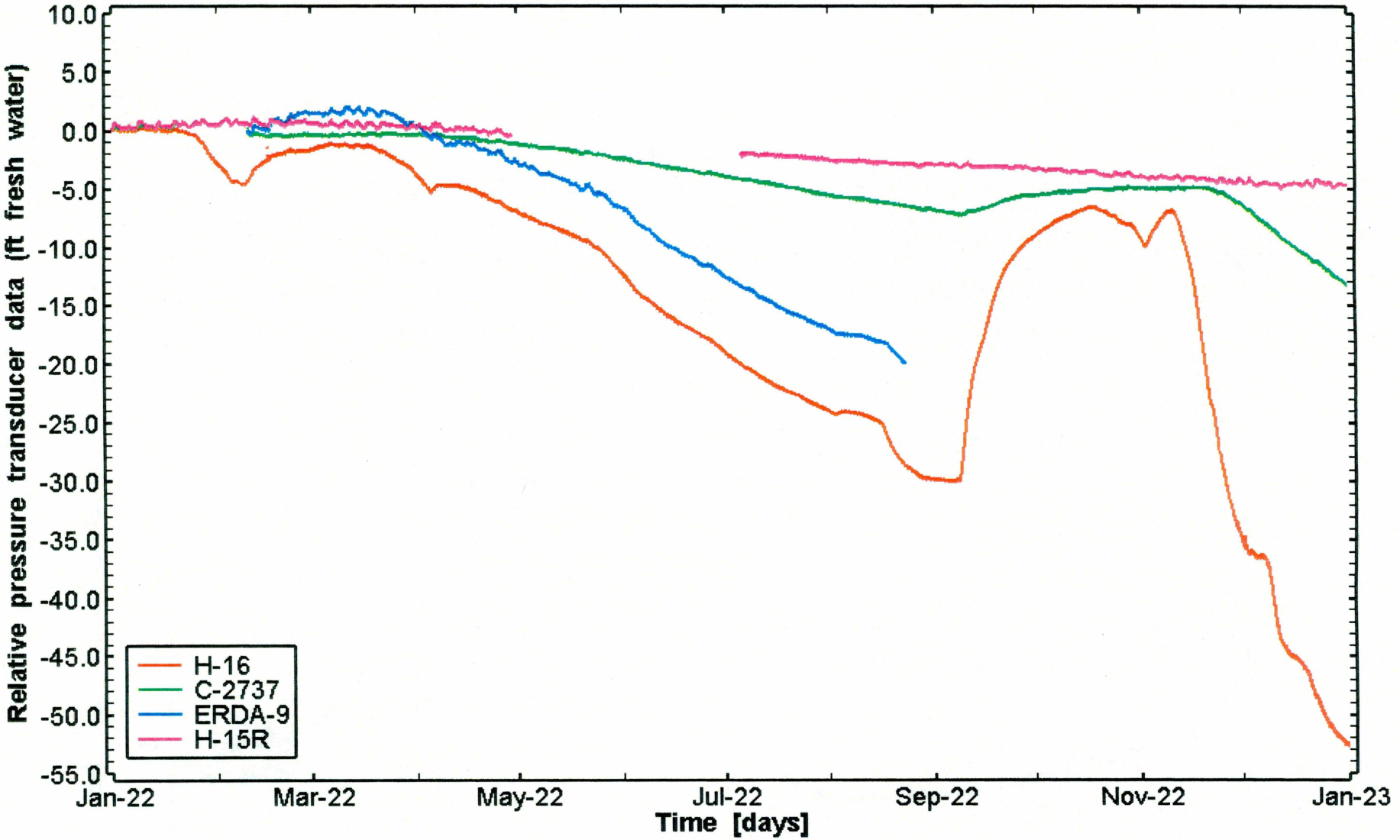

Figure 4. Four wells were affected by shaft leakage starting in early January 2022. Data gaps are identified in individual well graphs.

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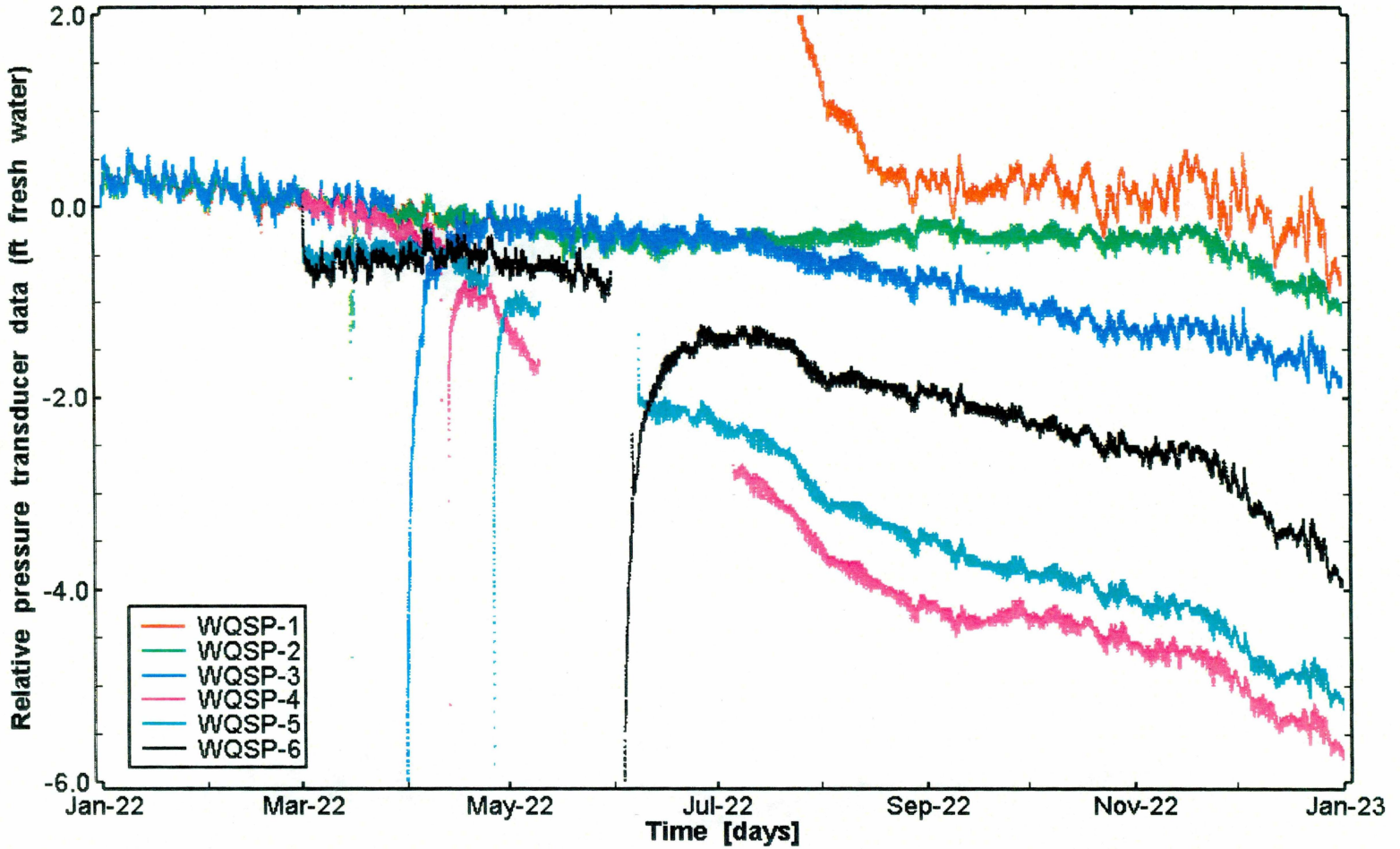

Figure 5. WQSP wells response. Data gaps are identified in individual well graphs.

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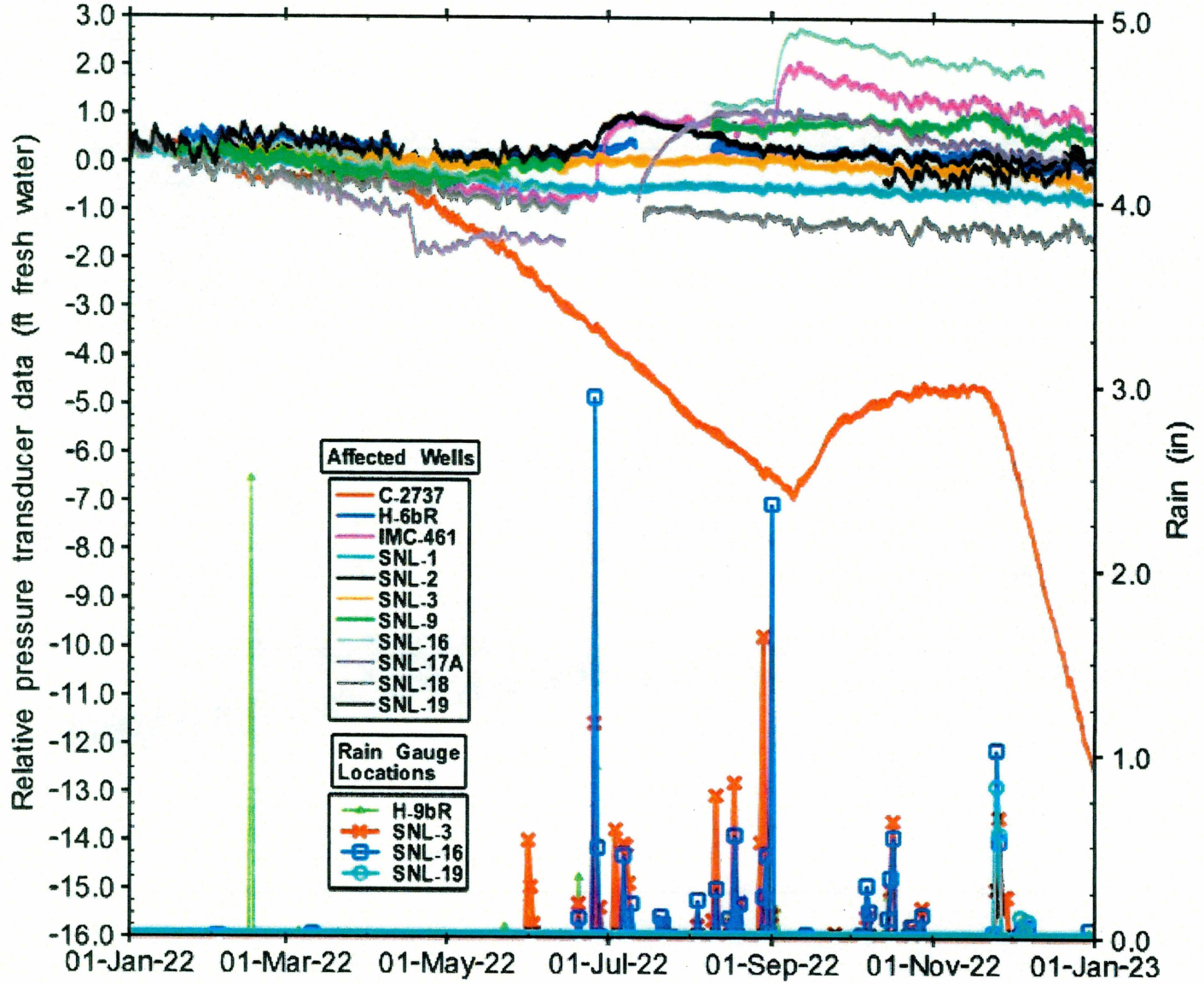

Figure 6. A group of eleven Culebra wells (C-2737, H-6bR, IMC-461, SNL-1, SNL-2, SNL-3, SNL-9, SNL-16, SNL-17A, SNL-18, and SNL-19) that demonstrate responses to precipitation events. Daily precipitation totals from four rain gauge sites are plotted as dotted lines.

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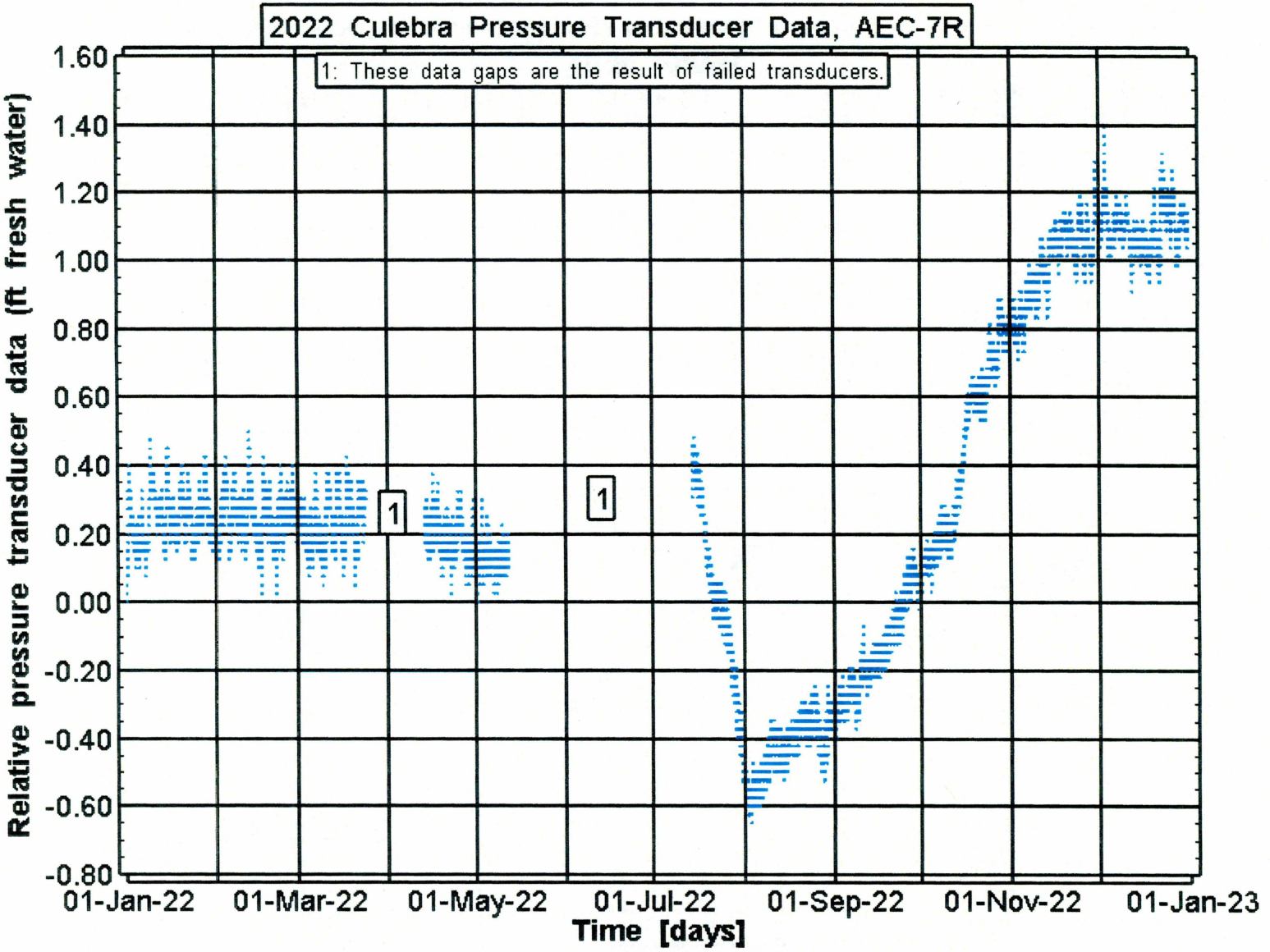

Figure 7. Well AEC-7R experienced a net change in hydraulic head of 1.11 ft fresh water in 2022.

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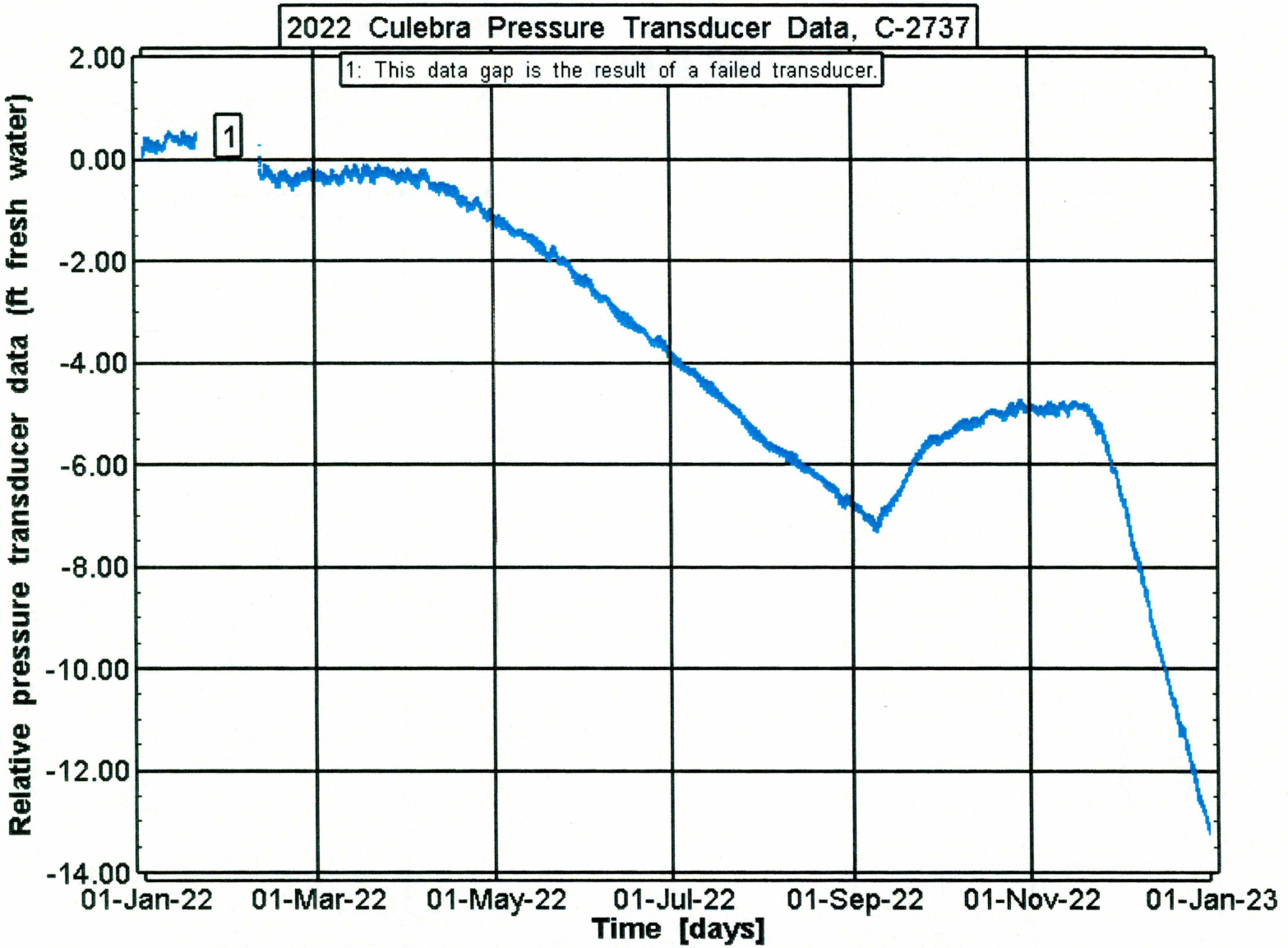

Figure 8. Well C-2737 experienced a net change in hydraulic head of -13.19 ft fresh water in 2022. This well was affected by shaft leakage.

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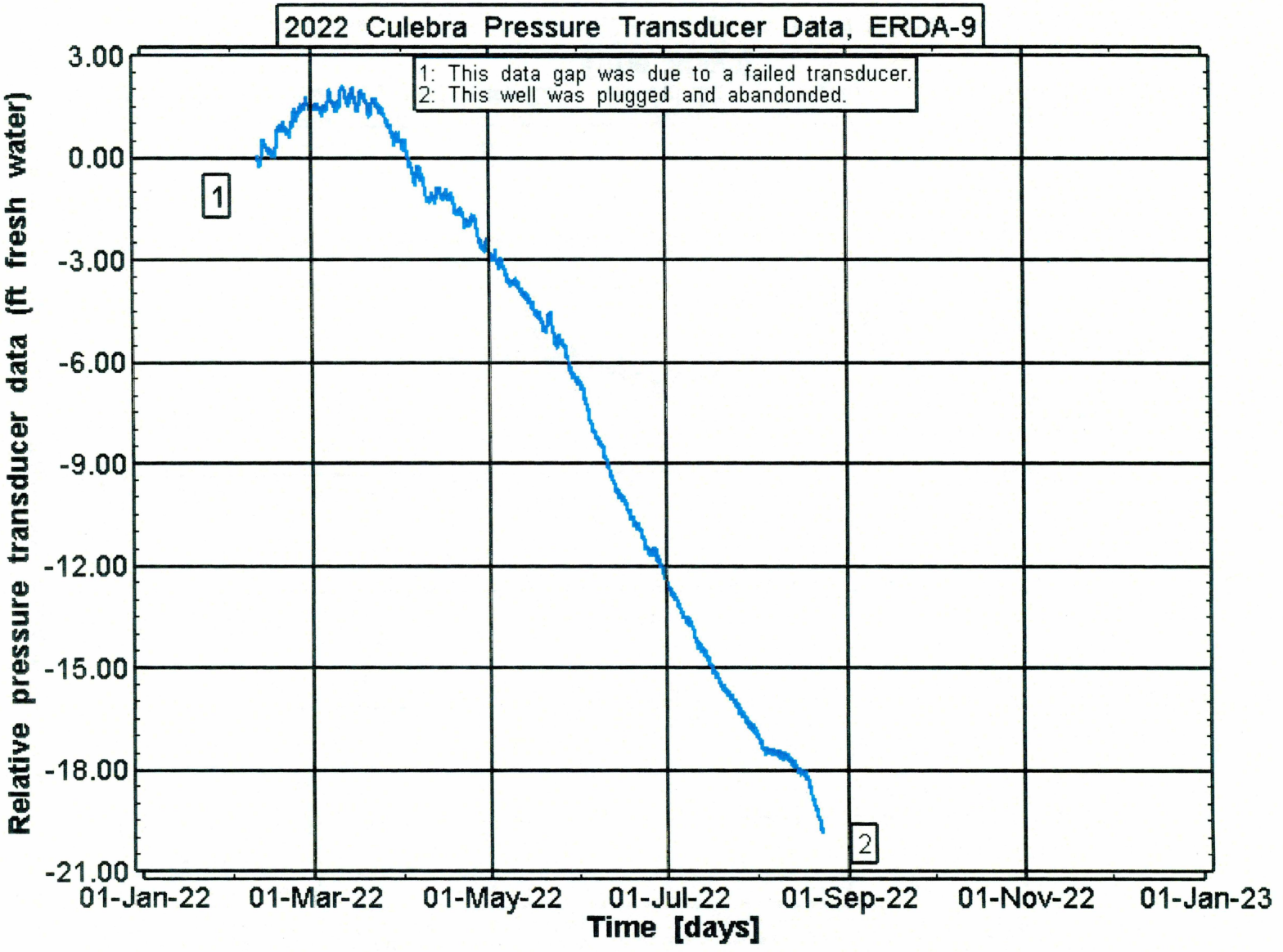

Figure 9. Well ERDA-9 experienced a net change in hydraulic head of -19.85 ft fresh water in 2022. This well was plugged and abandoned.

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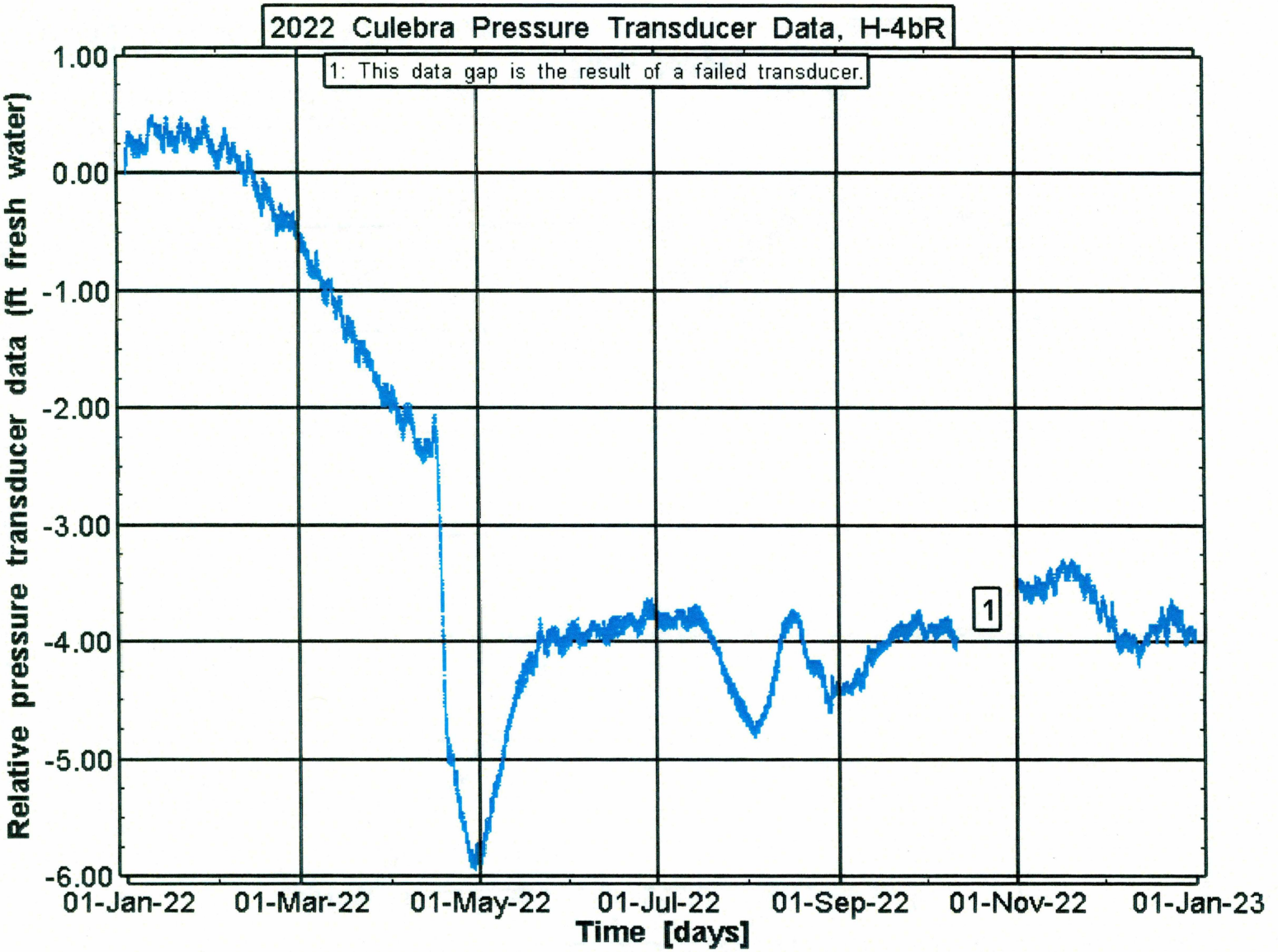

Figure 10. Well H-4bR experienced a net change in hydraulic head of -3.99 ft fresh water in 2022. This well was affected by NWRA.

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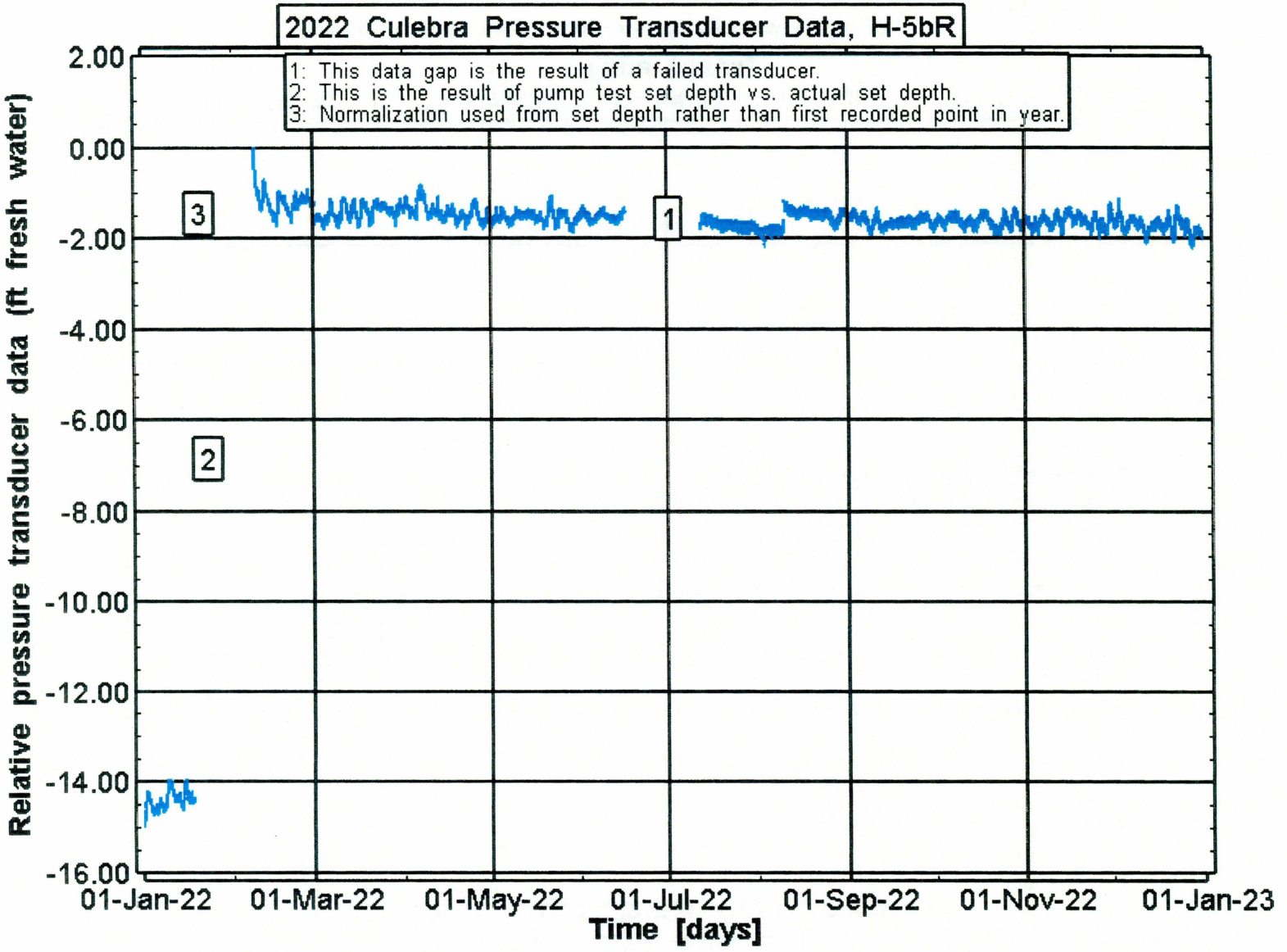

Figure 11. Well H-5bR experienced a net change in hydraulic head of -1.56 ft fresh water in 2022. This well has been subject to hydrologic purges and a slug test.

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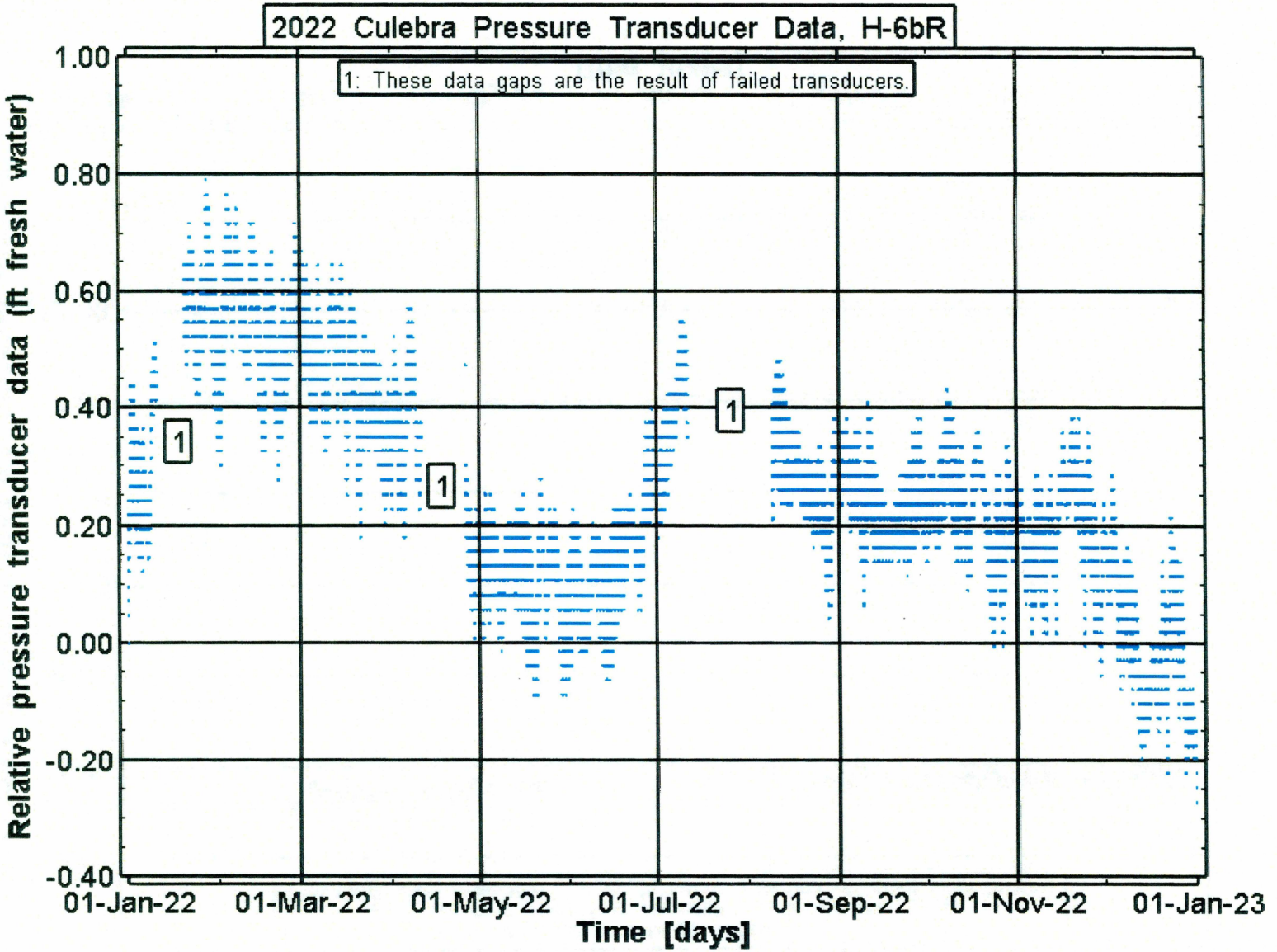

Figure 12. Well H-6bR experienced a net change in hydraulic head of -0.25 ft fresh water in 2022.

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Figure 13. Well H-9bR experienced a net change in hydraulic head of -13.07 ft fresh water in 2022.

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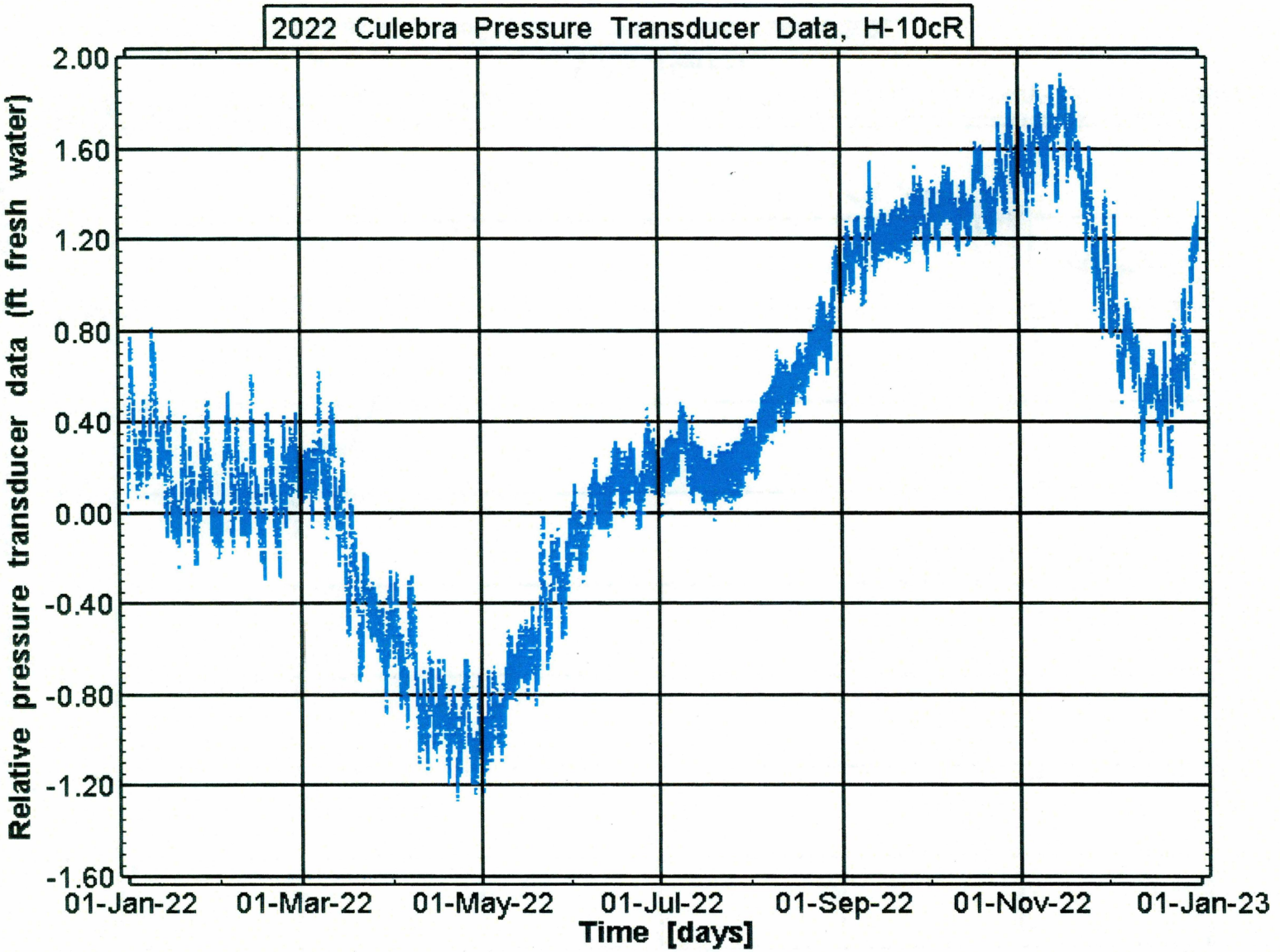

Figure 14. Well H-10cR experienced a net change in hydraulic head of 1.34 ft fresh water in 2022.

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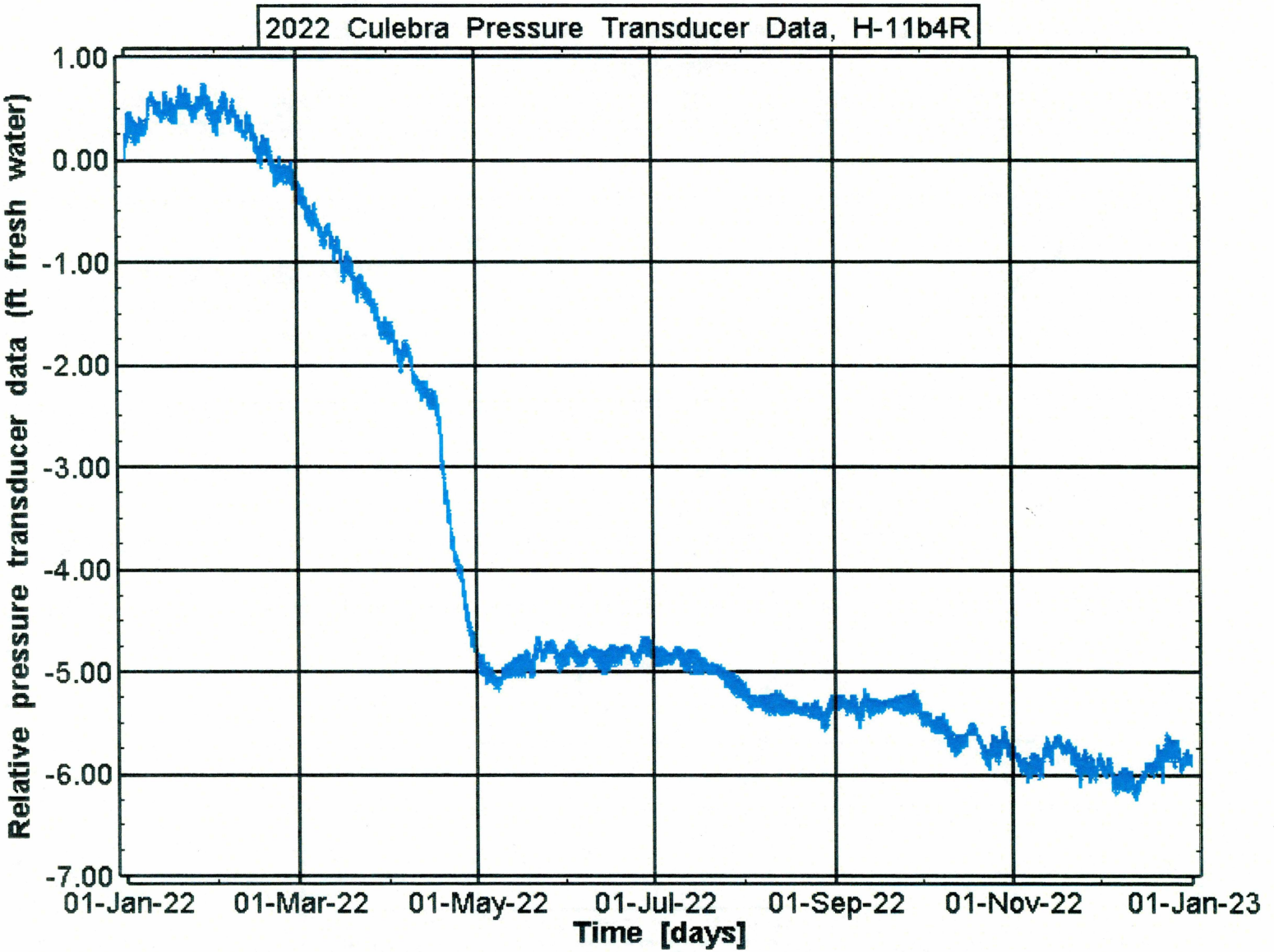

Figure 15. Well H-11b4R experienced a net change in hydraulic head of -5.87 ft fresh water in 2022. This well was affected by NWRA.

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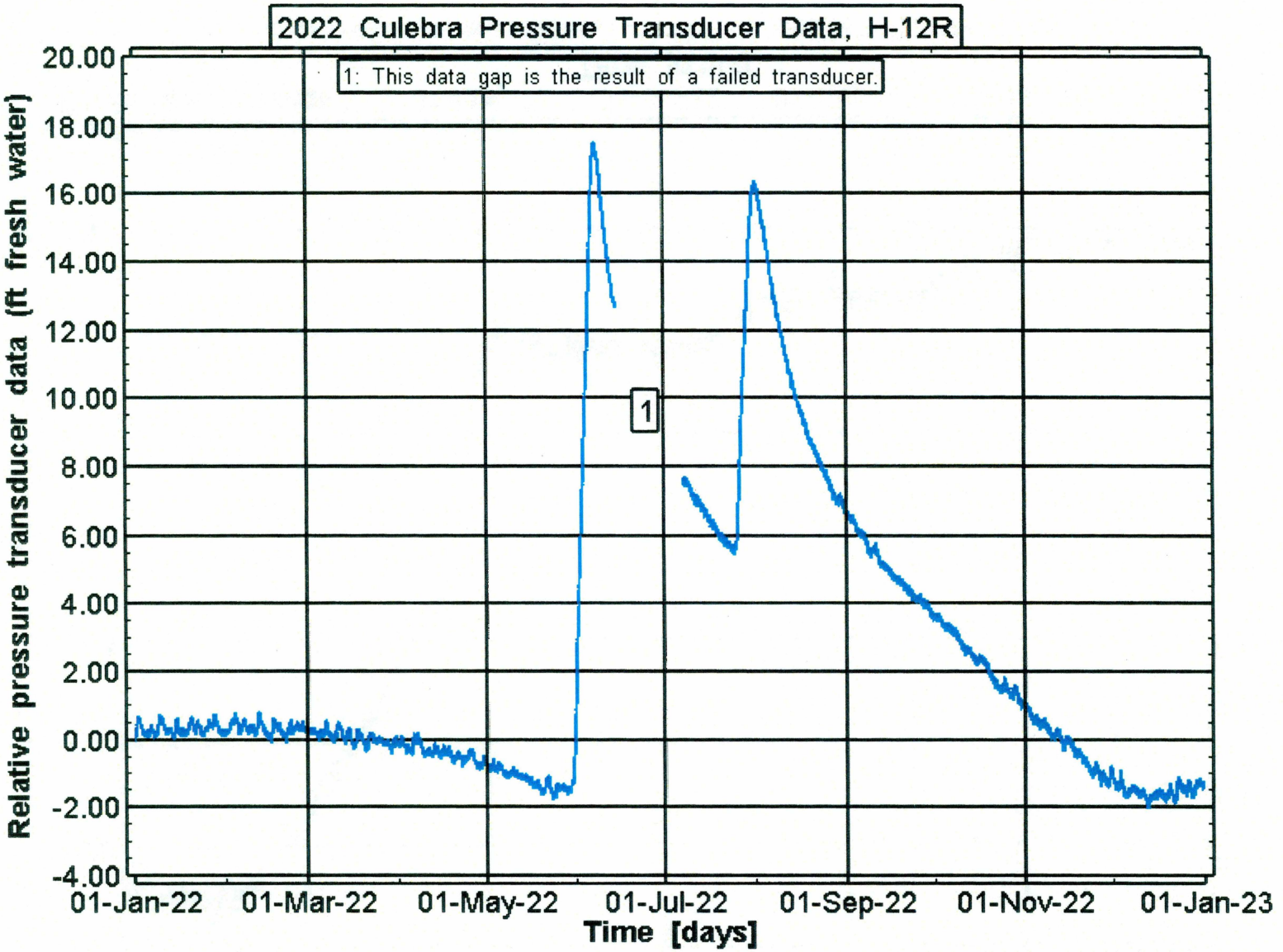

Figure 16. Well H-12R experienced a net change in hydraulic head of -1.30 ft fresh water in 2022. This well was affected by NWRA.

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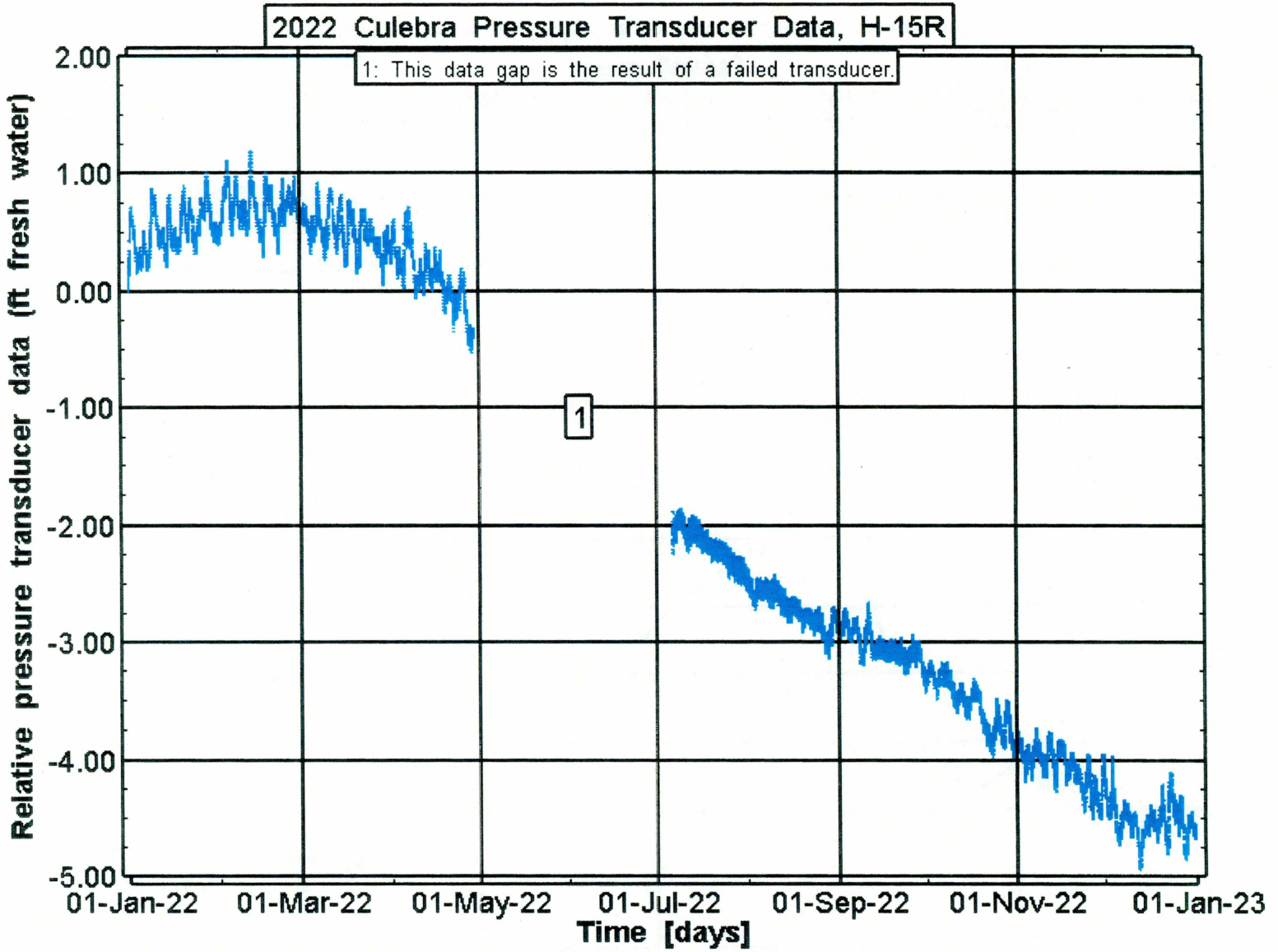

Figure 17. Well H-15R experienced a net change in hydraulic head of -4.58 ft fresh water in 2022.

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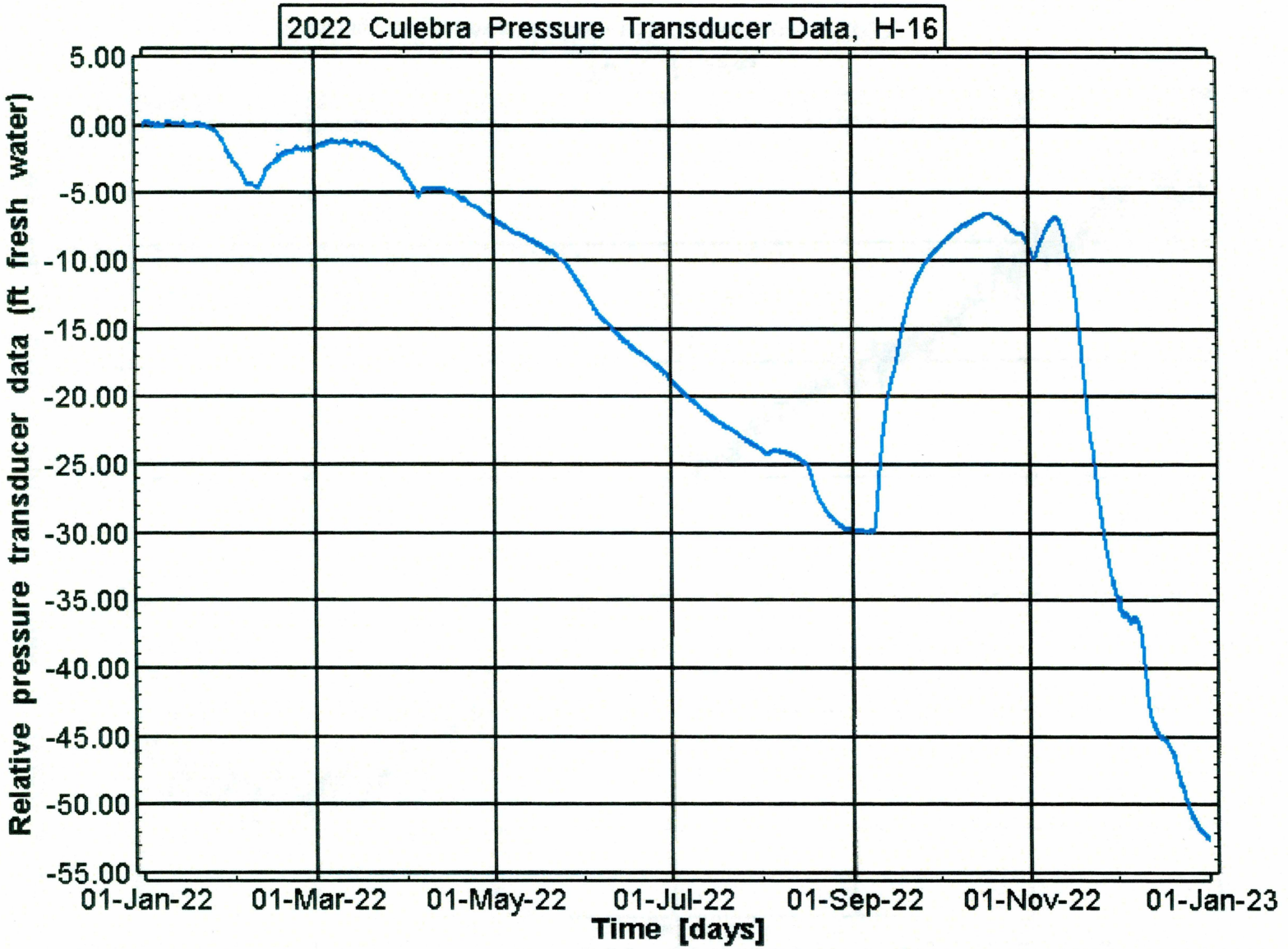

Figure 18. H-16 experienced a net change in hydraulic head of -52.56 ft fresh water in 2022. This well was affected by shaft leakage.

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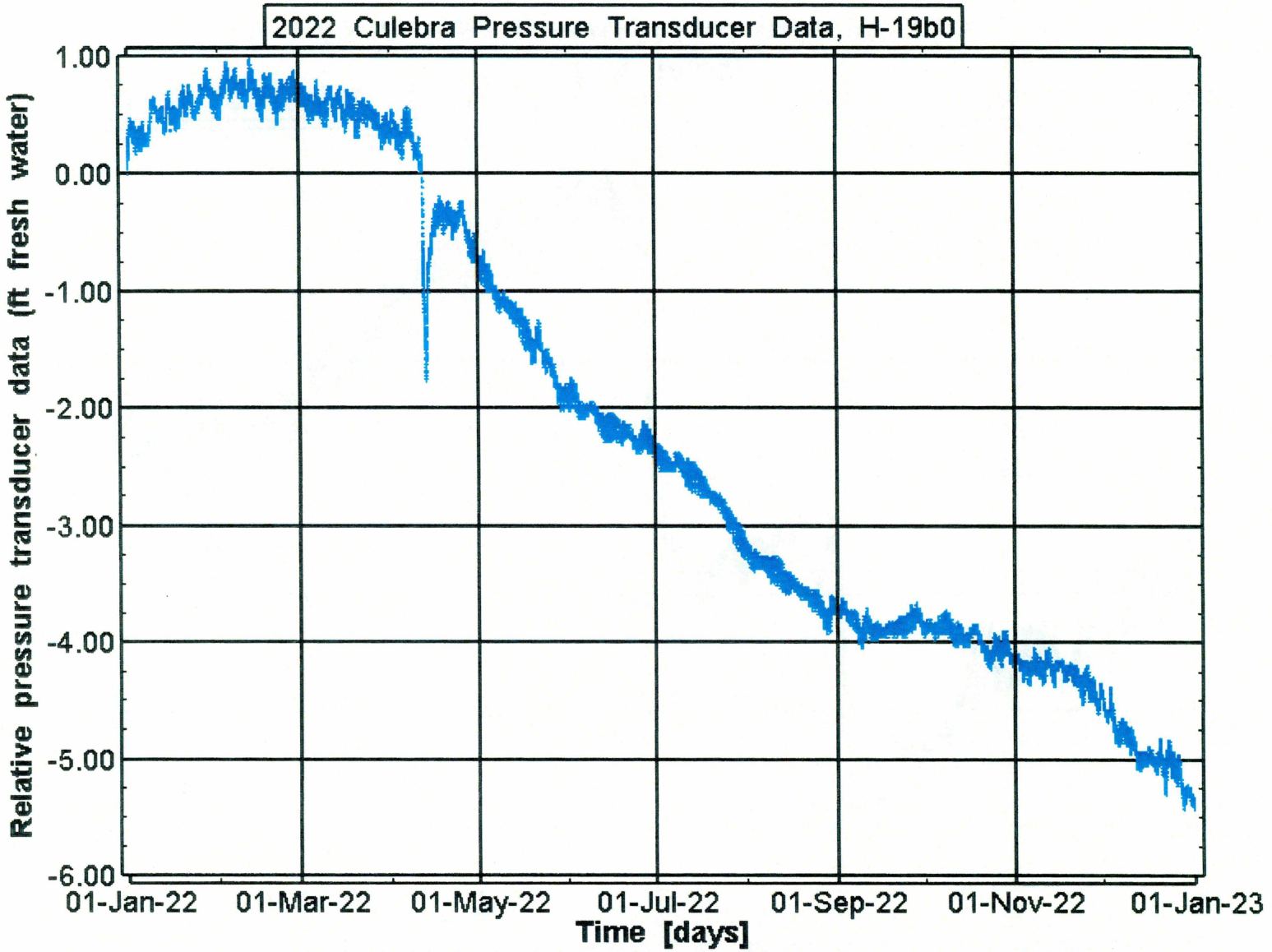

Figure 19. Well H-19b0 experienced a net change in hydraulic head of -5.42 ft fresh water in 2022. This well was affected by NWRA.

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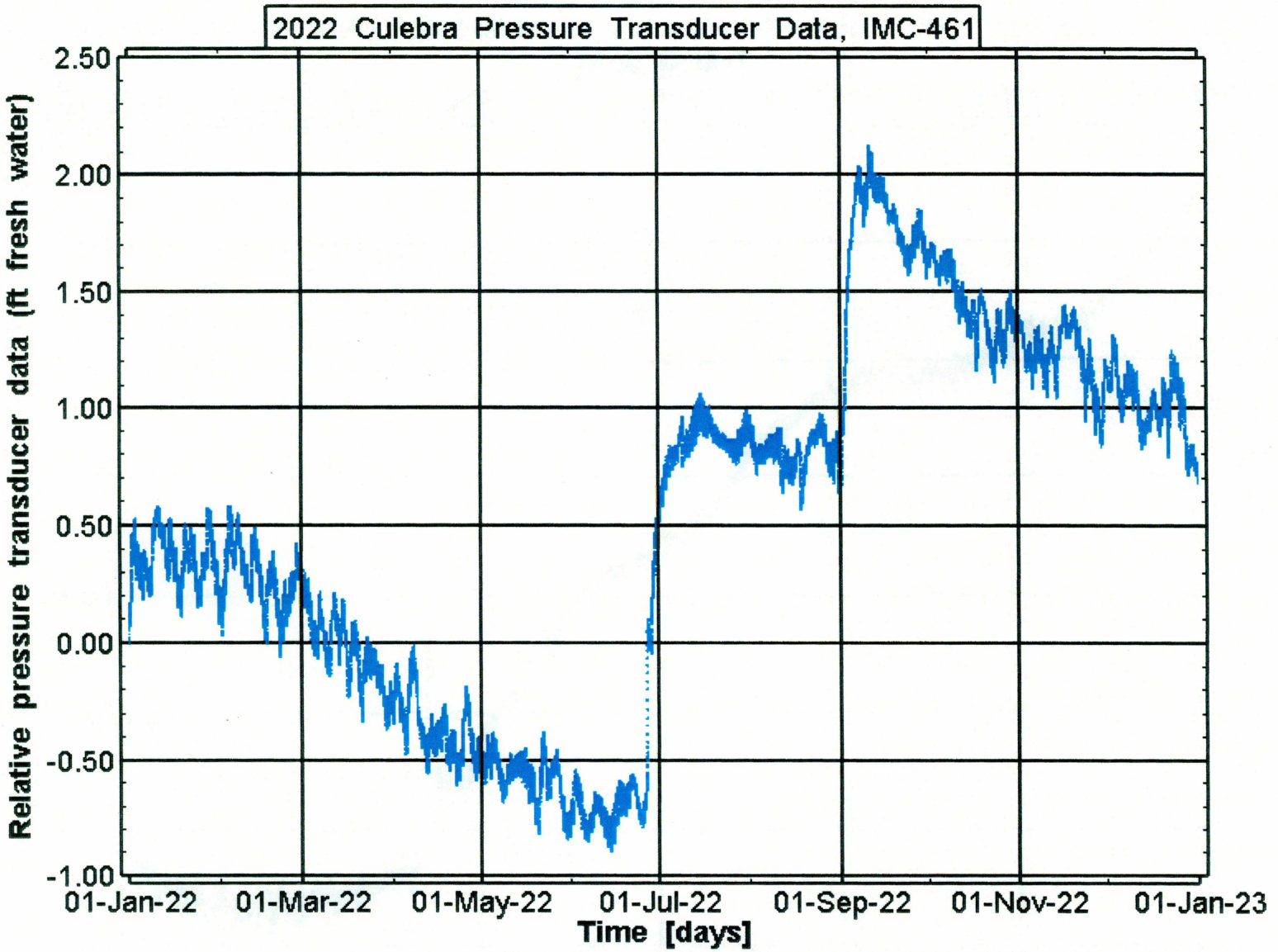

Figure 20. Well IMC-461 experienced a net change in hydraulic head of 0.73 ft fresh water in 2022. This well was affected by NWRA.

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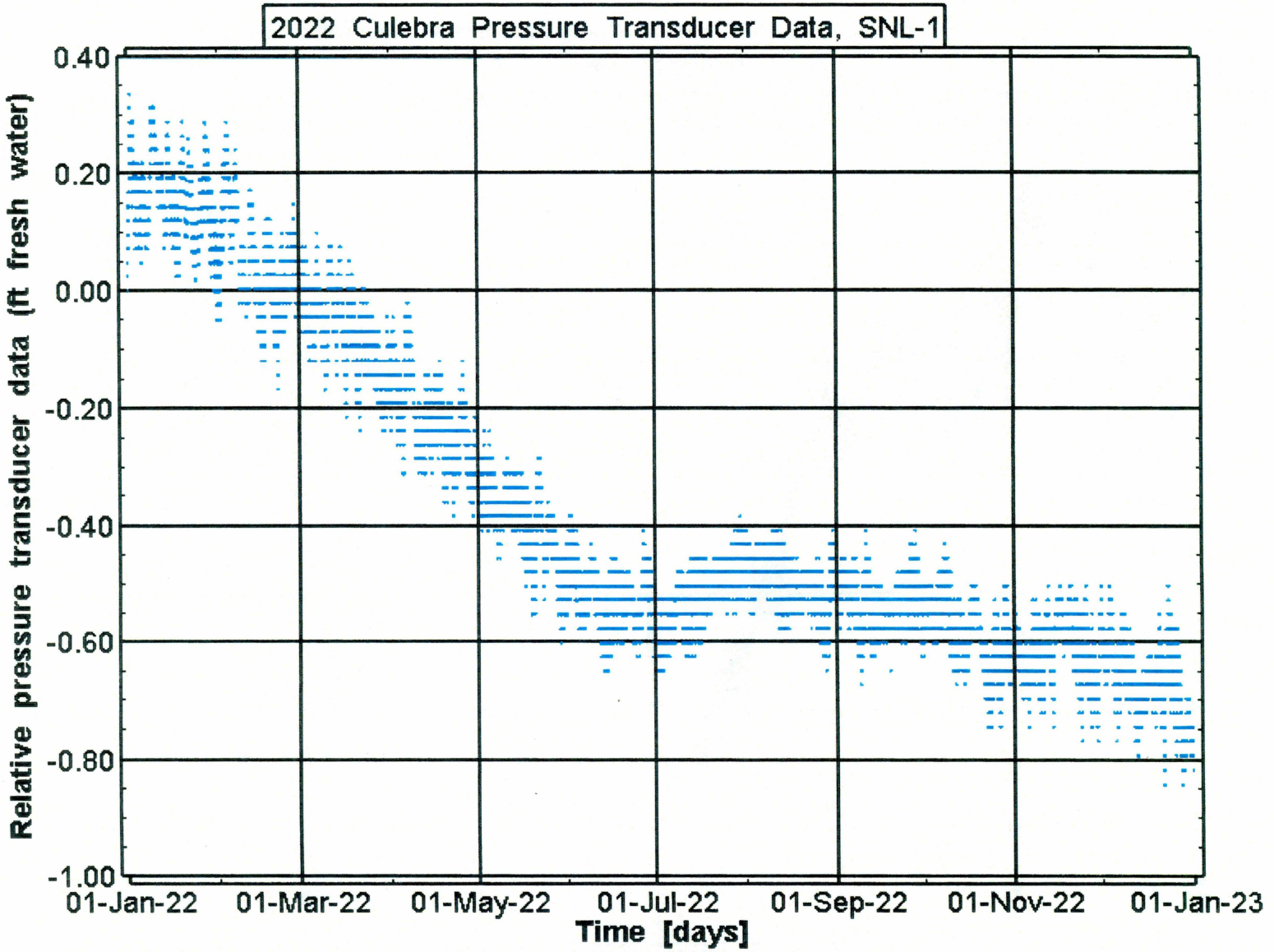

Figure 21. Well SNL-1 experienced a net change in hydraulic head of -0.77 ft fresh water in 2022.

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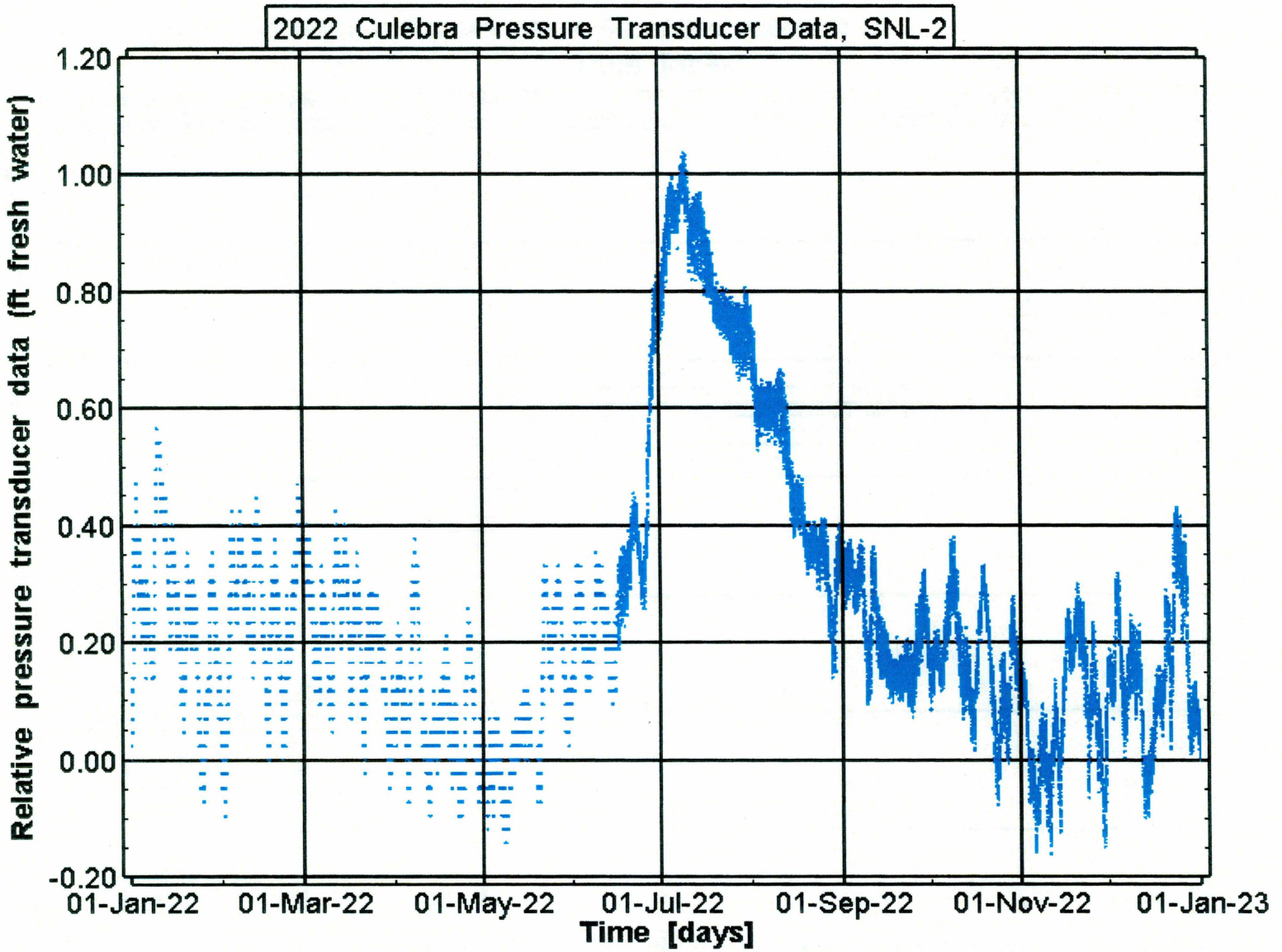

Figure 22. Well SNL-2 experienced a net change in hydraulic head of 0.05 ft fresh water in 2022. This well was affected by NWRA.

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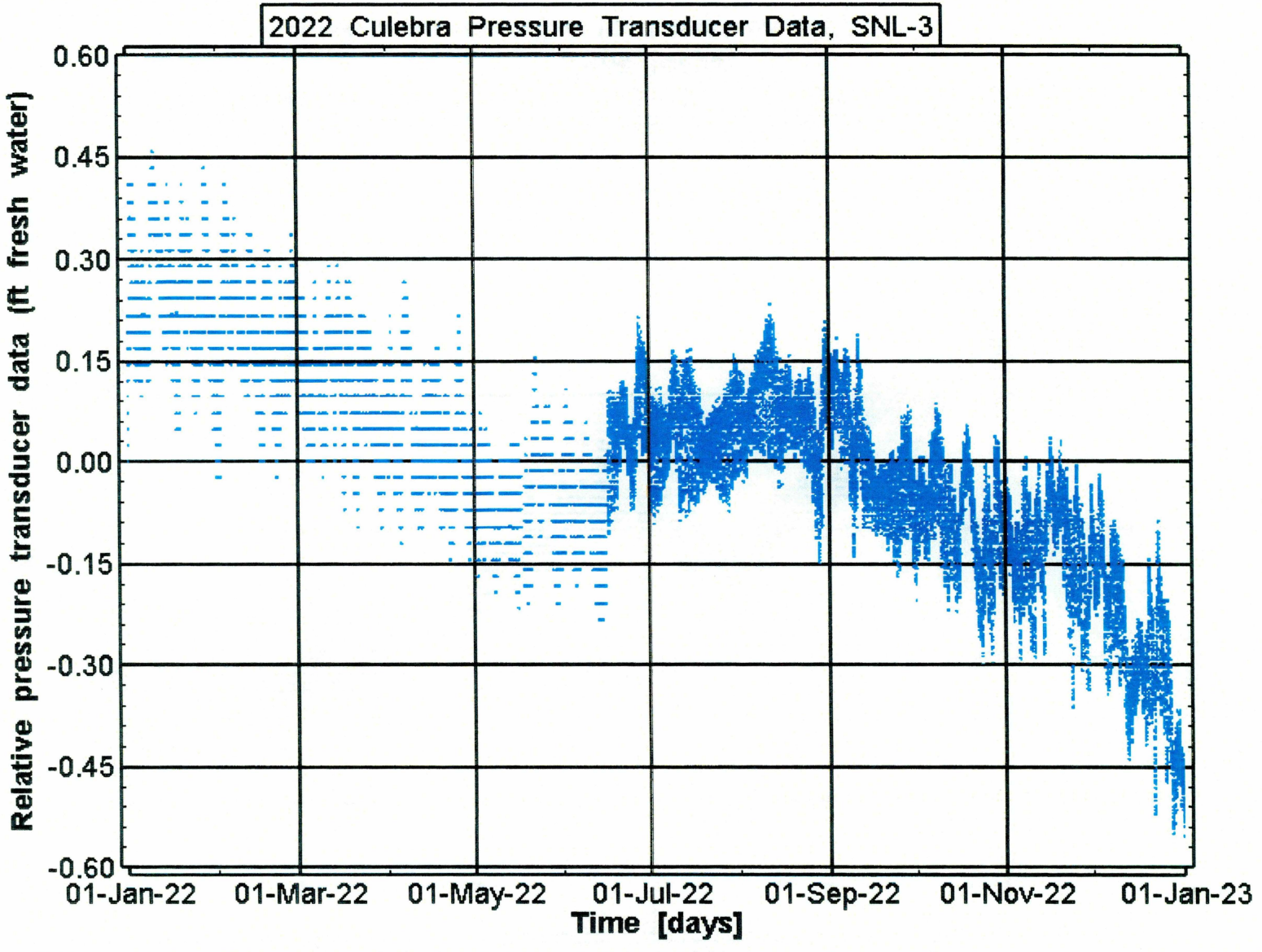

Figure 23. Well SNL-3 experienced a net change in hydraulic head of -0.49 ft fresh water in 2022.

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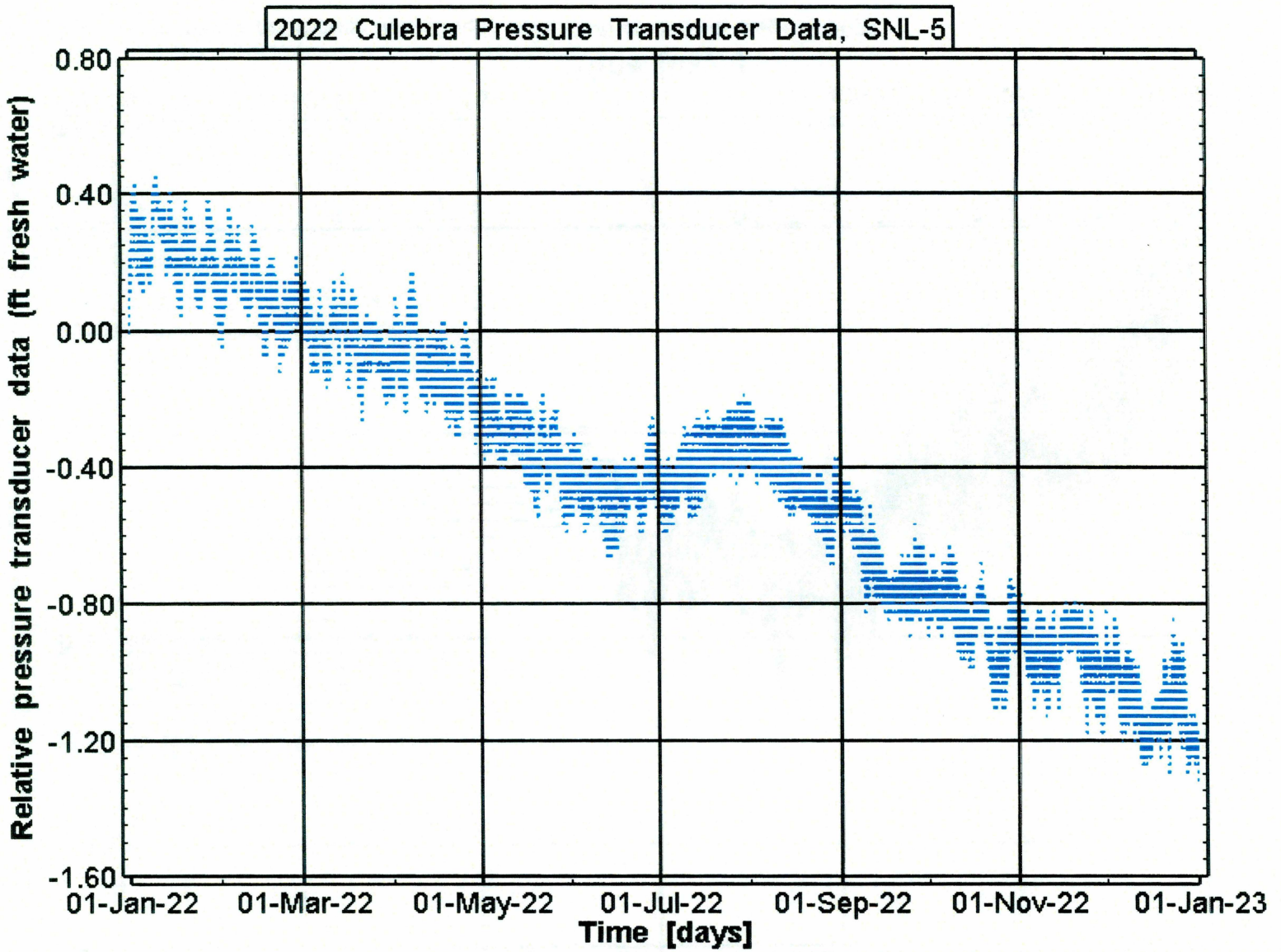

Figure 24. Well SNL-5 experienced a net change in hydraulic head of -1.25 ft fresh water in 2022.

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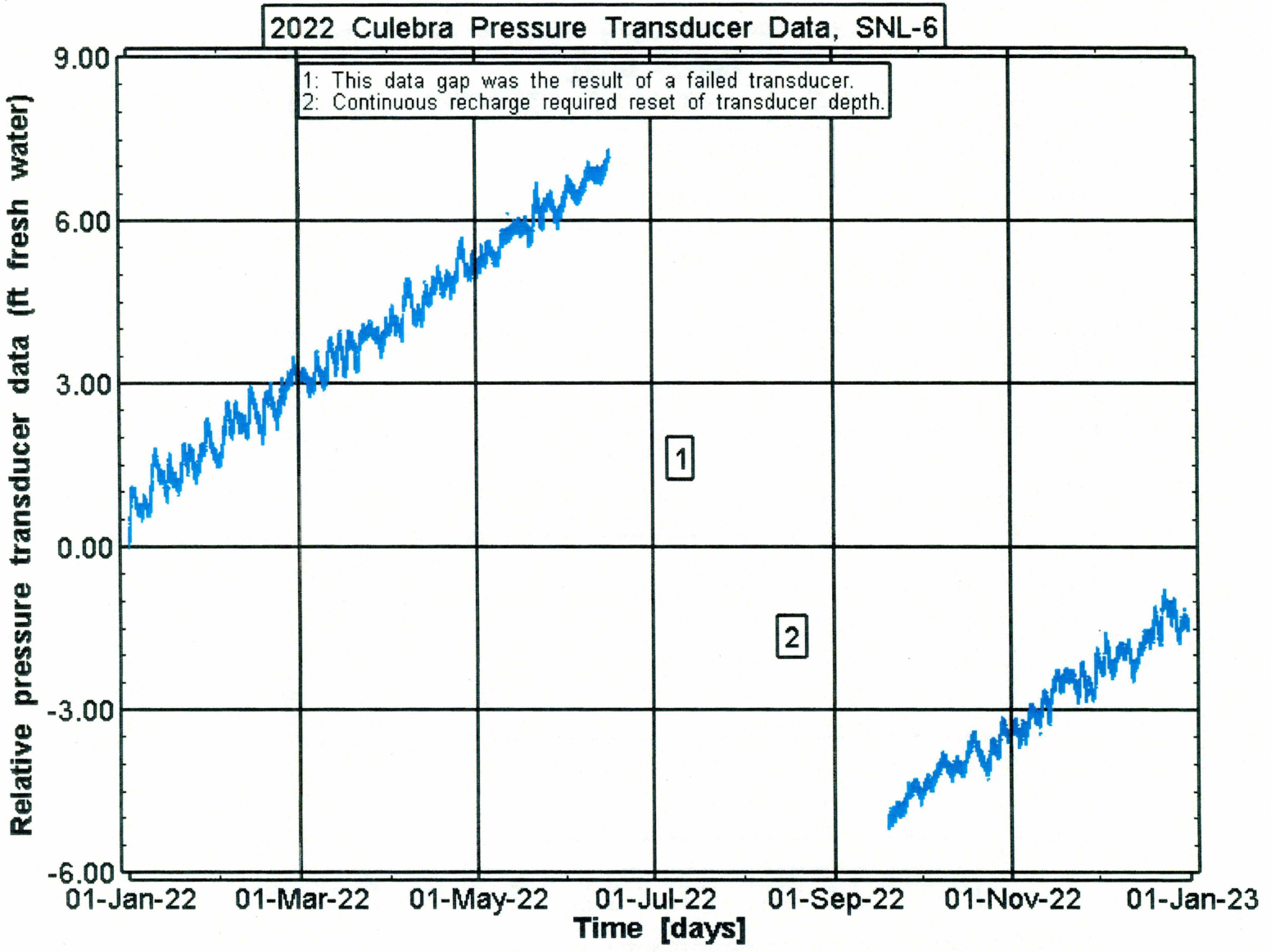

Figure 25. Well SNL-6 experienced a net change in hydraulic head of 13.66 ft fresh water in 2022. The well is in long-term recovery from well development.

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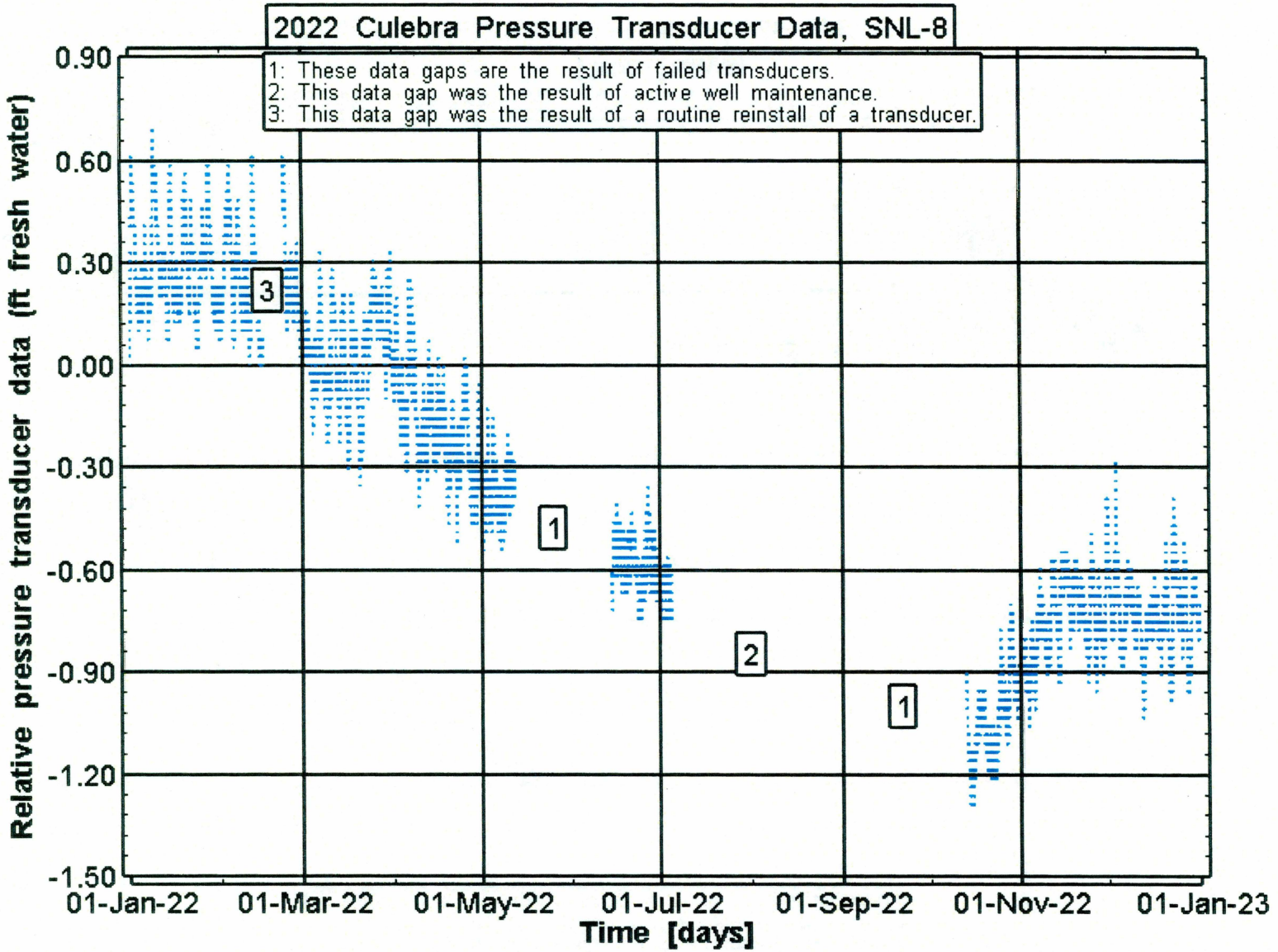

Figure 26. Well SNL-8 experienced a net change in hydraulic head of -0.70 ft fresh water in 2022.

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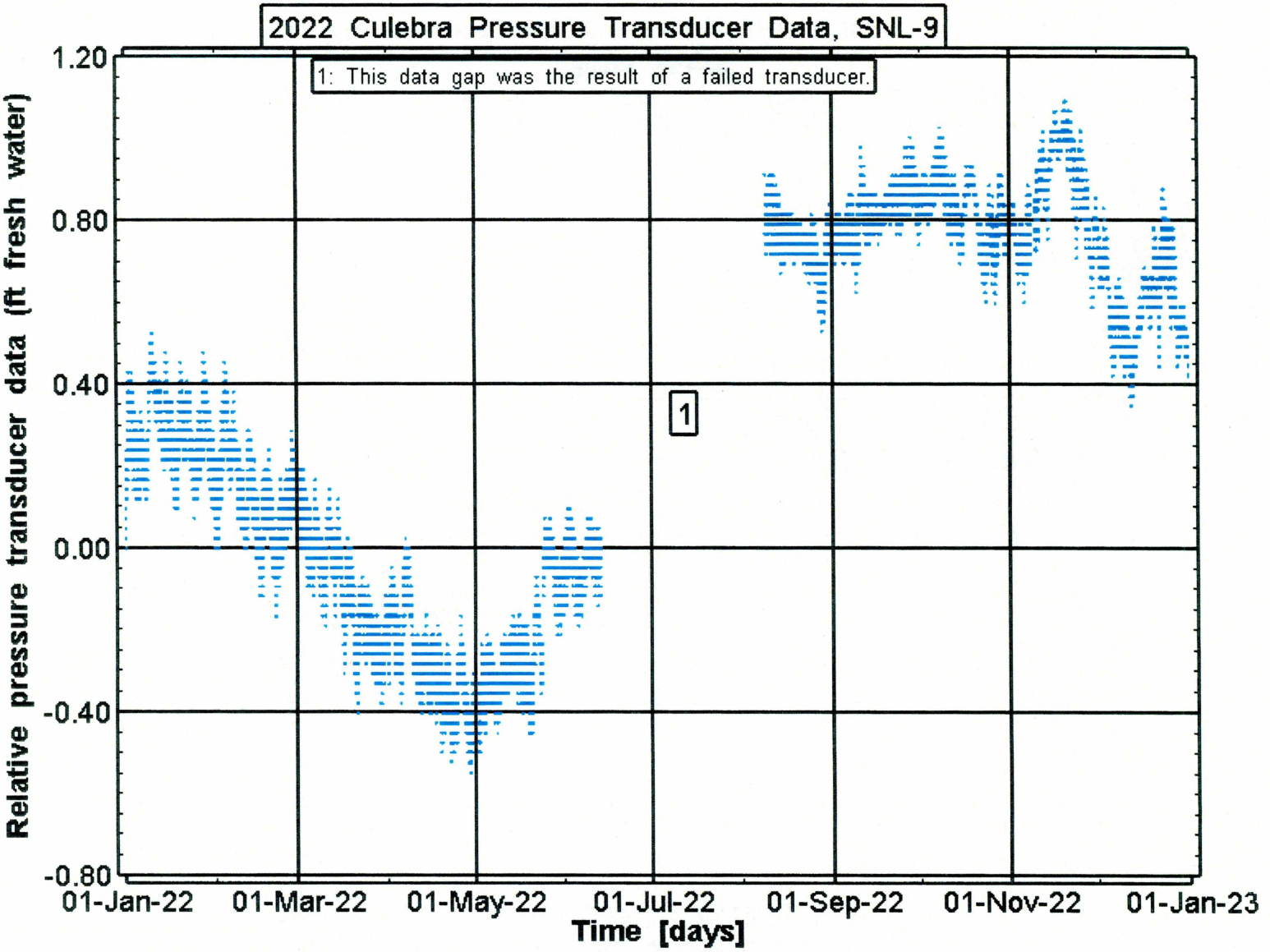

Figure 27. Well SNL-9 experienced a net change in hydraulic head of 0.44 ft fresh water in 2022.

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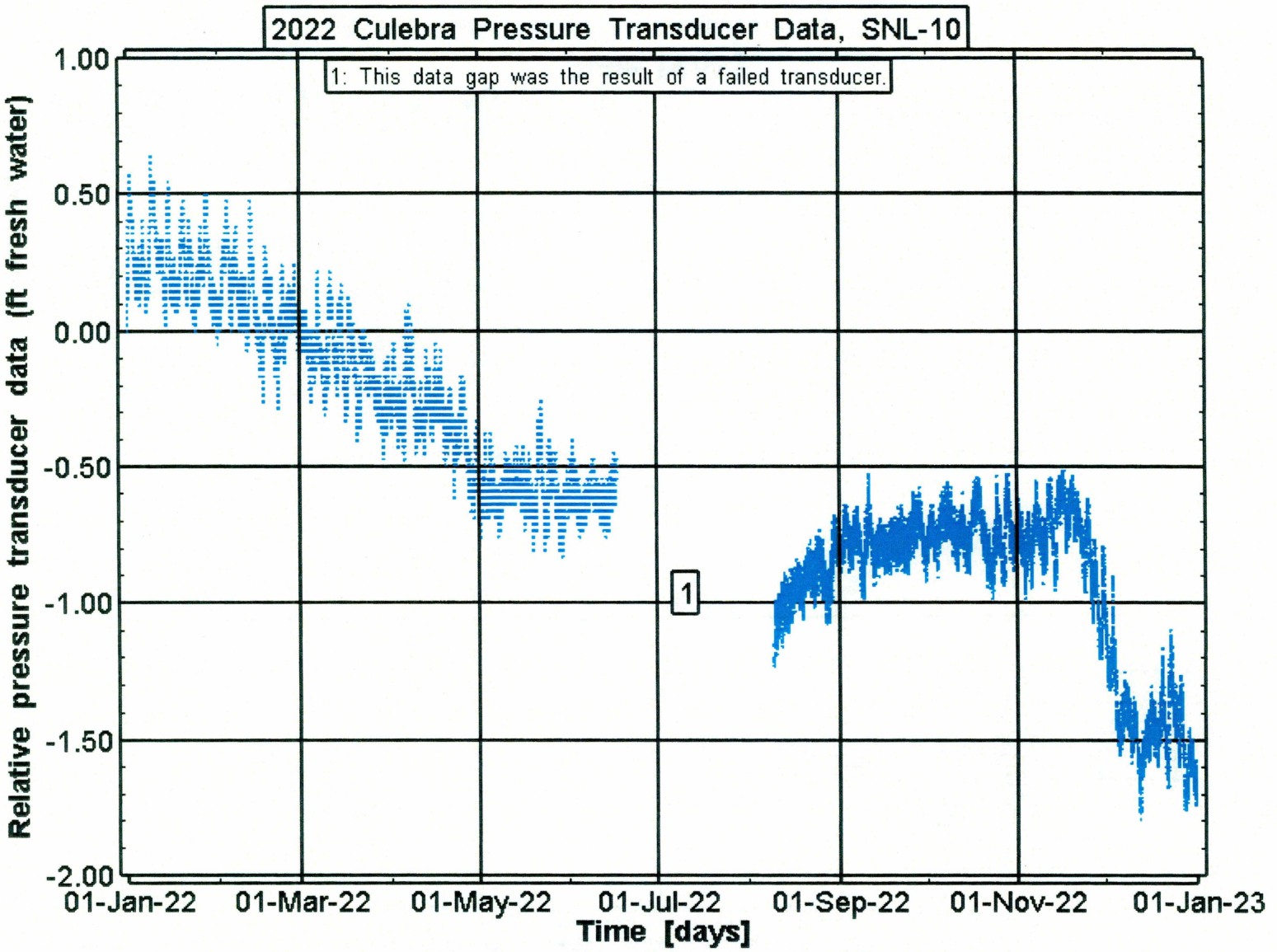

Figure 28. Well SNL-10 experienced a net change in hydraulic head of -1.68 ft fresh water in 2022.

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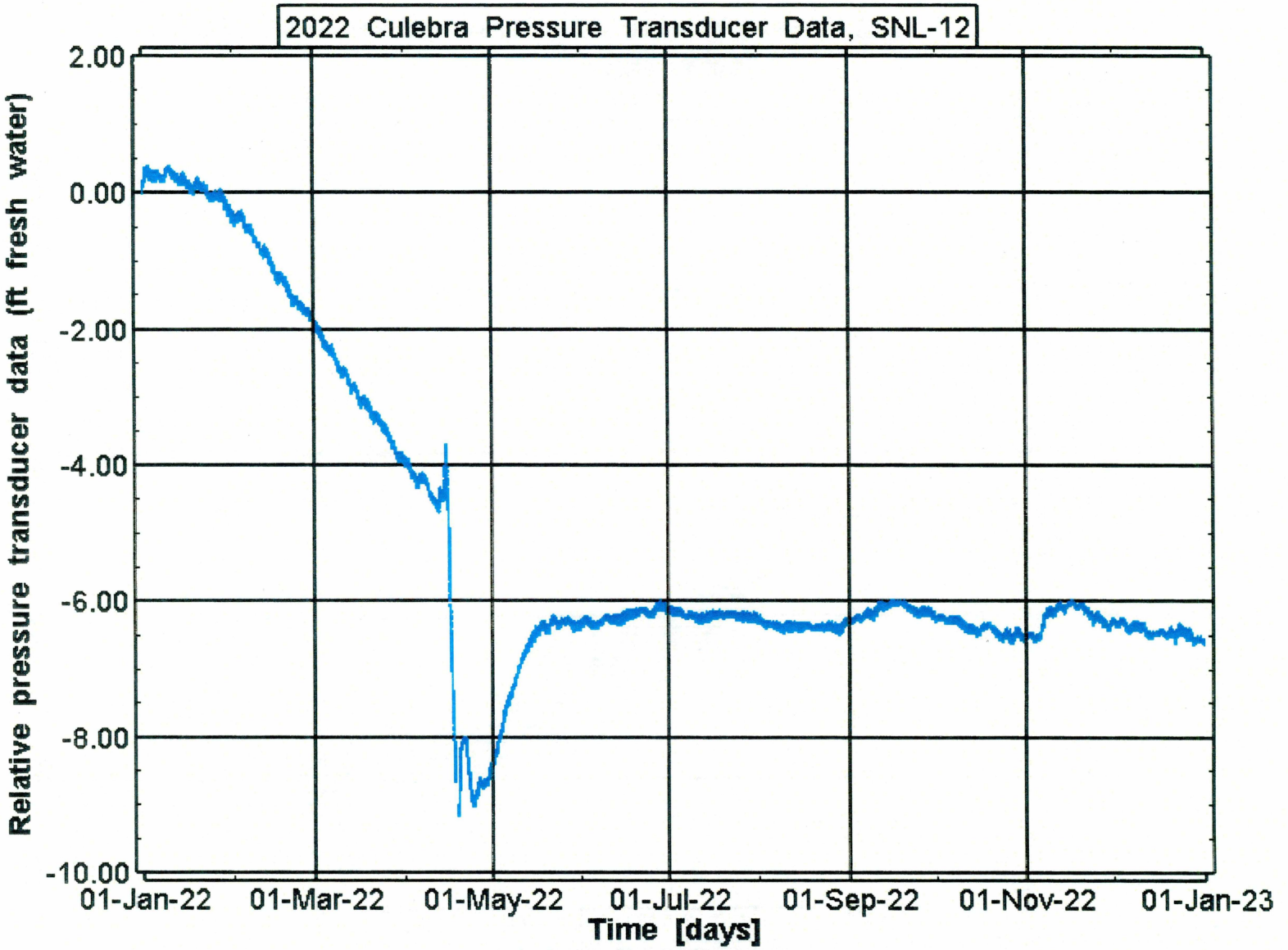

Figure 29. Well SNL-12 experienced a net change in hydraulic head of -6.60 ft fresh water in 2022. This well was affected by NWRA.

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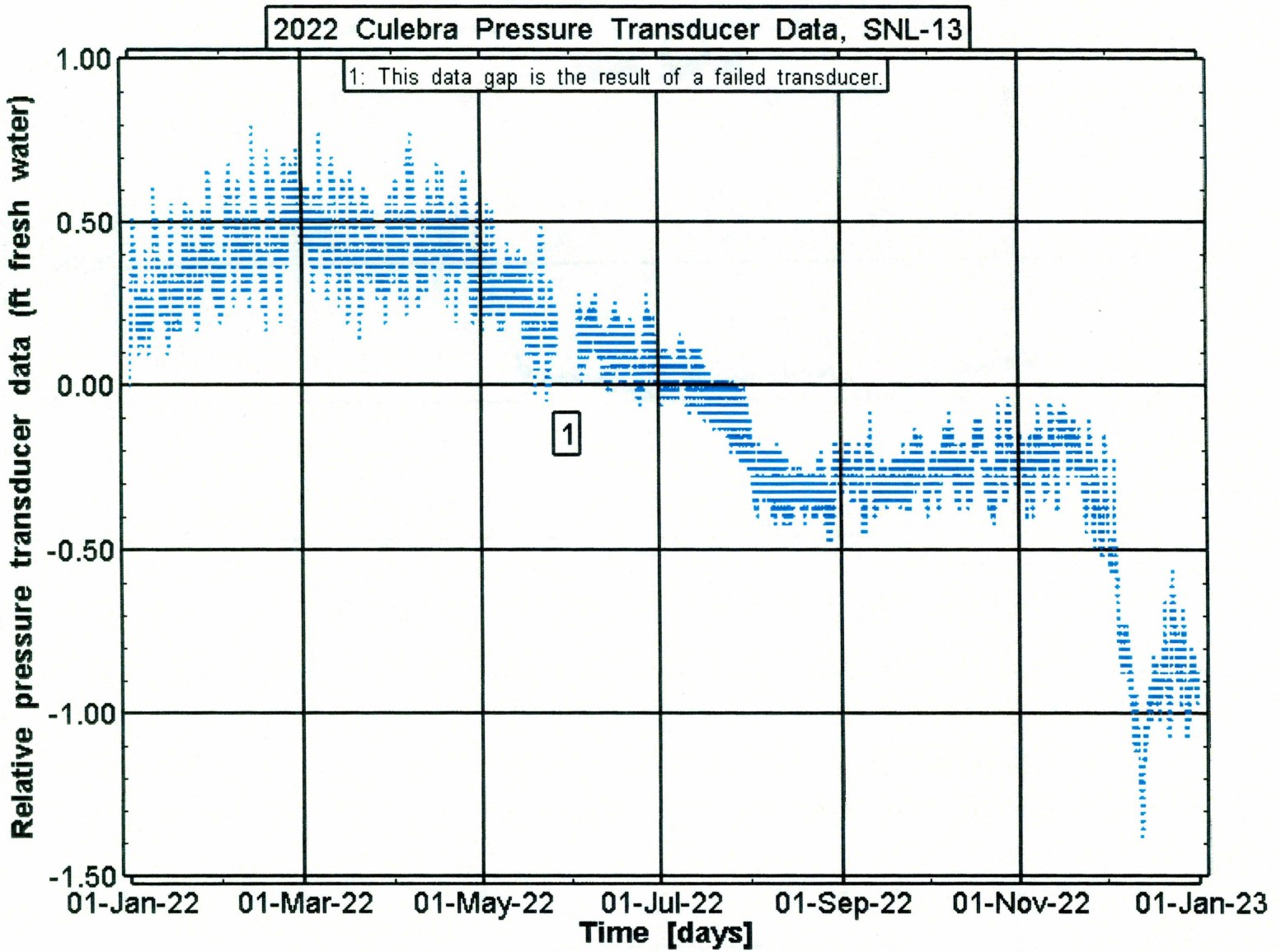

Figure 30. Well SNL-13 experienced a net change in hydraulic head of -0.90 ft fresh water in 2022.

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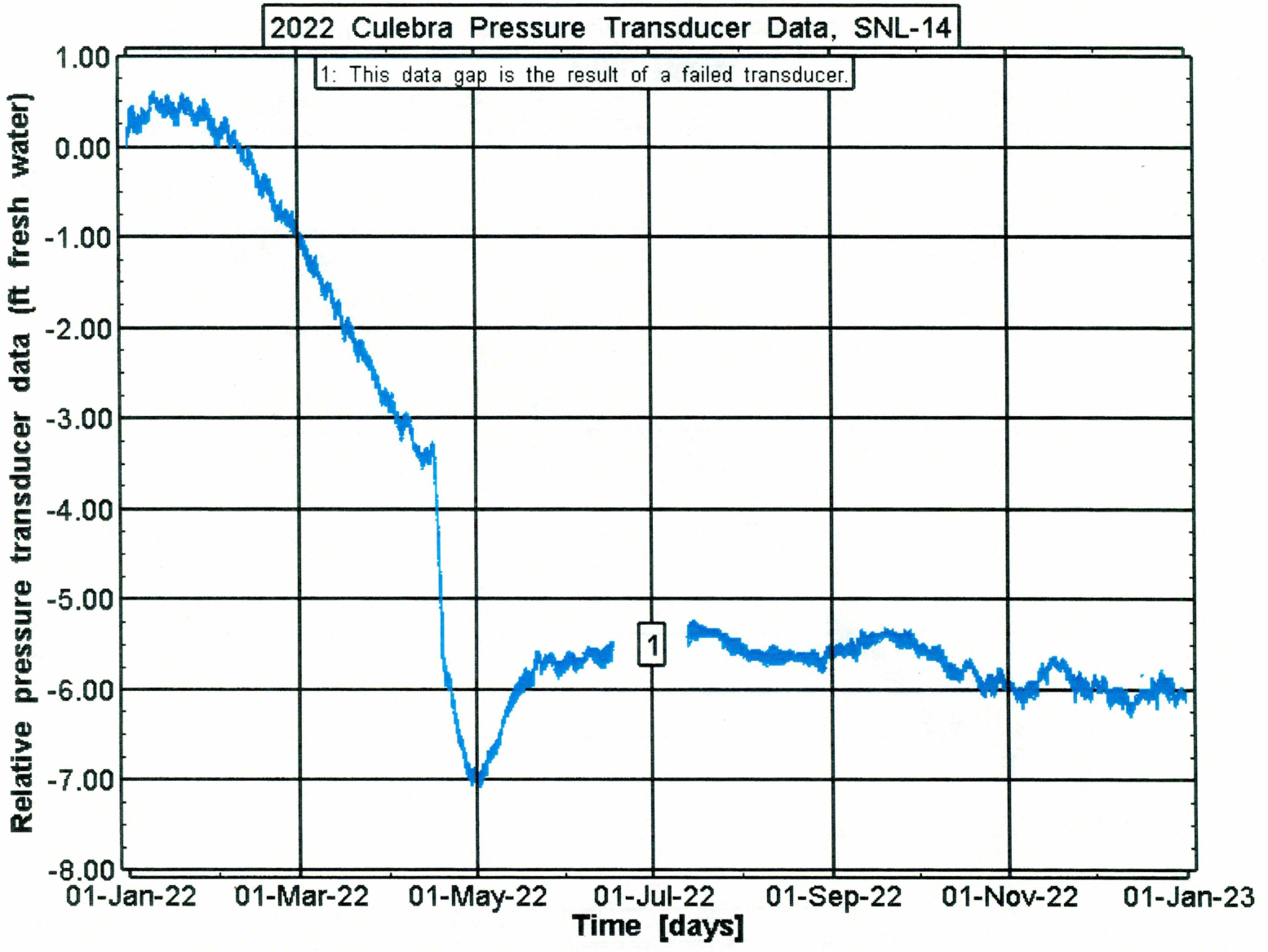

Figure 31. Well SNL-14 experienced a net change in hydraulic head of –6.05 ft fresh water in 2022. This well was affected by NWRA.

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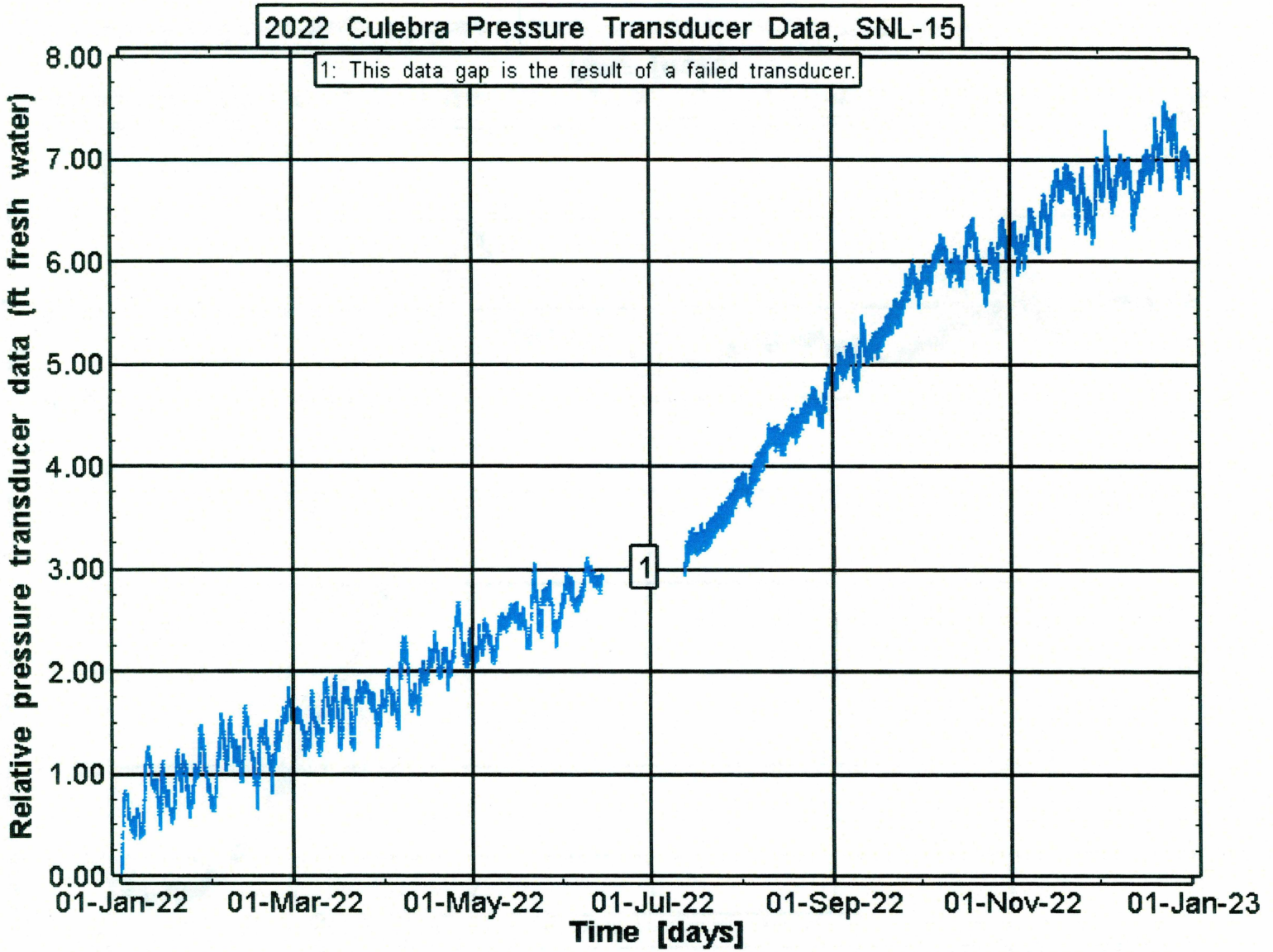

Figure 32. Well SNL-15 experienced a net change in hydraulic head of 6.92 ft fresh water in 2022. The well is in long-term recovery from well development.

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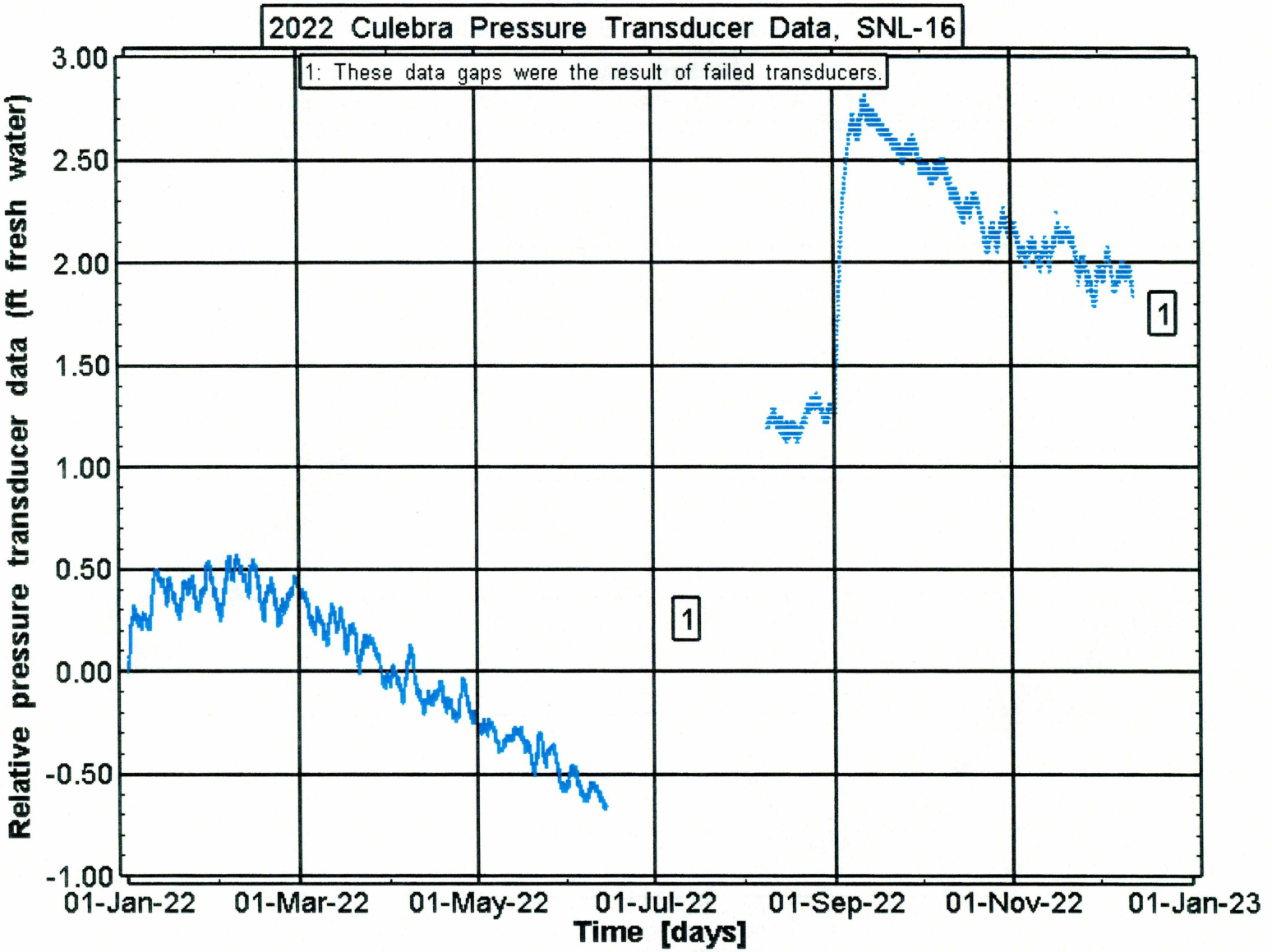

Figure 33. Well SNL-16 experienced a net change in hydraulic head of 1.86 ft fresh water in 2022. This well was affected by NWRA.

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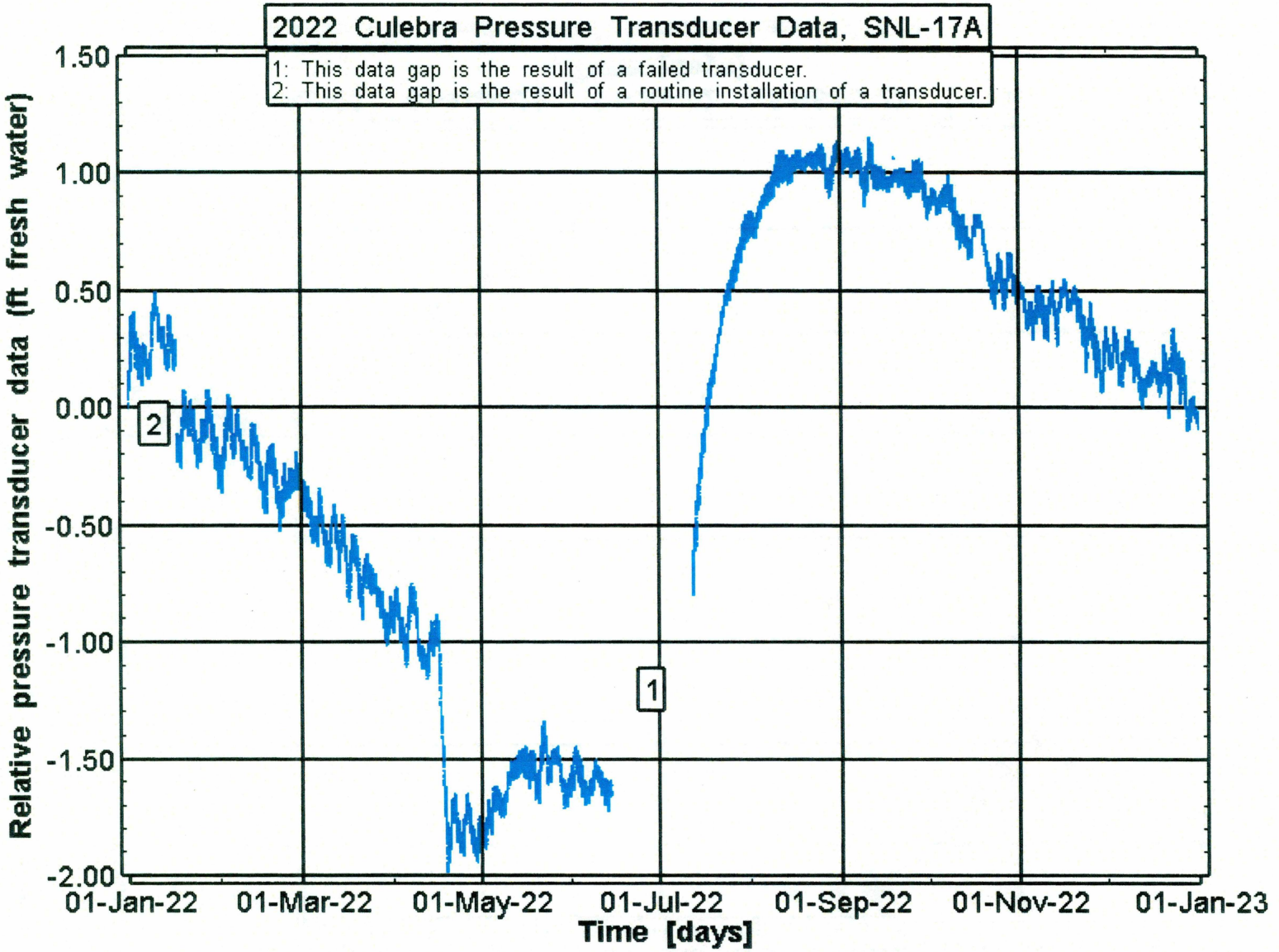

Figure 34. Well SNL-17A experienced a net change in hydraulic head of -0.05 ft fresh water in 2022. This well was affected by NWRA.

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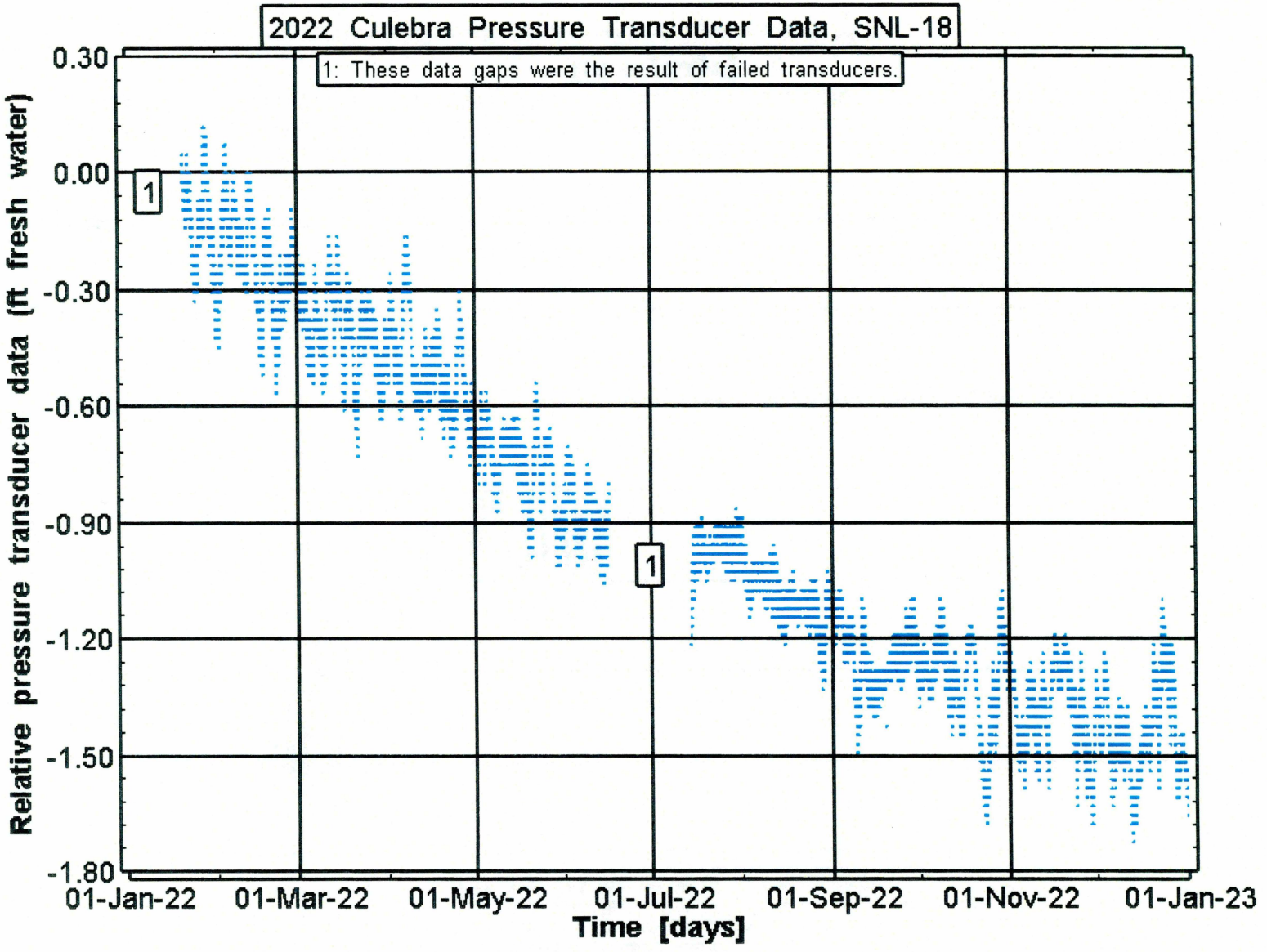

Figure 35. Well SNL-18 experienced a net change in hydraulic head of -1.61 ft fresh water in 2022.

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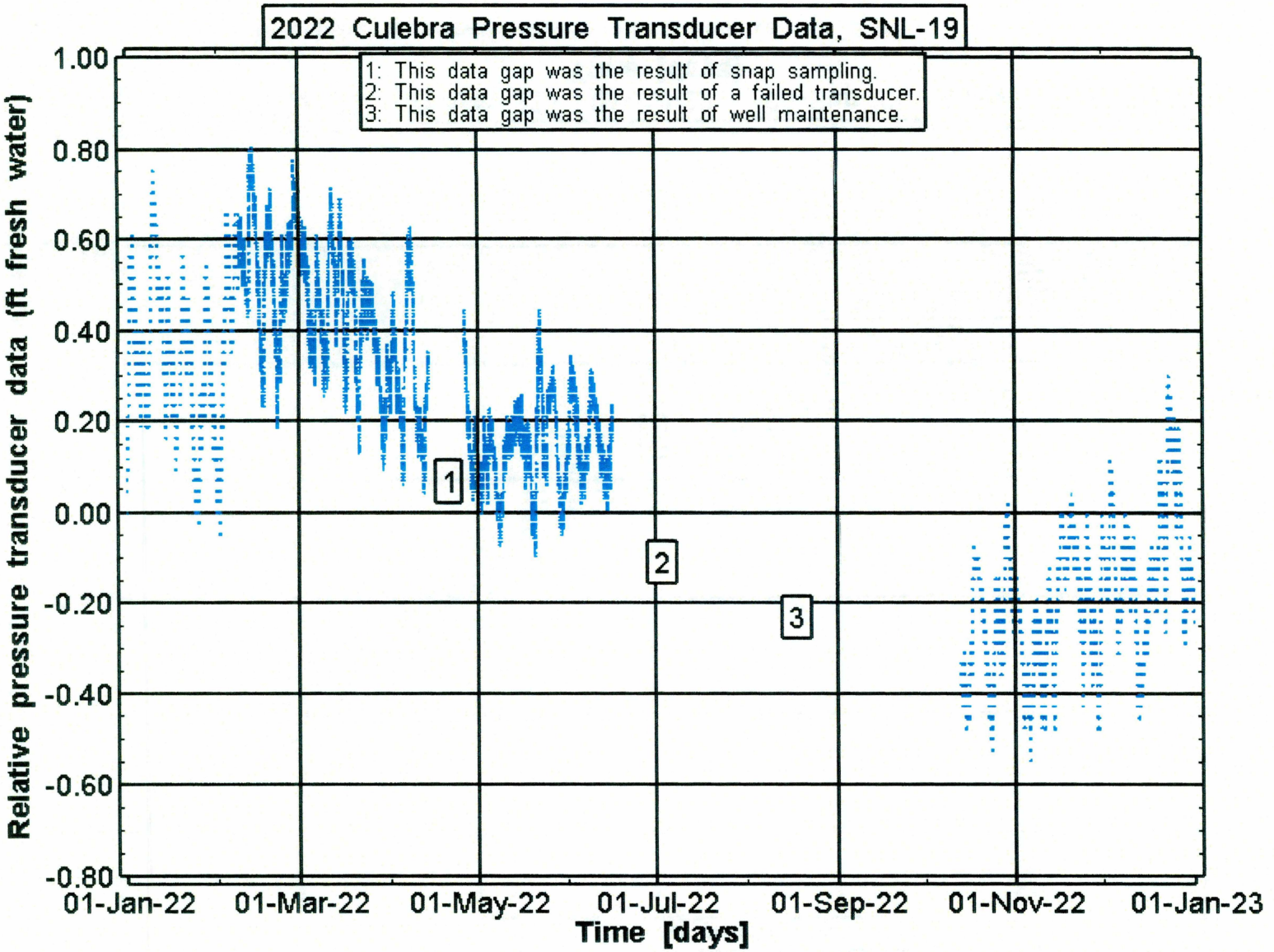

Figure 36. Well SNL-19 experienced a net change in hydraulic head of -0.19 ft fresh water in 2022.

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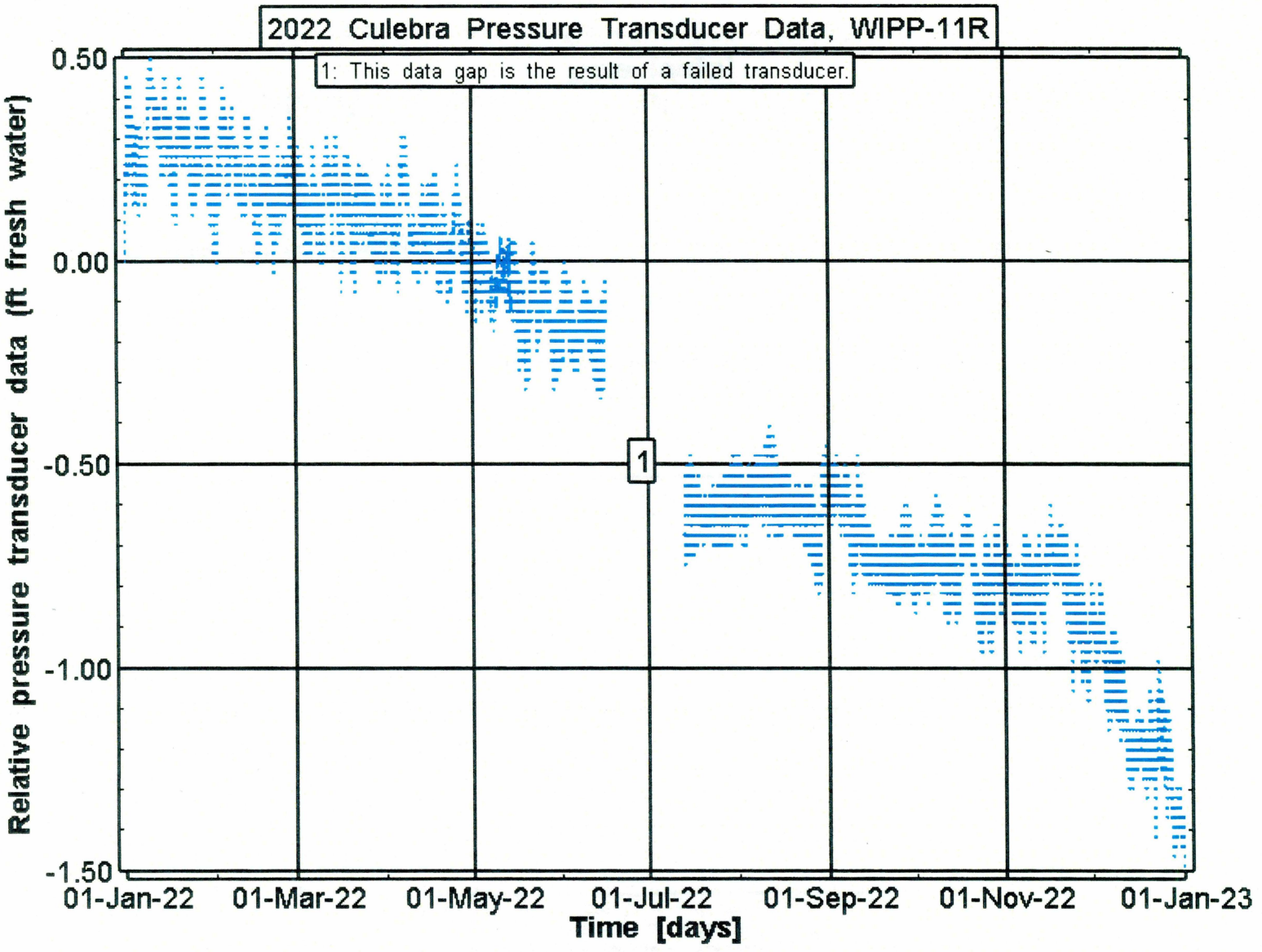

Figure 37. Well WIPP-11R experienced a net change in hydraulic head of -1.42 ft fresh water in 2022.

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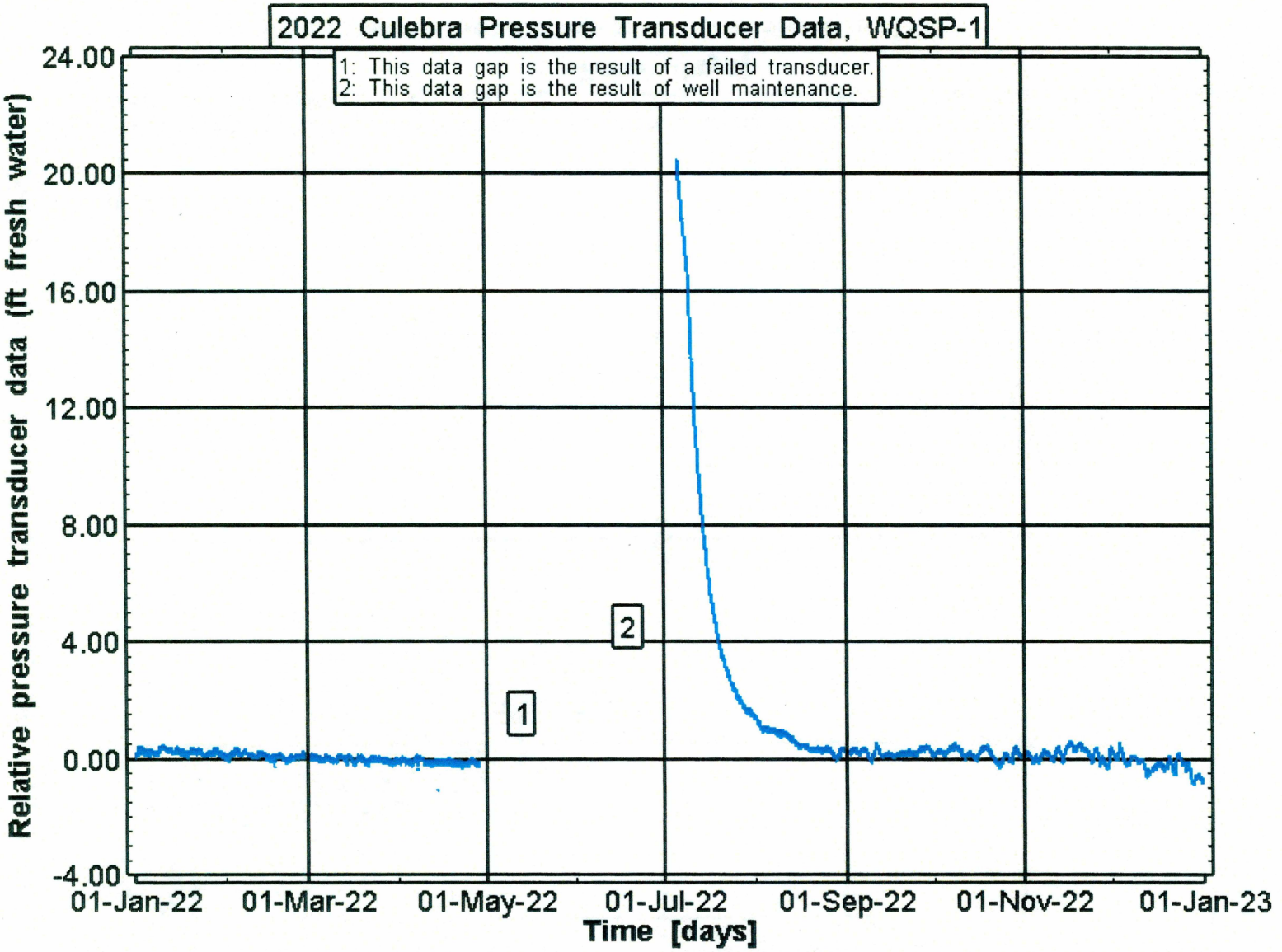

Figure 38. Well WQSP-1 experienced a net change in hydraulic head of -0.70 ft fresh water in 2022.

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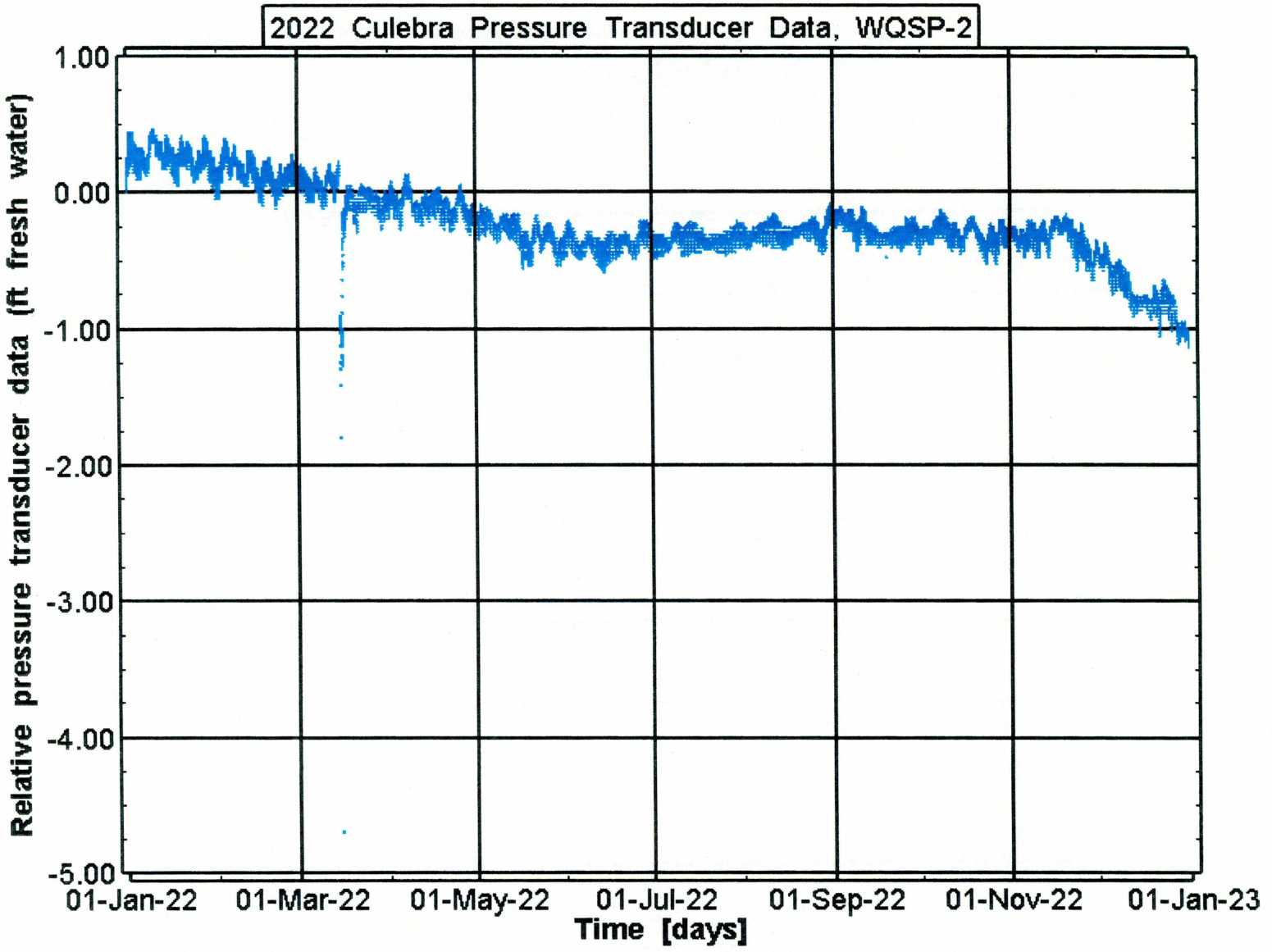

Figure 39. Well WQSP-2 experienced a net change in hydraulic head of -1.08 ft fresh water in 2022.

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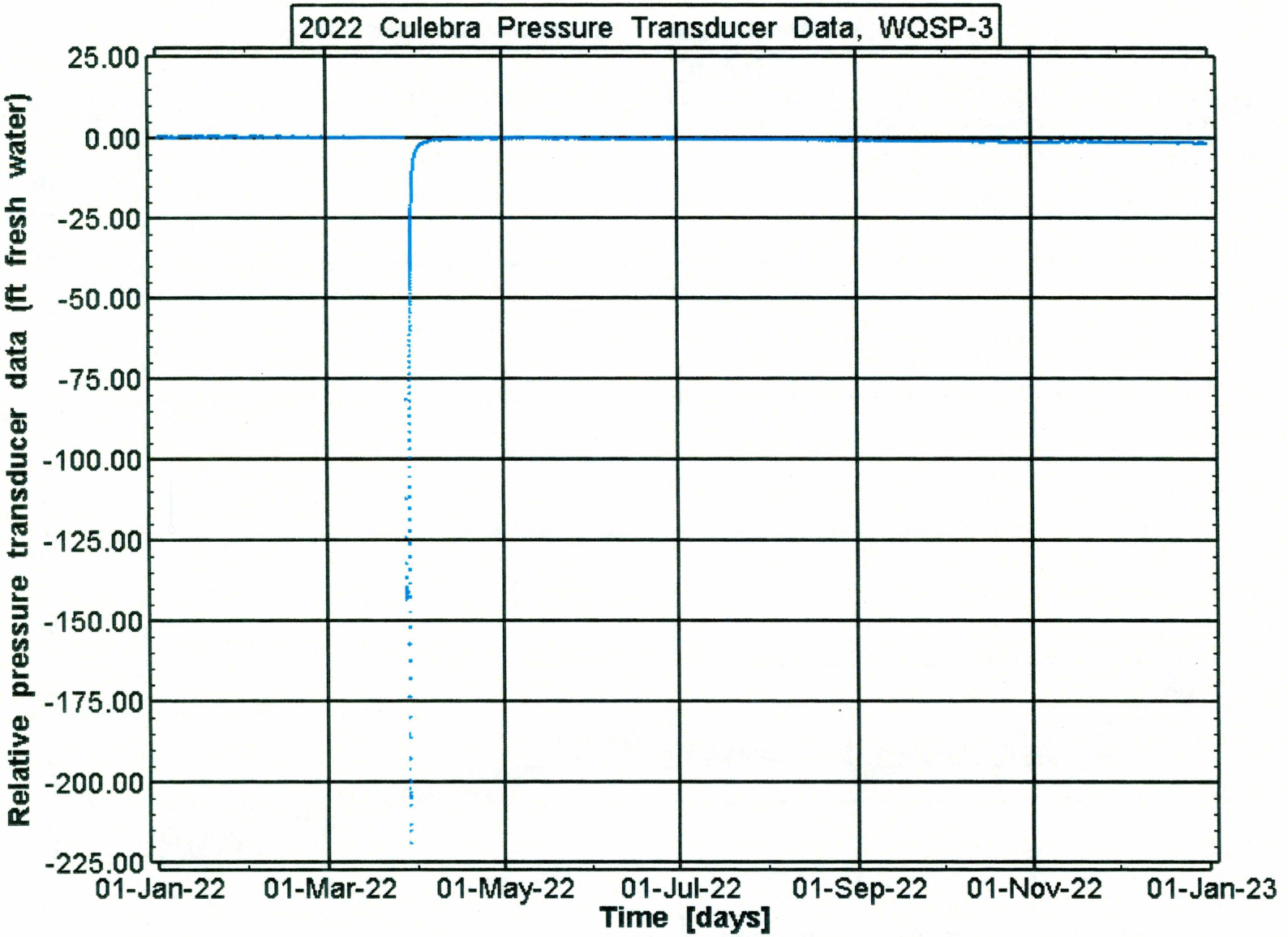

Figure 40. Well WQSP-3 experienced a net change in hydraulic head of -1.84 ft fresh water in 2022.

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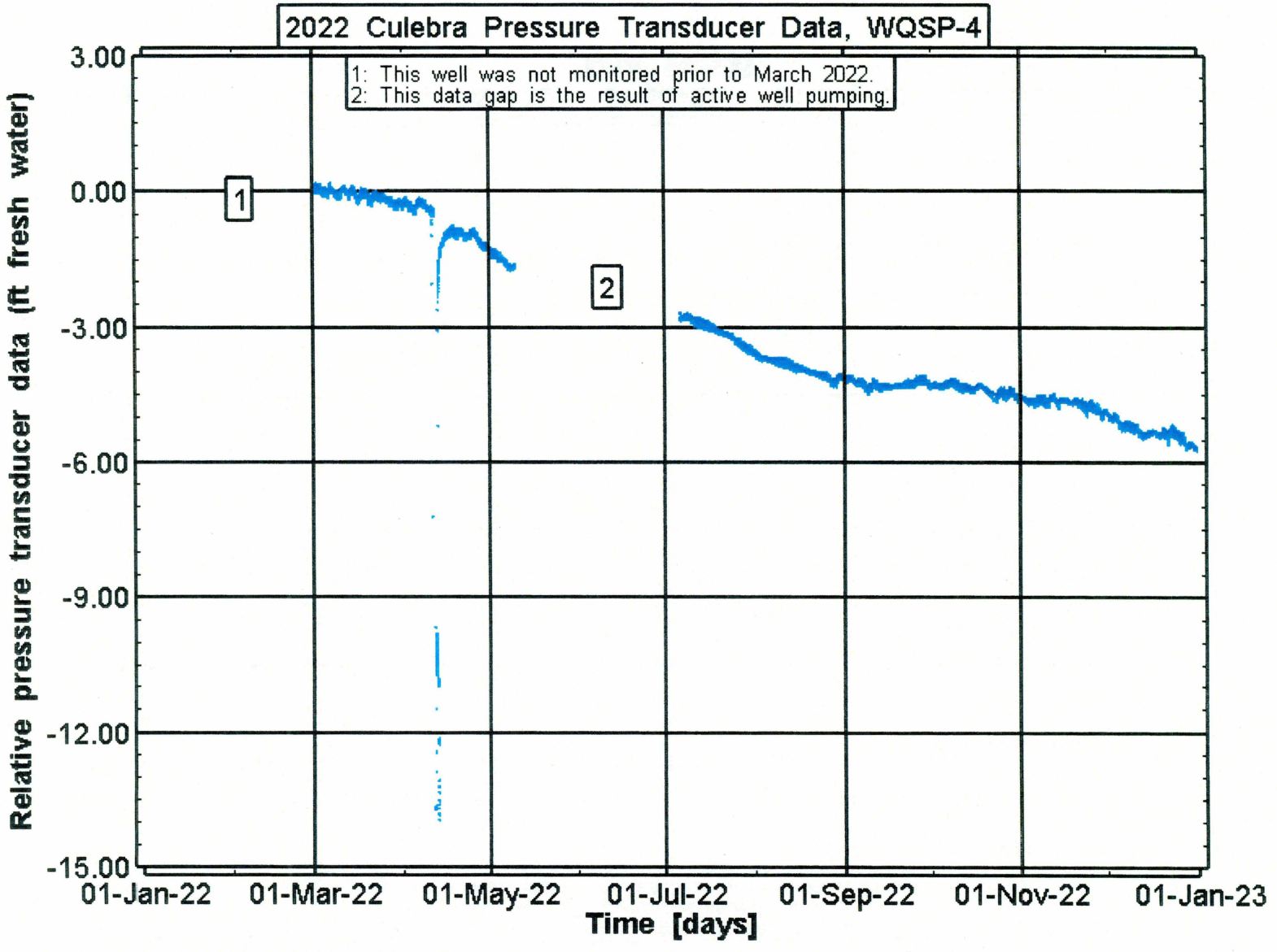

Figure 41. Well WQSP-4 experienced a net change in hydraulic head of -5.71 ft fresh water in 2022.

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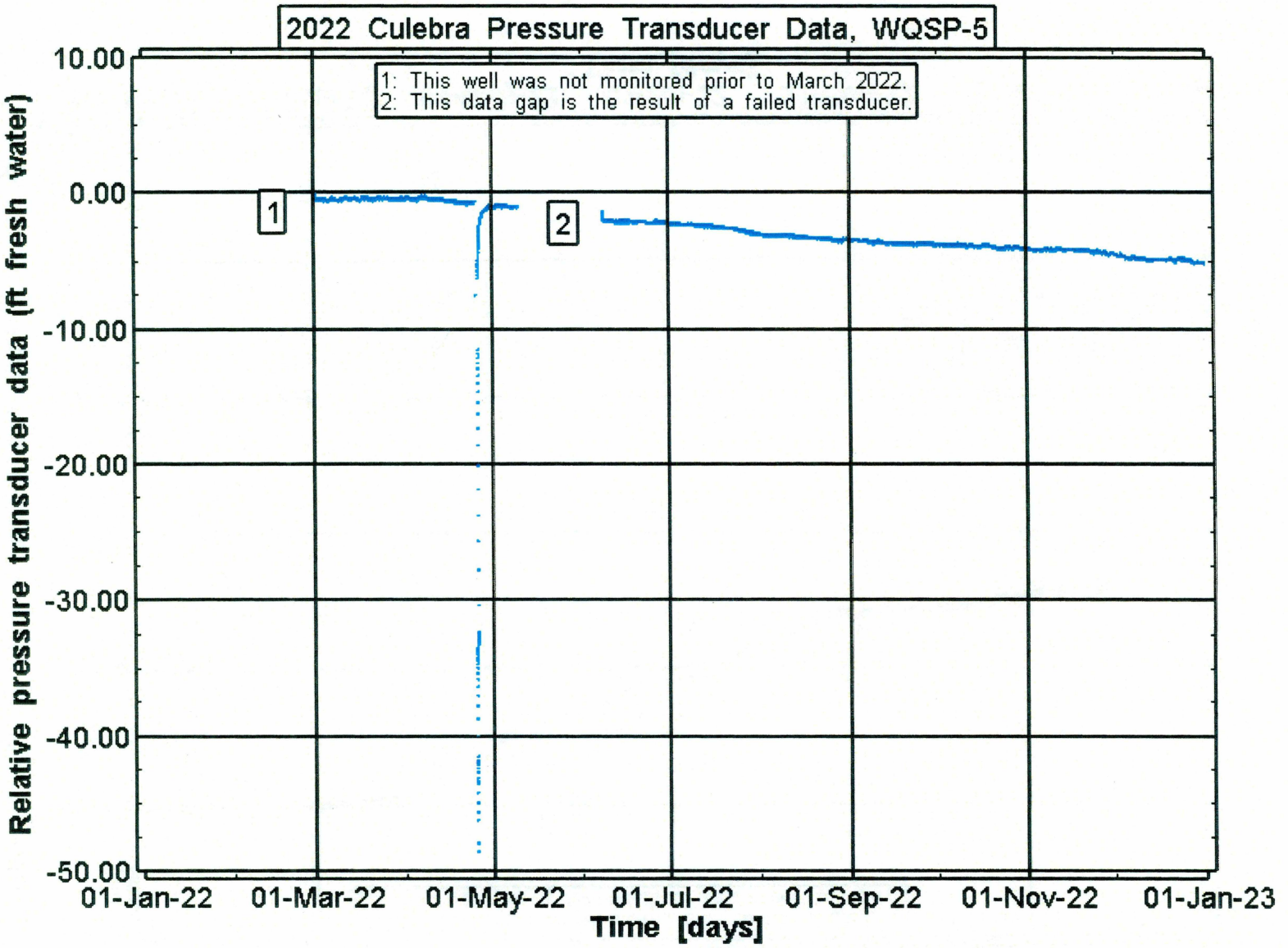

Figure 42. Well WQSP-5 experienced a net change in hydraulic head of -5.19 ft fresh water in 2022.

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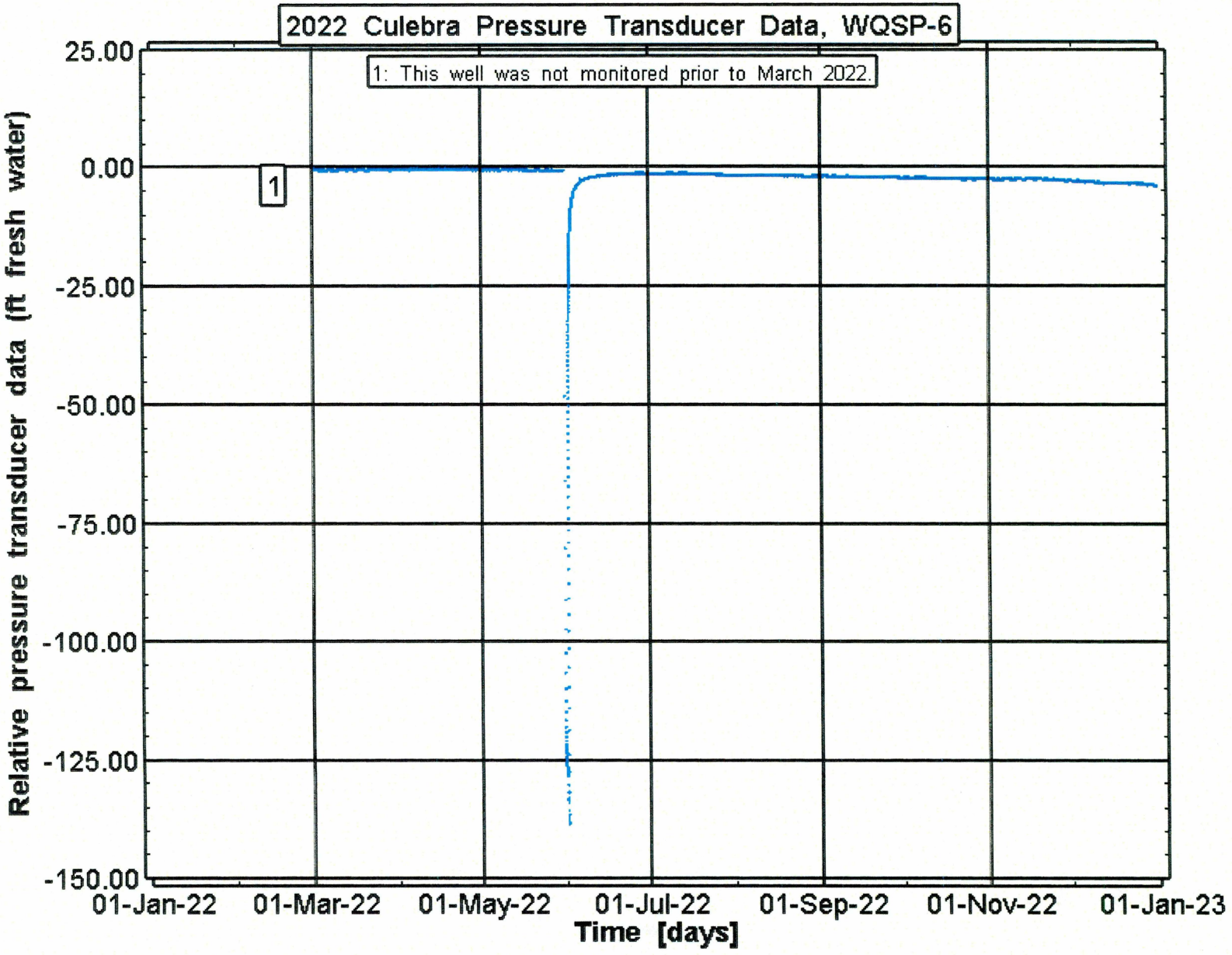

Figure 43. Well WQSP-6 experienced a net change in hydraulic head of -3.96 ft fresh water in 2022.

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