eki environment & water

TECHNICAL MEMORANDUM

TO: Panola County Groundwater Conservation District

FROM: Hugo Perea, Ph.D., EKI Environment & Water, Inc.
Clark Woolf, EKI Environment & Water, Inc.
Wade Oliver, P.G., EKI Environment & Water, Inc.

DATE: 21 May 2026

RE: Monitoring Program Evaluation and Technical Assessment of the Proposed East Texas Water Supply Project

1. Introduction

1.1 Background

The Panola County Groundwater Conservation District (District or PGCD) engaged EKI Environment & Water, Inc. (EKI) to conduct a Monitoring Program Evaluation and Desired Future Condition (DFC) Impact Analysis for the Carrizo-Wilcox Aquifer in Panola County. This Technical Memorandum documents findings from both tasks and provides technical context to inform the District's ongoing groundwater management.

Panola County is located in East Texas and overlies the Carrizo-Wilcox Aquifer system, a major aquifer as defined by the Texas Water Development Board (TWDB). Within the county, the aquifer system primarily includes the Upper Wilcox, Middle Wilcox, and Lower Wilcox formations. The geology of Panola County is such that the Carrizo-Wilcox — particularly the Middle Wilcox — is effectively the sole productive aquifer available to groundwater users. A small number of wells produce from the Lower Wilcox, though that interval is associated with poorer water quality. The Carrizo is not widely present in the county.

1.2 Regulatory Framework

Groundwater conservation districts (GCDs) are Texas' preferred method of groundwater management. GCDs within a groundwater management area (GMA) work together to set long-term regulatory goals known as Desired Future Conditions (DFCs). For the Carrizo-Wilcox Aquifer in GMA 11 (which contains Panola County), the DFC adopted during the most recently completed round of joint groundwater planning is an average drawdown in Panola County of no more than 21 feet between 2013 and 2080. This is a county-average target: drawdown in portions of the county may exceed 21 feet without necessarily violating the DFC if the county-wide average remains at or below the threshold.

TWDB uses the adopted DFCs, together with the groundwater availability model (GAM) for the northern portion of the Carrizo-Wilcox Aquifer, to estimate the Modeled Available Groundwater. The MAG represents the volume of groundwater that can be produced while still achieving the DFC. For Panola County, the MAG for the Carrizo-Wilcox Aquifer is 4,999 acre-feet per year (ac-ft/yr) (GMA 11, 2021 Joint Planning; GAM Run 21-016). The MAG is a planning metric, not a regulatory cap on pumping. The DFC — not the MAG — is the primary management objective.

1.3 Purpose and Scope

This Technical Memorandum addresses two tasks:

Task 1: Monitoring Program Evaluation — Review and characterize the District's monitoring well network, evaluate water level trends and measurement frequency, summarize GCD-permitted well production and TWDB county-wide pumpage estimates, and assess current conditions relative to the DFC and MAG.

Task 2: GAM Impact Analysis — Evaluate the potential impacts on the District's DFC and MAG of a large proposed East Texas water supply project using the GAM.

2. Task 1: Monitoring Program Evaluation

2.1 Well Inventory and Monitoring Network

2.1.1 Well Inventory

The District's well database (as of November 2025) contains records for 4,933 unique wells. The inventory by well status is presented in Table 2-1.

Table 2-1. Panola County GCD Well Inventory by Status

Well Status	Count
Active	2,312
Inactive	1,211
Plugged	838
Other (Drilled, Completed, Unknown, etc.)	572
Total	**4,933**

Oil and gas-related uses (oil and gas supply, rig supply, and frac pond operations) represent the largest category by number of wells, collectively accounting for over 1,400 wells across all reporting years. Water sales (92 wells), poultry operations (81 wells), public water supply (42 wells), and irrigation (27 wells) are other significant use categories. Oil and gas-related wells represent the most dynamic segment of the permitted well inventory, reflecting variability in industry activity in the region.

2.1.2 Water Level Monitoring Network

Of the District's wells, 2,001 wells have at least one water level measurement. District monitoring efforts increased around 2011, with the District collecting hundreds of measurements annually since that time. Beginning in 2018, the frequency of measurement at individual wells increased substantially, reflecting a shift toward monthly or quarterly monitoring at many wells.

Based on measurement records from 2015 through 2025, the 222 wells with at least annual monitoring are classified by measurement frequency in Table 2-2.

Table 2-2. Monitoring Wells by Measurement Frequency (2015–2025)

Monitoring Frequency	Number of Wells
Approximately monthly (~12 measurements/yr)	102
Approximately quarterly (~4 measurements/yr)	24
Approximately annual (~1 measurement/yr)	96
Total regularly monitored wells	**222**

An additional 699 wells have one or more water level records between 2015–2025. However, with fewer than two years of data or fewer than one measurement per year on average, these wells can supplement spatial coverage but are not suitable for trend analysis.

The District's monitoring approach aims to achieve spatial coverage across the county. The TWDB water well numbering grid, which corresponds to USGS 7.5-minute quadrangles, is shown as gray grid lines in Figure 2-1. Most of the TWDB water well numbering grids contain several wells, indicating the District has good spatial coverage of its monitoring network. The spatial distribution of monitoring wells by frequency is shown in Figure 2-1. Annual monitoring activity statistics are summarized in Table 2-3.

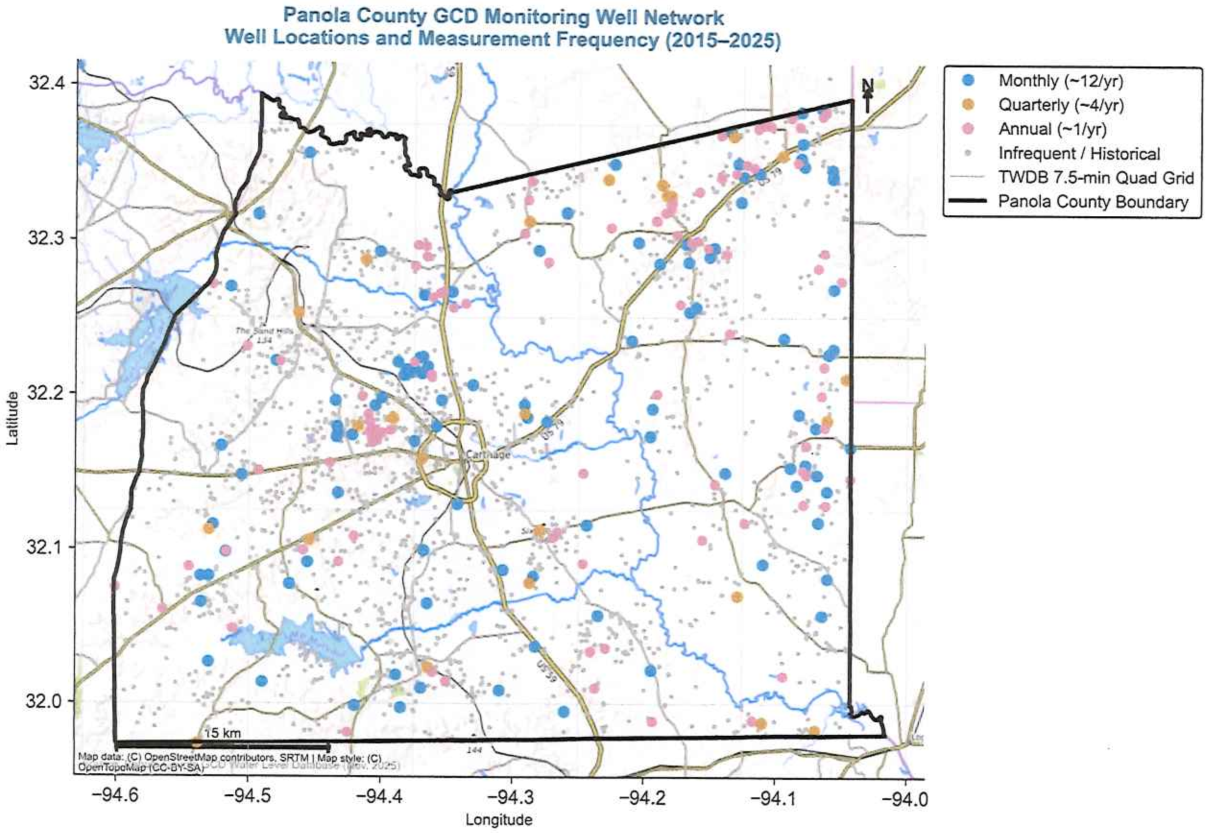


Figure 2-1. Panola County GCD monitoring well network, 2015–2025.

Table 2-3. Annual Monitoring Activity Summary, 2011–2025

Year	Wells Measured	Total Measurements	Median DTW (ft)
2011	203	204	50.0
2012	199	204	60.0
2013	226	250	60.0
2014	161	206	61.0
2015	137	141	54.0
2016	225	236	42.0
2017	113	202	38.2
2018	219	957	41.9
2019	177	1,324	44.0
2020	182	1,500	47.7
2021	236	1,583	43.0
2022	139	1,261	37.5
2023	140	1,261	34.1
2024	109	1,218	35.0
2025	119	972	30.6

DTW = depth to water below land surface. Median DTW is used in preference to average DTW because it is less sensitive to changes in the mix of shallow and deep wells measured each year.

2.2 Water Level Conditions and Trends

2.2.1 Data Quality Assurance

Prior to analysis, the water level dataset was reviewed to identify and exclude anomalous measurements. The review identified 93 records with negative depth-to-water (DTW) values, associated with 10 unique wells. Negative DTW values indicate that water levels are above the measurement reference point (i.e., the well is artesian or flowing under pressure). These records were flagged and excluded from the trend analysis, but are noted as potentially representing wells in areas of elevated aquifer pressure. No records with DTW values greater than 500 feet were identified. After quality assurance review, the clean dataset contains 12,627 records across 2,001 unique wells.

2.2.2 Current Water Level Conditions

Water levels measured across the monitoring network from 2011 to 2025 indicate generally stable to rising conditions. The county-wide median depth to water has decreased from approximately 50–61 feet in the 2011–2015 period to approximately 30–35 feet in 2023–2025, reflecting shallower water levels (i.e., rising water levels). This trend is confirmed by the well-by-well trend analysis in Section 2.2.3.

The monitoring period (2011–2025) began with extreme drought conditions, but has since seen average to above average precipitation. Annual precipitation at Carthage has generally exceeded the long-term normal of approximately 50 inches per year, with most years ranging from approximately 43 to 66 inches (Open-Meteo historical climate data). This above-normal precipitation likely contributes to aquifer recharge and is one important factor contributing to the stable-to-rising water level pattern observed during the monitoring period. Observed median depth to water and annual precipitation are shown together in Figure 2-2. The upper panel shows the DFC-equivalent rate of decline (+0.31 ft/yr) for reference. A secondary line in the lower panel shows the same trend using only wells measured in five or more consecutive years (consistent cohort, n=95). The analysis demonstrates that the overall trend is not an artifact of increased monitoring during the period.

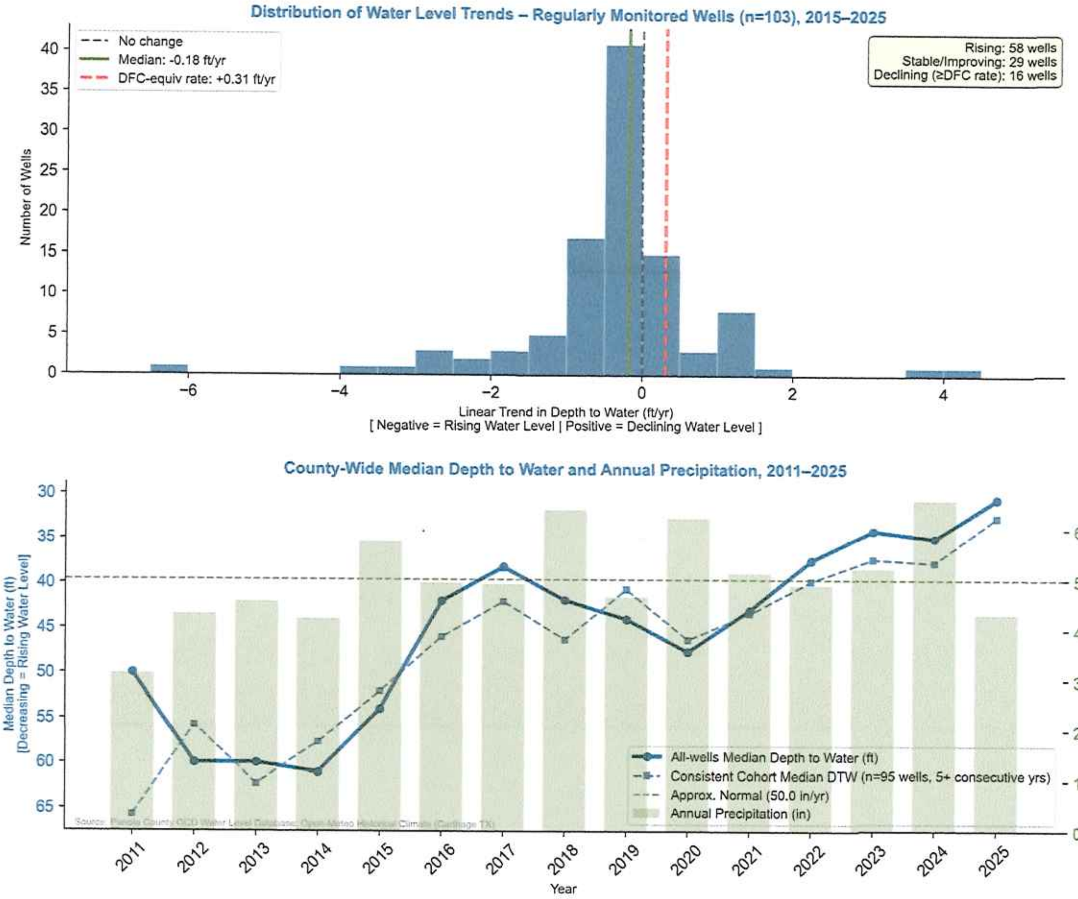


Figure 2-2. Water level trends among 103 regularly monitored wells (upper) and county-wide median depth to water with annual precipitation (lower), 2011–2025.

2.2.3 Water Level Trend Analysis

A quantitative trend analysis was performed for wells with at least five years of data and at least one measurement per year on average during 2015–2025. This yielded a dataset of 103 wells. Annual median DTW values per well were used to reduce noise from within-year variation.

The median trend across the 103-well network is –0.18 ft/yr (rising water levels; negative sign indicates decreasing depth to water). The mean trend is –0.31 ft/yr. The standard deviation of 1.27 ft/yr reflects meaningful heterogeneity across the network, with some wells showing rapid improvement and others showing gradual decline. Results by trend category are presented in Table 2-4.

Table 2-4. Distribution of Water Level Trends Among Regularly Monitored Wells, 2015–2025

Trend Category	Wells	% of Network
Rising water levels (trend < –0.1 ft/yr)	58	56%
Stable (trend –0.1 to +0.31 ft/yr)	29	28%
Declining at or above DFC-equivalent rate (trend > +0.31 ft/yr)	16	16%
Total	**103**	**100%**

The DFC-equivalent rate (+0.31 ft/yr) is the rate of water level decline that, if sustained linearly from 2013 to 2080, would accumulate to 21 feet of drawdown.

The majority of regularly monitored wells (84%) show stable or rising water levels during 2015–2025. Sixteen wells (16%) exhibit declining trends at a rate that, if sustained to 2080, could approach or exceed 21 feet of cumulative drawdown.

2.3 Groundwater Production

2.3.1 GCD-Permitted Well Production

The District tracks monthly production from permitted wells. Annual production totals by use category for 2017–2025 are presented in Table 2-5 and Figure 2-3. Total production reported to the District has ranged from approximately 2,270 ac-ft/yr (2017) to 5,809 ac-ft/yr (2022). Oil and gas-related water use is the dominant driver of year-to-year variability. Public water supply production is the most consistent category, averaging approximately 1,160 ac-ft/yr.

Table 2-5. GCD-Permitted Groundwater Production by Use Category (ac-ft/yr), 2017–2025

Year	Oil & Gas	Public Water Supply	Water Sales	Agricultural	Mining	Commercial/ Industrial	Total
2017	390	1,219	121	241	216	83	2,270
2018	538	1,318	519	312	162	99	2,948
2019	1,621	1,162	736	312	104	116	4,051
2020	2,914	1,202	900	222	141	102	5,481
2021	3,573	1,230	493	278	135	59	5,768
2022	3,508	1,290	564	201	154	92	5,809
2023	2,834	1,092	586	245	39	97	4,893
2024	916	1,032	403	237	151	61	2,800
2025	2,775	1,086	531	217	197	79	4,885

2.3.2 TWDB County-Wide Pumpage Estimates

TWDB independently estimates county-wide groundwater pumpage through its Water Use Survey program. These estimates are developed using two methods. Surveyed estimates represent pumpage reported directly to TWDB by water utilities, industrial users, and other entities participating in the annual water use survey. Non-surveyed estimates represent pumping estimated by TWDB for water users who do not directly report to the survey program, using standard statewide methods (e.g., derived from land use data and population estimates). These estimates carry greater uncertainty than direct survey data.

The non-surveyed TWDB estimates, which have increased substantially in recent years, primarily reflect TWDB estimates of oil and gas exploration and production water use in Panola County — operations that are not required to report to the TWDB water use survey. Given the methodological differences between District and TWDB-estimated pumping, it is likely that the District's estimate is more reliable in the case of Panola County. TWDB county-wide pumpage estimates are summarized in Table 2-6.

Table 2-6. TWDB County-Wide Groundwater Pumpage Estimates, Panola County, 2000–2023

Year	Surveyed (ac-ft/yr)	Non-Surveyed (ac-ft/yr)	Total (ac-ft/yr)
2000	1,957	2,032	3,989
2001	2,947	2,053	5,000
2002	2,249	2,049	4,298
2003	2,316	2,041	4,357
2004	2,259	2,032	4,291
2005	2,224	1,148	3,372
2006	2,458	1,234	3,692
2007	2,301	1,091	3,392
2008	2,156	2,477	4,633
2009	1,914	2,796	4,710
2010	4,218	3,441	7,659
2011	2,533	2,998	5,531
2012	2,258	2,543	4,801
2013	1,861	3,529	5,390
2014	1,670	4,508	6,178
2015	1,743	3,552	5,295
2016	1,496	2,584	4,080
2017	1,365	2,686	4,051
2018	1,606	4,484	6,090
2019	1,468	5,283	6,751
2020	1,451	6,078	7,529
2021	1,462	6,399	7,861
2022	1,477	6,870	8,347
2023	1,585	6,296	7,881

Source: TWDB Water Use Survey (SumFinal dataset), accessed November 2025.

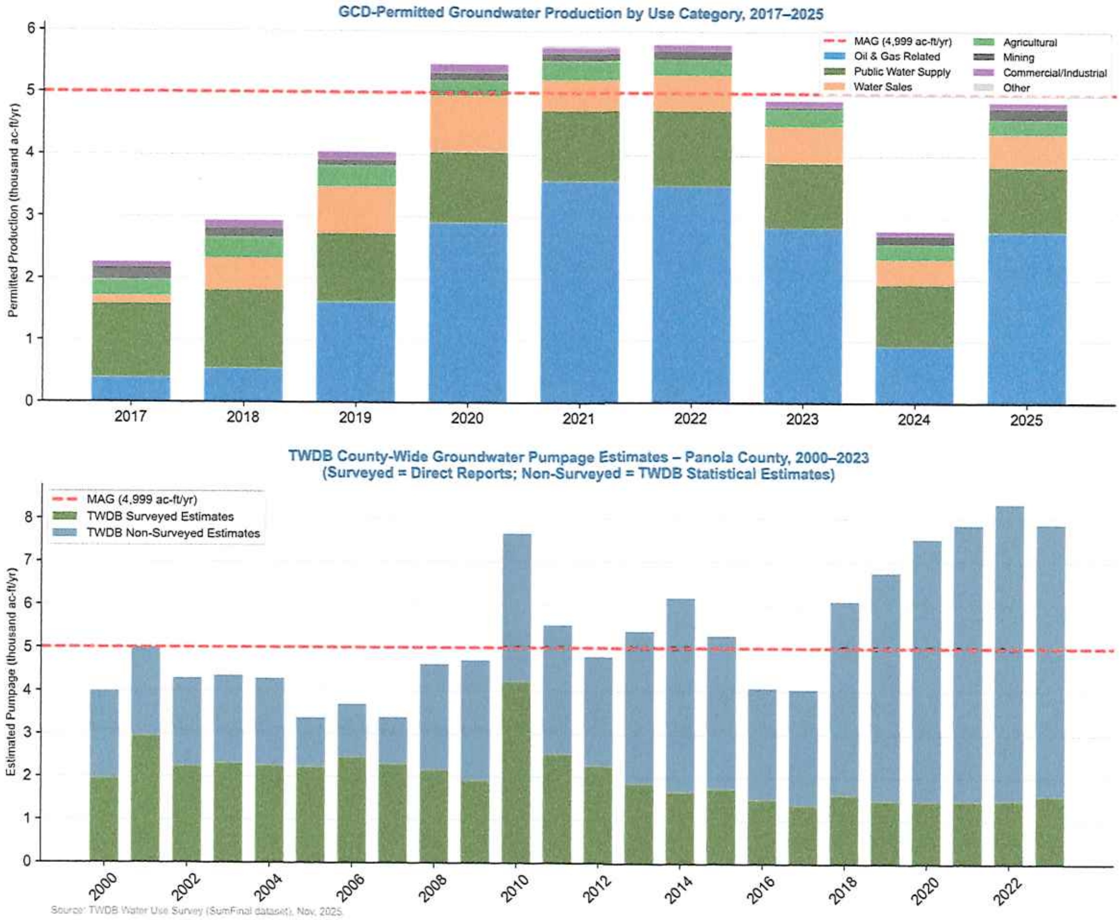


Figure 2-3. GCD-permitted production by use category, 2017–2025 (upper), and TWDB county-wide pumpage estimates, 2000–2023 (lower).

2.4 Comparison to DFC and MAG

2.4.1 Comparison to MAG

GCD-permitted production exceeded the MAG of 4,999 ac-ft/yr in three of the nine years with complete data (2020, 2021, and 2022), peaking at 5,809 ac-ft/yr in 2022. Production has been at or below the MAG in six of nine years and returned below the MAG in 2023–2025 as oil and gas activity moderated. The MAG should be understood as a planning metric: isolated annual exceedances do not by themselves indicate that the aquifer is being over-developed, particularly when observed water levels remain stable, as they have in Panola County.

2.4.2 GMA 11 Pumping Relative to MAGs

To better understand another potential source of Panola County's relatively stable water levels, we compared 2023 actual pumping (as estimated by TWDB) to MAGs for all counties in GMA 11 producing from the Carrizo-Wilcox Aquifer. This comparison is presented in Figure 2-4 and Table 2-7.

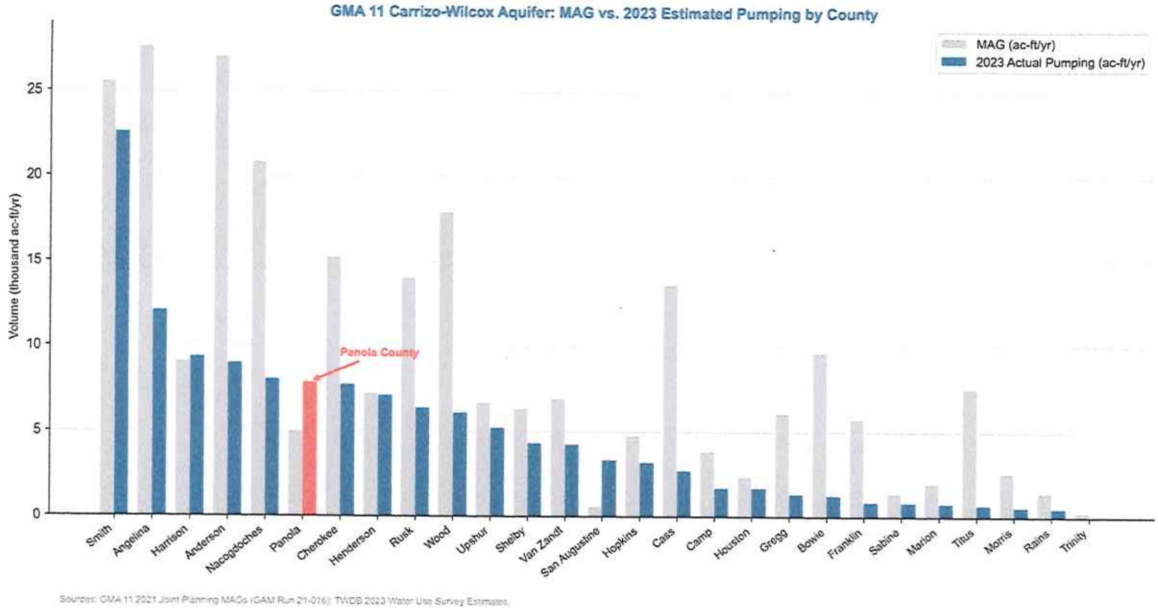


Figure 2-4. GMA 11 Carrizo-Wilcox Aquifer: MAG versus 2023 estimated pumping by county.

Table 2-7. GMA 11 Carrizo-Wilcox Aquifer — MAG vs. 2023 Estimated TWDB Pumping

County	MAG (ac-ft/yr)	2023 Pumping (ac-ft/yr)	Pumping as % of MAG
Anderson	27,024	8,996	33%
Angelina	27,611	12,104	44%
Cherokee	15,241	7,757	51%
Harrison	9,096	9,363	103%
Henderson	7,222	7,105	98%
Houston	2,355	1,692	72%
Nacogdoches	20,859	8,046	39%
Panola	4,999	7,881	158%
Rusk	14,018	6,379	46%
Sabine	1,310	832	64%
San Augustine	3,760	3,351	89%
Shelby	6,319	4,313	68%
Smith	25,546	22,607	88%
Trinity	9,460	<100	<1%
Upshur	6,657	5,209	78%
Wood	17,902	6,089	34%

2023 pumping figures are TWDB county-wide pumpage estimates (Water Use Survey). Sources: GMA 11 2021 Joint Planning MAGs (GAM Run 21-016); TWDB 2023 Water Use Survey (including non-surveyed estimates).

The regional comparison reveals that the majority of GMA 11 counties are pumping significantly below their MAGs — in several cases, less than 40% of the MAG. The DFC of 21 feet of average drawdown in Panola County was established based on a GAM simulation in which each county was pumping at the level of the MAG. If GMA 11 counties are collectively pumping well below what was modeled in the DFC run, the aquifer has experienced less stress than was modeled, contributing to less actual drawdown than the model projected. This regional effect — combined with above-normal precipitation during the monitoring period — likely explains the stable-to-rising water level conditions observed in Panola County, and should be kept in mind when evaluating how representative current conditions are of long-term aquifer behavior.

2.4.3 Summary of Monitoring Findings

Based on the monitoring data reviewed, the DFC has not been reached and current trends do not indicate a risk of not achieving the DFC. Observed water levels during 2011–2025 show no systematic declining trend approaching 21 feet of cumulative drawdown from 2013 baseline conditions. Median depth to water across the monitoring network has decreased (risen) during this period. Of the 103 wells analyzed, 84% show stable or rising water levels. Further, the District's monitoring well network is robust and defensible, with an excellent spatial distribution of wells and a monthly measurement frequency in many wells demonstrating both annual and sub-annual water level changes.

3. Task 2: GAM Impact Analysis

3.1 Model Description

The TWDB Groundwater Availability Model for the northern portion of the Queen City-Sparta and Carrizo-Wilcox aquifer systems (GAM Run 21-016) was used for this analysis. The GAM is the TWDB's standard tool for evaluating groundwater availability in GMA 11 and serves as the "best available science" for MAG calculations.

The model simulates groundwater flow in four aquifer layers in Panola County. The Middle Wilcox is the dominant productive layer. All drawdown values are expressed as the average decline in water levels (in feet) relative to 2013 baseline conditions, consistent with the DFC metric. The Carrizo-Wilcox combined average drawdown for Panola County is computed as an average across all model cells in all four Carrizo-Wilcox layers.

3.2 Scenario Description

Three GAM scenarios were developed to evaluate the potential impact on the DFC and MAG in Panola County of a planned large water supply project in Henderson, Anderson, and Houston counties approximately 80 miles west of the District.

Scenario 1 — Sustained: Continued groundwater pumping in Panola County at a rate approximating current pumping (3,909 ac-ft/yr), without the proposed East Texas water supply project. This scenario represents expected future conditions if the project does not proceed and current pumping patterns in the District are maintained. Note that it does not incorporate estimated current pumping outside PGCD.

Scenario 2 — Project: Panola County pumping at 3,909 ac-ft/yr plus the incremental drawdown from the proposed East Texas water supply project. When compared with Scenario 1, this scenario quantifies the project's impact on water levels and the DFC in Panola County.

Scenario 3 — With East Texas Project and Meeting DFC: Panola County pumping was adjusted to achieve the DFC of 21 feet of average drawdown with the East Texas Project also included in the model run. This run approximates an "updated MAG" for Panola County GCD if the East Texas project proceeds. The result was 4,740 acre-feet per year, a reduction of 259 acre-feet per year from the current MAG of 4,999 acre-feet per year.

3.3 Drawdown Results

3.3.1 Layer-by-Layer Results

Tables 3-1 through 3-3 present average drawdown by aquifer layer and decade for Scenarios 1 and 2. Because each model layer covers a different spatial extent within Panola County, these per-layer averages are not directly comparable to the DFC (which uses the combined Carrizo-Wilcox spatial average; see Section 3.4).

Table 3-1. Average Drawdown by Aquifer Layer — Scenario 1: Sustained (ft from 2013 baseline)

Aquifer Layer	2020	2030	2040	2050	2060	2070	2080
Upper Wilcox	4.3	5.5	5.8	5.9	6.0	6.0	6.0
Middle Wilcox	13.8	15.9	16.5	16.7	16.8	16.8	16.9
Lower Wilcox	18.5	21.1	21.8	22.1	22.2	22.2	22.3

Table 3-2. Average Drawdown by Aquifer Layer — Scenario 2: With East Texas Project (ft from 2013 baseline)

Aquifer Layer	2020	2030	2040	2050	2060	2070	2080
Upper Wilcox	4.6	6.1	6.5	6.6	6.6	6.6	6.6
Middle Wilcox	14.3	17.0	17.7	17.9	17.9	17.9	17.9
Lower Wilcox	19.2	22.6	23.4	23.6	23.7	23.7	23.7

Table 3-3. Incremental Drawdown Attributable to East Texas Project (Scenario 2 minus Scenario 1, ft)

Aquifer Layer	2020	2030	2040	2050	2060	2070	2080
Upper Wilcox	0.3	0.6	0.7	0.7	0.7	0.6	0.6
Middle Wilcox	0.5	1.1	1.2	1.2	1.1	1.1	1.1
Lower Wilcox	0.7	1.5	1.6	1.5	1.5	1.4	1.4

Key observations from the layer-by-layer results: Drawdown is greatest in the western portion of Panola County and decreases to the east, reflecting the influence of regional pumping centers to the west of the county. The Lower Wilcox shows the highest average drawdown per layer (exceeding 21 ft even in the Sustained Scenario), reflecting regional pressure decline rather than local overpumping; the Lower Wilcox has limited production in Panola County due to poorer water quality. The Middle Wilcox, as the primary productive layer, shows drawdown of approximately 16.9 feet (Sustained) and 17.9 feet (Project) at 2080. The incremental drawdown from the East Texas project averages approximately 1.1 feet for the Middle Wilcox and 1.4 feet for the Lower Wilcox at 2080.

3.3.2 Drawdown Maps

Spatial drawdown patterns are presented in Figures 3-1 through 3-6 as contour maps with labeled contours overlaid on a topographic basemap. Contour intervals are 2 feet for the Sustained and Project scenarios and 1 foot for the incremental drawdown maps.

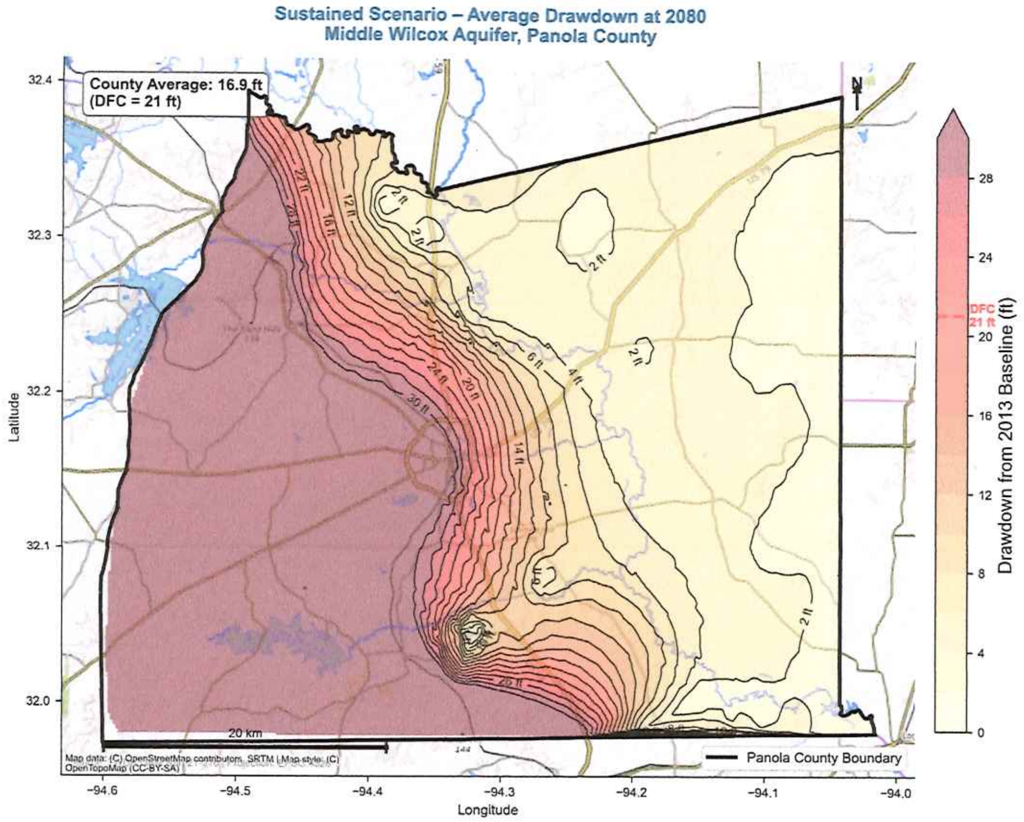


Figure 3-1. Scenario 1 (Sustained) — average drawdown at 2080, Middle Wilcox Aquifer.

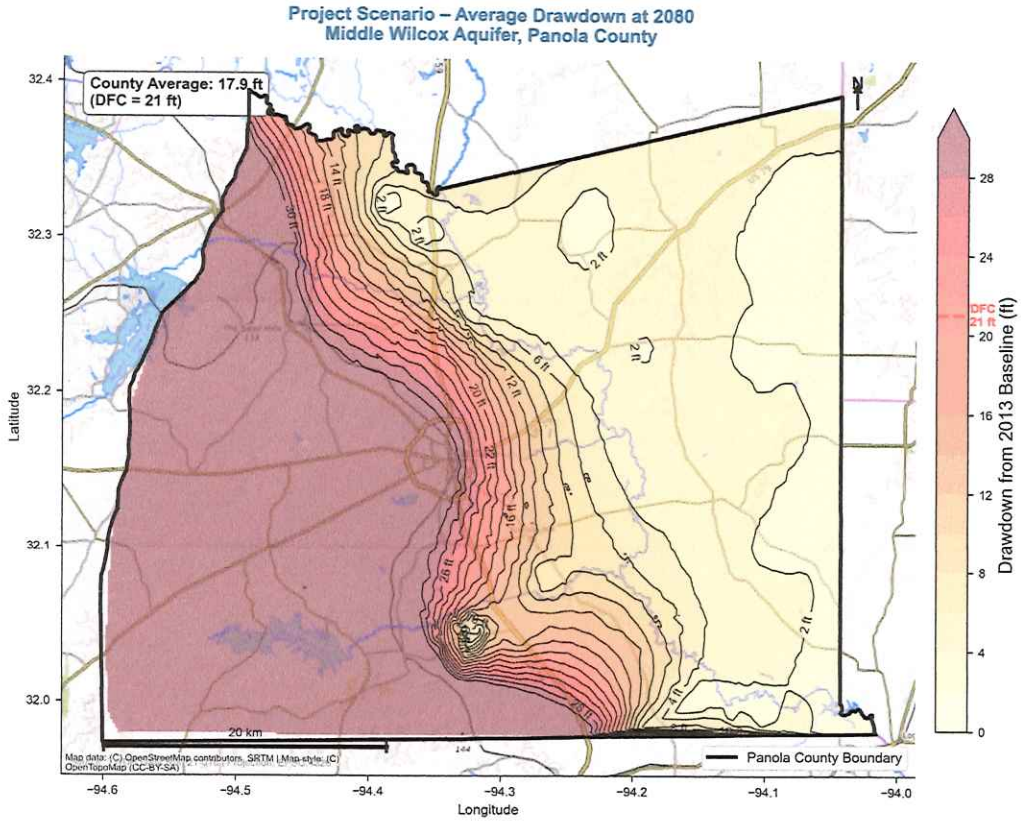


Figure 3-2. Scenario 2 (With East Texas Project) — average drawdown at 2080, Middle Wilcox Aquifer.

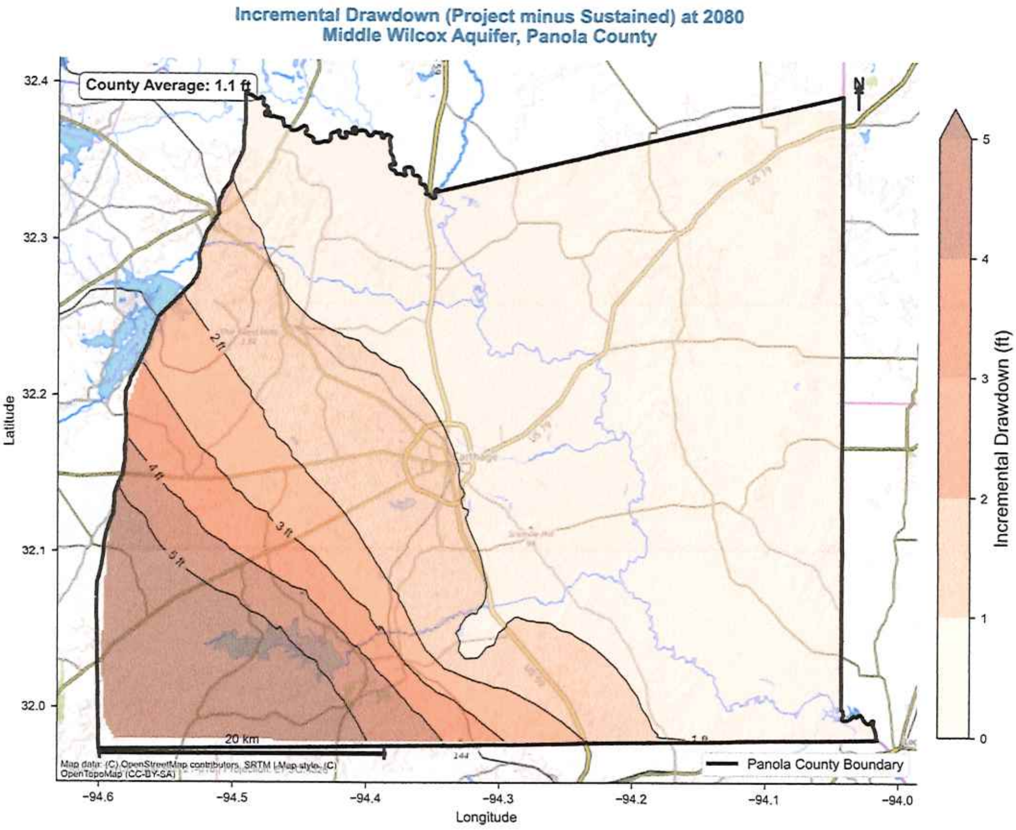


Figure 3-3. Incremental drawdown at 2080, Middle Wilcox Aquifer (Scenario 2 minus Scenario 1).

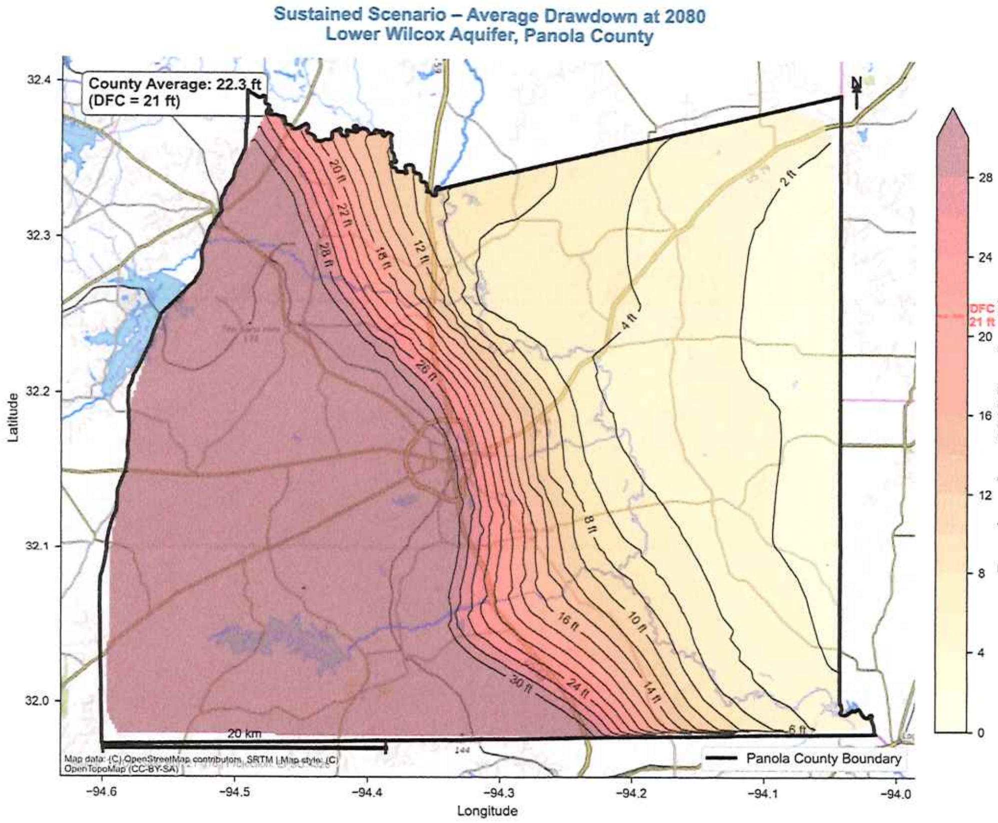


Figure 3-4. Scenario 1 (Sustained) — average drawdown at 2080, Lower Wilcox Aquifer.

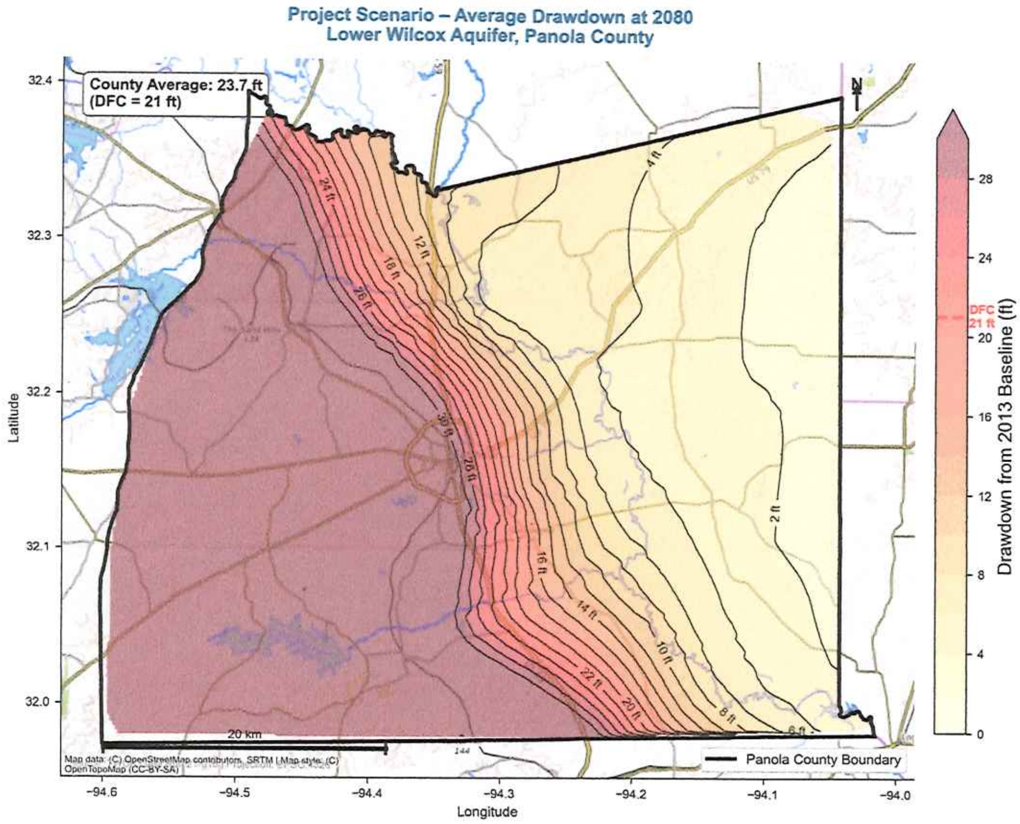


Figure 3-5. Scenario 2 (With East Texas Project) — average drawdown at 2080, Lower Wilcox Aquifer.

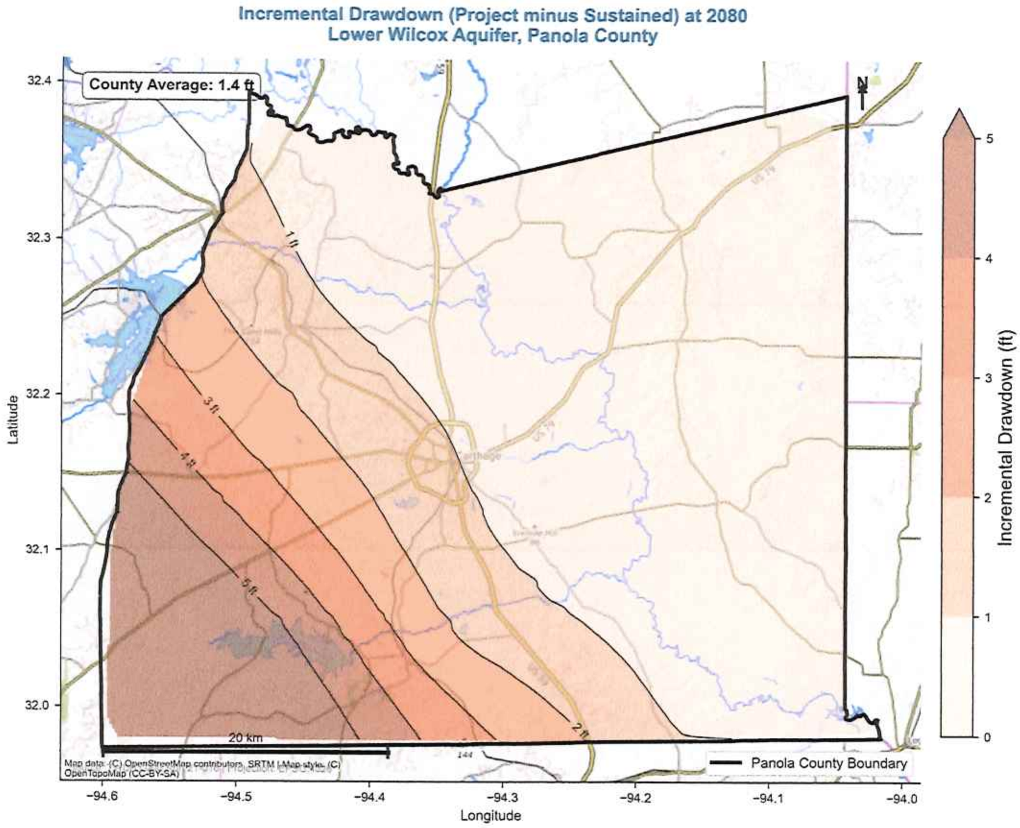


Figure 3-6. Incremental drawdown at 2080, Lower Wilcox Aquifer (Scenario 2 minus Scenario 1).

3.4 Comparison to DFC

The combined Carrizo-Wilcox average drawdown for Panola County is compared to the DFC in Table 3-4 for all three scenarios.

Table 3-4. Projected Carrizo-Wilcox Average Drawdown vs. DFC — All Scenarios, Panola County

Metric	Scenario 1: Sustained	Scenario 2: With Project	Scenario 3: With Project (at MAG)
Panola County Pumping	3,909 ac-ft/yr	3,909 ac-ft/yr	4,740 ac-ft/yr
Average Drawdown at 2080	~16 ft	~17 ft	~21 ft
Panola County DFC for the Carrizo-Wilcox Aquifer	21 ft	21 ft	21 ft
Margin below DFC	**~5 ft**	**~4 ft**	**0 ft (at DFC)**

Scenario 1 (Sustained, no project): Projected average drawdown of approximately 16 feet at 2080, approximately 5 feet below the DFC. Under current pumping conditions and without the project, Panola County is well-positioned to achieve the DFC.

Scenario 2 (With East Texas Project): Projected average drawdown of approximately 17 feet at 2080, approximately 4 feet below the DFC. The project adds approximately 1 foot of average drawdown to Panola County, reducing but not eliminating the margin below the DFC.

Scenario 3 (With East Texas Project, at MAG): If the East Texas project proceeds, model results indicate Panola County could produce at an estimated 4,740 ac-ft/yr and still achieve the DFC. This rate is 259 ac-ft/yr less than the current MAG (4,999 ac-ft/yr), reflecting the change required to offset the project's incremental contribution to drawdown in Panola County.

4. Conclusions and Recommendations

Several key conclusions and recommendations from this analysis are included below:

1. Water levels are stable to rising under current conditions. Observed water levels across the Panola County monitoring network (2011–2025) show a predominantly stable-to-rising pattern. Trend analysis across 103 regularly monitored wells confirms that 84% show stable or improving conditions. The current period has been climatologically wet and neighboring counties in GMA 11 are not currently pumping at a level consistent with their MAGs. Detailed water level trends for select monitoring wells are shown in Appendix A.

2. The proposed East Texas project adds approximately 1 foot of incremental drawdown to Panola County. This incremental impact is concentrated in the western portion of the county. Projected drawdown at current pumping levels remains approximately 4 feet below the DFC even with the project.

3. If the East Texas project proceeds, the updated estimated MAG is 4,740 ac-ft/yr. This groundwater availability is 259 ac-ft/yr less than the current MAG.

4. TWDB non-surveyed pumping estimates substantially exceed GCD-permitted production. The difference is primarily attributable to TWDB estimates for oil and gas-related water use. The District's own production records provide a more direct measure of permitted groundwater use within the county. However, given the importance of the TWDB water use survey estimates for water availability studies and planning, we recommend collaborating with TWDB to further reconcile the differences and potentially provide updated values.

5. Track oil and gas water use proactively. Oil and gas-related water use has been the primary driver of production variability and the primary cause of years when GCD-permitted production exceeded the MAG. Continued monitoring is important for understanding potential short- and long-term impacts on the aquifer.

6. Track groundwater pumping in neighboring GMA 11 counties. The analysis demonstrated that pumping rates in neighboring counties can influence water levels in Panola County.

7. The District has a well-distributed and technically defensible groundwater monitoring network. The spatial and temporal distribution of water level monitoring allows the District to defensibly demonstrate compliance with DFCs.

5. References

TWDB. 2025. Water Use Survey — Historical Groundwater Pumping Estimates. Accessed November 2025.

TWDB. 2021. Modeled Available Groundwater for the Carrizo-Wilcox, Queen City, and Sparta Aquifers in Groundwater Management Area 11 — 2021 Joint Planning (GAM Run 21-016 MAG). Austin, TX.

Panola County Groundwater Conservation District. 2025. Water Level Data Export, November 2025.

Panola County Groundwater Conservation District. 2025. Permitted Well Production Export, November 2025.

Open-Meteo. 2025. Historical Climate Data — Carthage, Texas (Latitude 32.157°N, Longitude 94.342°W). Accessed February 2026. https://archive-api.open-meteo.com

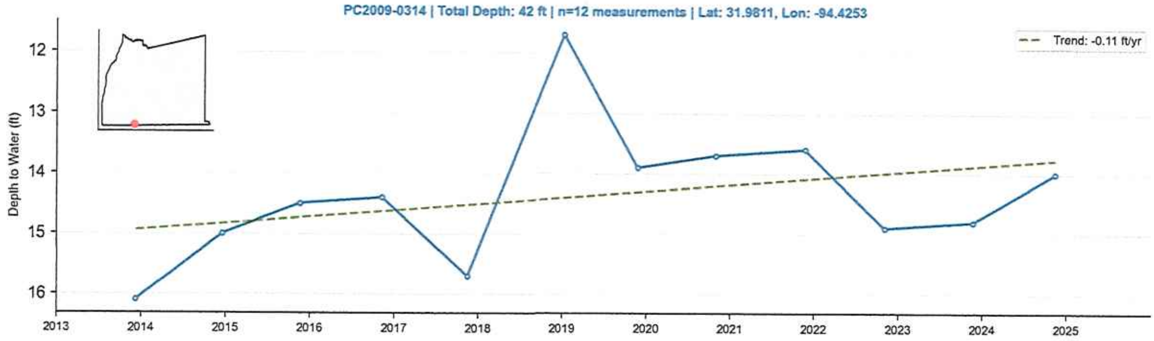
Appendix A

Monitoring Well Hydrographs

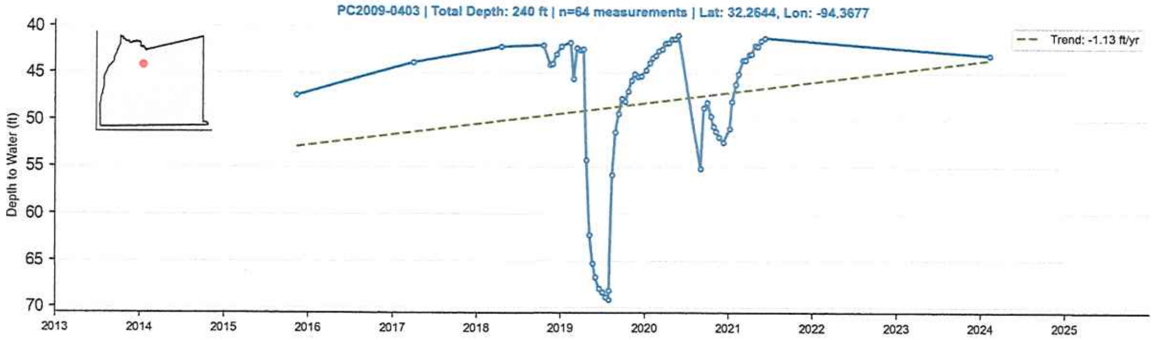
Hydrographs for the 103 wells meeting the threshold for trend analysis (at least five years of data and approximately annual or more frequent monitoring during 2015–2025) are presented in the following appendix. Each panel shows the measured depth-to-water record from 2013 through 2025, with a linear trend line overlaid.

Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 1 of 26

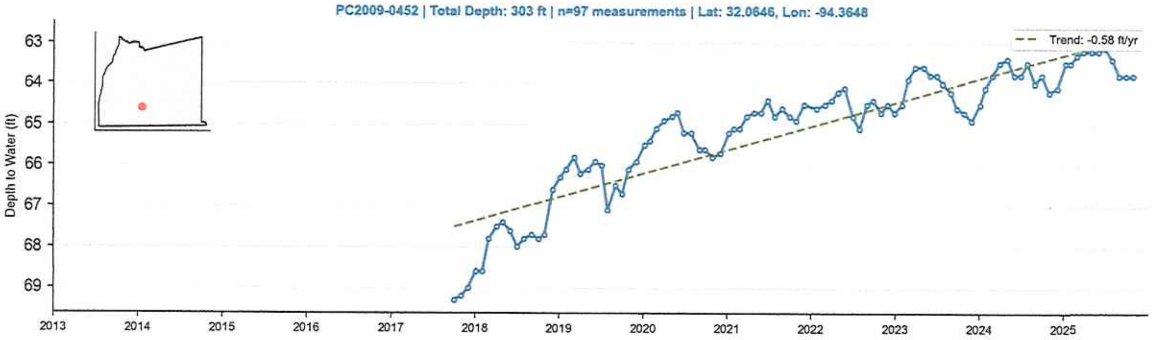
PC2009-0314 | Total Depth: 42 ft | n=12 measurements | Lat: 31.9811, Lon: -94.4253



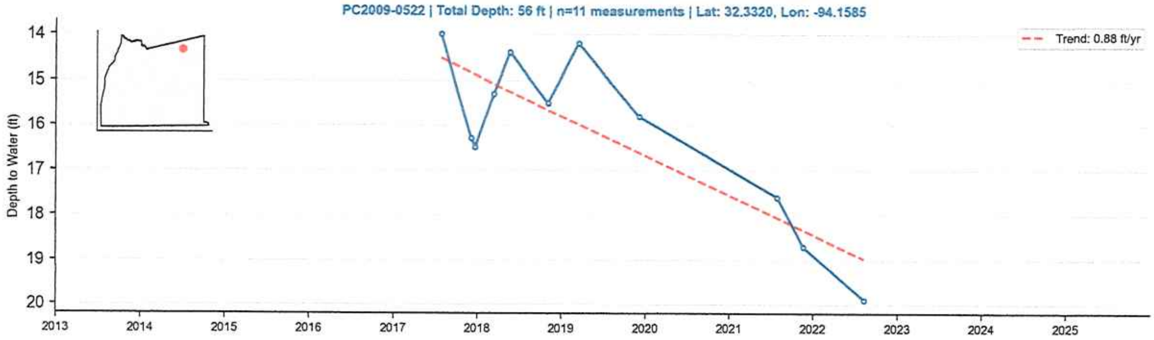
PC2009-0403 | Total Depth: 240 ft | n=64 measurements | Lat: 32.2644, Lon: -94.3677



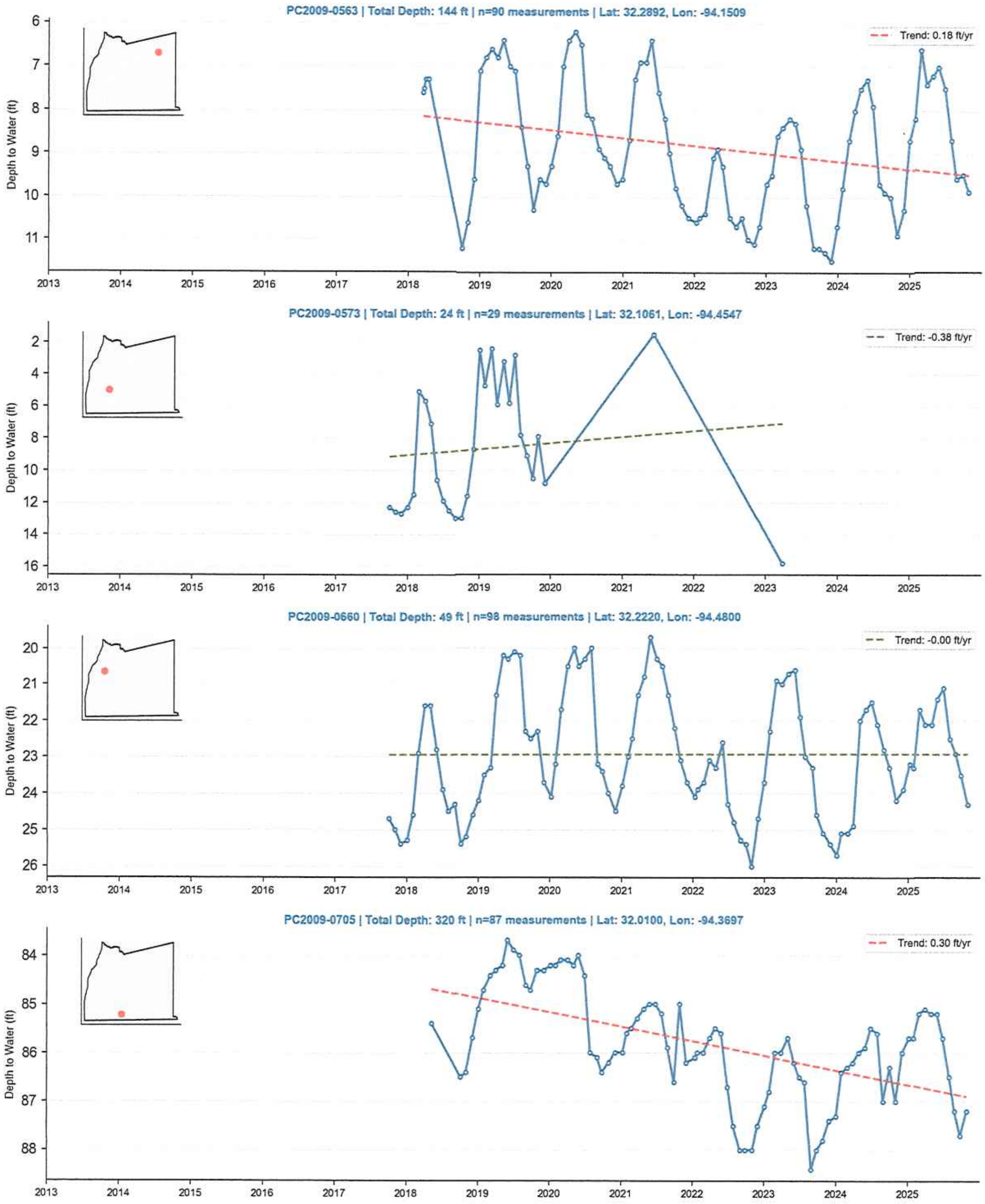
PC2009-0452 | Total Depth: 303 ft | n=97 measurements | Lat: 32.0646, Lon: -94.3648

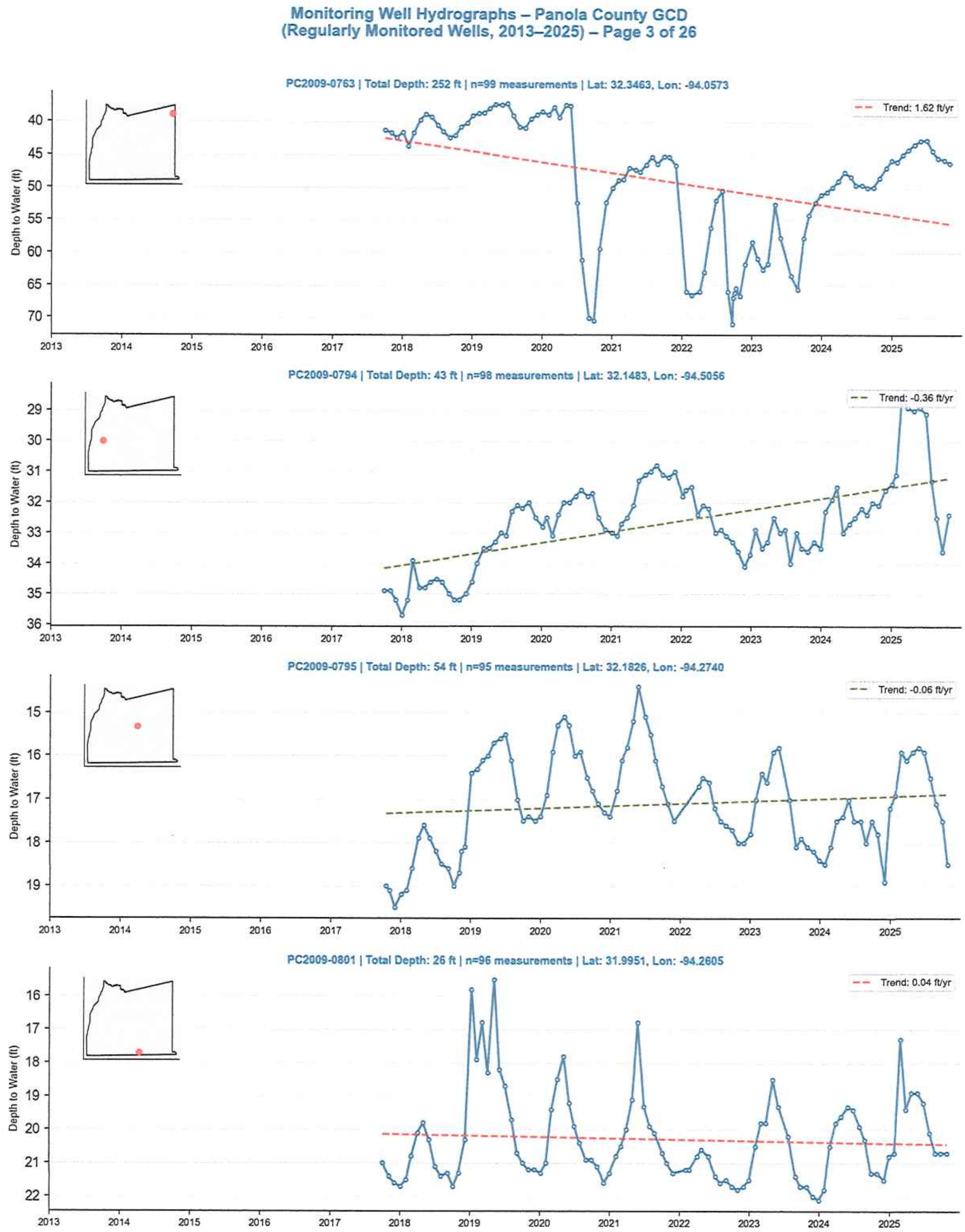


PC2009-0522 | Total Depth: 56 ft | n=11 measurements | Lat: 32.3320, Lon: -94.1585



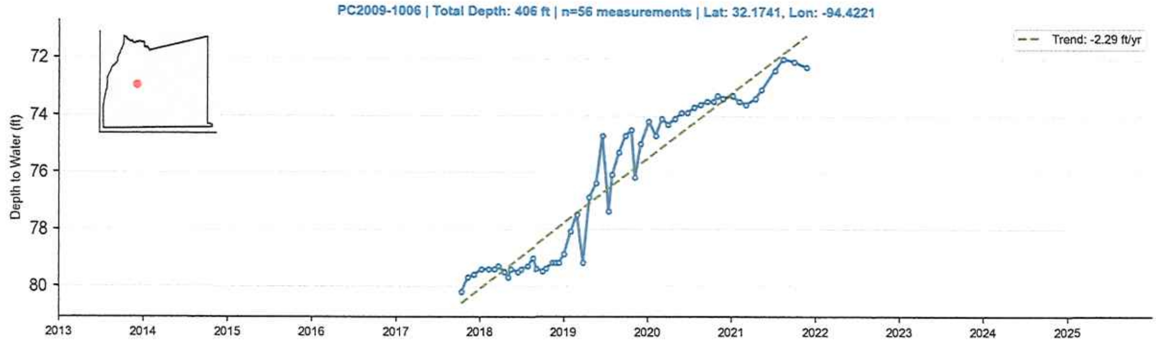
**Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 2 of 26**



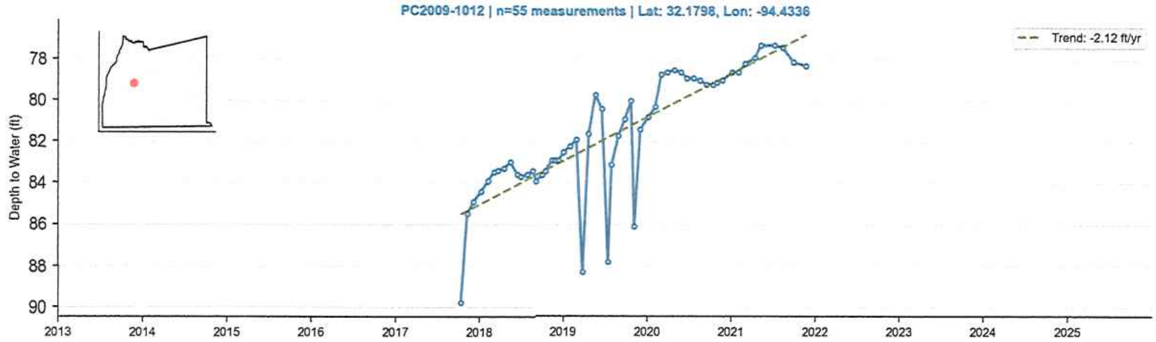

Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 3 of 26
PC2009-0763 | Total Depth: 252 ft | n=99 measurements | Lat: 32.3463, Lon: -94.0573
Trend: 1.62 ft/yr
PC2009-0794 | Total Depth: 43 ft | n=98 measurements | Lat: 32.1483, Lon: -94.5056
Trend: -0.36 ft/yr
PC2009-0795 | Total Depth: 54 ft | n=95 measurements | Lat: 32.1826, Lon: -94.2740
Trend: -0.06 ft/yr
PC2009-0801 | Total Depth: 26 ft | n=96 measurements | Lat: 31.9951, Lon: -94.2605
Trend: 0.04 ft/yr
Depth to Water (ft)

Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 4 of 26

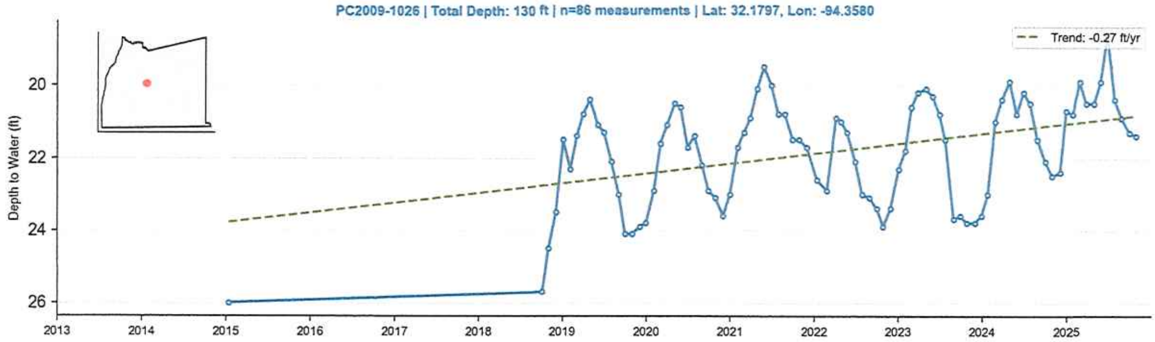
PC2009-1006 | Total Depth: 406 ft | n=56 measurements | Lat: 32.1741, Lon: -94.4221



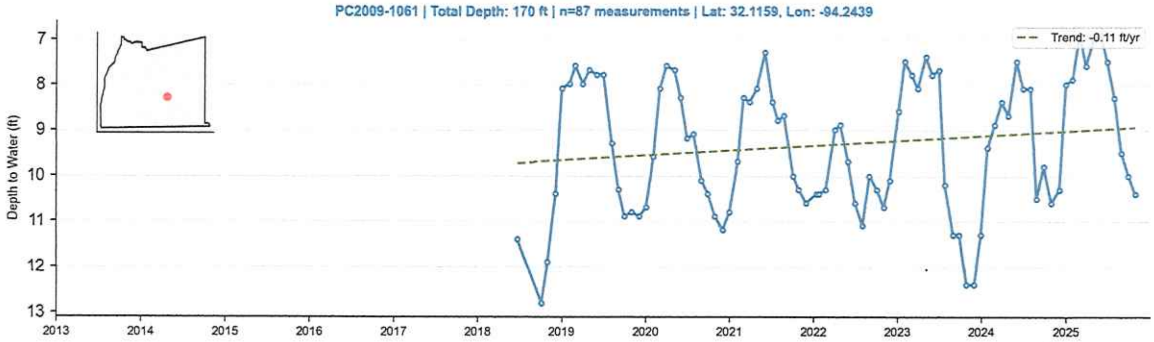
PC2009-1012 | n=55 measurements | Lat: 32.1798, Lon: -94.4336



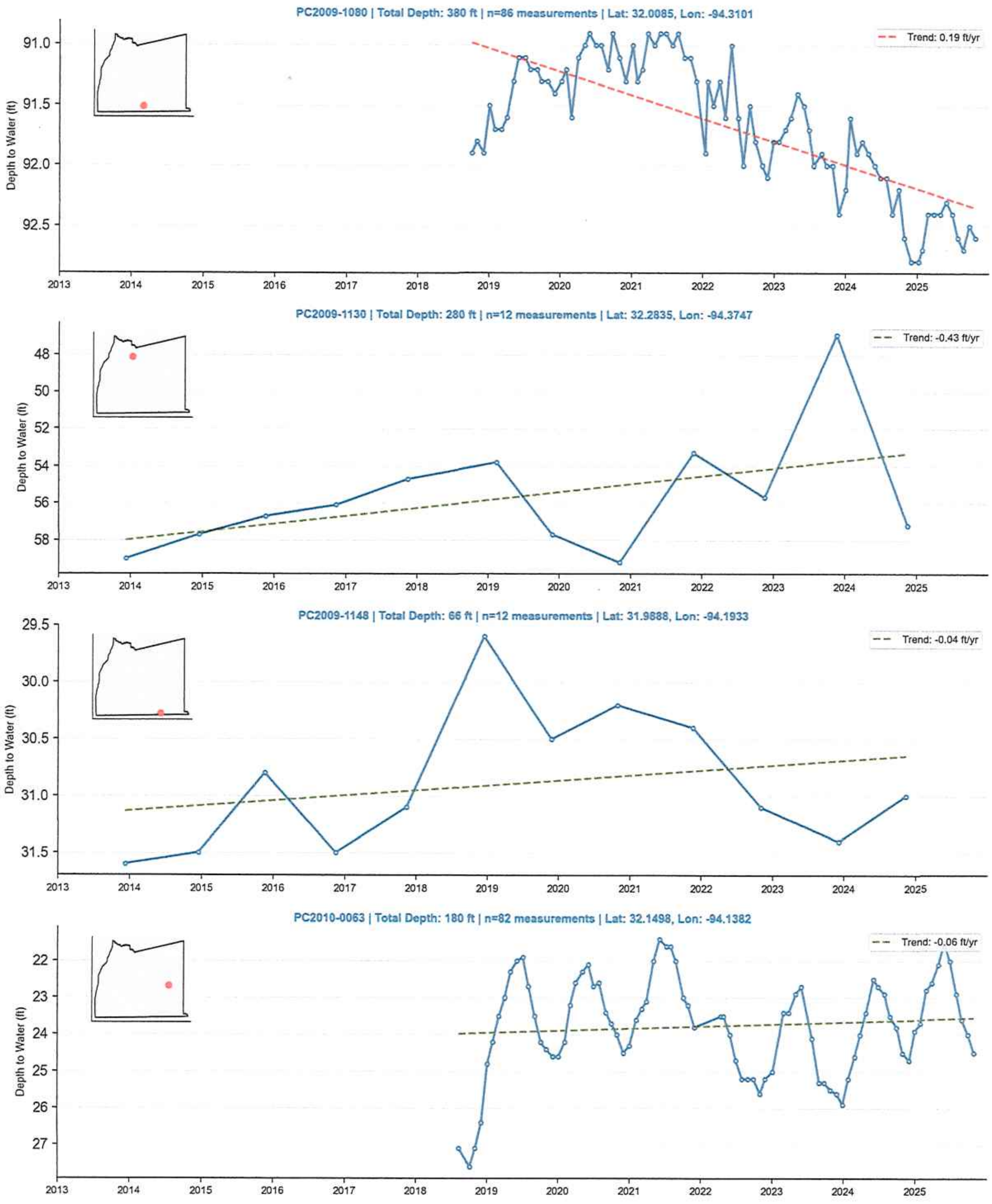
PC2009-1026 | Total Depth: 130 ft | n=86 measurements | Lat: 32.1797, Lon: -94.3580

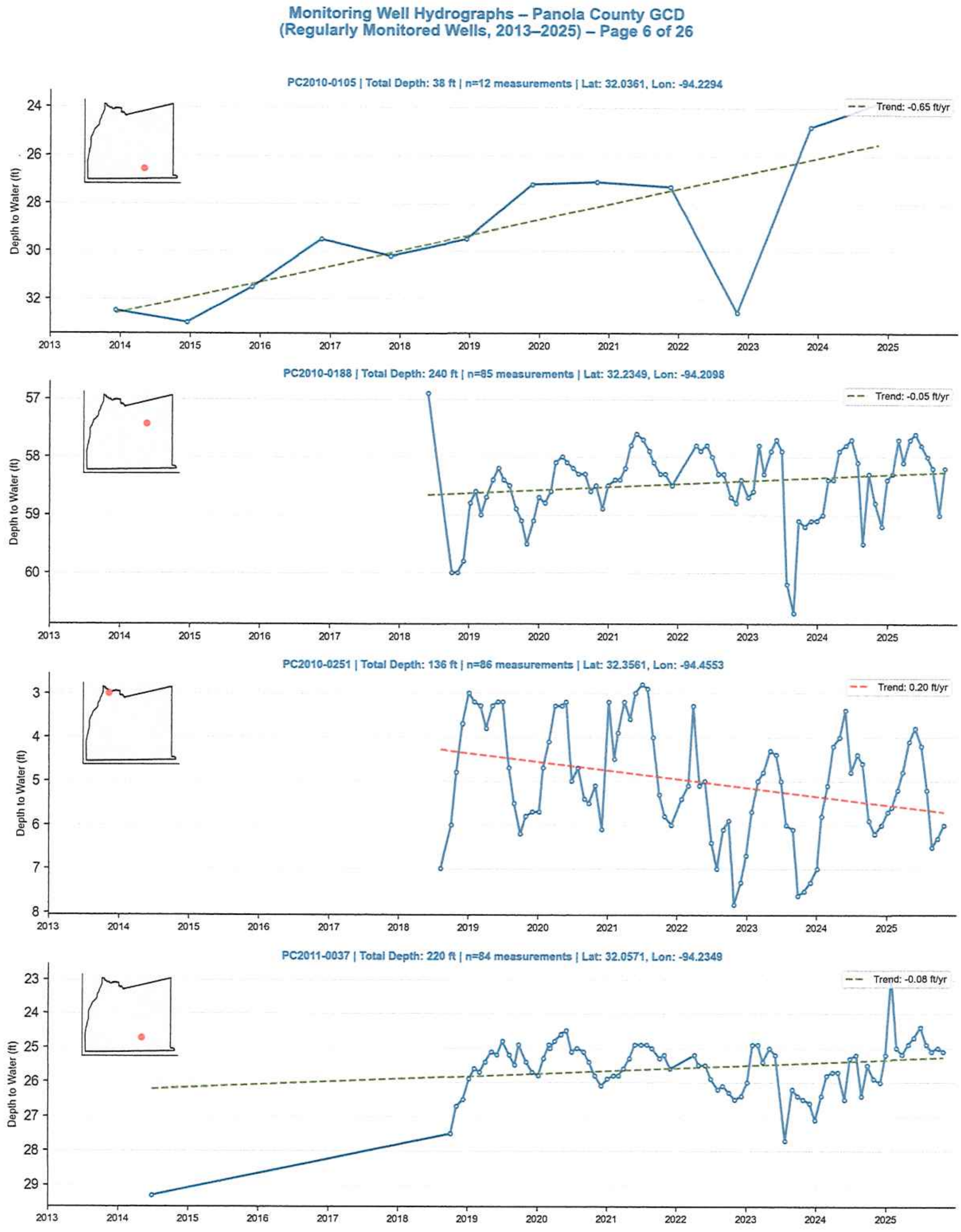


PC2009-1061 | Total Depth: 170 ft | n=87 measurements | Lat: 32.1159, Lon: -94.2439

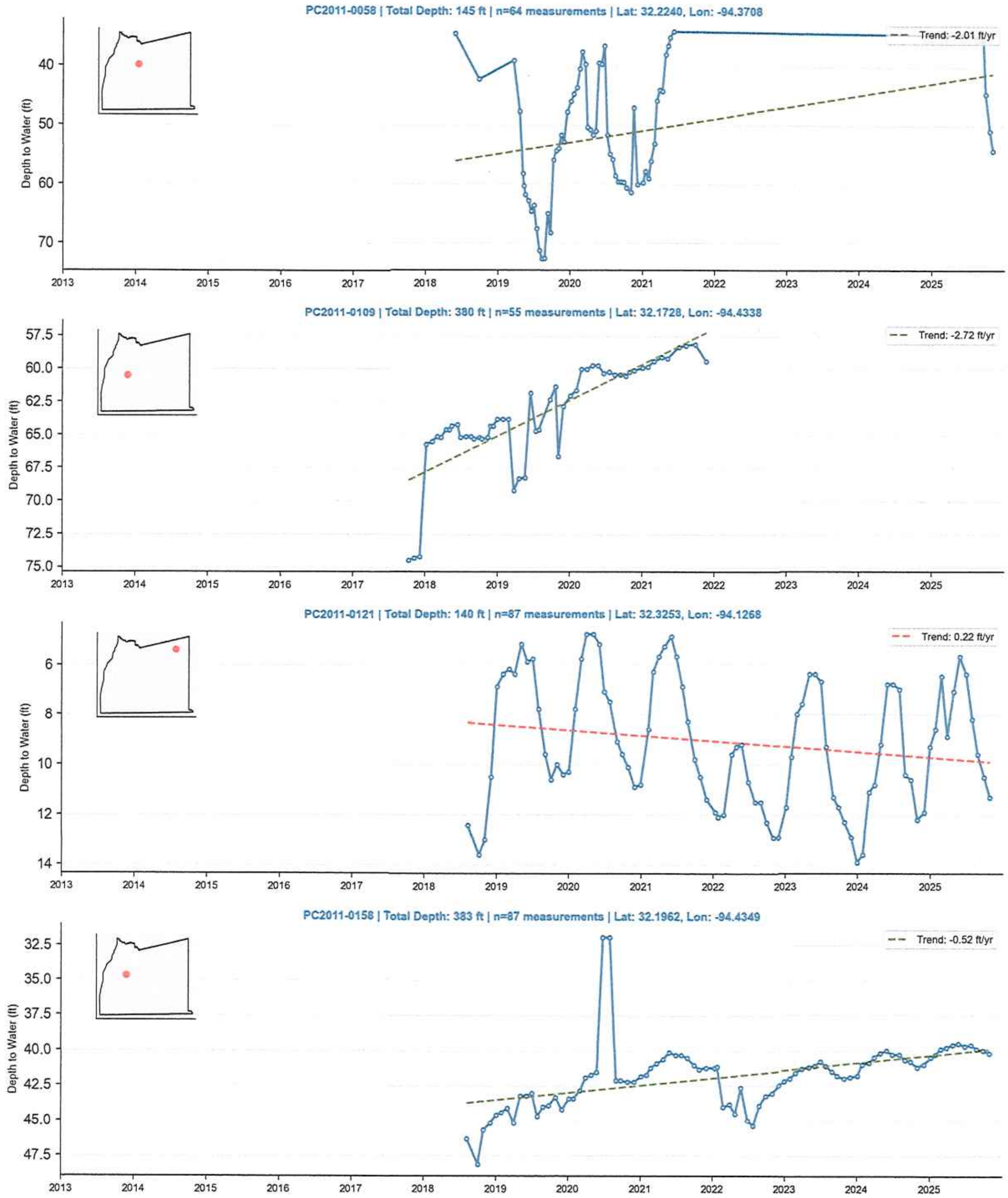


Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 5 of 26

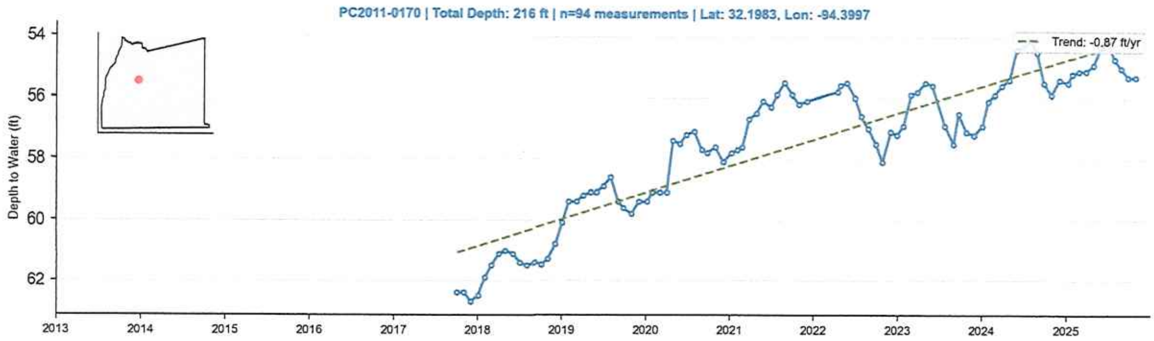


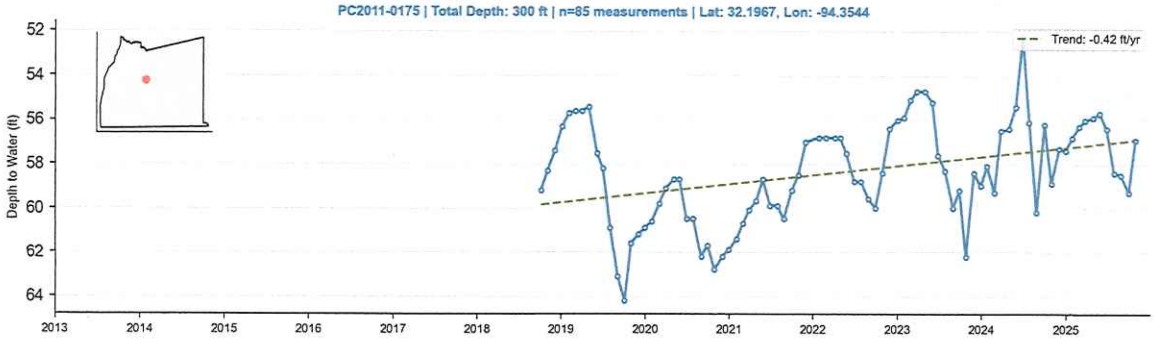

Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 6 of 26
PC2010-0105 | Total Depth: 38 ft | n=12 measurements | Lat: 32.0361, Lon: -94.2294
Trend: -0.65 ft/yr
PC2010-0188 | Total Depth: 240 ft | n=85 measurements | Lat: 32.2349, Lon: -94.2098
Trend: -0.05 ft/yr
PC2010-0251 | Total Depth: 136 ft | n=86 measurements | Lat: 32.3561, Lon: -94.4553
Trend: 0.20 ft/yr
PC2011-0037 | Total Depth: 220 ft | n=84 measurements | Lat: 32.0571, Lon: -94.2349
Trend: -0.08 ft/yr
Depth to Water (ft)

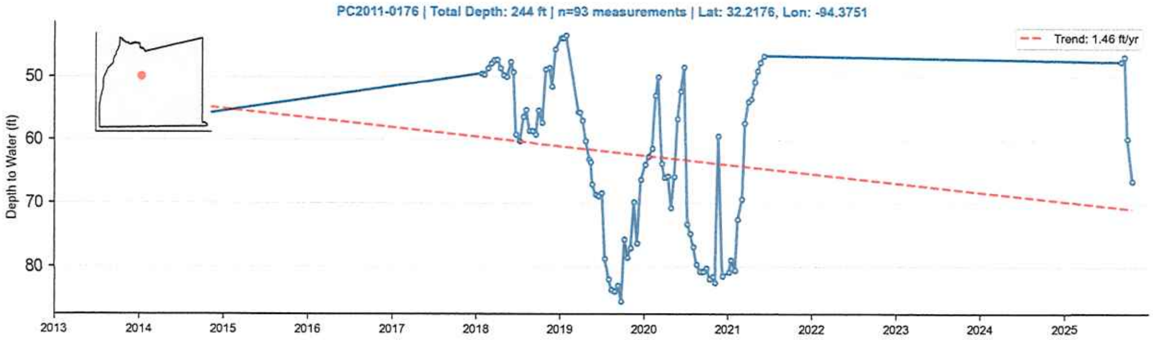
Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 7 of 26

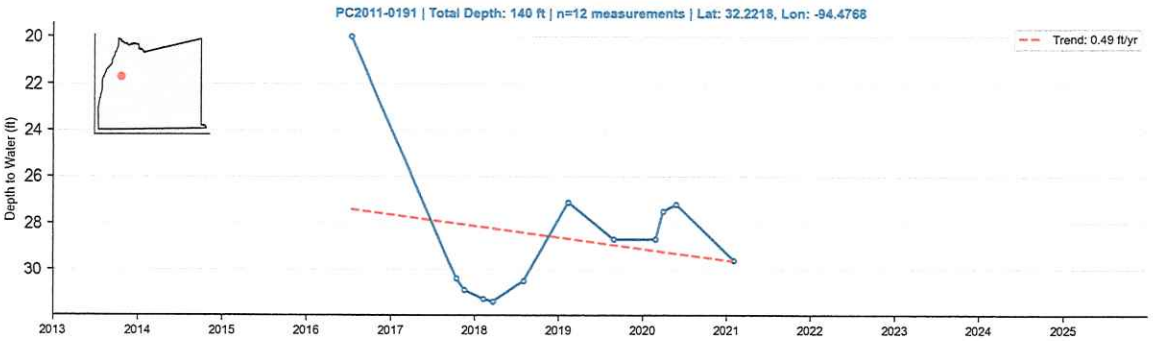


Monitoring Well Hydrographs – Panola County GCD (Regularly Monitored Wells, 2013–2025) – Page 8 of 26

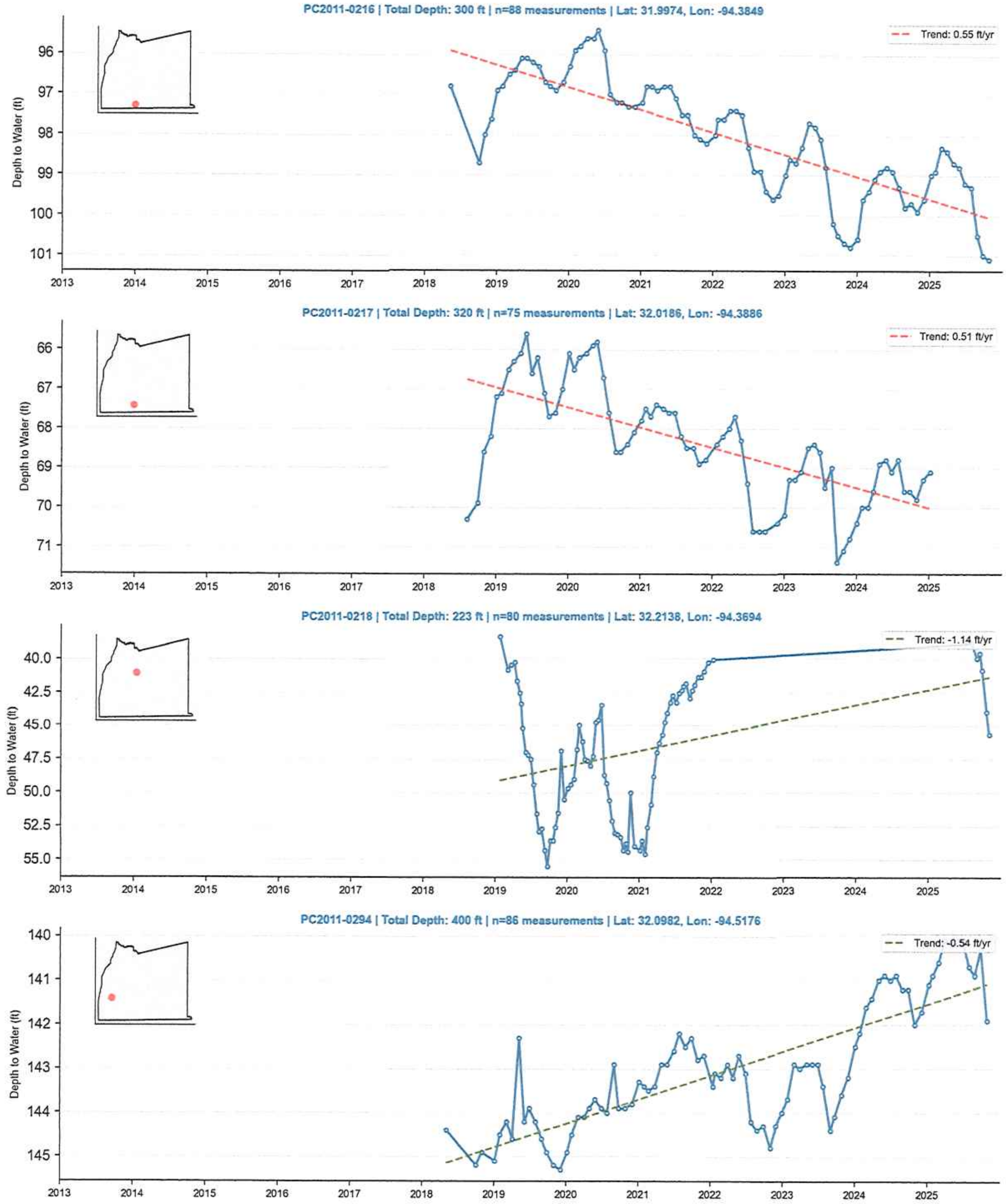




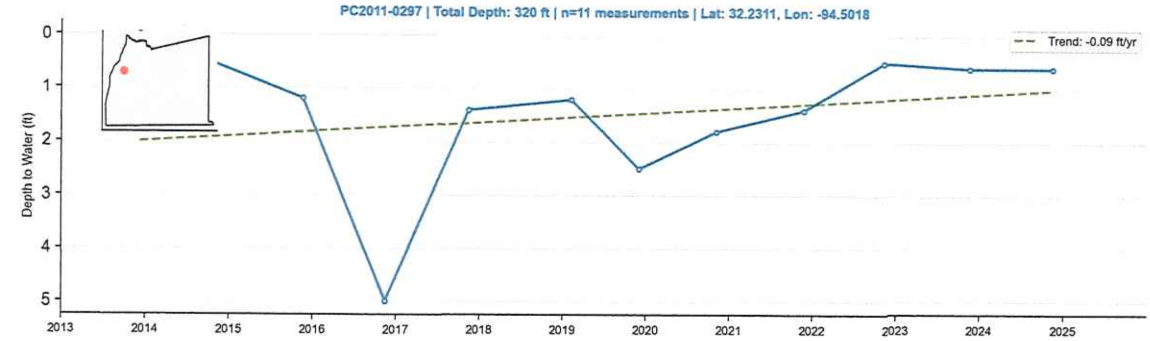


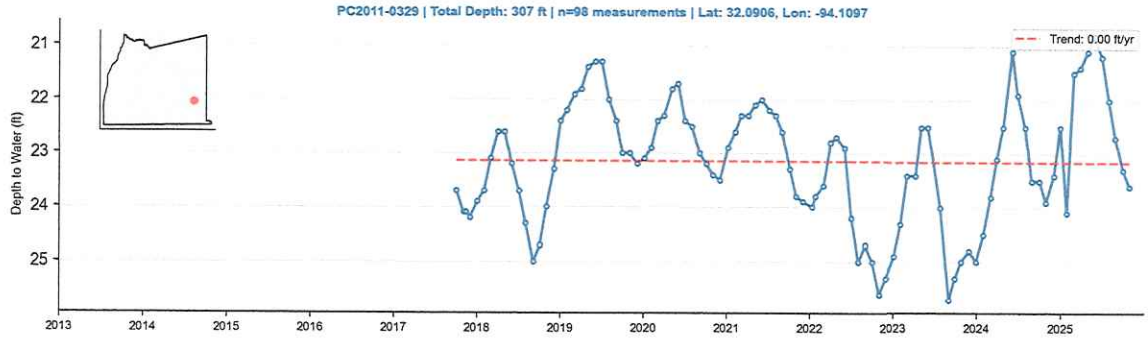


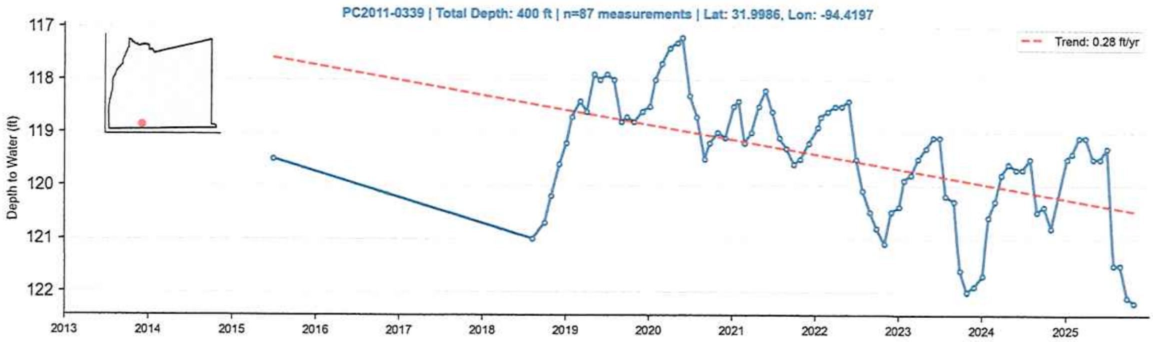
Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 9 of 26

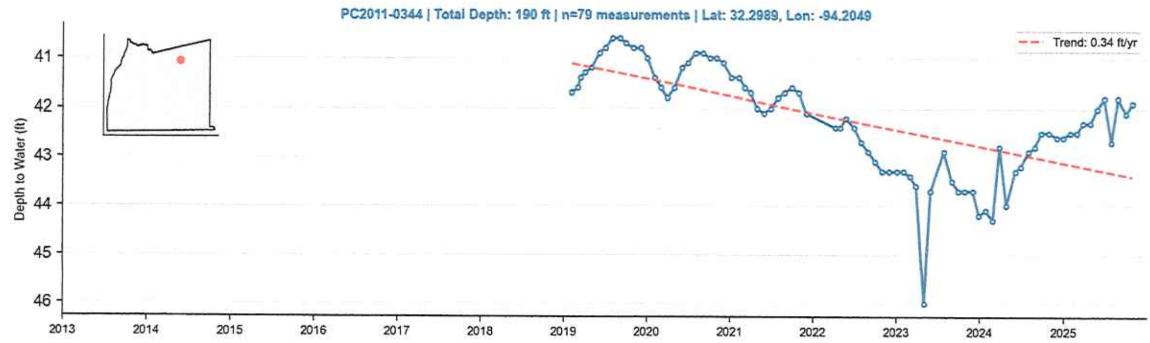


Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 10 of 26

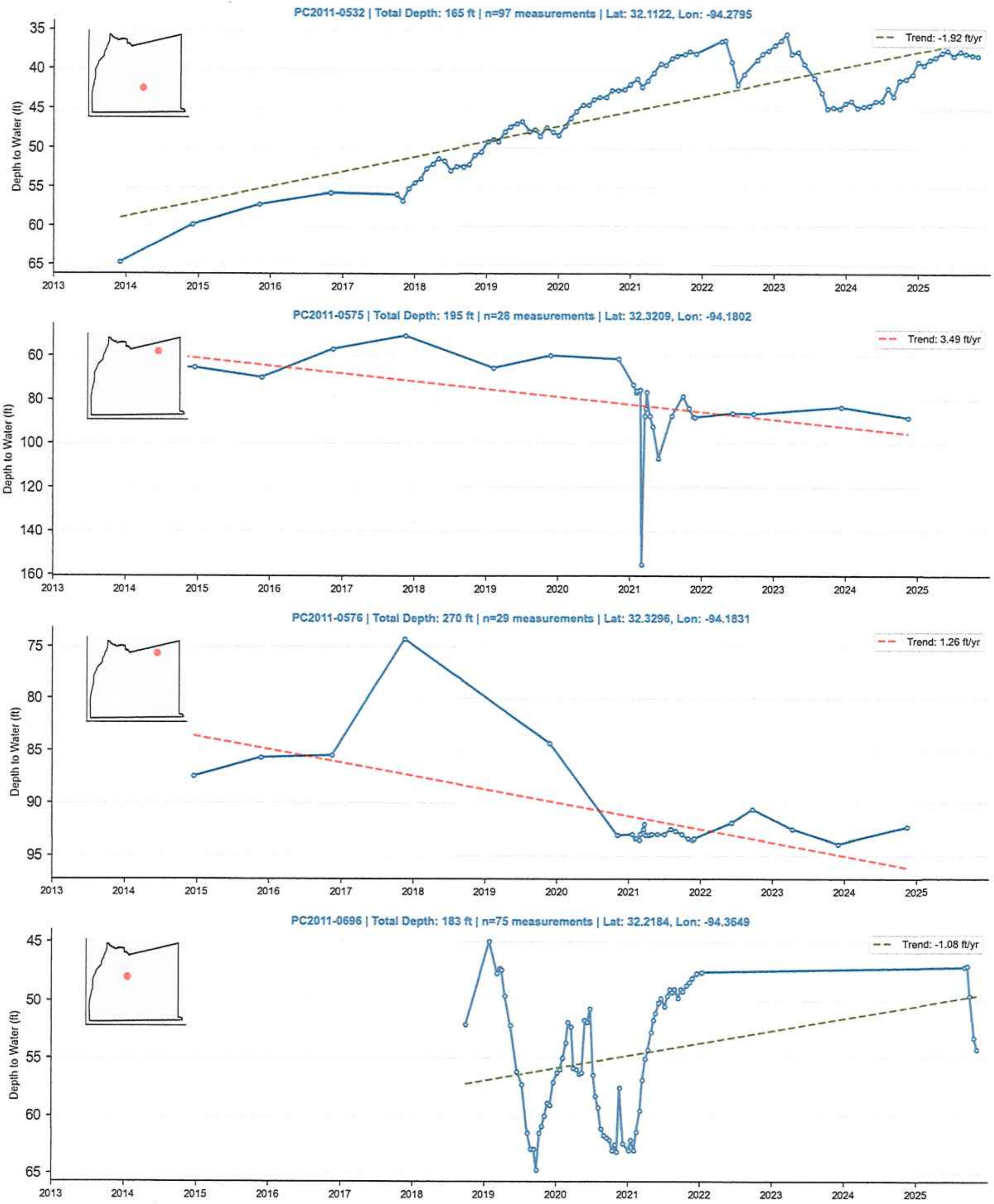




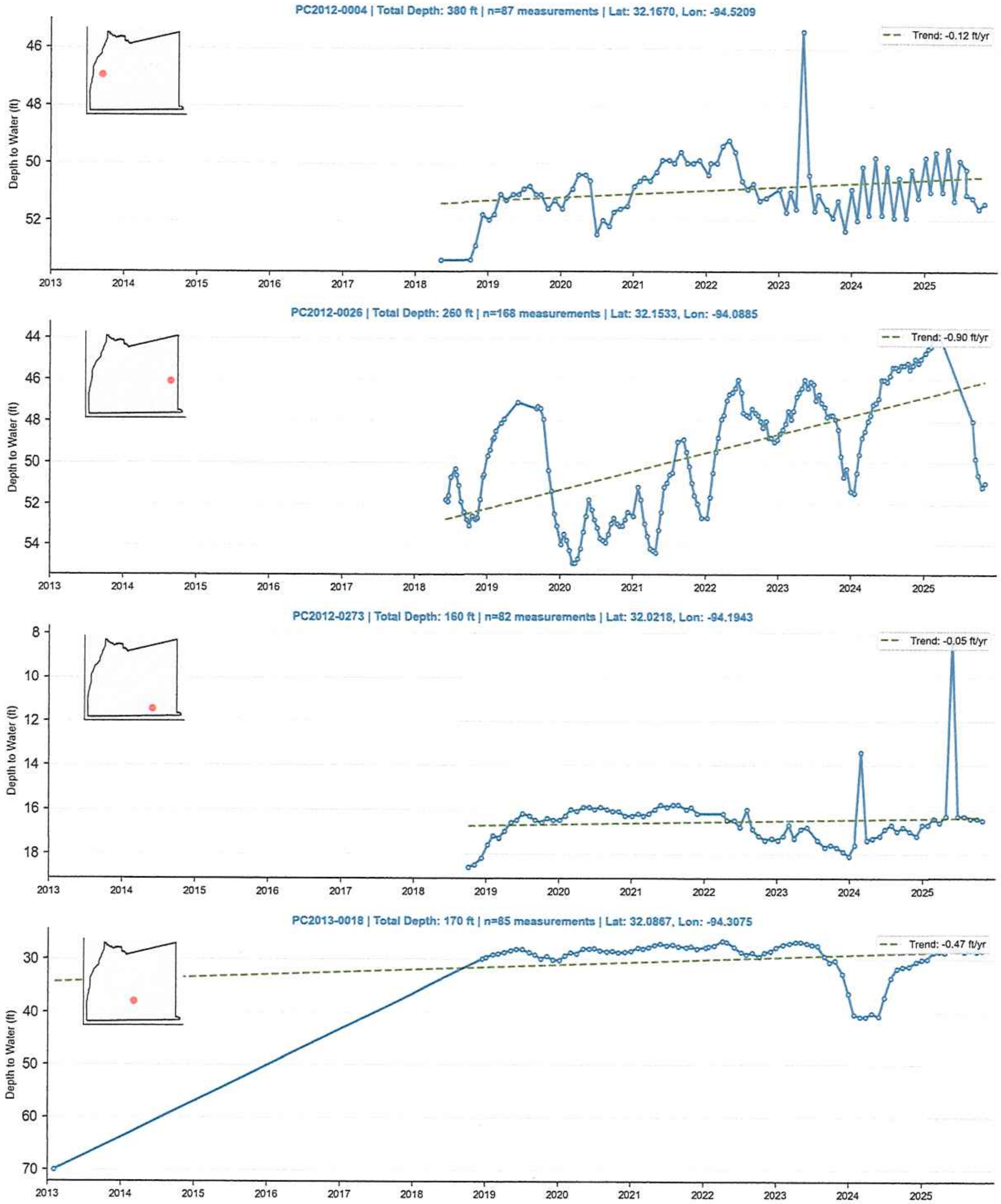




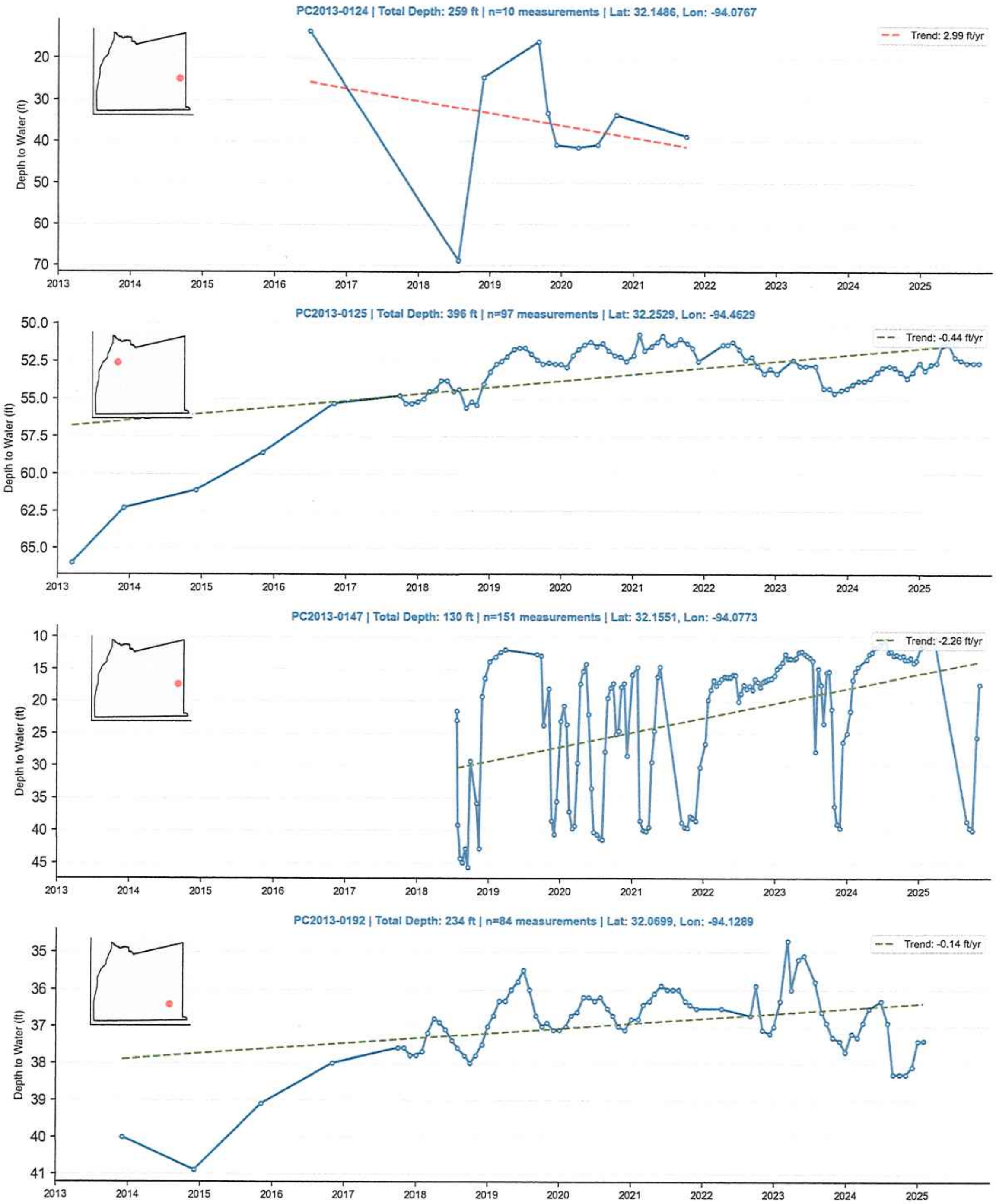
Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 11 of 26



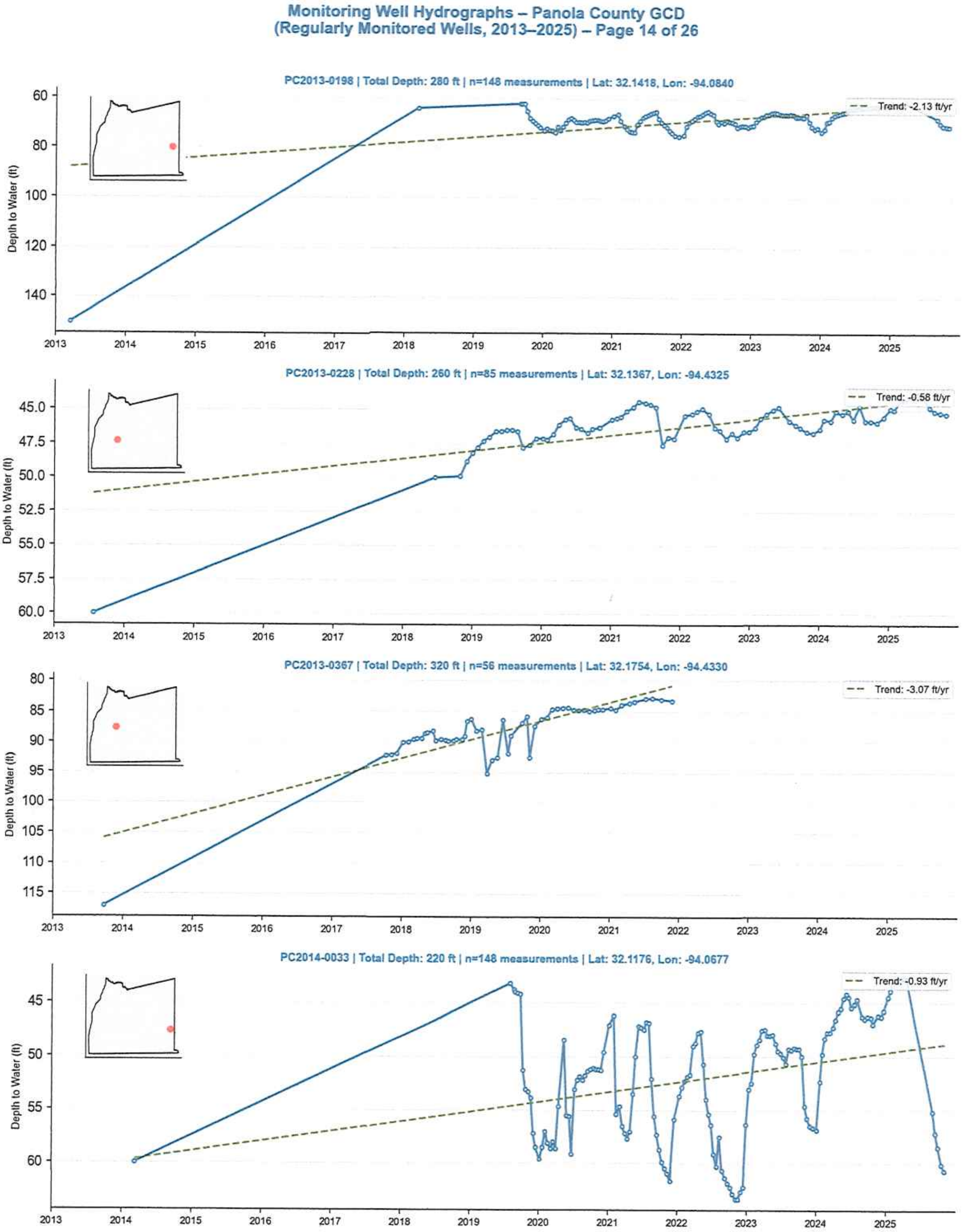
Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 12 of 26



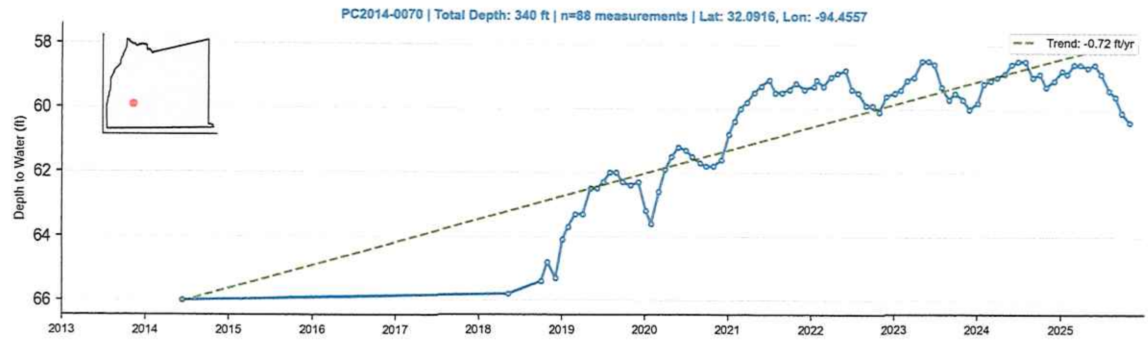
Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 13 of 26

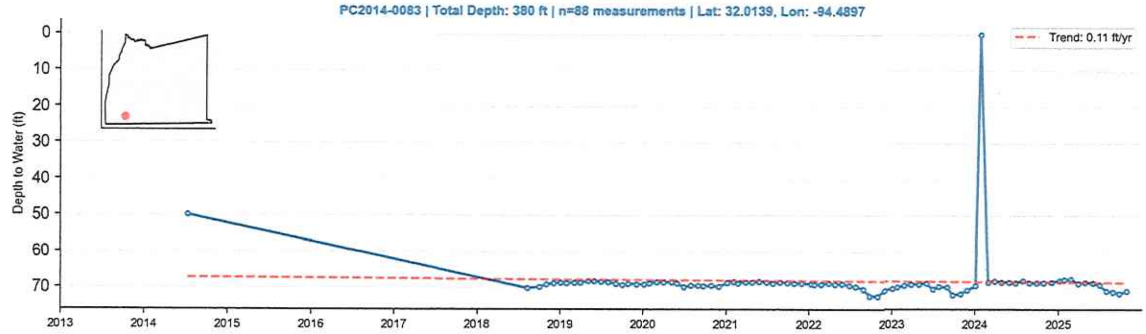


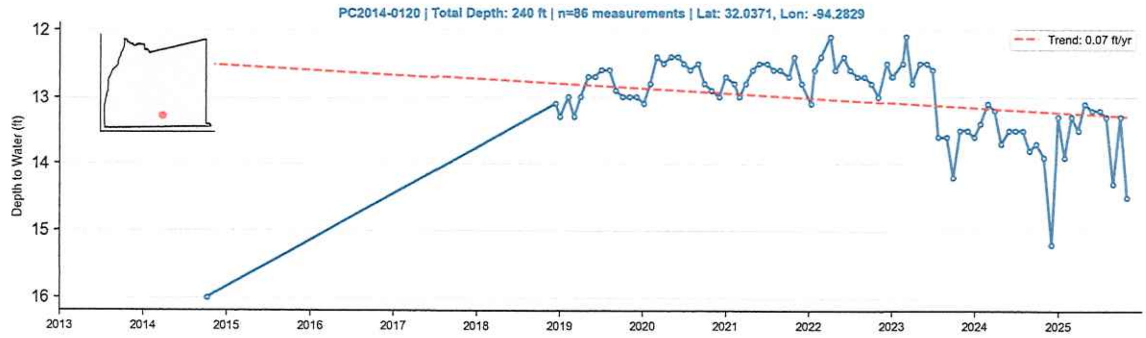
eki environment & water

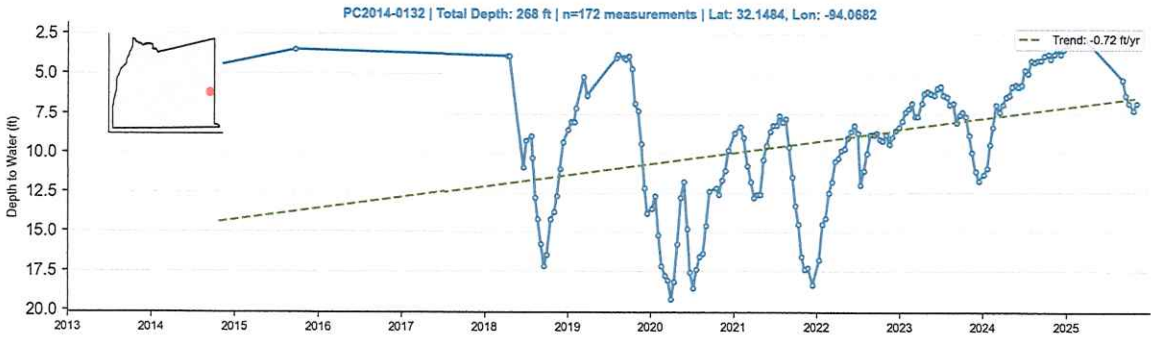


Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 15 of 26

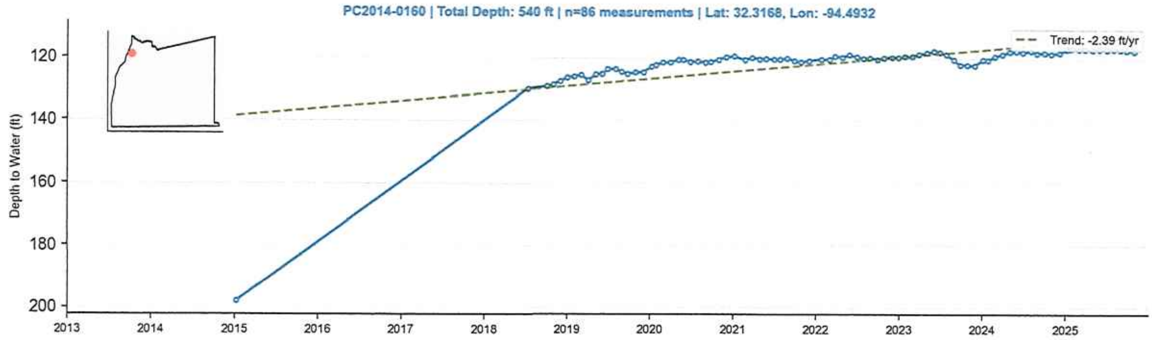


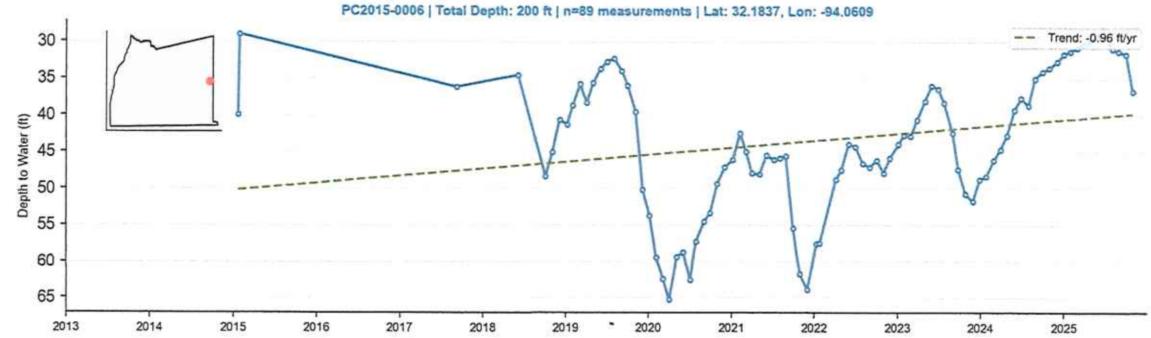


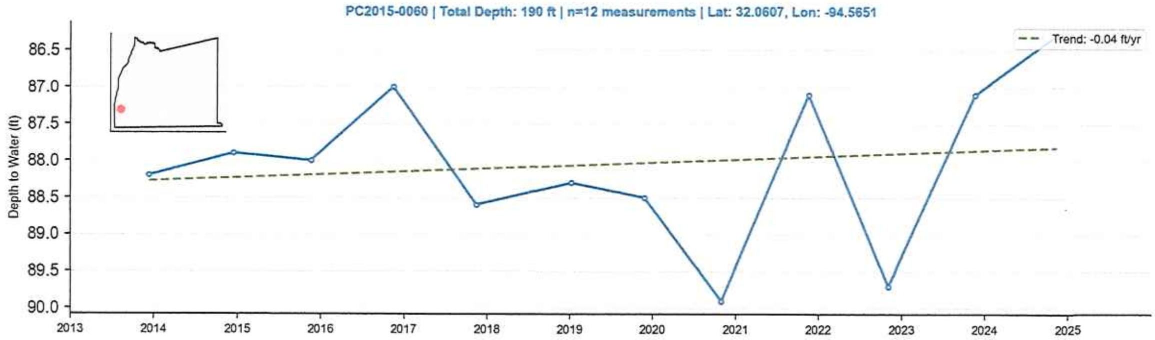


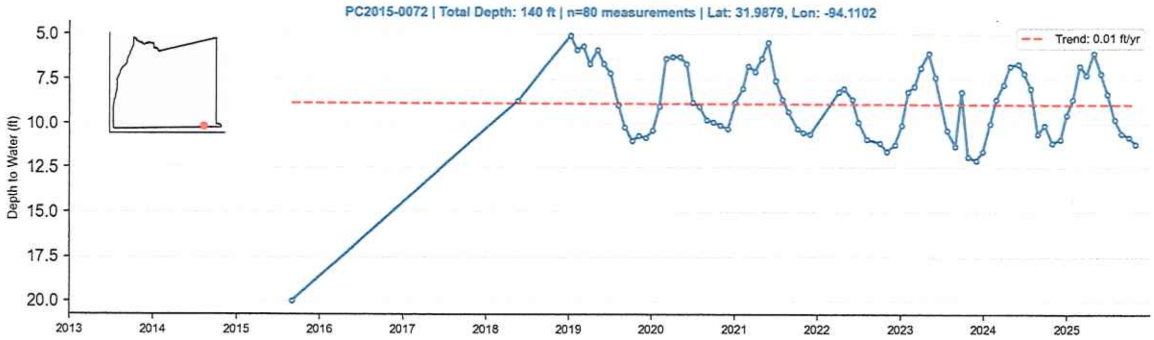


Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 16 of 26

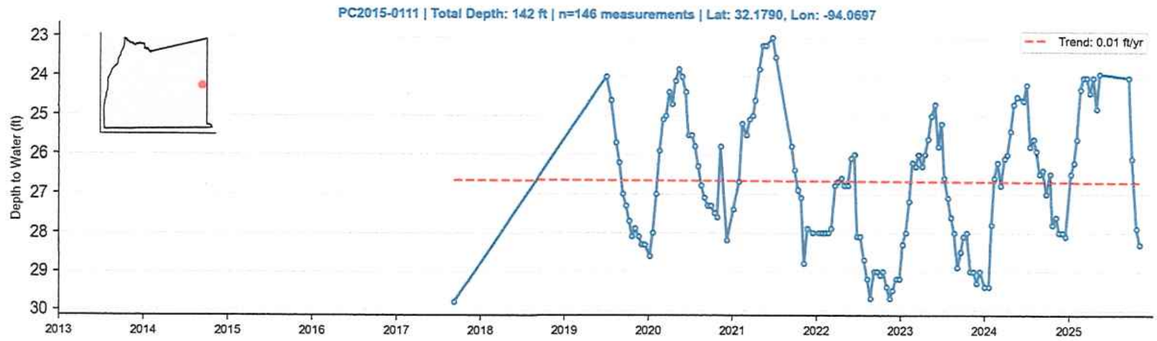


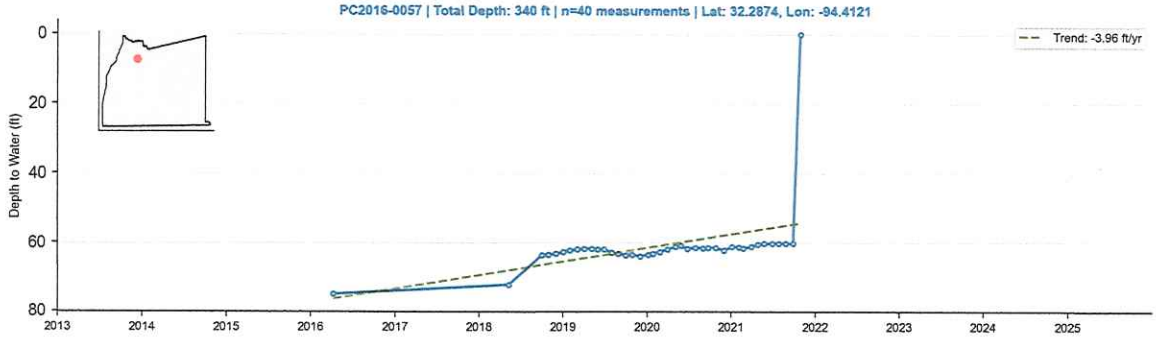


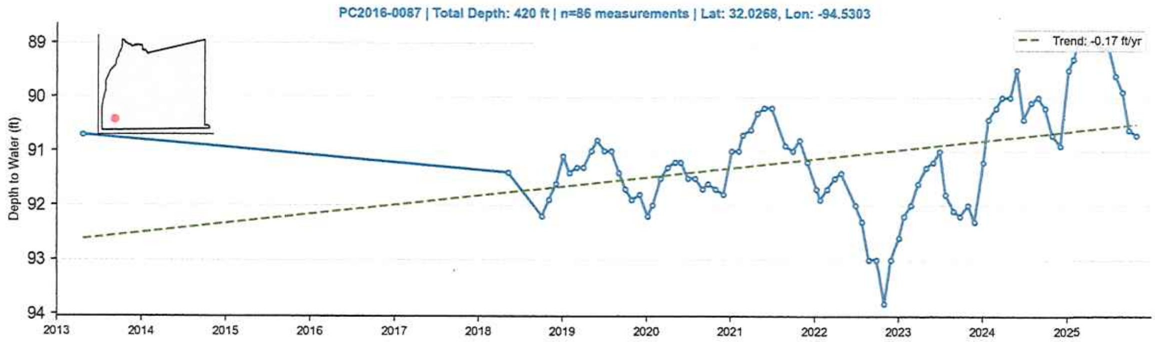


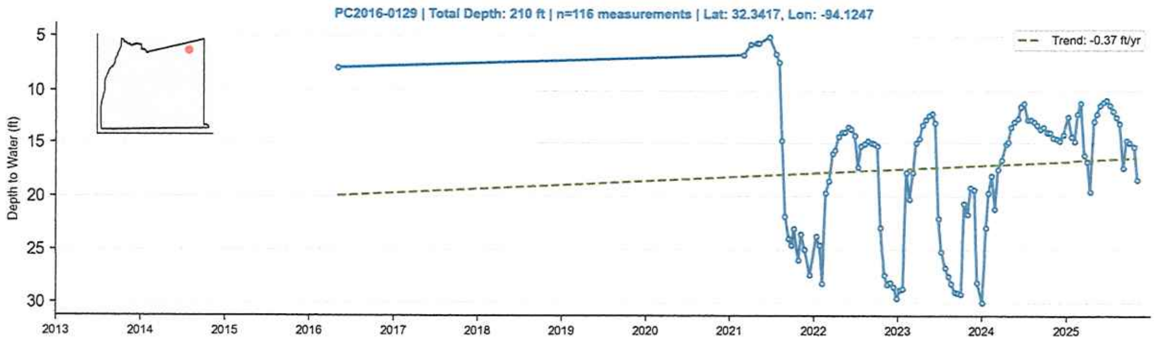


**Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 17 of 26**



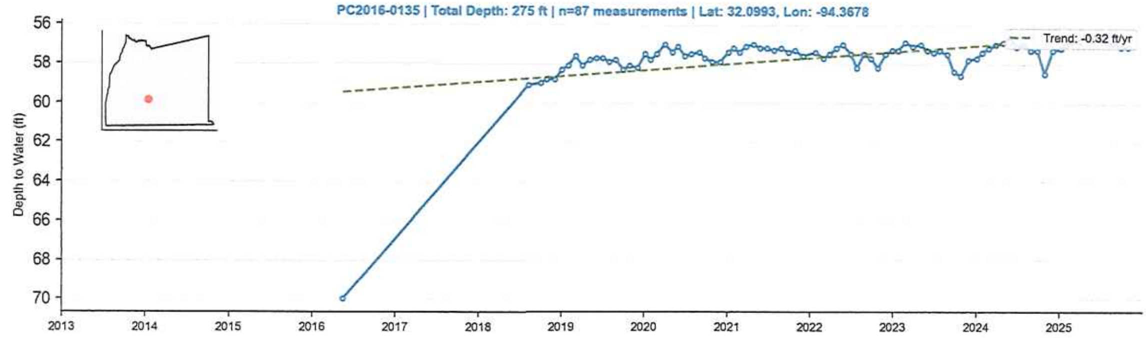




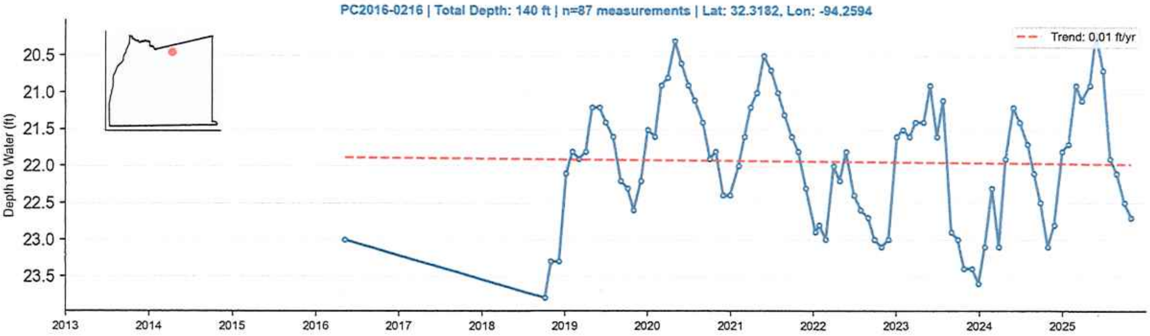


**Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 18 of 26**

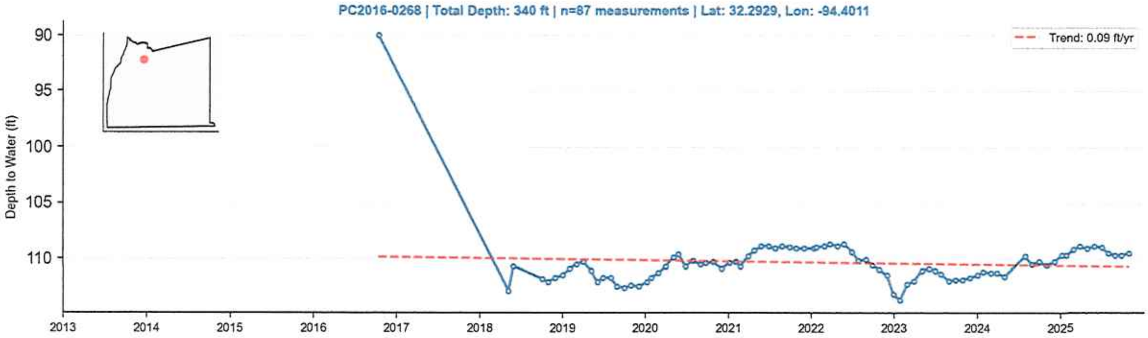
PC2016-0135 | Total Depth: 275 ft | n=87 measurements | Lat: 32.0993, Lon: -94.3678



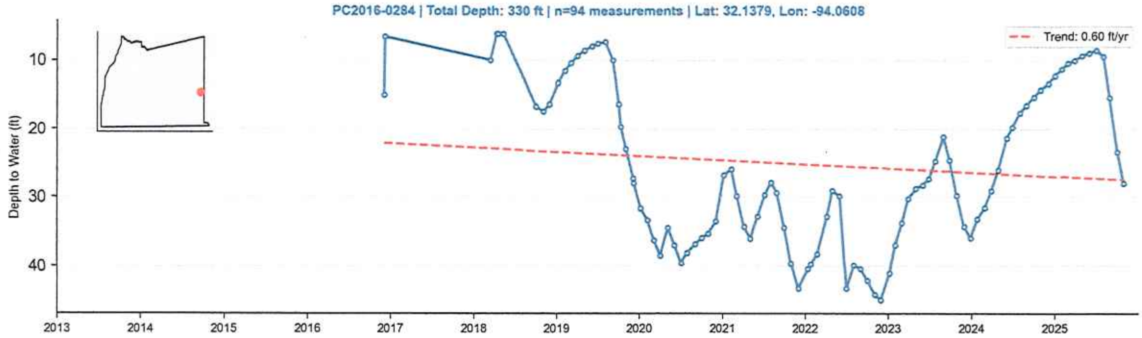
PC2016-0216 | Total Depth: 140 ft | n=87 measurements | Lat: 32.3182, Lon: -94.2594



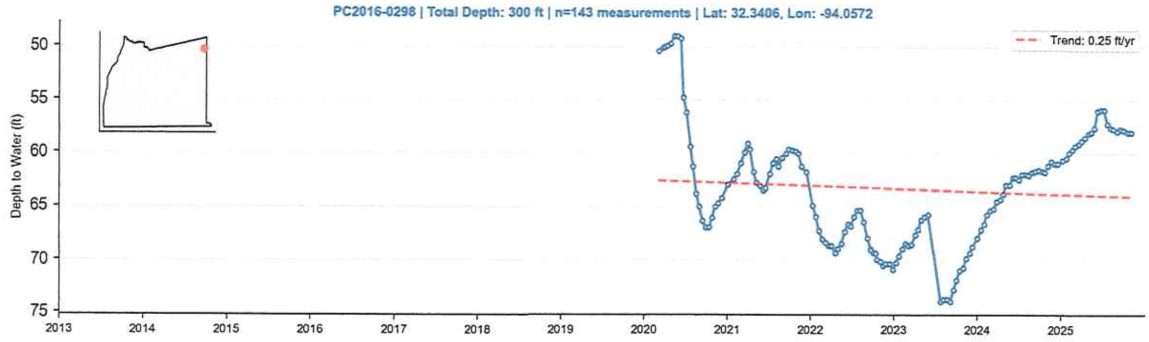
PC2016-0268 | Total Depth: 340 ft | n=87 measurements | Lat: 32.2929, Lon: -94.4011

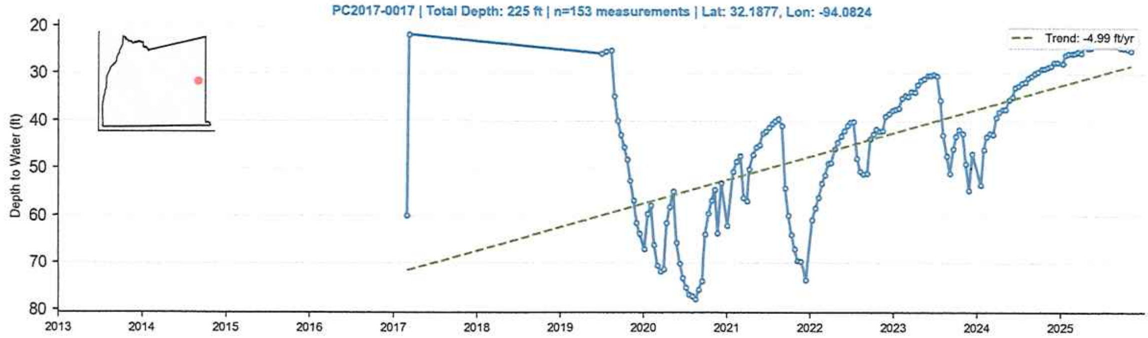


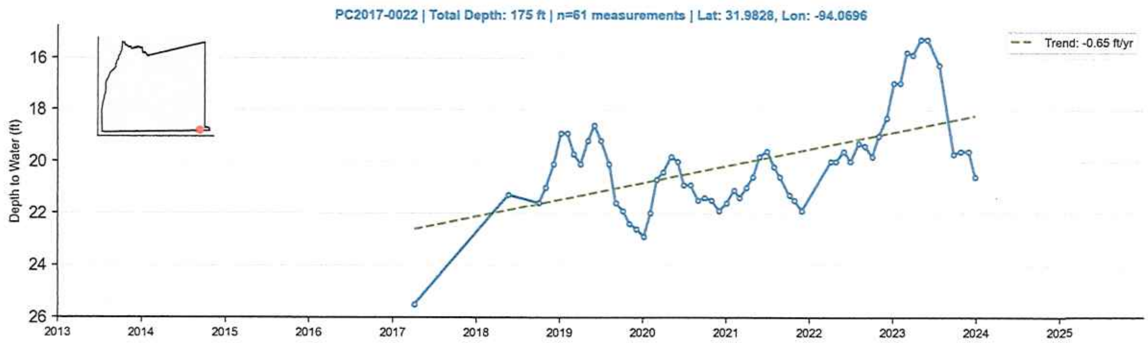
PC2016-0284 | Total Depth: 330 ft | n=94 measurements | Lat: 32.1379, Lon: -94.0608

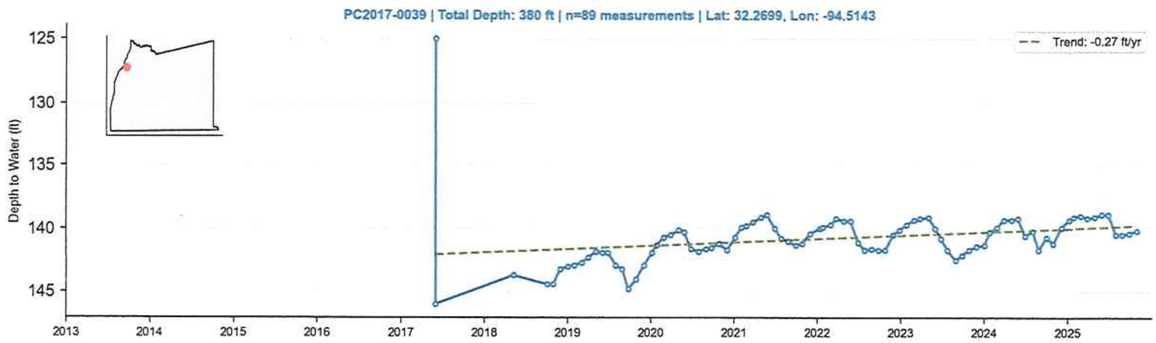


Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 19 of 26



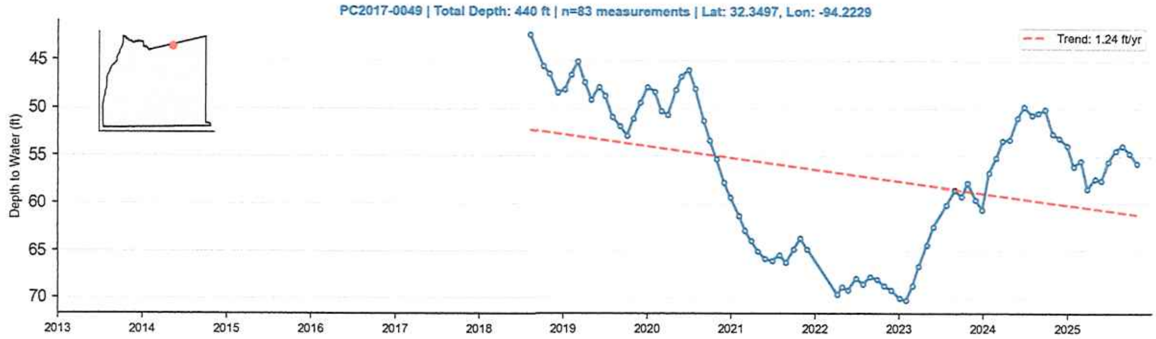




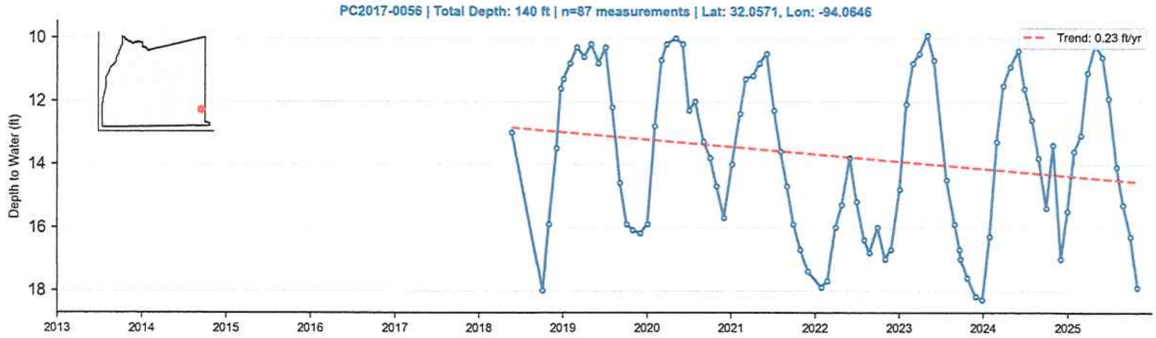


Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 20 of 26

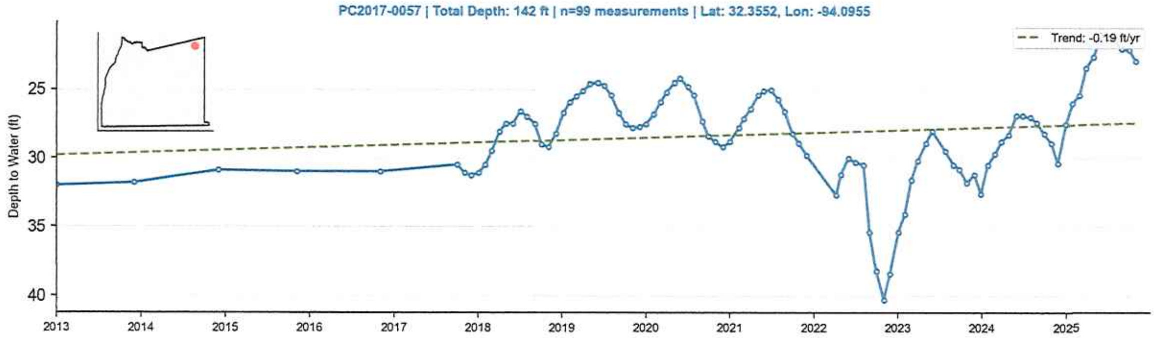
PC2017-0049 | Total Depth: 440 ft | n=83 measurements | Lat: 32.3497, Lon: -94.2229



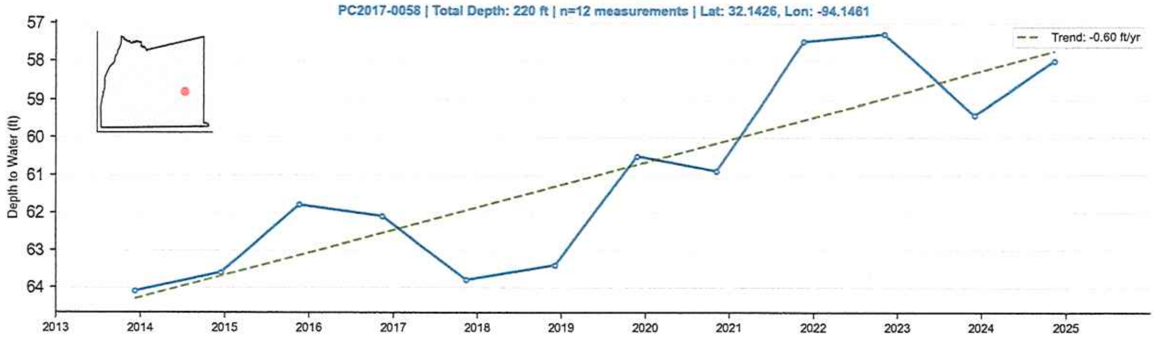
PC2017-0056 | Total Depth: 140 ft | n=87 measurements | Lat: 32.0571, Lon: -94.0646



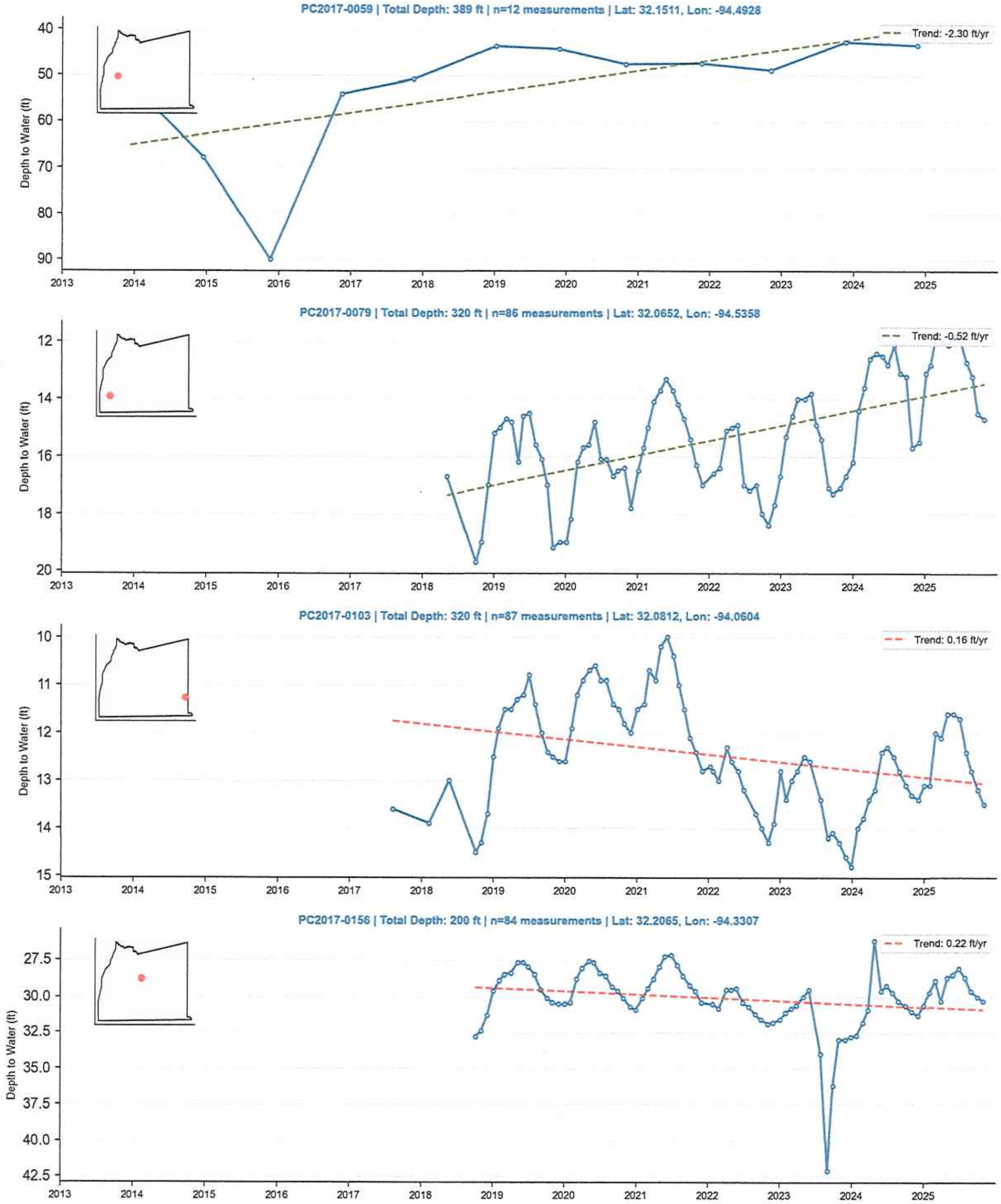
PC2017-0057 | Total Depth: 142 ft | n=99 measurements | Lat: 32.3552, Lon: -94.0955

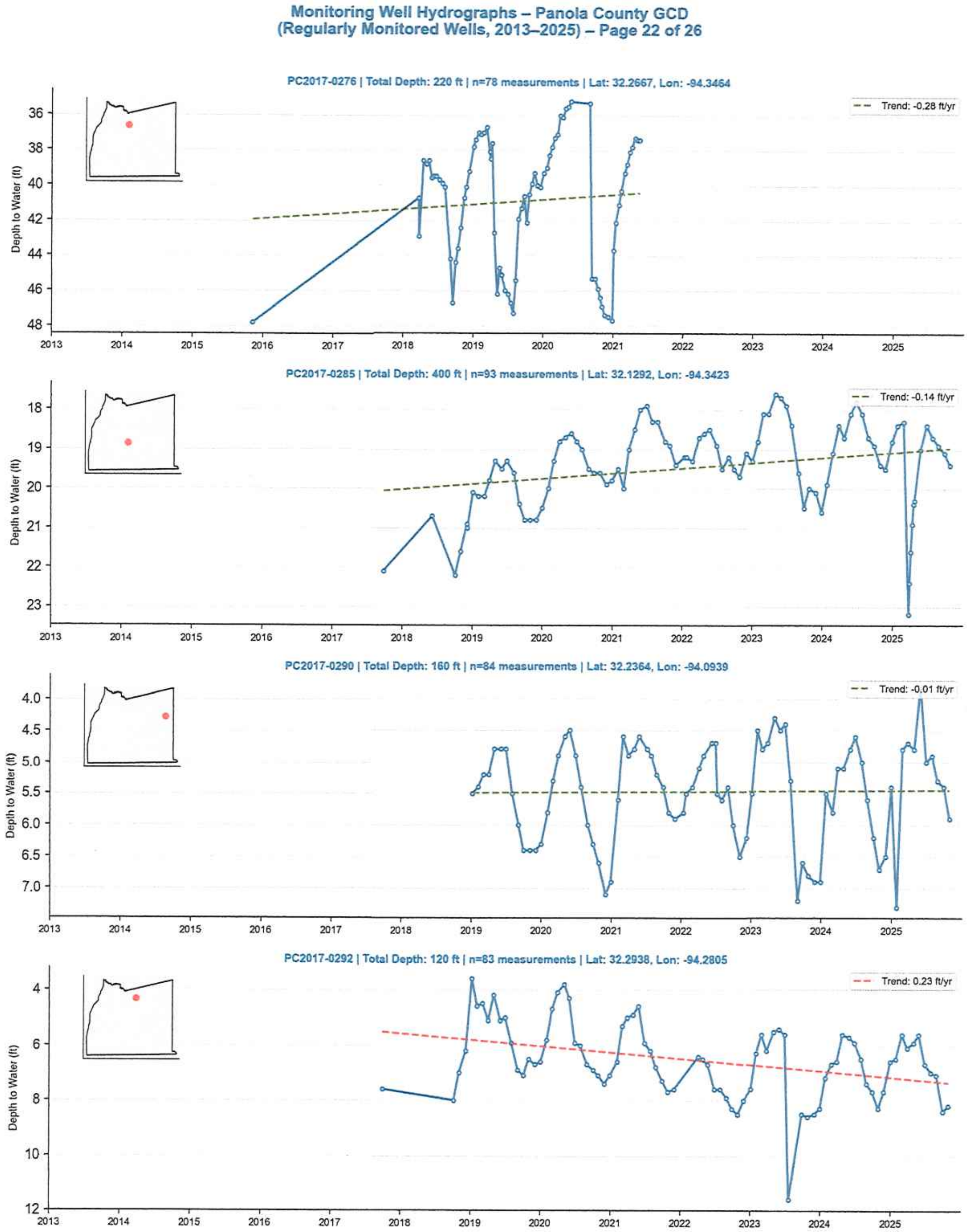


PC2017-0058 | Total Depth: 220 ft | n=12 measurements | Lat: 32.1426, Lon: -94.1461



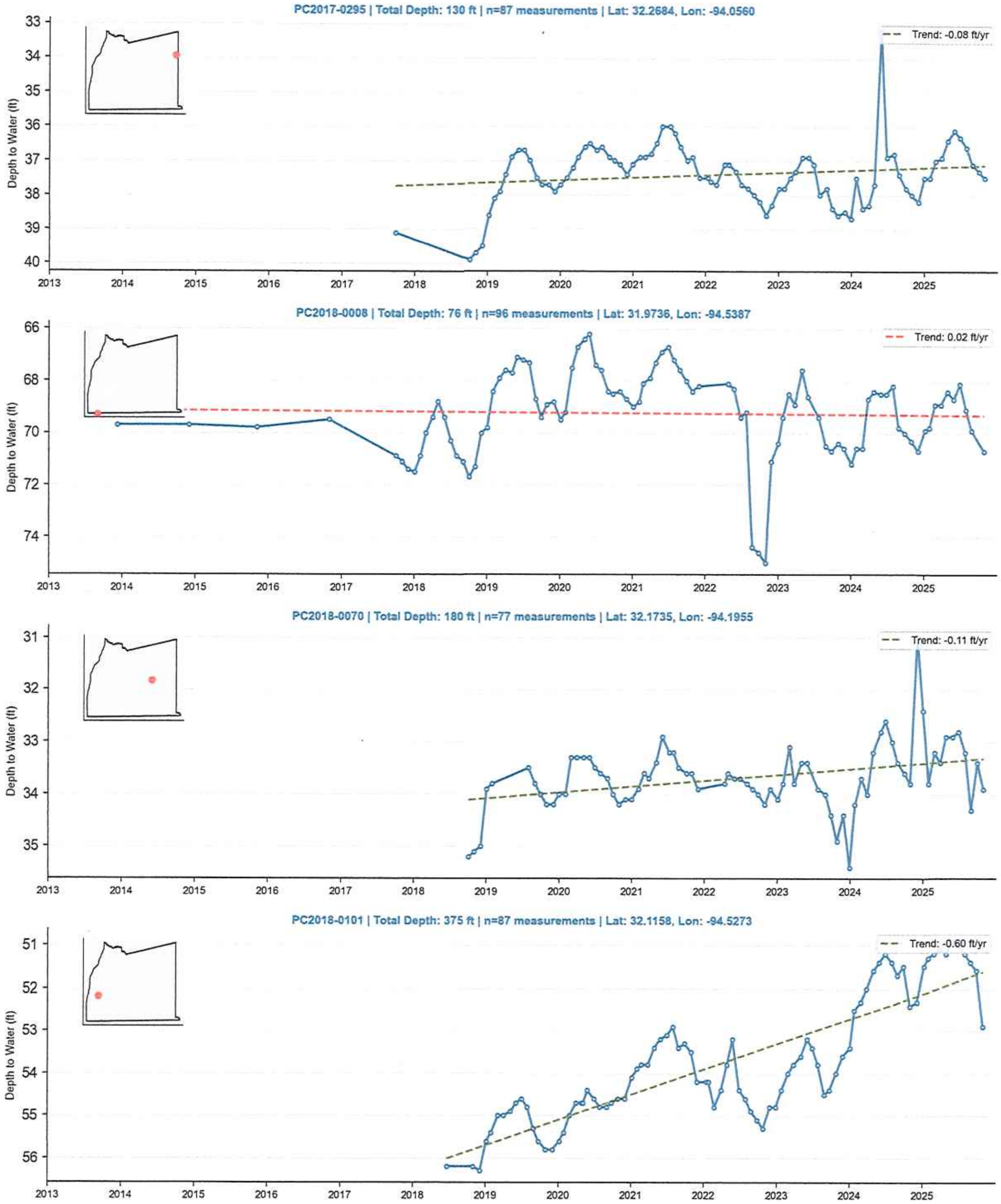
**Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 21 of 26**



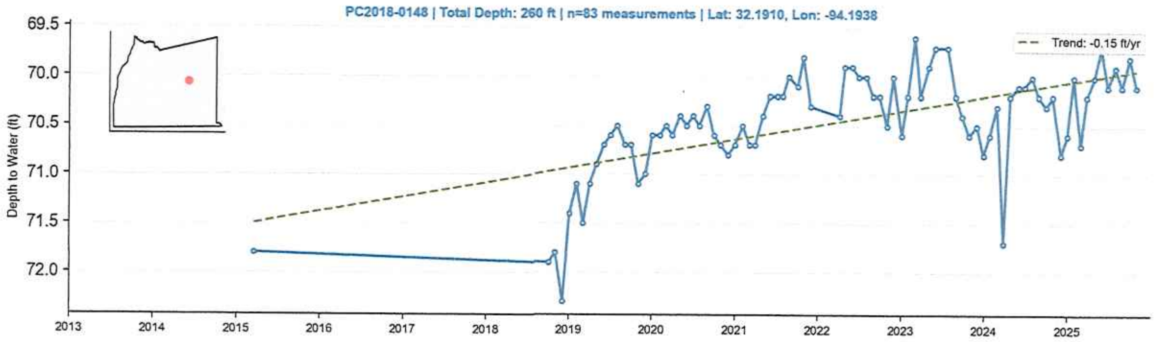

Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 22 of 26
PC2017-0276 | Total Depth: 220 ft | n=78 measurements | Lat: 32.2667, Lon: -94.3464
Trend: -0.28 ft/yr
PC2017-0285 | Total Depth: 400 ft | n=93 measurements | Lat: 32.1292, Lon: -94.3423
Trend: -0.14 ft/yr
PC2017-0290 | Total Depth: 160 ft | n=84 measurements | Lat: 32.2364, Lon: -94.0939
Trend: -0.01 ft/yr
PC2017-0292 | Total Depth: 120 ft | n=83 measurements | Lat: 32.2938, Lon: -94.2805
Trend: 0.23 ft/yr
Depth to Water (ft)
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025

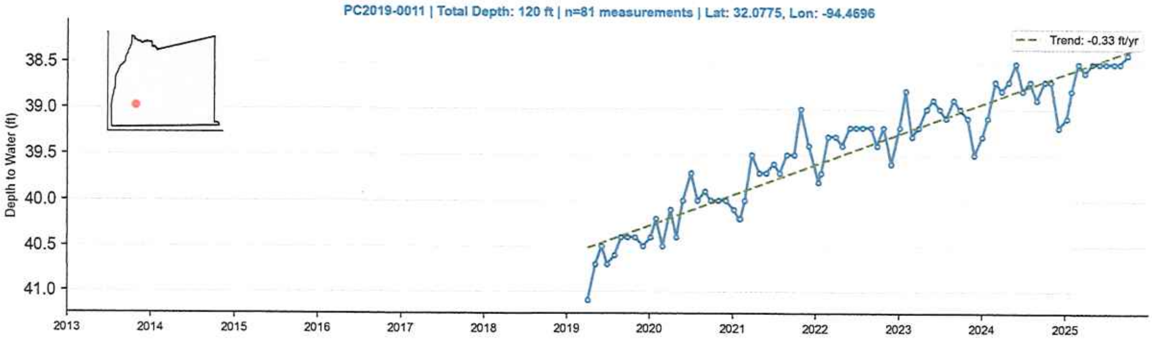
eki environment & water

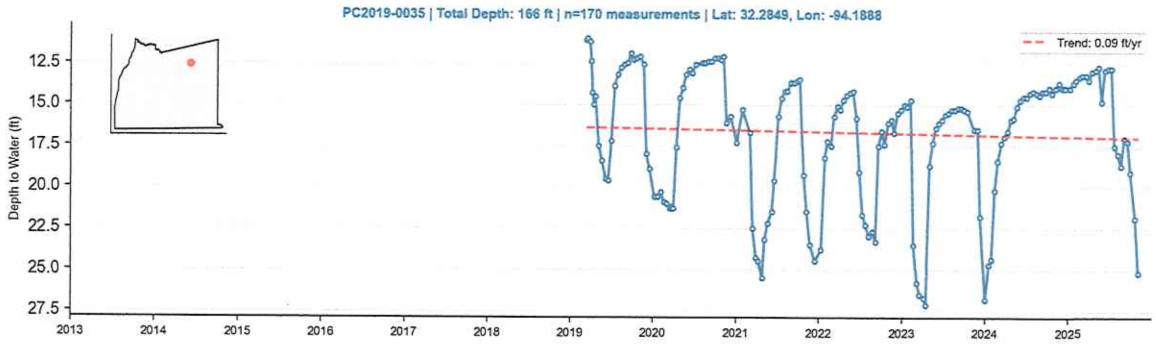
**Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 23 of 26**

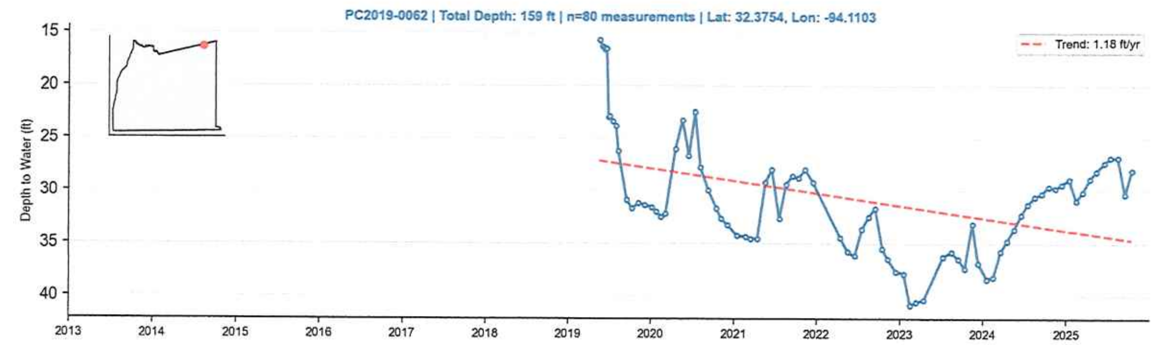


**Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 24 of 26**

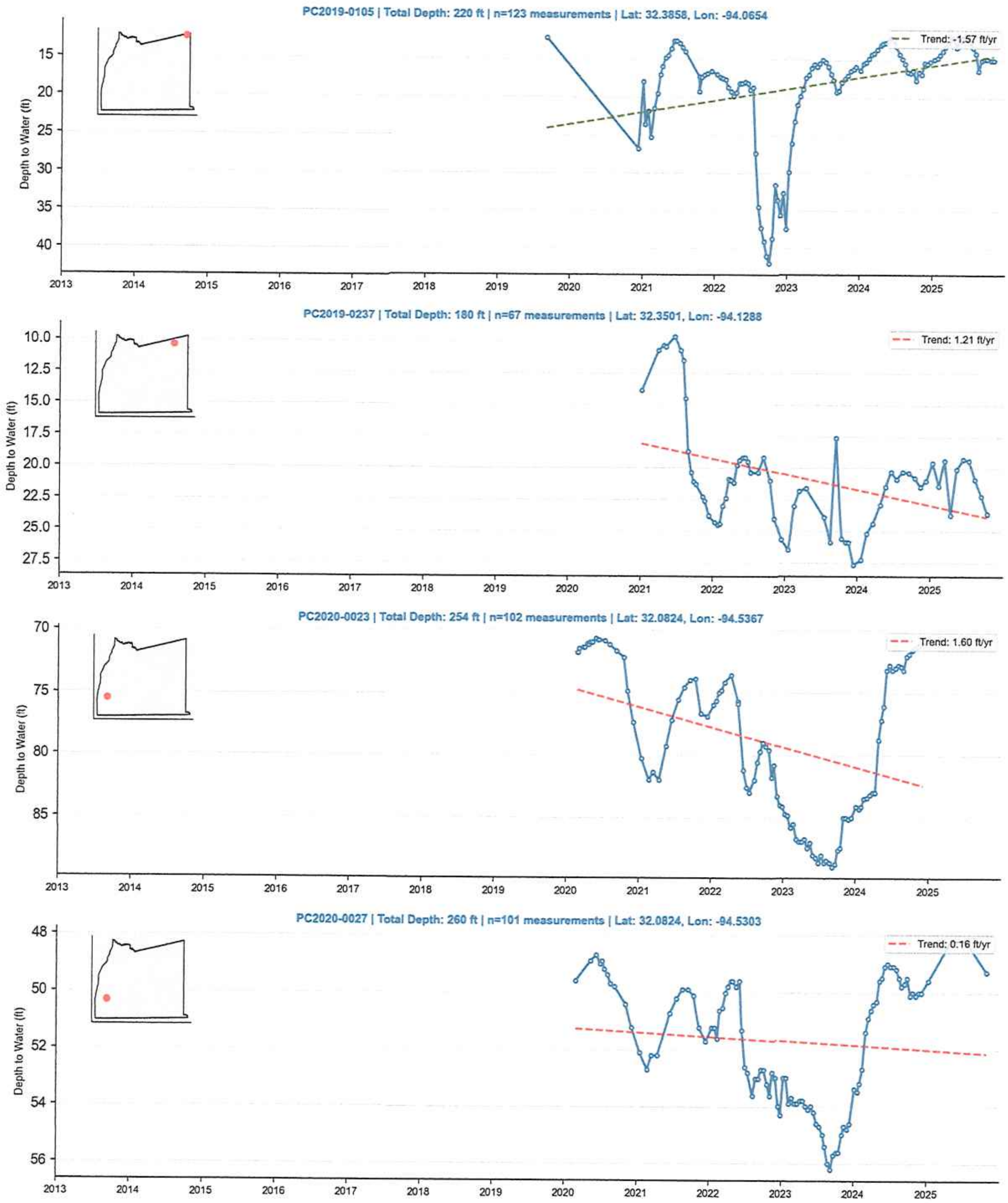








Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 25 of 26



Monitoring Well Hydrographs – Panola County GCD
(Regularly Monitored Wells, 2013–2025) – Page 26 of 26