

Shallow Aquifer Monitoring in the Walla Walla Basin
2017-2018 Water Year
Final Report



In Cooperation with:



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Shallow Aquifer Monitoring in the Walla Walla Basin

Introduction

Overview

Since 2001 the Walla Walla Basin Watershed Council (WWBWC) has collected data from a network of monitoring wells in the Walla Walla River Valley as part of its long-term efforts to understand the shallow (unconfined) alluvial aquifer. The primary objectives of this network are to provide data necessary for informed water management in the bi-state basin and help water and fisheries managers in the basin better understand surface-groundwater interactions as they relate to salmon recovery and groundwater sustainability. The monitoring network is also used to track the effectiveness of artificial managed aquifer recharge projects currently in operation and provide data for hydrologic modeling projects.

This past year, funding wasn't available to monitor wells in Washington. We're hopeful funding will return and we can continue to monitor water levels of the shallow aquifer on the Washington side of the Walla Walla Basin. The WWBWC worked with the Oregon Water Resource Department (OWRD) and Washington Department of Ecology (WDOE) to develop protocols for monitoring well locations, measurement, and maintenance. Many of the original monitoring wells in the network were established or drilled by OWRD and WDOE. Other partners in the basin such as Hudson Bay District Improvement Company, Gardena Farms Irrigation District #13, Walla Walla River Irrigation District, Fruitvale Water Users Association, The Native Creek Society, the City of Walla Walla and dozens of private property owners have contributed to expansion of the monitoring network by providing well access, supplying historical information and making contact with prospective participants. Some of the dedicated monitoring wells were established as part of WWBWC's managed aquifer recharge program. See Table 1 for a summary of the established monitoring wells we are currently monitoring in Oregon.

Table 1. Overview of the Shallow Aquifer Monitoring Network.

Monitoring Group	State	Number of Wells
OWRD	Oregon	10
WWBWC	Oregon	61

Well monitoring consists of measuring the groundwater level (the depth to water), water temperature and specific conductance. The well monitoring network is comprised of two types of monitoring wells: continuous monitoring wells that are instrumented with pressure transducers that log water level at a programmed interval (typically every 15 or 60 minutes), and non-continuous wells, which are measured manually approximately every three months. Temperature and conductivity measurements are taken quarterly at both types of monitoring wells if access permits.

The WWBWC has continued to update and maintain a Monitoring Well Database with historical records and information about wells in the network. The database includes landowner contact information, water rights, well logs, USGS, WDOE and OWRD historical water level measurements, well GPS coordinates, elevation, maps, and photos of the wells. Wells in the monitoring network have been surveyed with survey-grade GPS units to determine accurate longitude, latitude and elevation data. The Monitoring Well Database serves as institutional

memory of the monitoring network and gives insight into historical uses and conditions of the wells and aquifer. It also allows WWBWC to easily share well information with the community and other agencies.

Shallow Aquifer Monitoring Area

The Walla Walla River basin is a bi-state region located in northeastern Oregon and southeastern Washington (Figure 1). The river basin covers approximately 1,760 square miles, with an underlying shallow alluvial aquifer of about 200 square miles (Figure 2). Shallow depth-to-water in certain locations in the valley and year-round supply make the shallow aquifer a highly important source of water for irrigated agricultural lands as well as domestic and livestock uses.



Figure 1. The bi-state Walla Walla River basin in northeastern Oregon and southeastern Washington. Due to lack of funding, we are currently not monitoring Washington wells

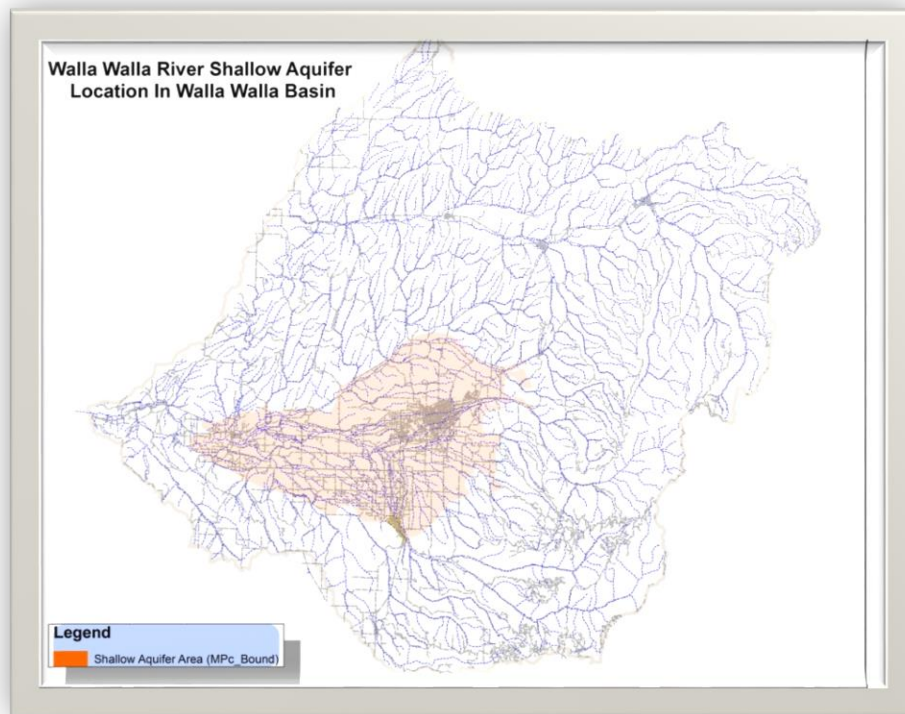


Figure 2. The Walla Walla River basin with the underlying shallow alluvial aquifer.

In addition to supplying water for the wells, the shallow alluvial aquifer also feeds the numerous springs, streams, and rivers of the Walla Walla basin. The high connectivity between the shallow aquifer and surface water bodies is important for enhancing base flows and cooling water temperatures for reintroduced salmon and threatened steelhead and bull trout in the basin.¹

Since 2001, the WWBWC and its partners have been building a community-based groundwater monitoring network. This network was developed to enhance knowledge about long-term water level trends and provide hydrogeological information. In 2001, only a dozen shallow aquifer wells were monitored in Oregon and Washington. These wells were inadequate to effectively monitor and manage the vast aquifer which supplies hundreds of domestic and agricultural wells, provides water for the dozens of creeks and springs throughout the valley, and discharges cool water into the Walla Walla River during base flows. As of 2018, the WWBWC and its state and local partners currently monitor 71 wells in Oregon (Figure 3).

Wells in the monitoring network currently include both urban and rural wells in and around Milton-Freewater and Umapine, OR, and historically in and around Walla Walla, College Place, Lowden, and Touchet, WA. The wells are owned by a variety of water users, including government agencies (state, county, and city), businesses, universities, and private landowners within the basin. Prior to drilling dedicated monitoring wells, most of the monitoring wells were irrigation (both active and abandoned) or old domestic wells owned by private land owners. All of the well owners participate voluntarily, aiding in the effort to understand and mitigate the decline of the aquifer, a critically important economic and ecological resource to the communities located within the Walla Walla basin.

¹ Winter, T.C., et al. 1998. *Ground Water and Surface Water: A Single Resource*. U.S. Geological Survey Circular 1139.

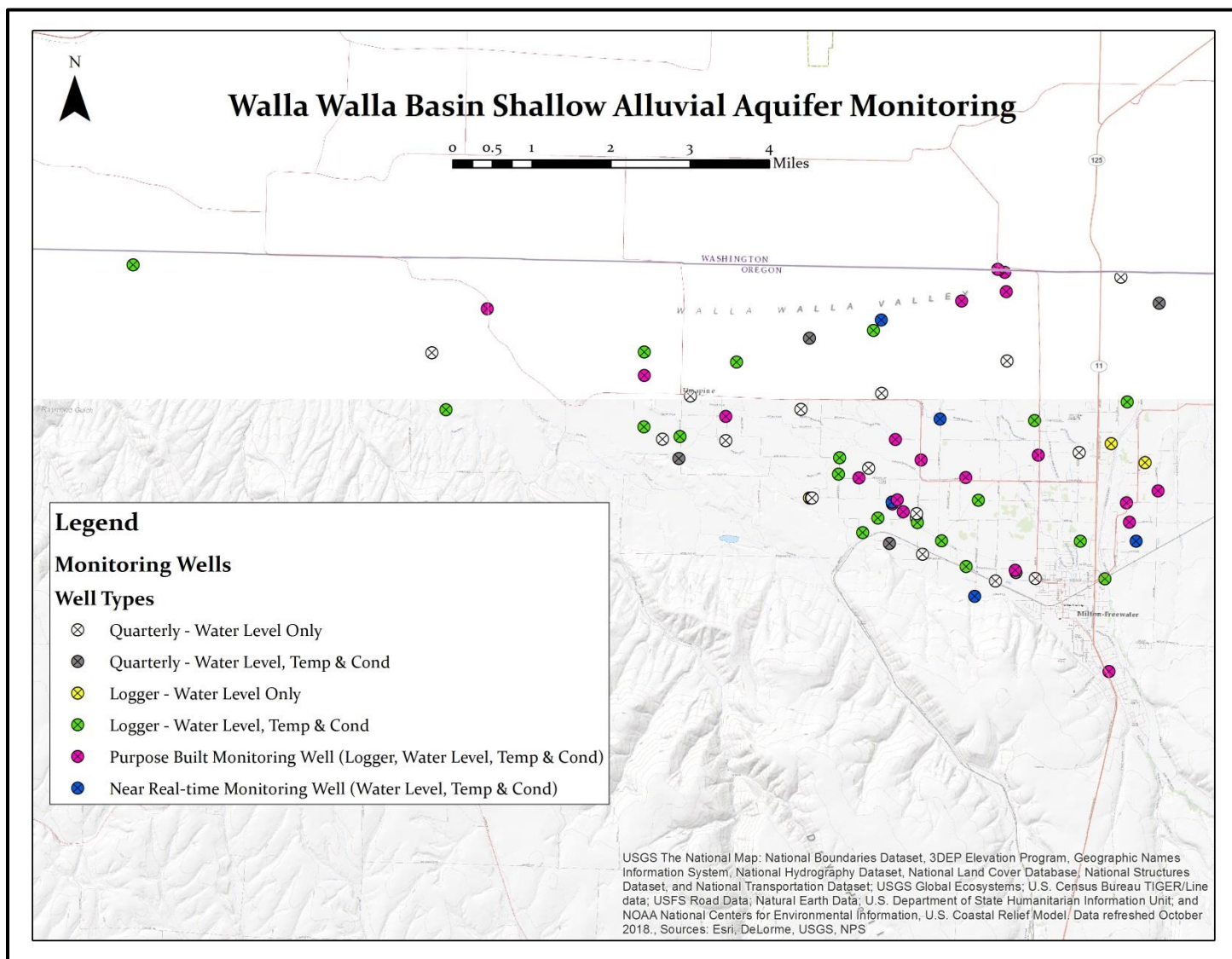


Figure 3. Map overview of wells in the Shallow Aquifer Monitoring Network as of September 2018. Due to lack of funding, we are currently not monitoring Washington wells.

Methodology

All monitoring was conducted according to our standard operating procedures² based on USGS, Washington and Oregon state methods for groundwater monitoring. [Click here for the WWBWC's Standard Operating Procedures](#)

Continuous and Non-continuous Wells

The WWBWC shallow groundwater alluvial aquifer well network includes both continuous and non-continuously monitored wells. As of September 2017, five of our groundwater monitoring locations have been equipped with a radio, solar panel, battery and datalogger capable of sending near-real time data through our telemetry network. The data are updated daily and available at the [Groundwater Monitoring page](#) on the WWBWC website. These data

² Walla Walla Basin Watershed Council 2018. *WWBWC Standard Operating Procedures – Version 1.3*. www.wwbwc.org.

are available year around but are particularly useful for tracking aquifer recharge water when the Johnson (GW_46), Lefore (GW_152), Chuckhole (GW_169), Mud Creek (GW_170) and Fruitvale (GW_171) recharge sites are operating during the winter months.

During the 2018 water year, about one third of the monitoring wells were continuously monitored using one of four different pressure transducers (Figure 4) that were suspended below the water level but not resting on the bottom of the well. Pressure transducers were suspended using 1/16th inch aviation cable, 14 gauge speaker wire, fishing line or a communication cable provided by the manufacturer. The pressure transducers electronically determine and record the water pressure (pounds per square inch or feet of water) and water temperature (either °F or °C) on a programmed log interval (typically every 15 or 60 minutes). Transducer data were downloaded on a quarterly schedule. Manual water level measurements were made during the quarterly download to standardize the pressure transducer data. Water level measurements were collected manually using an e-tape (Solinst Water Level Meter, Model 102, www.solinst.com). All water level values were measured from an established measurement point, adjusted for top of grade (“stickup height”) and recorded as “feet below ground surface.”

Although it would be ideal to have all of the wells instrumented for continuous data collection, many abandoned and irrigation wells have small access ports or the pump is in the way, prohibiting deployment of a pressure transducer. Static (non-continuous) wells provide an inexpensive way to collect “snap shot” information of the aquifer and track trends throughout the valley. Wells not instrumented with a pressure transducer were monitored quarterly. Manual measurements were taken using the e-tape from an established measurement point, adjusted for top of grade (“stickup height”) and recorded as “feet below ground surface.” At irrigation wells, pump condition (on or off) was recorded during each visit. A summary of continuous and non-continuous monitoring wells is shown in Table 2.



Figure 4. Pressure transducers used in the Shallow Aquifer Monitoring Network. Continuously monitored wells were equipped with one of the above types of pressure transducers.

Well Type	State	Number of Wells
Continuous, includes temperature and conductivity	Oregon	43
Continuous, without temperature and conductivity	Oregon	5
Non-continuous, includes temperature and conductivity	Oregon	6
Non-continuous, without temperature and conductivity	Oregon	17

Table 2. Summary of well types in the Shallow Aquifer Monitoring Network.

Temperature and Conductivity Sampling

Where well access permitted, temperature and conductivity were measured on a quarterly basis. Water samples were taken when the pressure transducer was downloaded or a water level measurement was taken. Water samples were collected using a bailer and transferred into a graduated cylinder³. Temperature and conductivity values were measured using a handheld conductivity meter (YSI 30, www.ysi.com). At irrigation wells, pump condition (on or off) was also recorded during each visit. Further details regarding transducer downloading, deployment, maintenance, and quarterly data collection can be found in the WWBWC 2018 Standard Operating Procedures - Version 1.3².

Gathering temperature and conductivity data when monitoring wells allows the WWBWC to better understand the hydrogeological connections between groundwater and surface water. By knowing the temperature and conductivity we are able to map where groundwater is contributing to surface flows and where surface water is recharging the aquifer.

Data Processing and Analysis

Most loggers used by WWBWC for groundwater monitoring were absolute (non-vented) pressure transducers, creating a need to compensate the water level data for atmospheric pressure. Using the AQUARIUS time series software (www.aquaticinformatics.com), water level data were corrected by subtracting barometric pressure collected by transducers located at several barometric monitoring stations throughout the valley (Figure 5). Also using AQUARIUS, water level logger data were converted from PSI to feet of water when necessary and graphed with manual water level measurements. Water level logger data were adjusted to correspond with manual water level measurements. This visual correction, facilitated by AQUARIUS software, replaces our previous method of using estimated cable length to determine “depth to water.” Pressure transducer “drift” was monitored and corrected in AQUARIUS by adjusting transducer data to manual water level measurements.

Data were graded to document logger hang-ups on pumps or other obstructions, well pumping during manual water measurement, and other irregularities affecting data quality.

³ Oregon Department of Environmental Quality 1998. *DEQ Lab’s Field Sampling Reference Guide*.

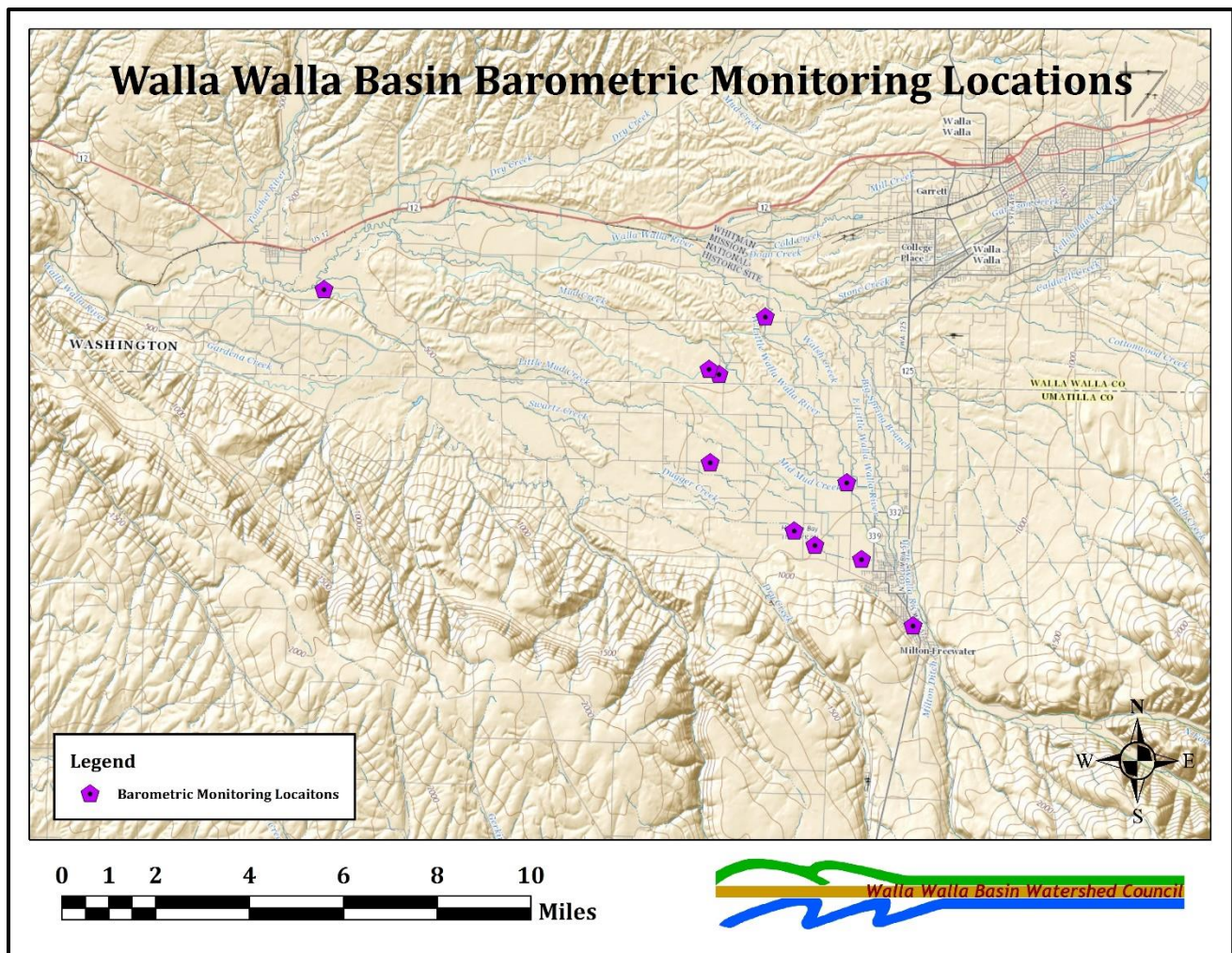


Figure 5. Barometric pressure transducer locations within the Shallow Aquifer Monitoring Network.

Results and Discussion

For all well data please visit the [WWBWC's Groundwater Monitoring Page](#). There you can view hydrographs and download data for the wells.

Historic Wells

Nine of the wells monitored in the shallow aquifer are historic wells with data going back as far as 1933 (Figure 6). These wells are used to see long term trends in the Walla Walla basin's shallow alluvial aquifer. All but two of these wells have shown a declining water level (GW_22 and GW_57, Figures 11-12). Groundwater declines could be related to the increasing number of wells and increasing water usage for domestic and agricultural activities requiring more water withdrawal than is sustainable for the basin's aquifer. Additionally, a significant water management change in 2001 could be having an effect on the basin's aquifer. In that year, the Civil Penalty Settlement Agreement between U.S. Fish and Wildlife Service and the three irrigation districts in the Walla Walla basin (Walla Walla River Irrigation District, Hudson Bay District Improvement Co, Gardena Farms Irrigation District #13) required that 18 cubic feet per second (cfs) remain in the Walla Walla River during summer months and be incrementally raised to 25 cfs during fall and spring. For the previous ~100 years, the Walla Walla River ran dry during the summer because all water was diverted for irrigation uses. This water flowed through the vast

array of irrigation ditches in the basin, providing groundwater recharge as seepage occurred within the ditch systems. Since the Settlement Agreement in 2001, less water has been flowing through the Walla Walla/Gardena/Hudson Bay systems during the summer months leading to a reduced amount of groundwater recharge through the ditch system. However, since the decline in the aquifer seems to have started prior to the 2001 Settlement Agreement, the reduced recharged from surface flows in the irrigation system does not fully explain the downward trend. Increased efficiency for irrigation (ditch piping projects and modern irrigation methods) has further reduced the amount of groundwater recharge from irrigation ditches and canals. Historic irrigation practices included flood irrigation, which allowed for groundwater recharge, while newer drip and sprinkler systems only deliver as much water as is needed. Also, many irrigators have begun using supplemental wells more than in the past and new irrigation wells have been drilled.

Three wells, GW_17, GW_19 and GW_20, were historically declining but, since water management changes in 2001 and the start of the WWBWC aquifer recharge program in the spring of 2004, have stabilized and possibly started to recover (Figures 13-15). Some of the historic wells are shallow hand-dug wells and have gone dry in the recent past. GW_25 has been dry since 2004 (Figure 16).

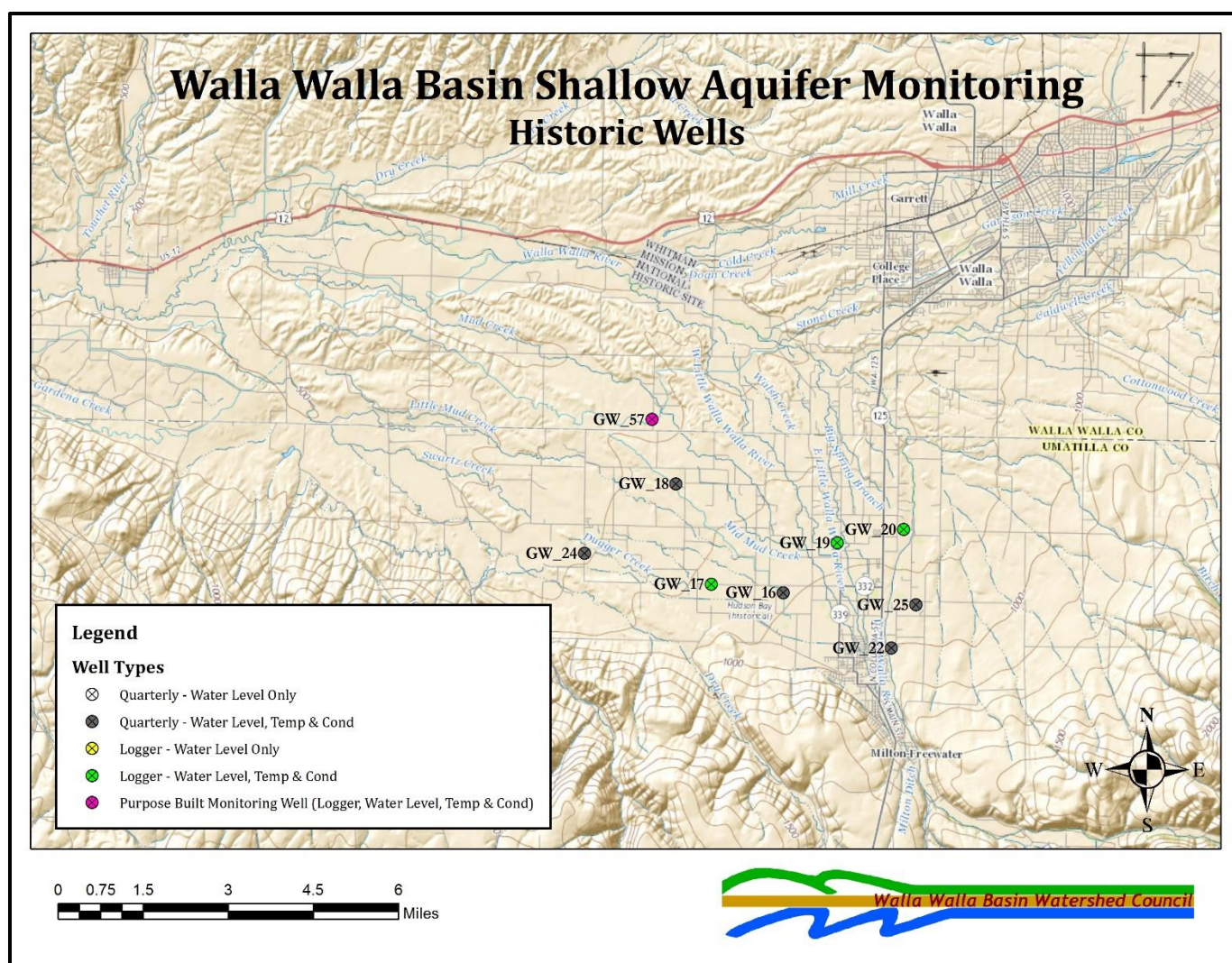


Figure 6. Historic wells included in the Shallow Aquifer Monitoring Network.

Declining Groundwater Levels in Touchet-Gardena Area Wells

Since 2011-2012, data indicate significant declines in groundwater levels in the Touchet-Gardena area (Figure 7). The monitoring wells south of the City of Touchet show declines of 0.25 to 0.5 feet per year from 2011 to 2017 in our historic data in Washington (GW_86, 106, 123, and 125, Figures 17-20). Declines in the Gardena area are dramatic, with annual drops of 1.5 to 4.2 feet beginning in 2011 shown in our current data in Oregon (GW_92, 68) and historic data in Washington (GW_82, 93, 124, 137, and 138, Figures 21-27). Although the cause is not certain, the downward trend correlates with the timing of water management changes in the region including two major ditch piping projects on the Gardena Farms Irrigation District delivery system completed in 2010 and 2012. Seepage data indicate that groundwater contributions make up a meaningful portion of Walla Walla River flows downstream of Touchet during the summer months⁴. As Touchet-Gardena area groundwater levels drop, one might expect a decrease in groundwater contributions to the river. The potential impact of groundwater declines for water users and on Walla Walla River flows may warrant a focused study on the surface water and groundwater interactions in this region. Unfortunately, funding wasn't available to monitor the wells in the Touchet-Gardena area on the Washington side. Since current data are available only for GW_68 and GW_92, the severity of groundwater declines in the region is difficult to characterize.

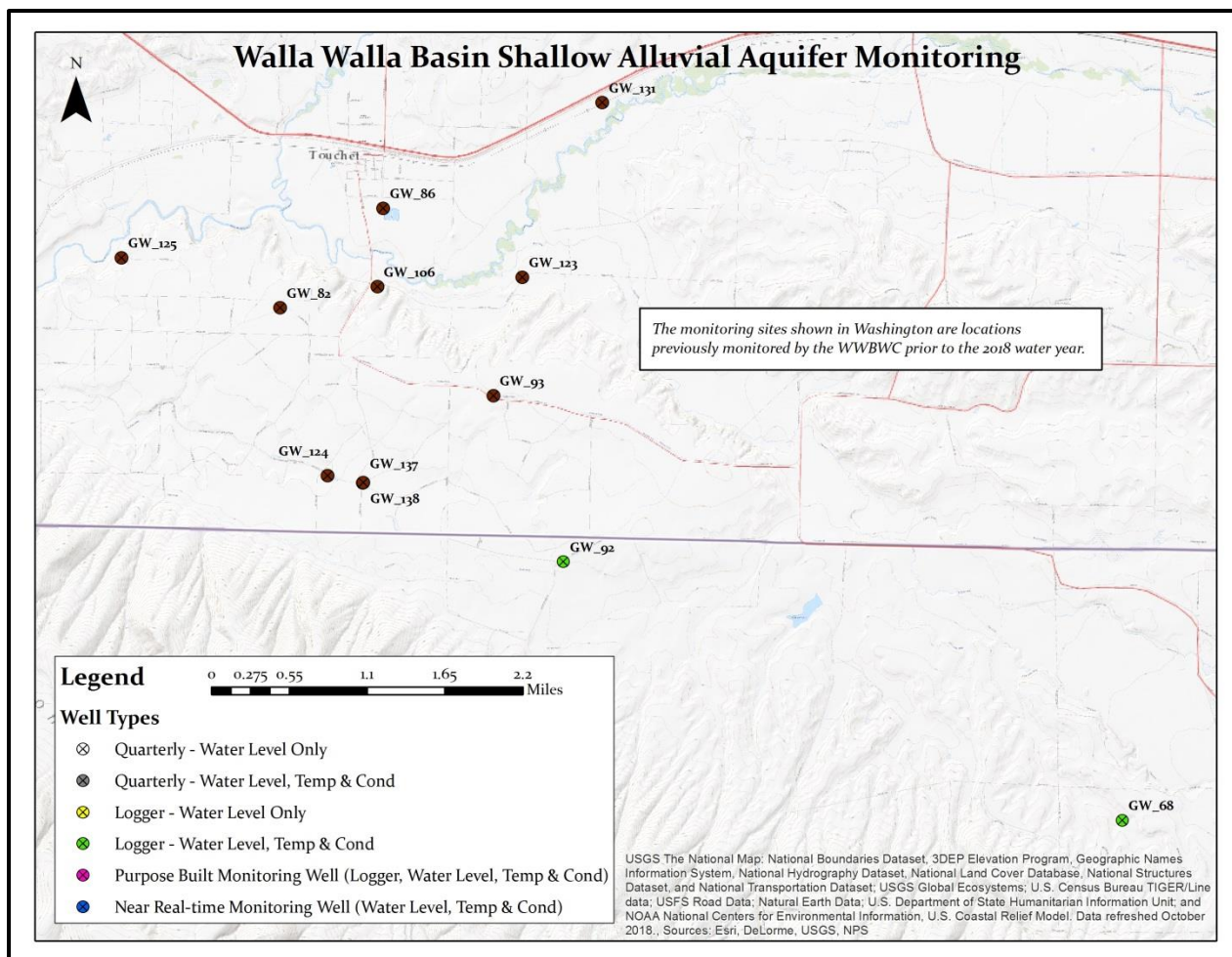


Figure 7. Monitoring wells in the Touchet-Gardena Area.

⁴ Baker T.W. 2017. *Walla Walla Basin Seasonal Seepage Assessments Report: Walla Walla River, Mill Creek, and Touchet River*. Walla Walla Basin Watershed Council. www.wwbwc.org.

Near Real-time Groundwater Monitoring

Over the last three years, the WWBWC has significantly expanded its telemetry system. Included in this expansion is the near real-time monitoring of groundwater levels at several locations around the valley. Currently, the WWBWC has five near real-time groundwater monitoring locations (Figure 8). These sites allow landowners, water managers and other interested parties to get a more up-to-date understanding on current groundwater levels. These near real-time monitoring locations also allow for better operation and tracking of managed aquifer recharge sites. Figure 9 is an example of the near real-time groundwater monitoring pages.

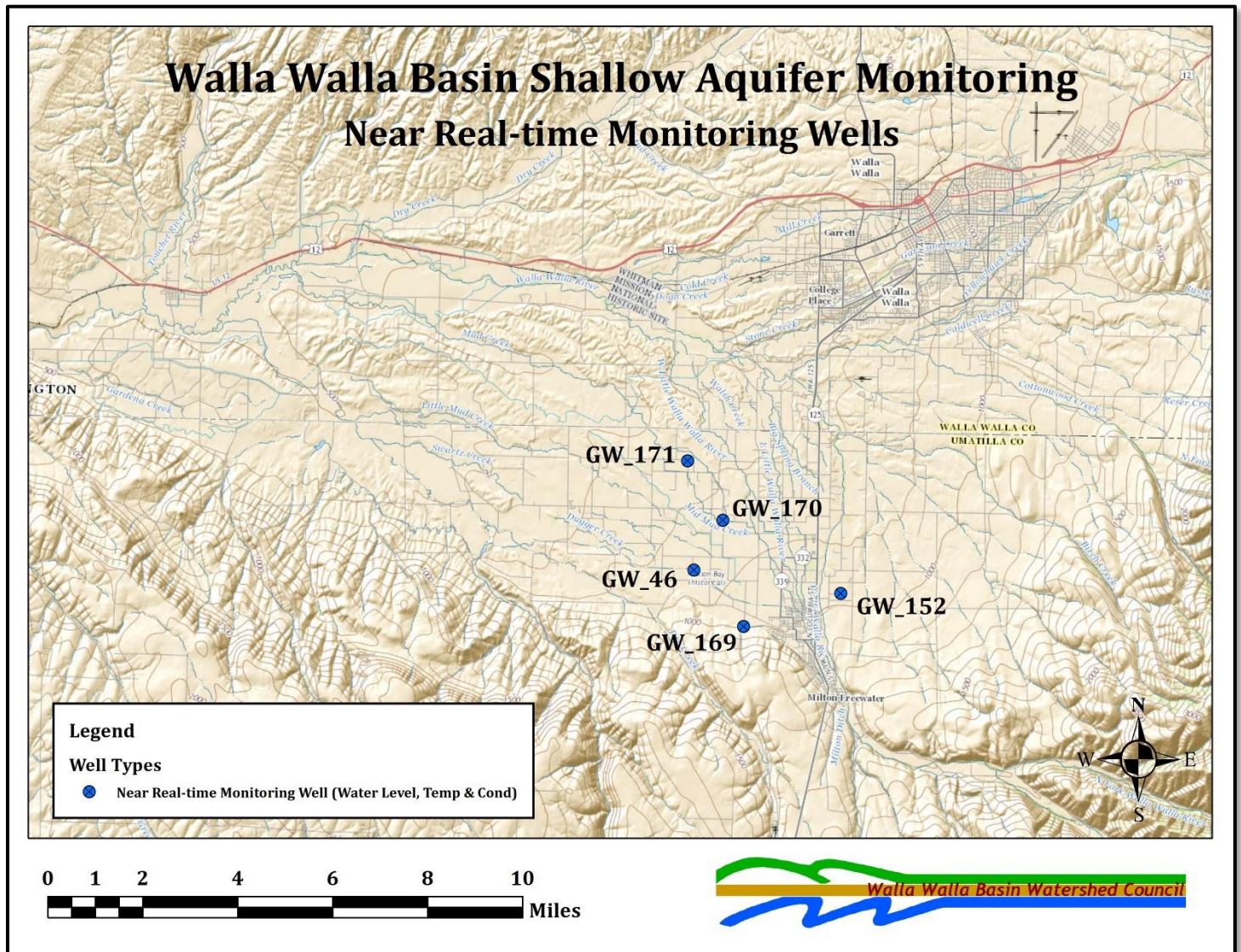


Figure 8. Near Real-time monitoring wells in the Walla Walla Valley.

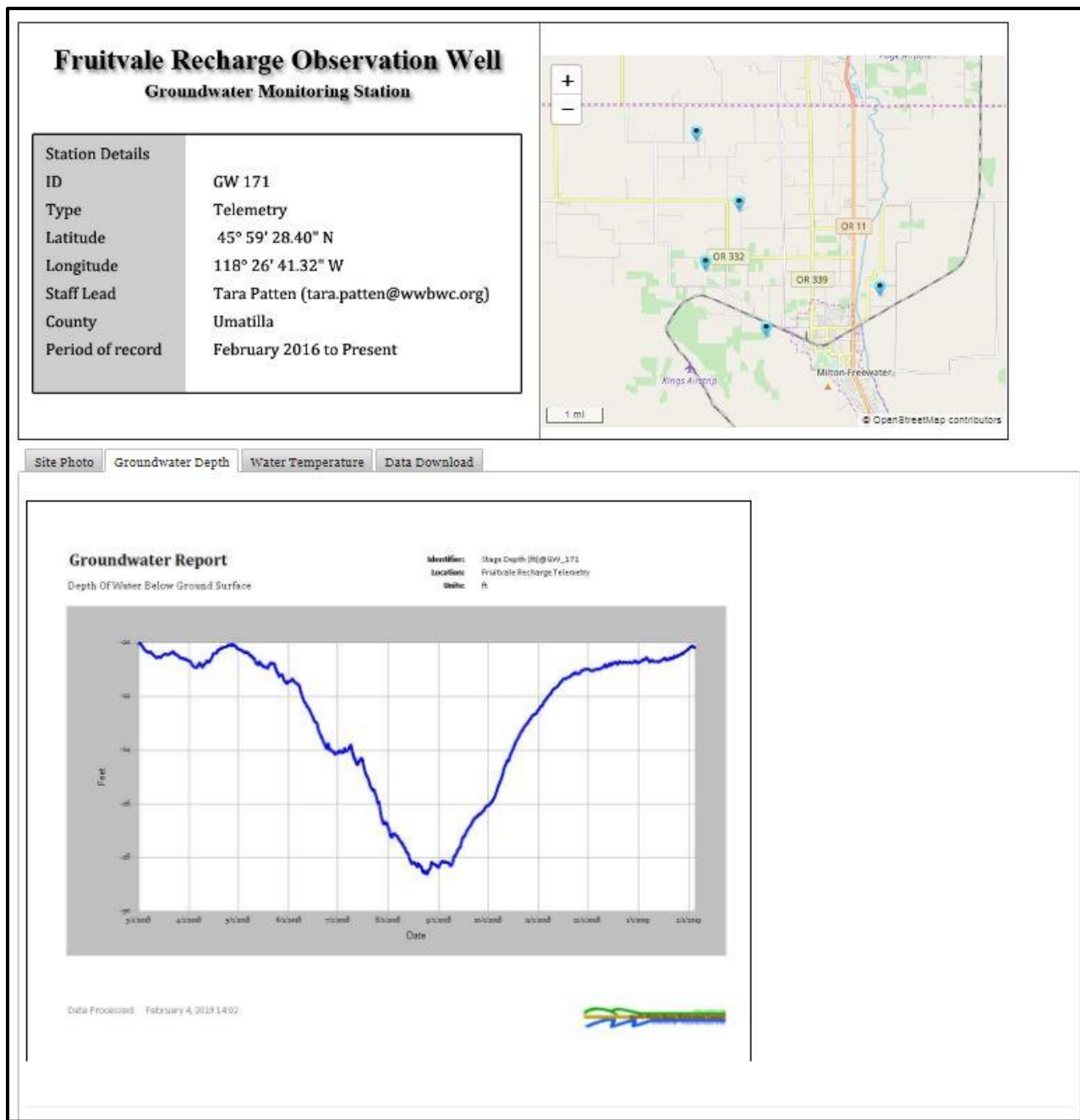


Figure 9. Example webpage for near real-time groundwater monitoring in the WWBWC's Shallow Aquifer Monitoring Network.

Areas of Groundwater Stability and Potential Positive Trends

Not all wells in the valley are showing groundwater declines. Groundwater levels in the upper Milton-Freewater and Umapine area (Figure 10) appear to be relatively stable (GW_14, 115, 31, 119, and 63, Figures 28-32). Monitoring wells at three managed aquifer recharge sites located between Milton-Freewater and Umapine, Northwest Umapine, Johnson, and Anspach, show potential positive trends. GW_141 (Figure 33) at the Anspach recharge site shows an increase of 6.5 ft. of the yearly deepest groundwater levels from 2014 to 2018. Similar results can be seen with monitoring wells at Johnson (GW_40, 45, 46, 47, 48, and 118, Figures 34-39) and Northwest Umapine (GW_34 and 144, Figures 40 and 41). The wells at the Johnson site show an average increase of 4.3 ft. of the yearly deepest groundwater levels between 2005 and 2018. The wells at the Northwest Umapine site show an average increase of 5.2 ft. of the yearly deepest groundwater levels between 2014 and 2018.⁵

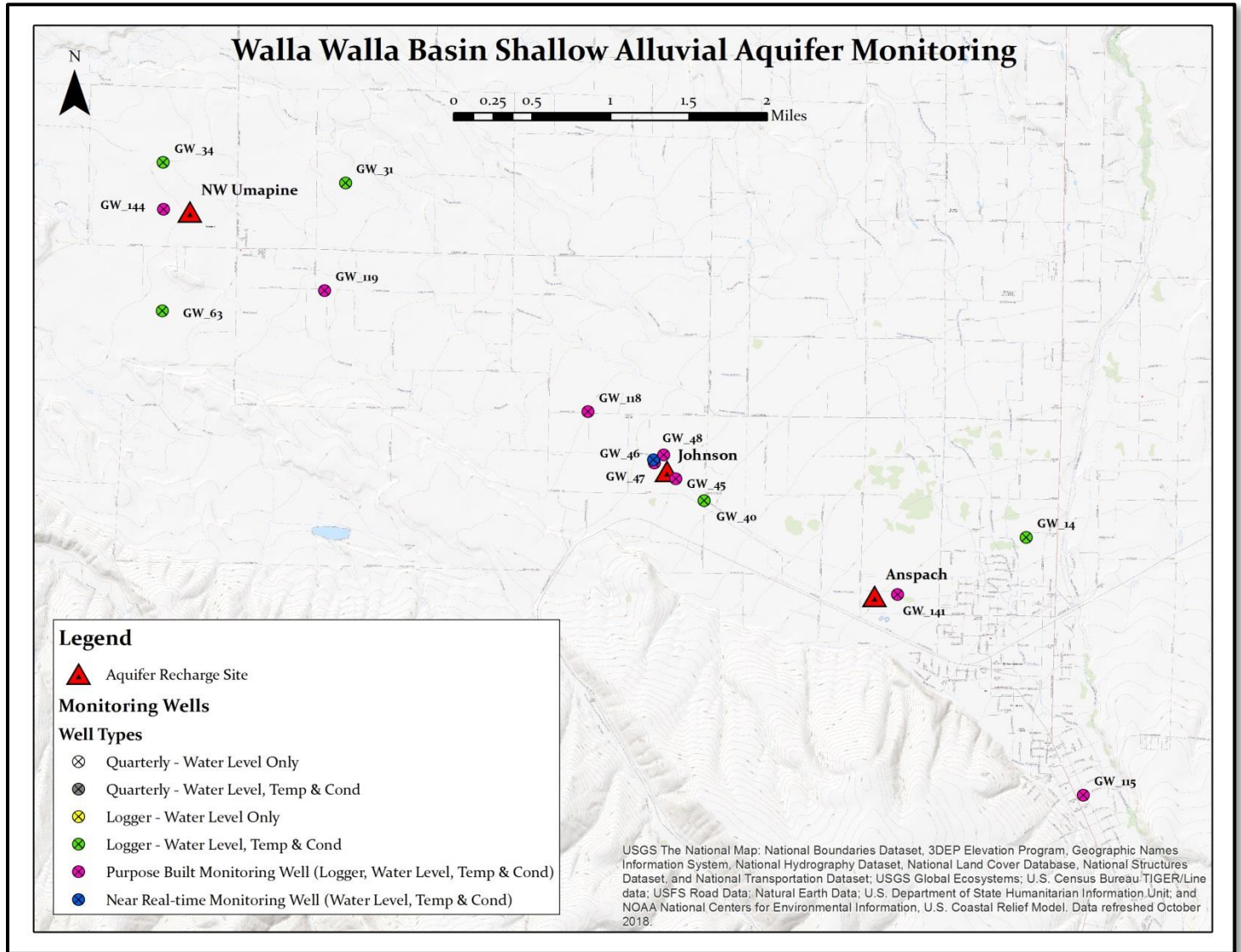


Figure 10. Monitoring wells showing stable and/or increasing groundwater levels in the Walla Walla Valley

⁵ Cobb M. 2018. *Oregon Walla Walla Basin Aquifer Recharge Report*. Walla Walla Basin Watershed Council. www.wwbwc.org

Summary

WWBWC's alluvial monitoring program, beginning with only a dozen wells in 2001, provides basin partners with a valuable understanding of groundwater conditions and trends during the last 17 years. Although we were unable to monitor wells on the Washington side of the basin during the 2018 water year, WWBWC continued to extend the data record for 71 alluvial aquifer wells in Oregon. WWBWC funders and basin partners continue to support and affirm the value of the shallow aquifer monitoring project as a vital component of current and future understanding of groundwater resources, aquifer decline and recharge, surface-groundwater interactions, and groundwater returns to the Walla Walla River. The well monitoring network data are being used to inform decisions about current and future aquifer recharge projects and are also supporting the on-going Walla Walla Basin Integrated Flow Enhancement Study. The data being collected will continue to provide insight for water management professionals and local communities to make water related decisions into the future.

The Shallow Aquifer Monitoring Project is successful not only in compiling aquifer data but also as a mechanism for community outreach because it depends heavily on voluntary land owner participation and local support. Many citizens have contributed vital information to the project and also have become more aware of the declining aquifer and other water issues in the Walla Walla basin.

Acknowledgments

We gratefully acknowledge the contributions of our generous funders including Bonneville Power Administration, Oregon Water Resources Department, and the Oregon Watershed Enhancement Board. Thanks also to local collaborators including private landowners, irrigation districts, and the City of Milton-Freewater for allowing property access for groundwater monitoring. Without their support this work would not be possible.

Appendix A

Hydrographs of wells mentioned in the report

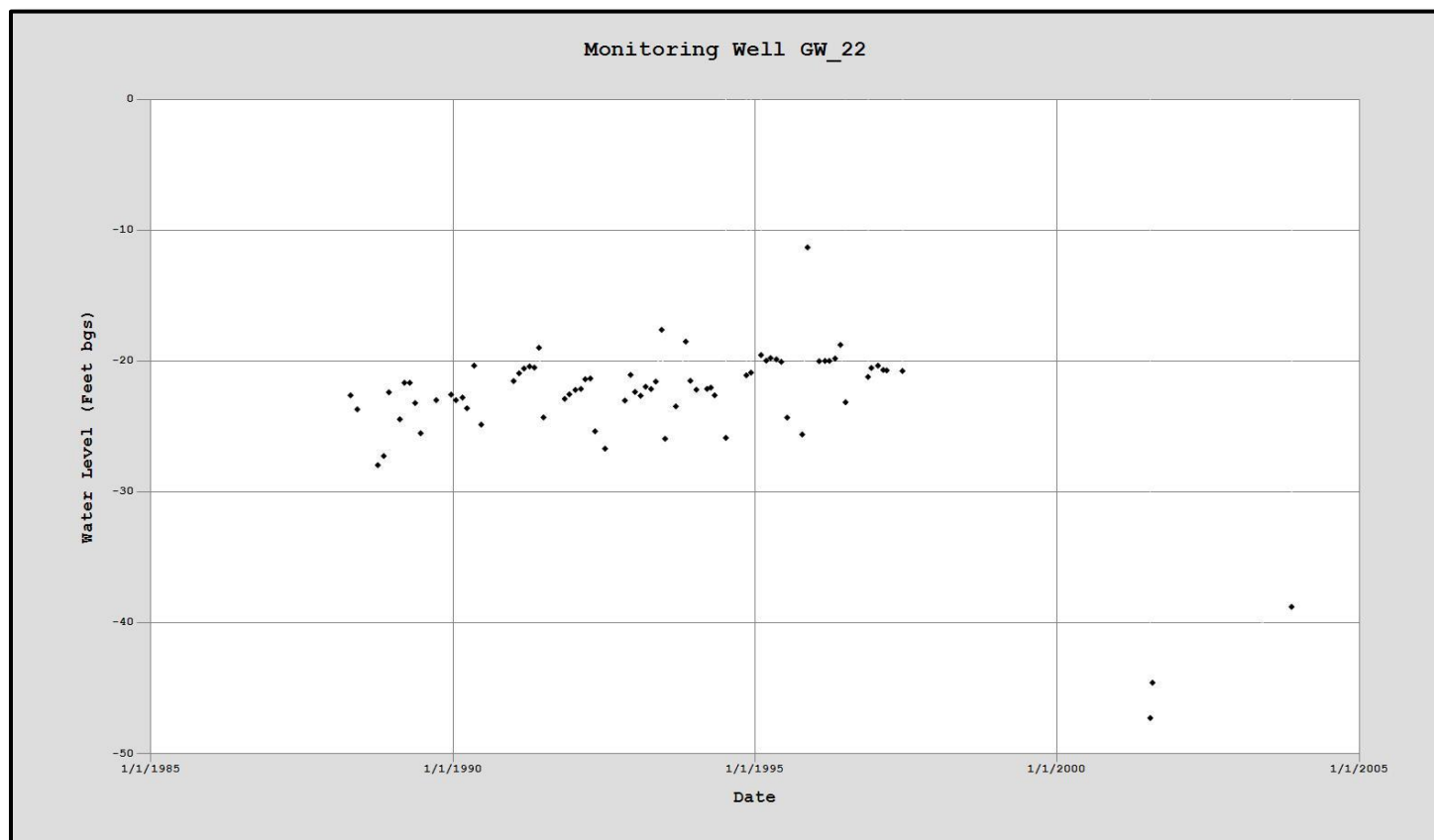


Figure 11. Manual water level measurements in feet below ground surface for the historic well GW_22 located in the WWBWC's Shallow Aquifer Monitoring Network.

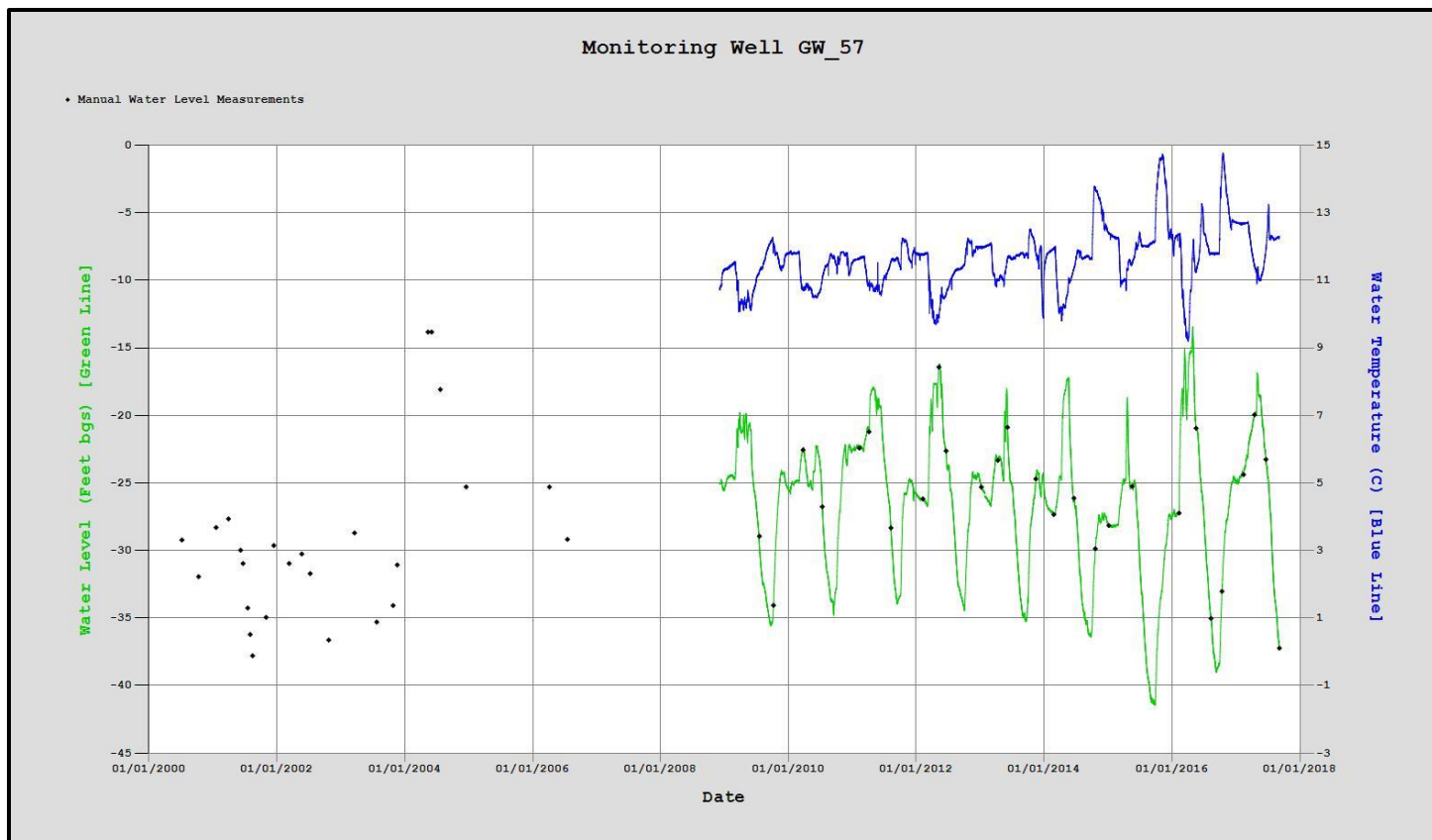


Figure 12. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the historic well GW_57 located in the WWBWC’s Shallow Aquifer Monitoring Network.

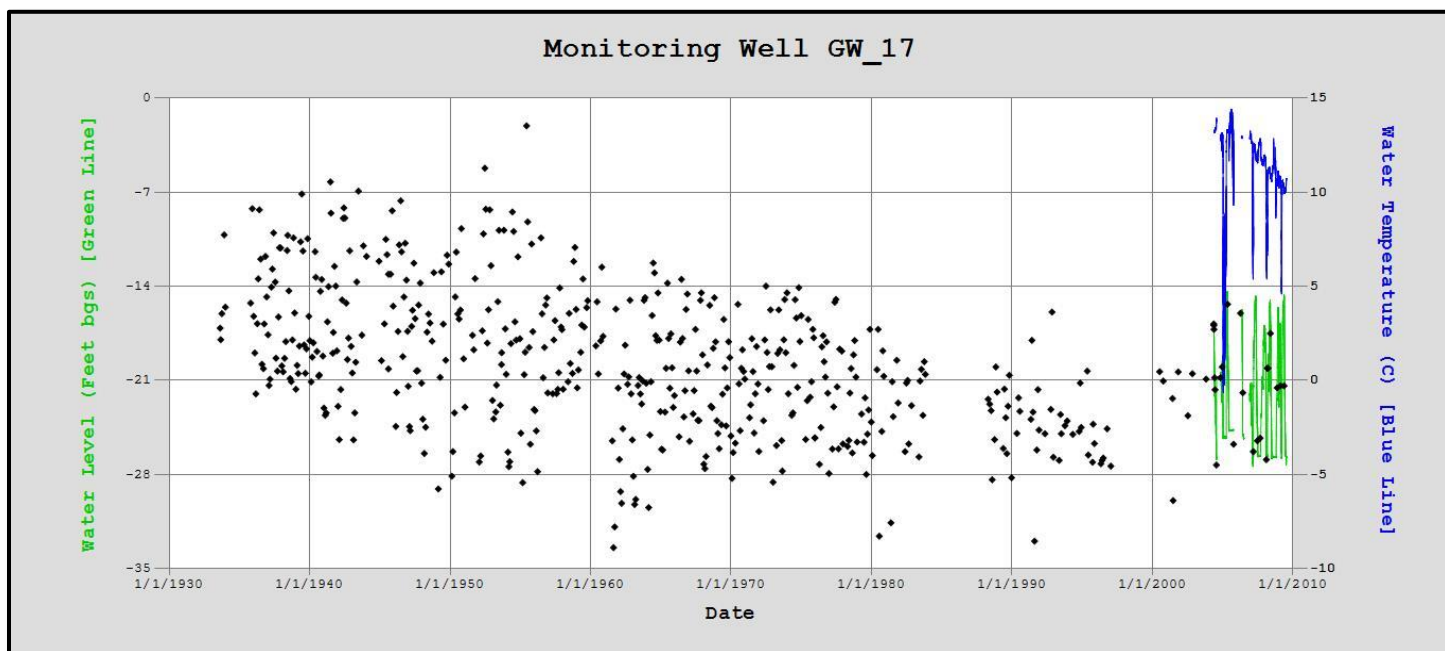


Figure 13. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the historic well GW_17 located in the WWBWC’s Shallow Aquifer Monitoring Network.

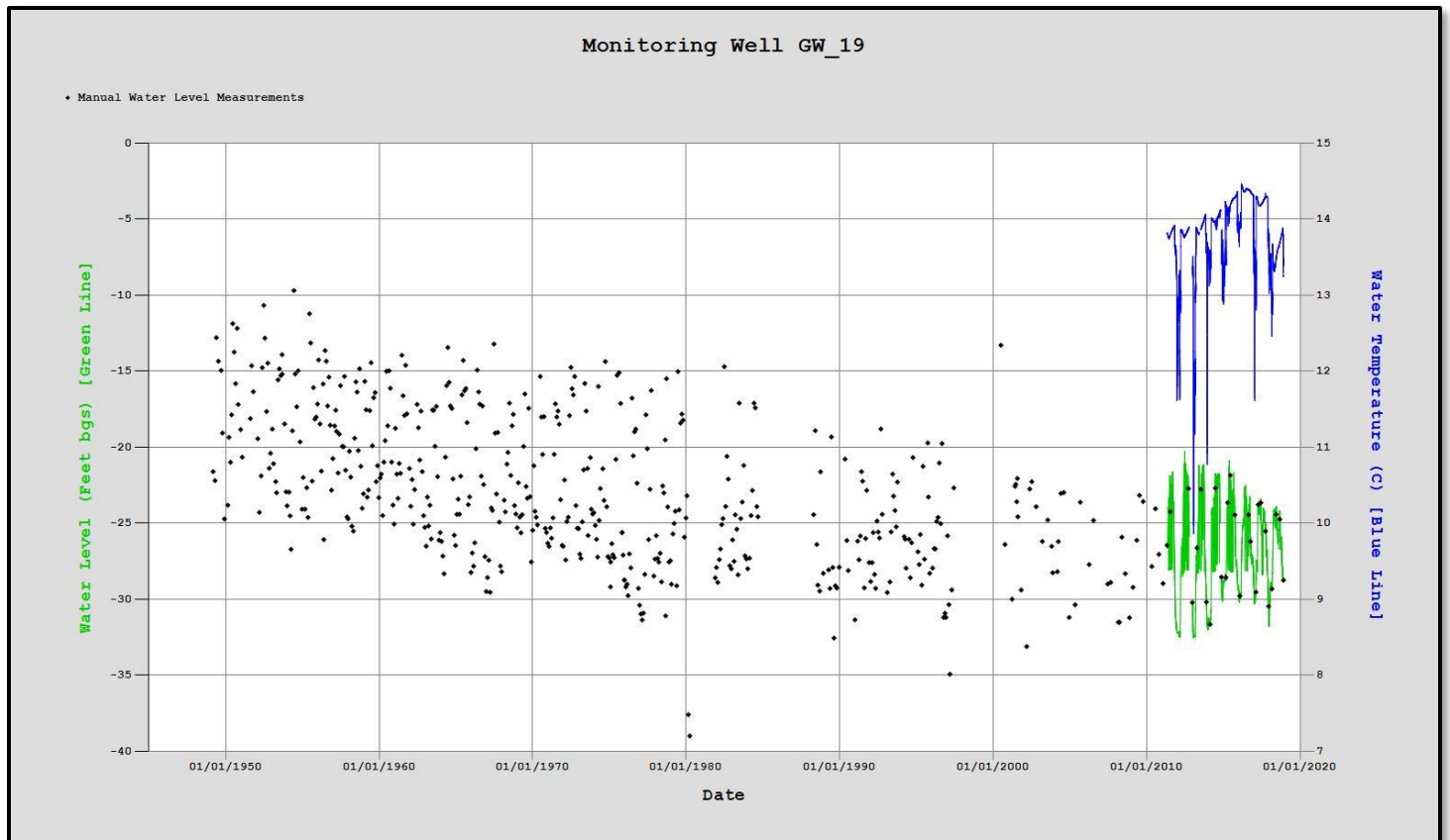


Figure 14. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the historic well GW_19 located in the WWBWC's Shallow Aquifer Monitoring Network.

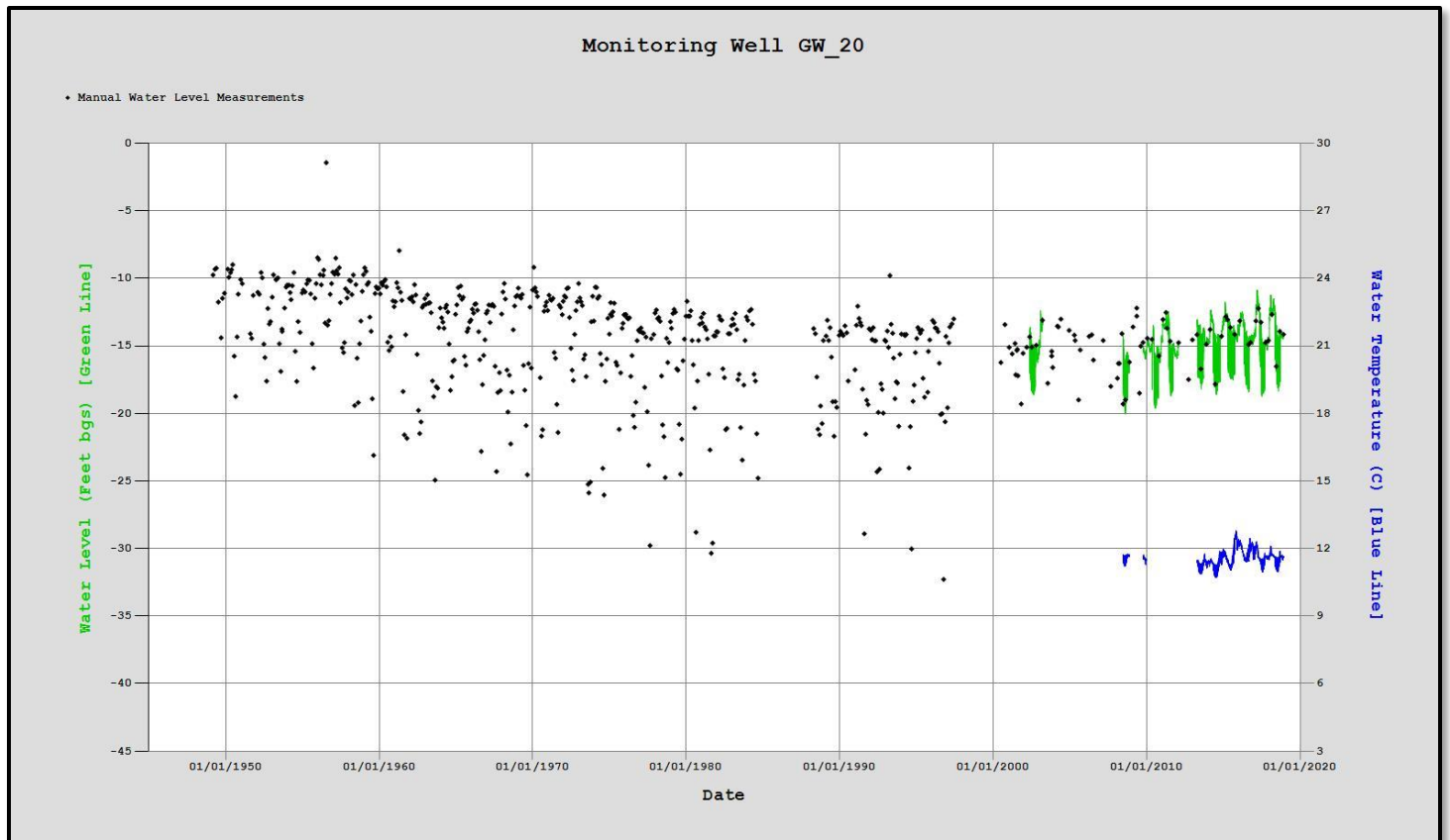


Figure 15. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the historic well GW_20 located in the WWBWC's Shallow Aquifer Monitoring Network.

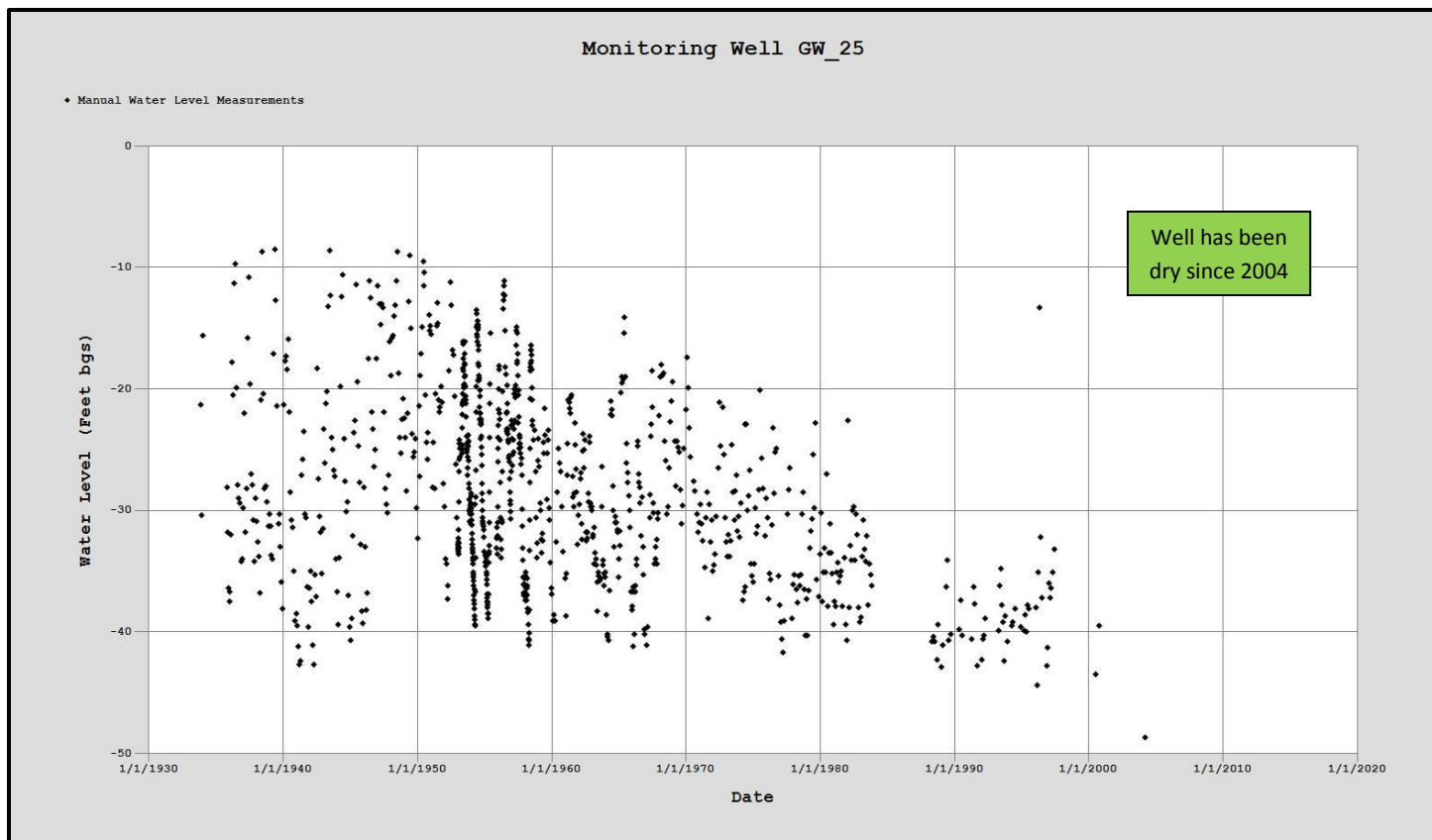


Figure 16. Manual water level measurements (black diamonds) in feet below ground surface for the historic well GW_25 located in the WWBWC's Shallow Aquifer Monitoring Network.

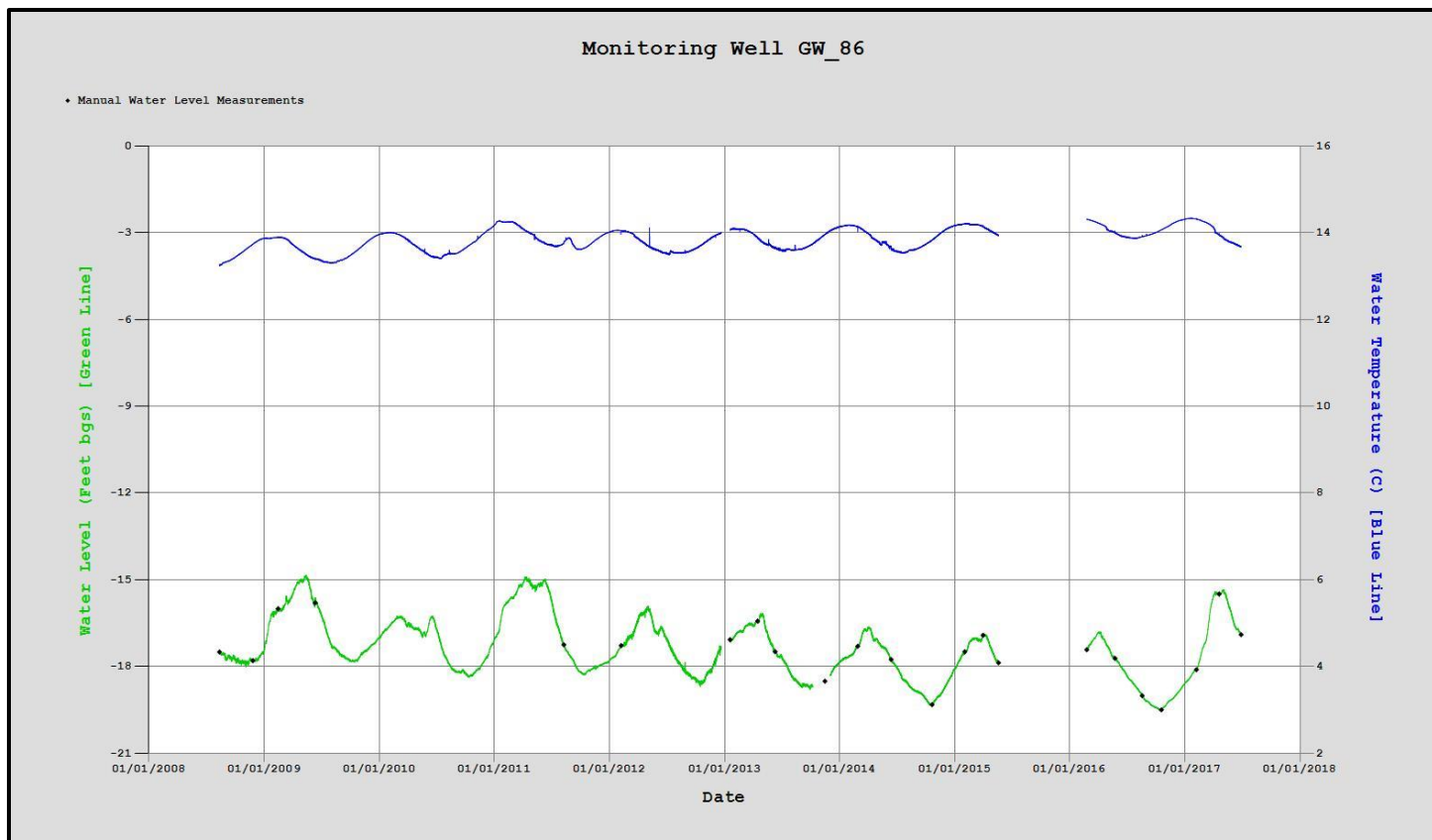


Figure 17. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_86 located in the WWBWC's Shallow Aquifer Monitoring Network.

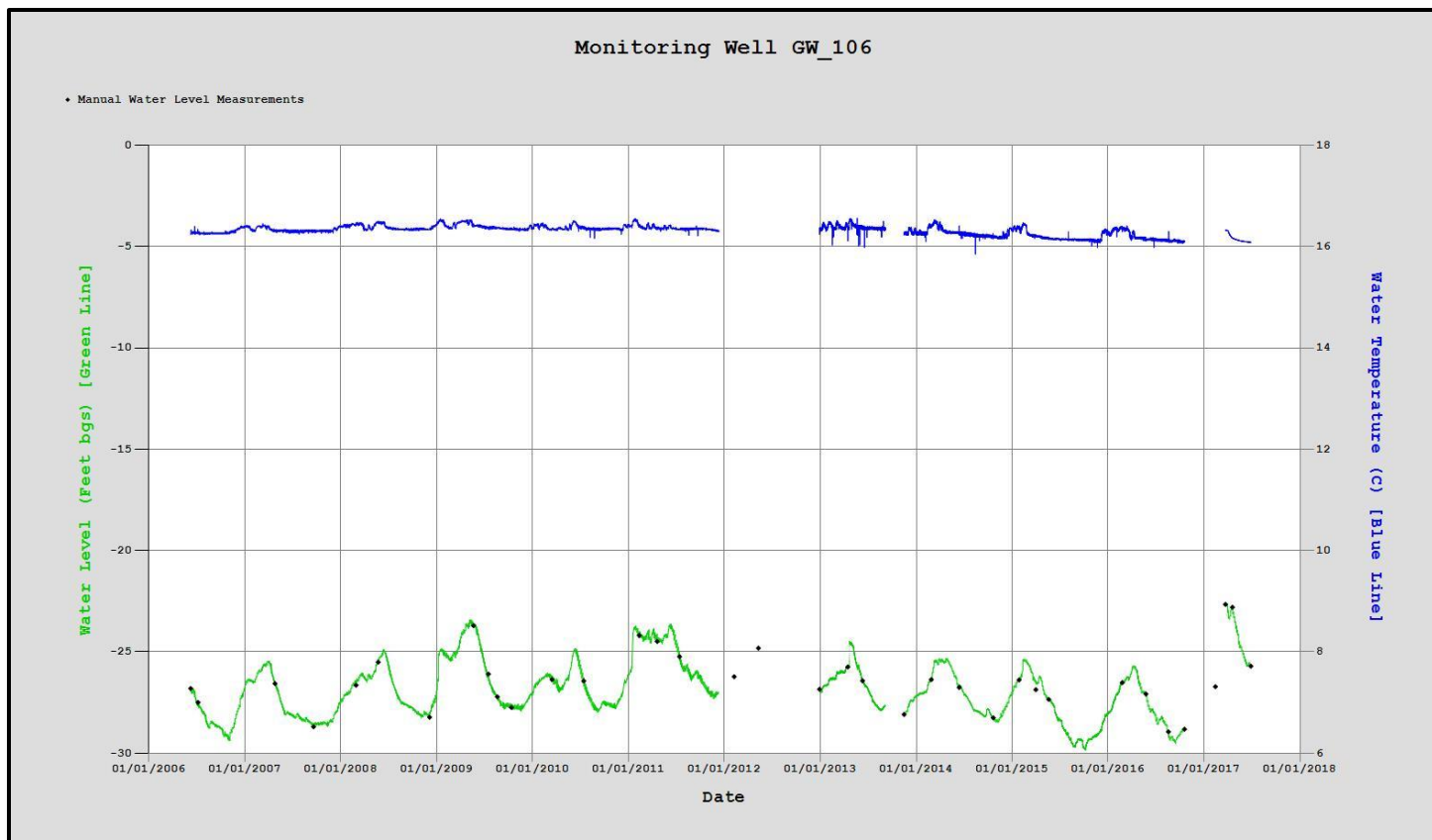


Figure 18. Manual water level measurements (black diamonds) in feet below ground surface for the well GW_106 located in the WWBWC's Shallow Aquifer Monitoring Network.

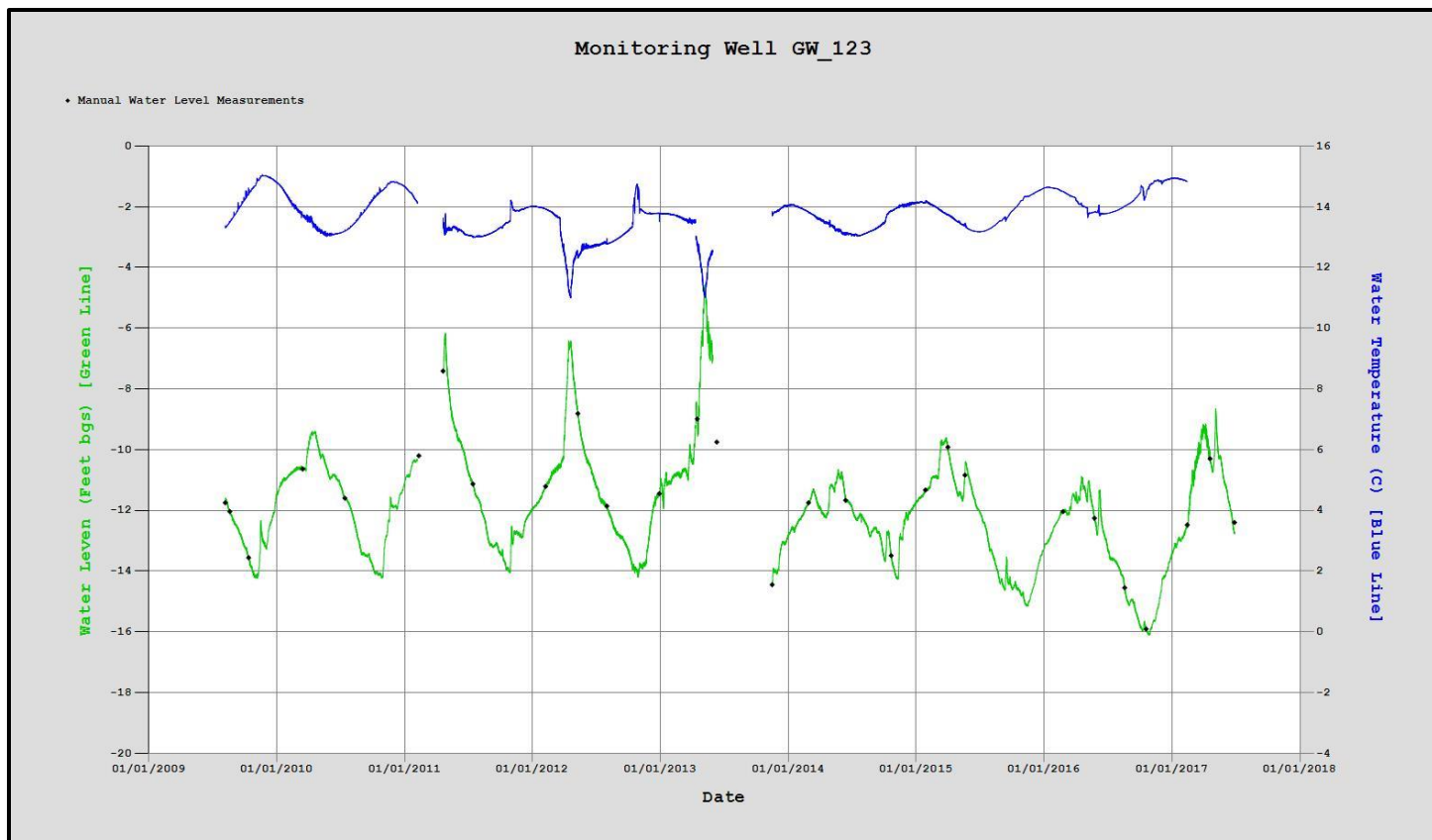


Figure 19. Pressure transducer data (blue line) in feet below ground surface for the near real-time well GW_123 located in the WWBWC's Shallow Aquifer Monitoring Network.

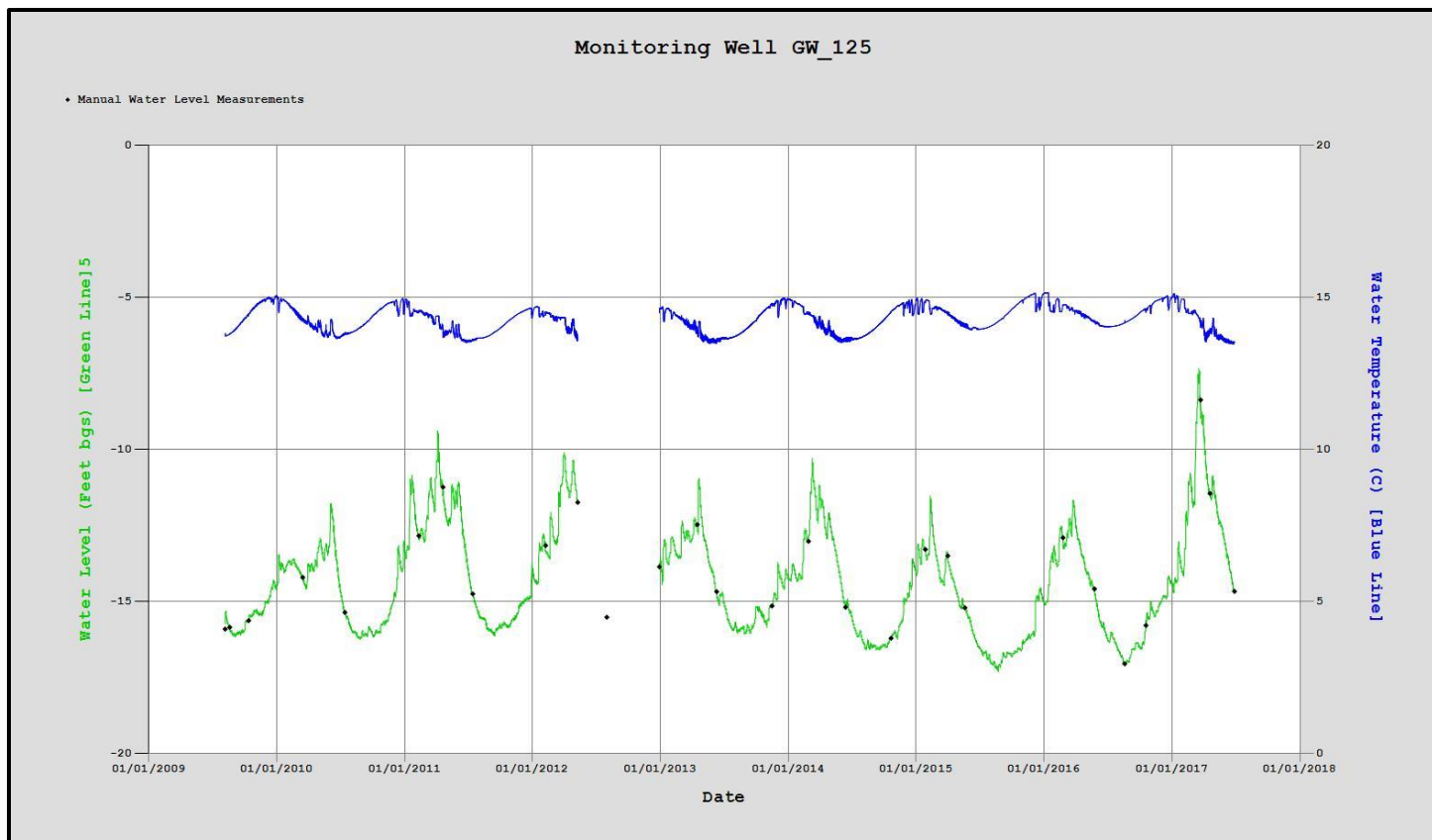


Figure 20. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_125 located in the WWBWC's Shallow Aquifer Monitoring Network.

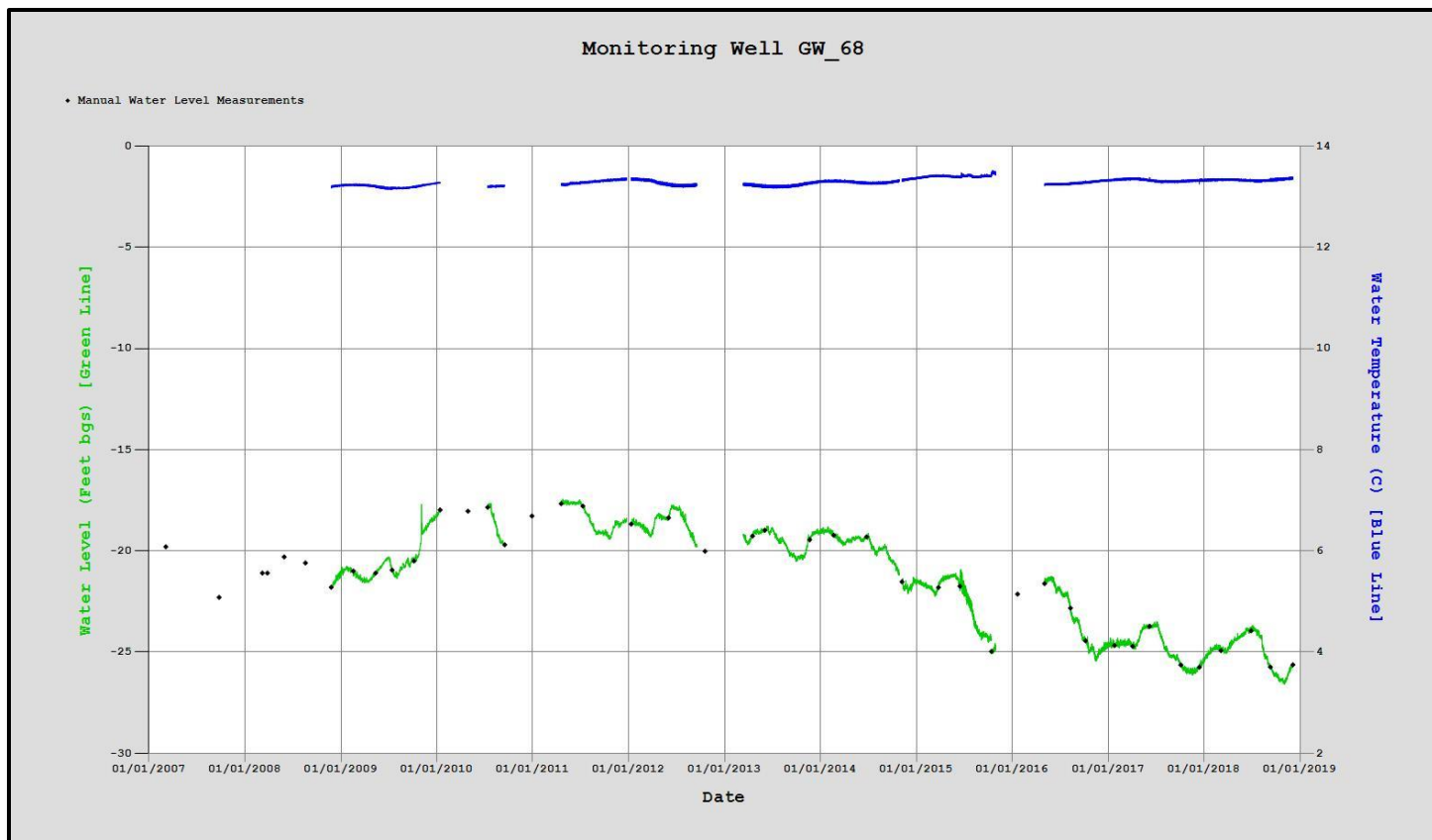


Figure 21. Manual water level measurements (black diamonds) in feet below ground surface for the well GW_68 located in the WWBWC's Shallow Aquifer Monitoring Network.

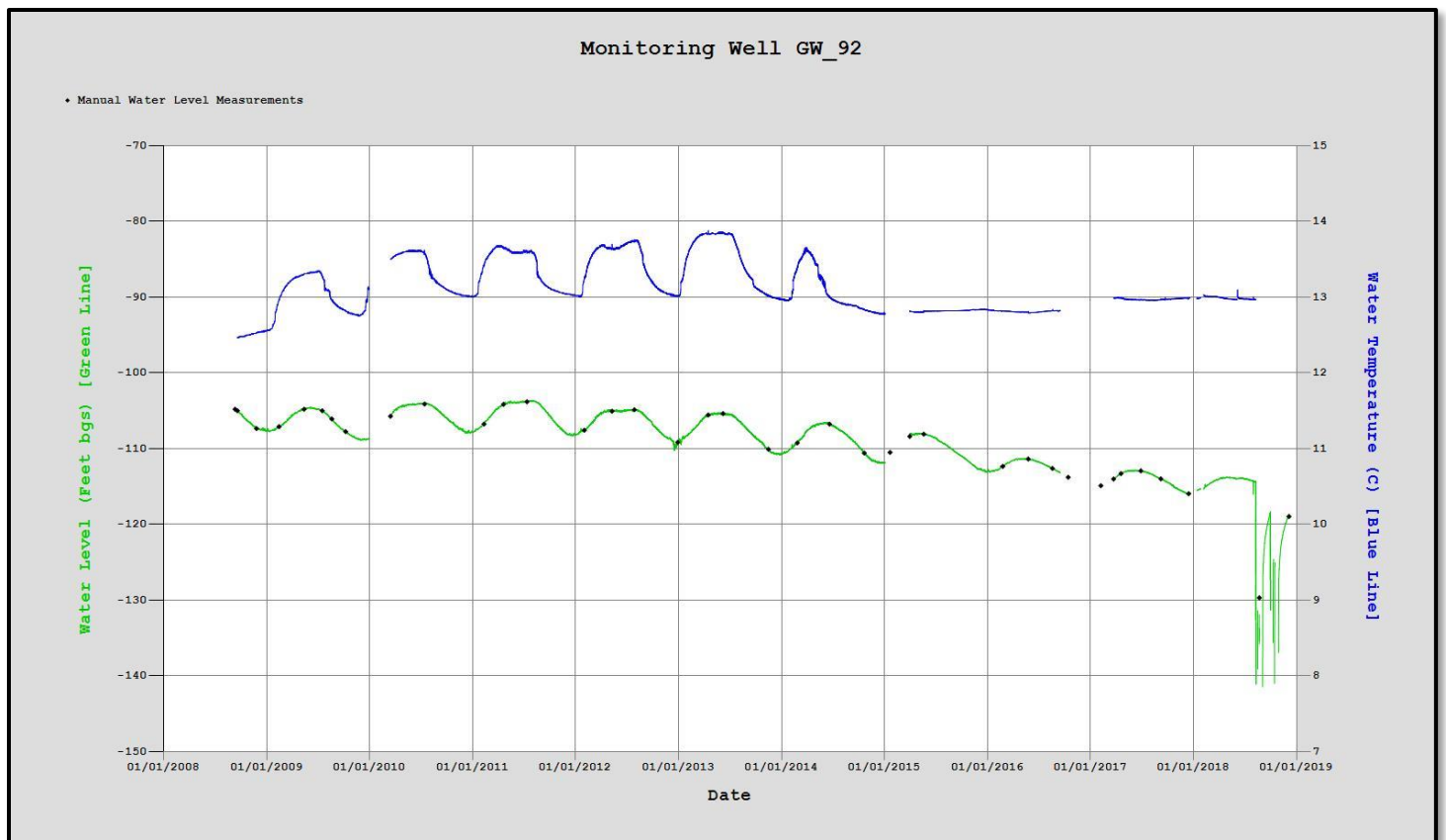


Figure 22. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_92 located in the WWBWC's Shallow Aquifer Monitoring Network.

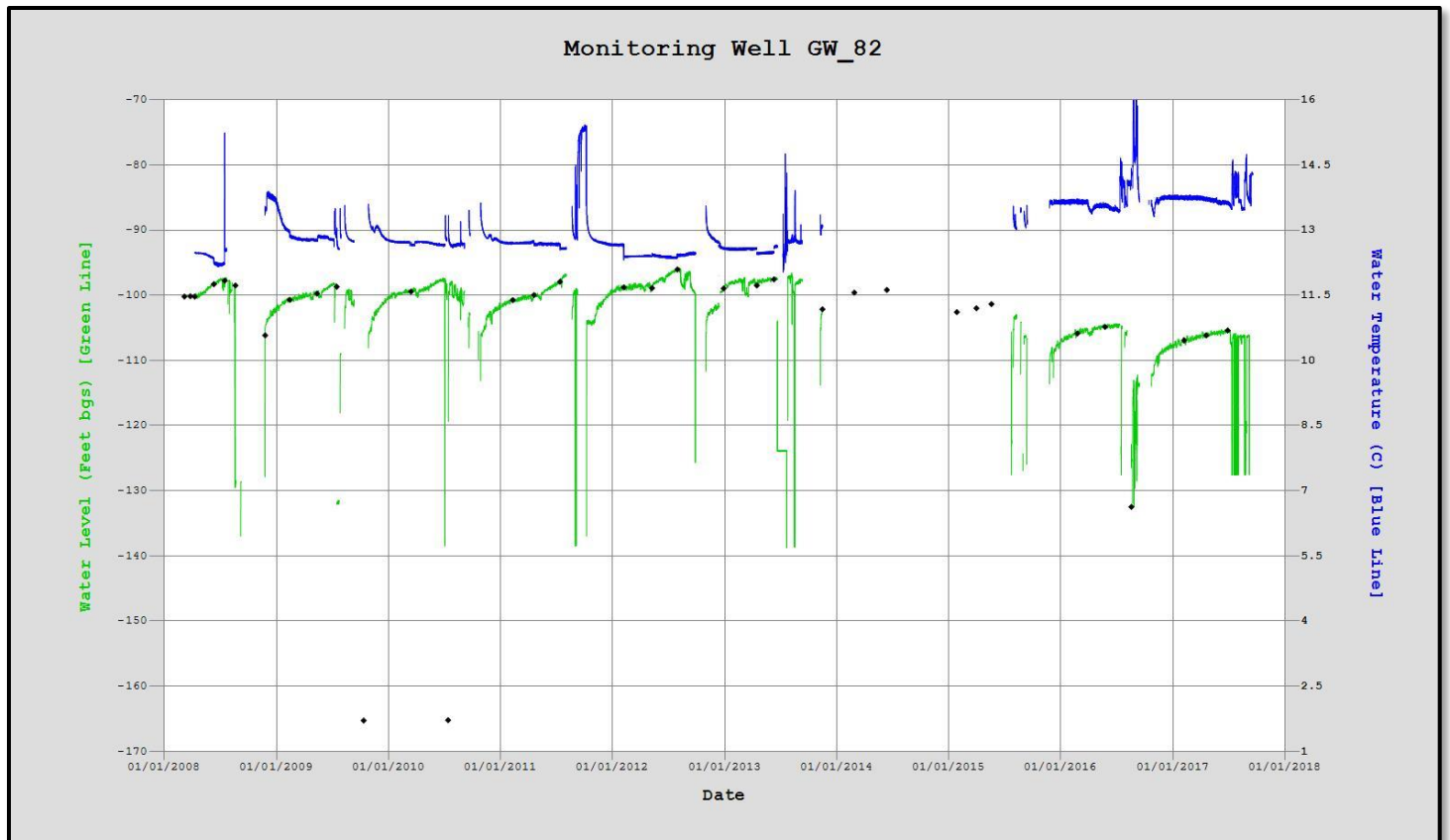


Figure 23. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_82 located in the WWBWC's Shallow Aquifer Monitoring Network.

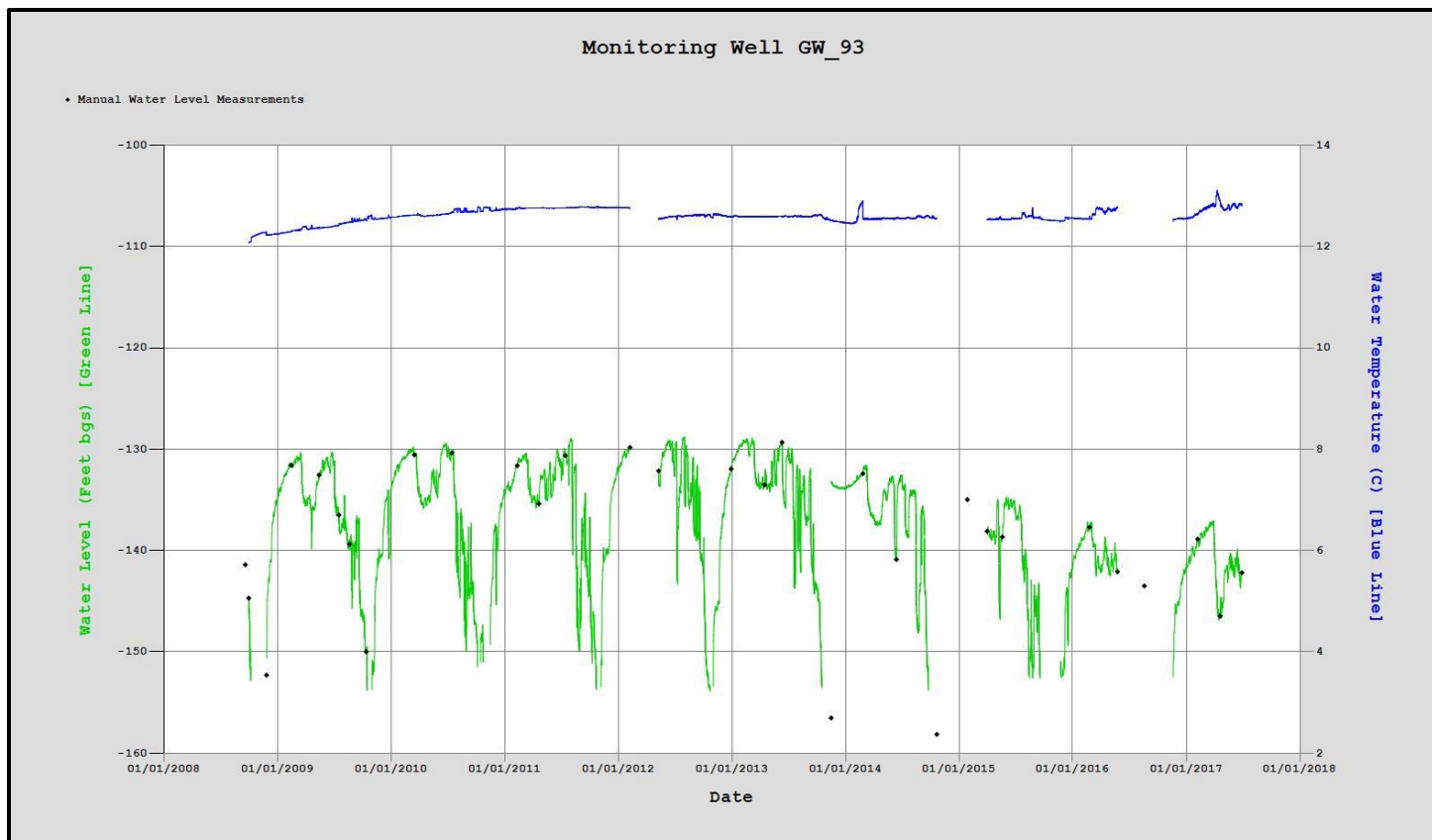


Figure 24. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_93 located in the WWBWC's Shallow Aquifer Monitoring Network.

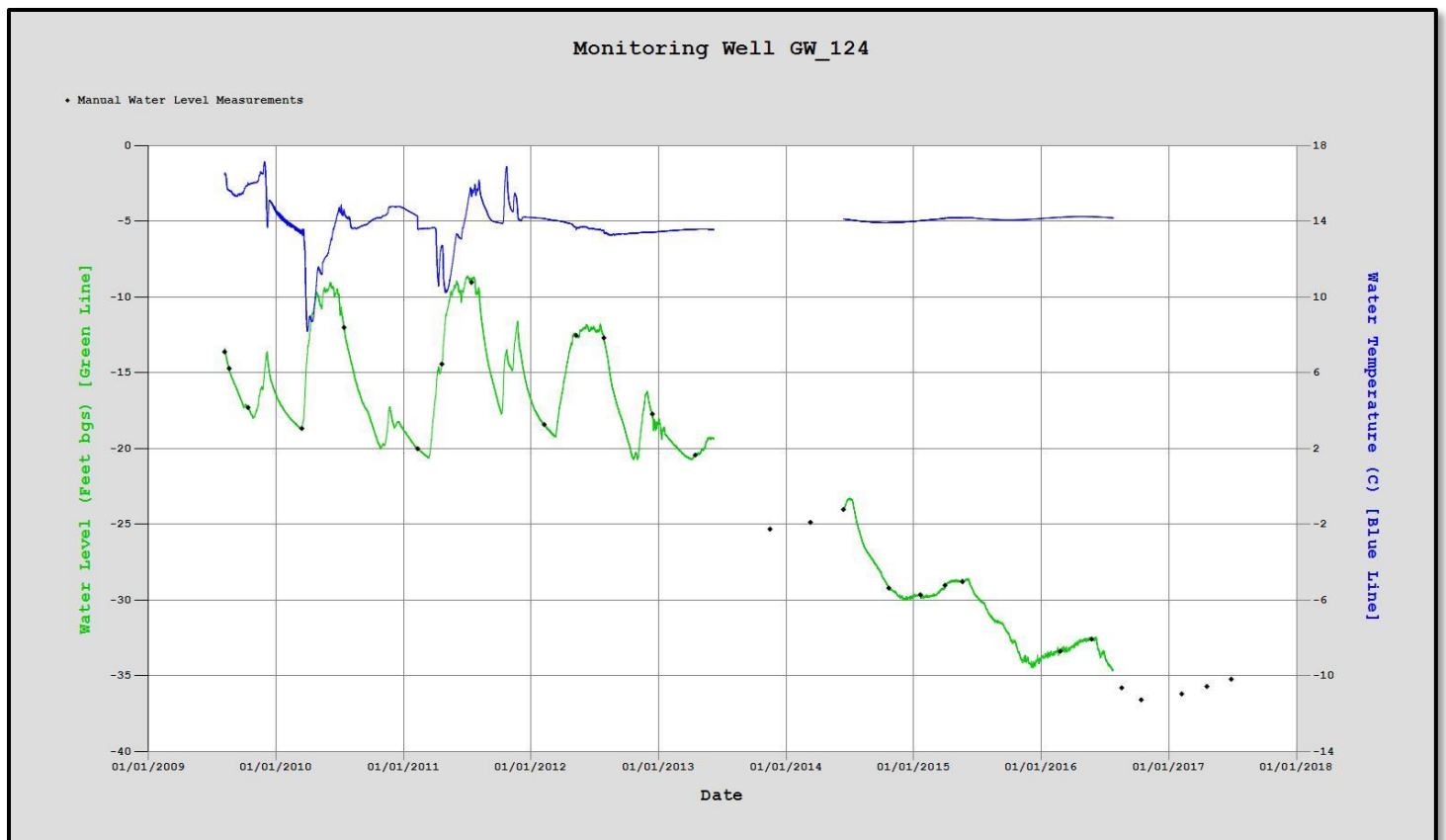


Figure 25. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_124 located in the WWBWC's Shallow Aquifer Monitoring Network.

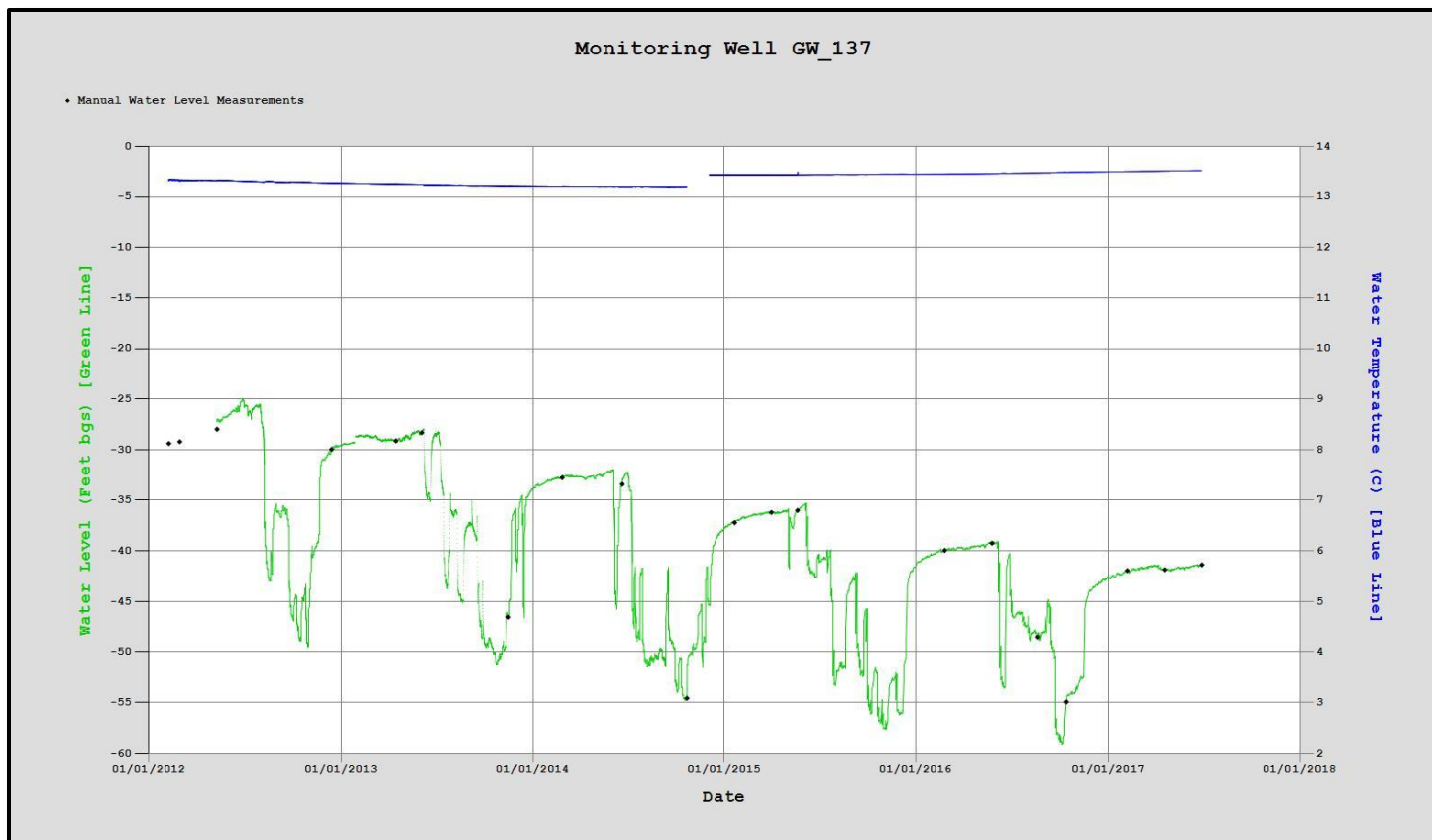


Figure 26. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_137 located in the WWBWC's Shallow Aquifer Monitoring Network.

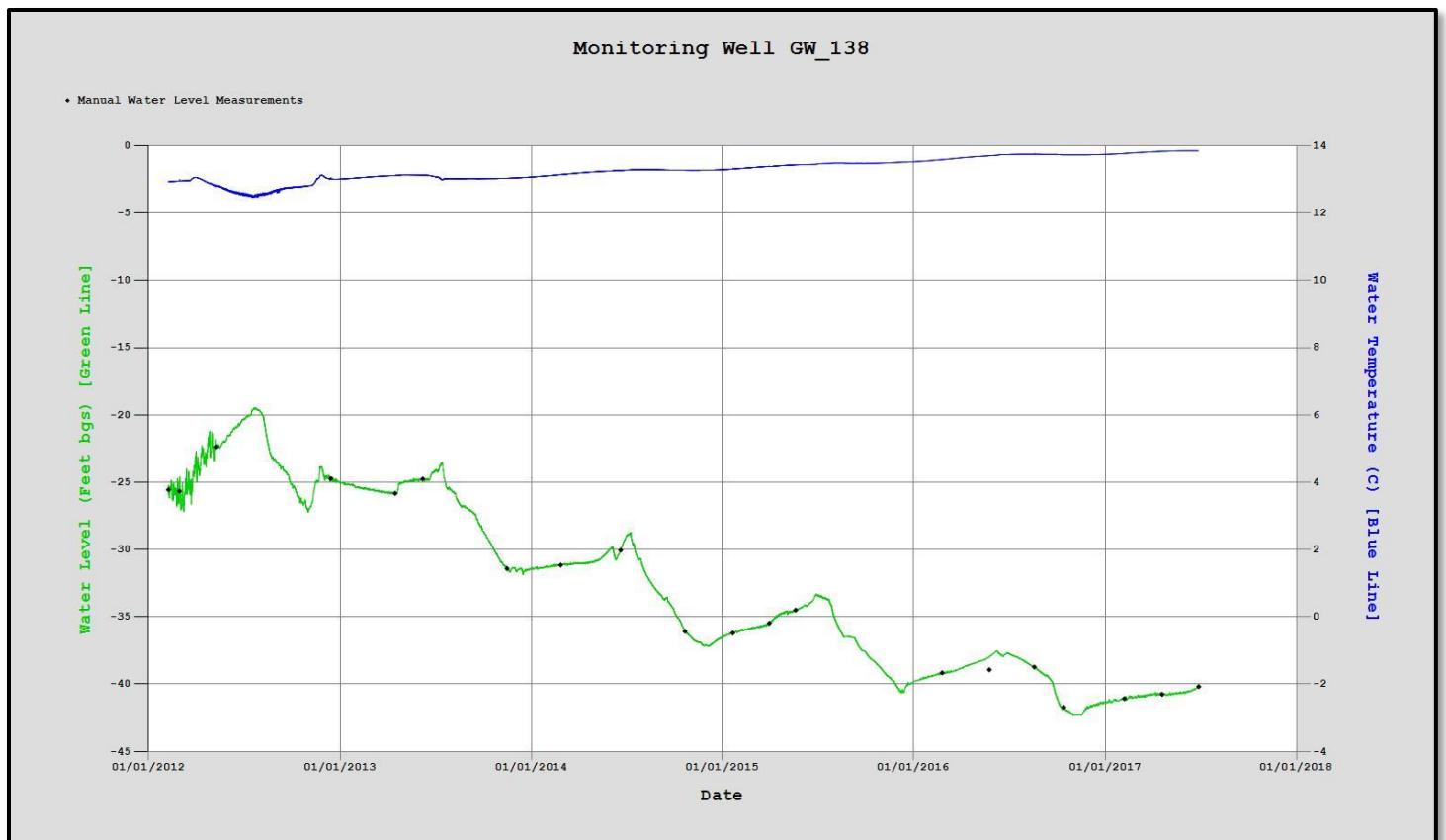


Figure 27. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_138 located in the WWBWC's Shallow Aquifer Monitoring Network.

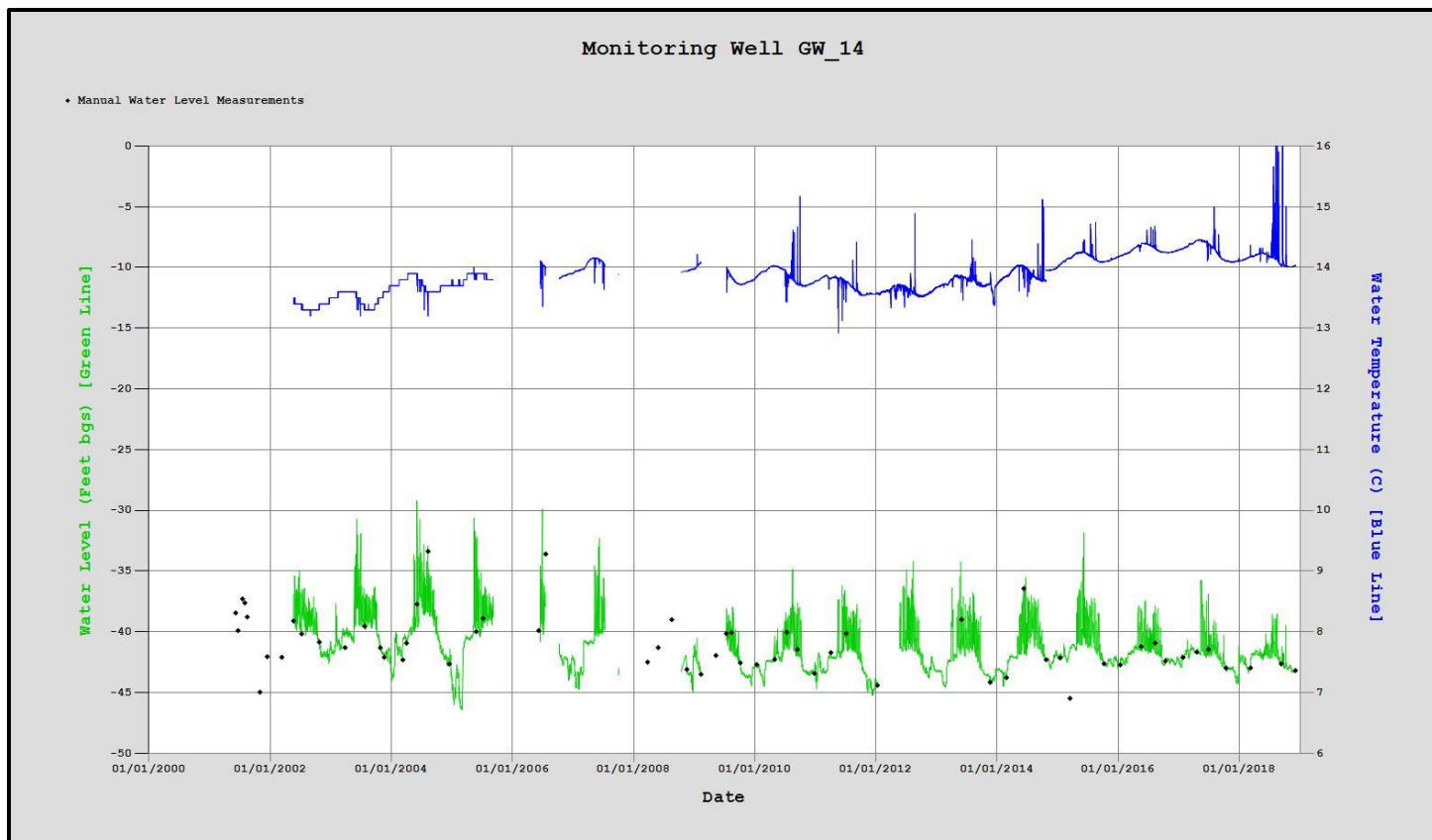


Figure 28. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_14 located in the WWBWC's Shallow Aquifer Monitoring Network.

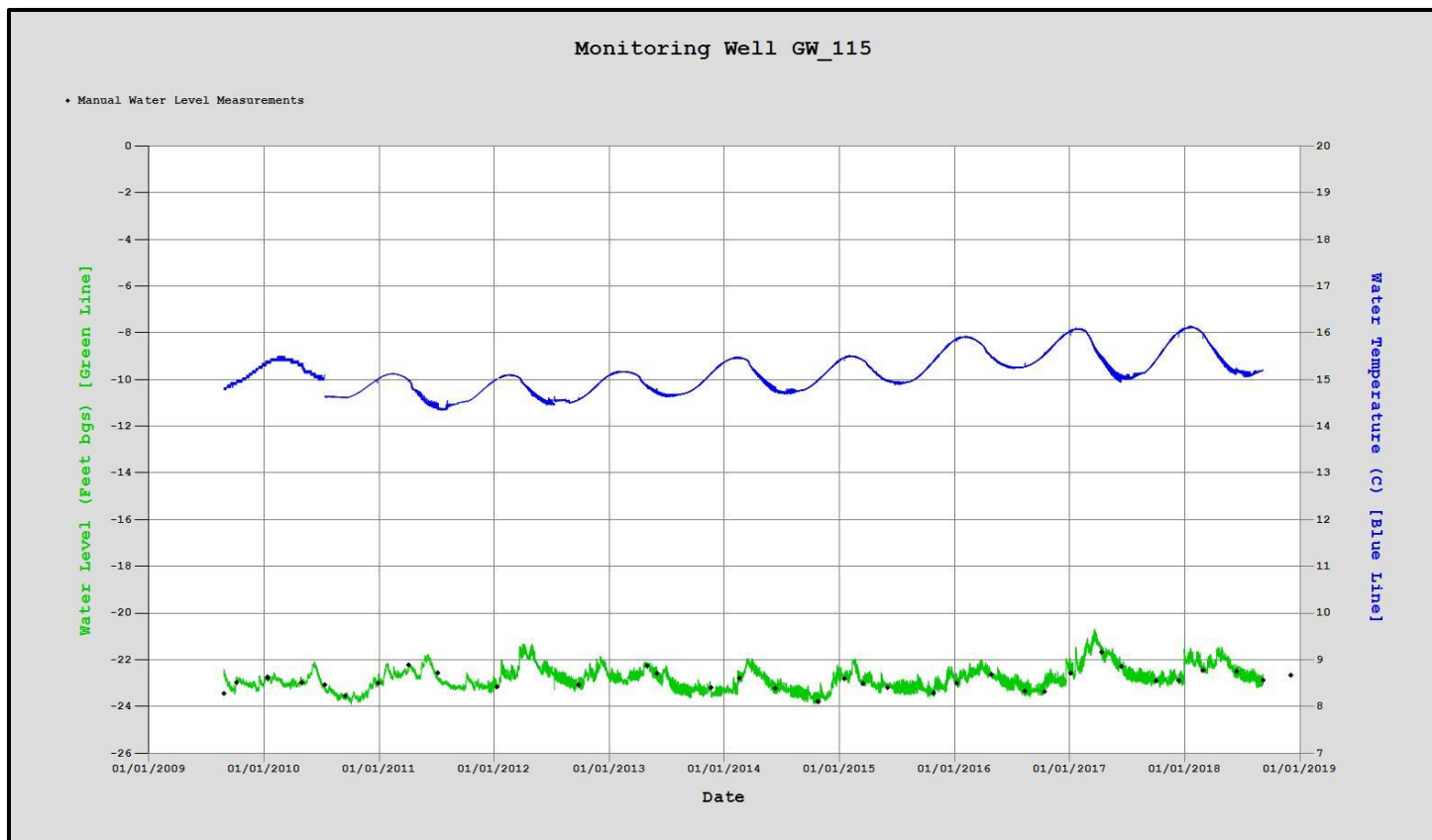


Figure 29. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_115 located in the WWBWC's Shallow Aquifer Monitoring Network.

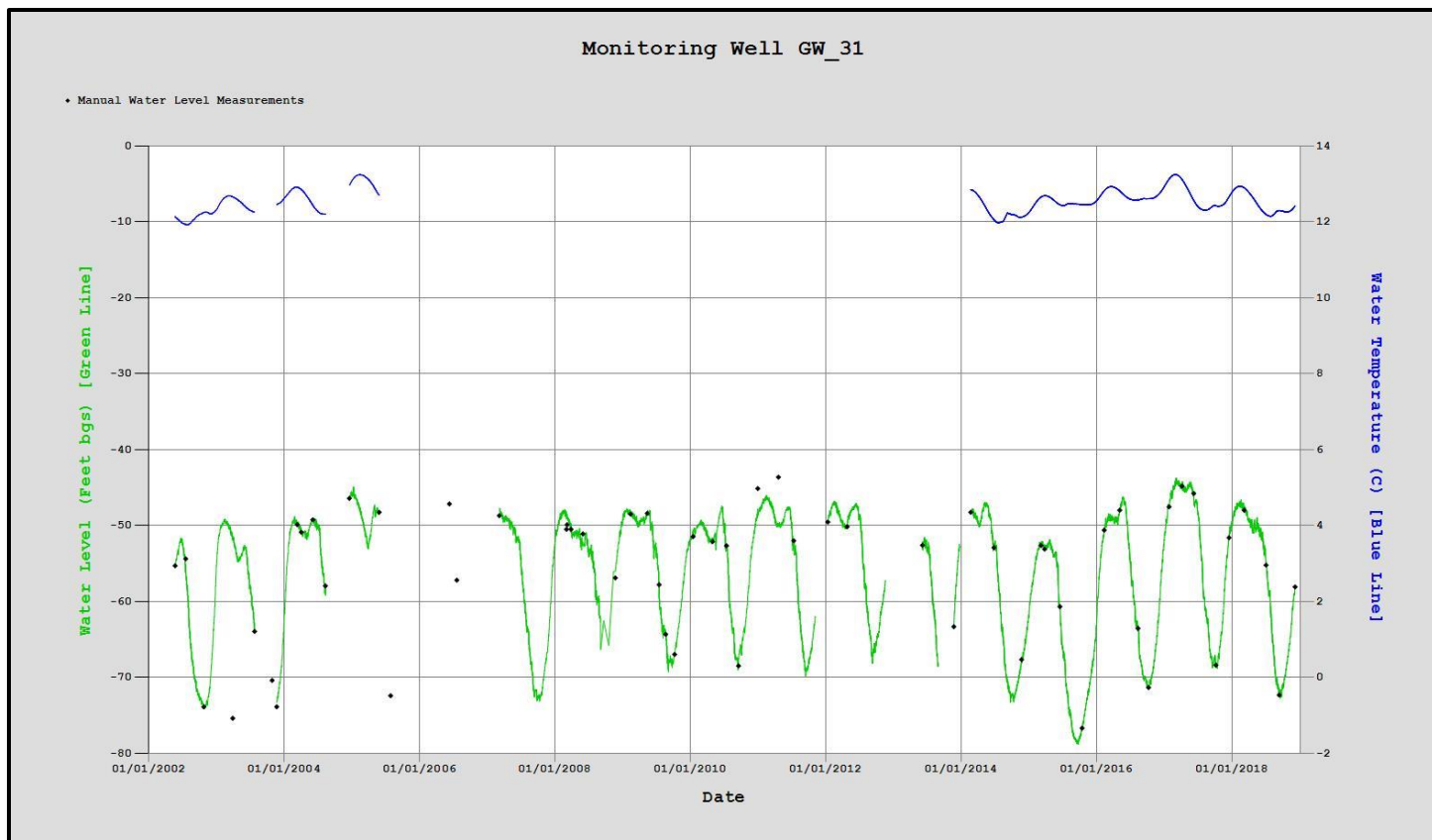


Figure 30. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_144 located in the WWBWC's Shallow Aquifer Monitoring Network.

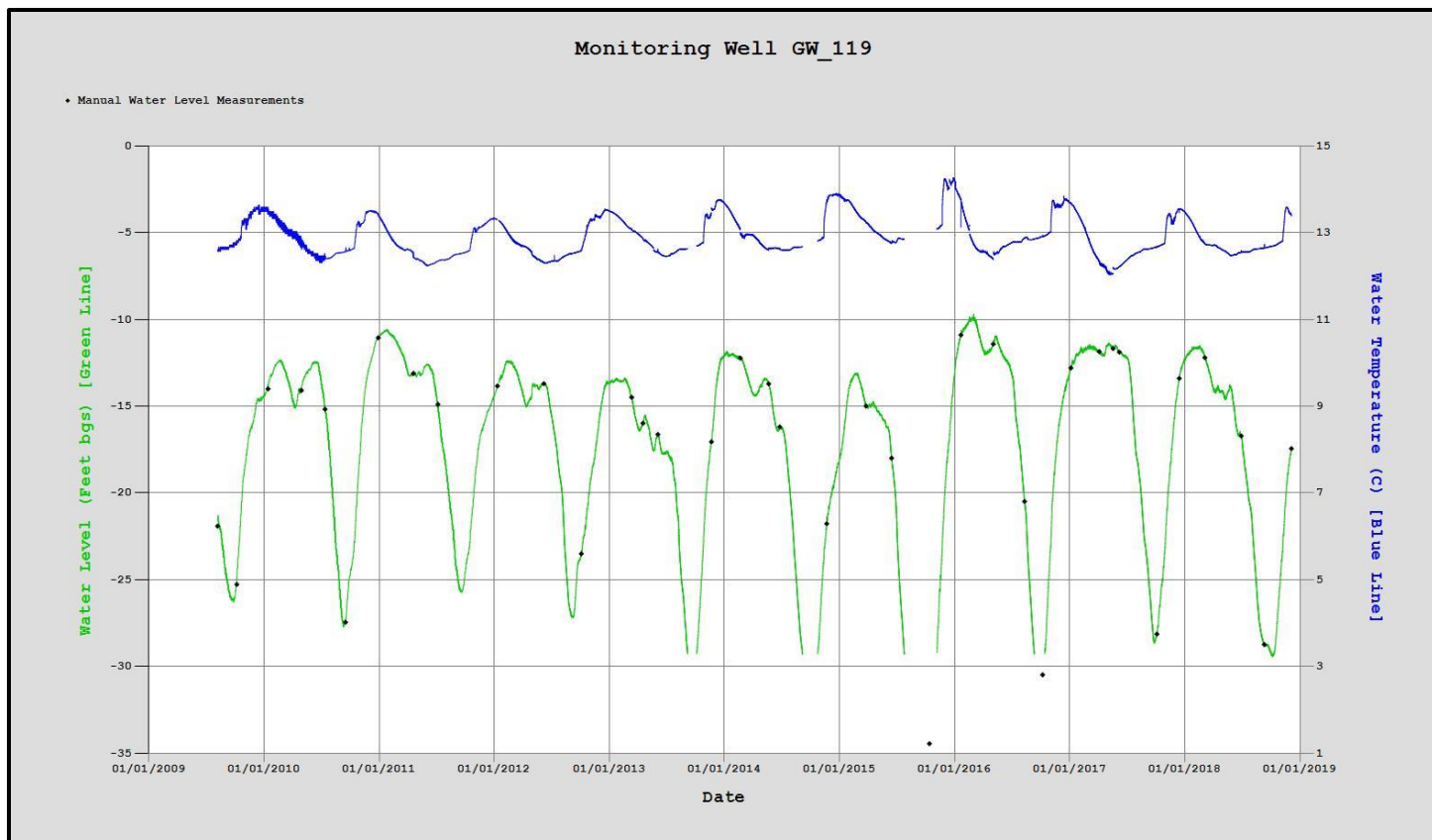


Figure 31. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_119 located in the WWBWC's Shallow Aquifer Monitoring Network.

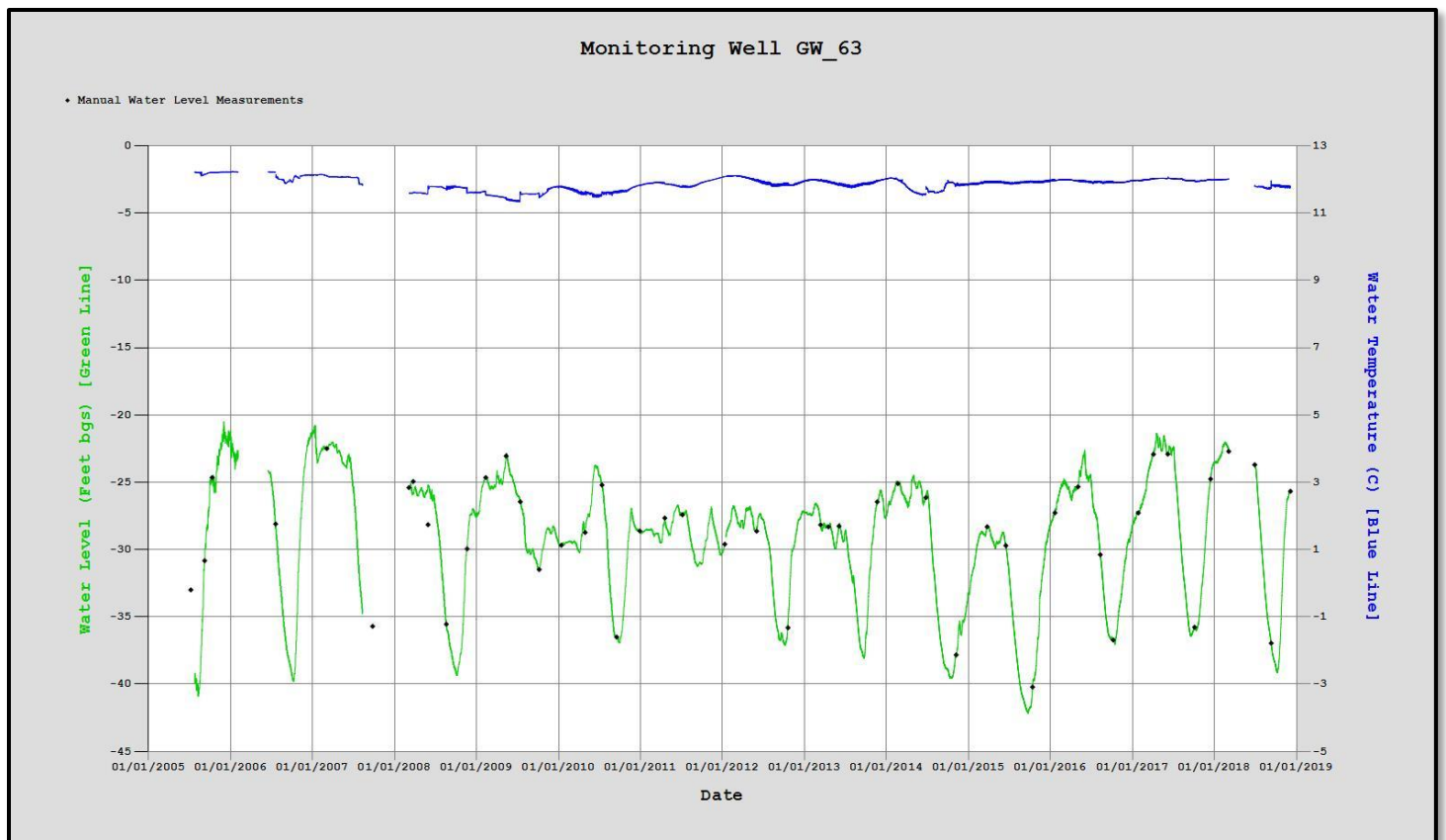


Figure 32. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_63 located in the WWBWC's Shallow Aquifer Monitoring Network.

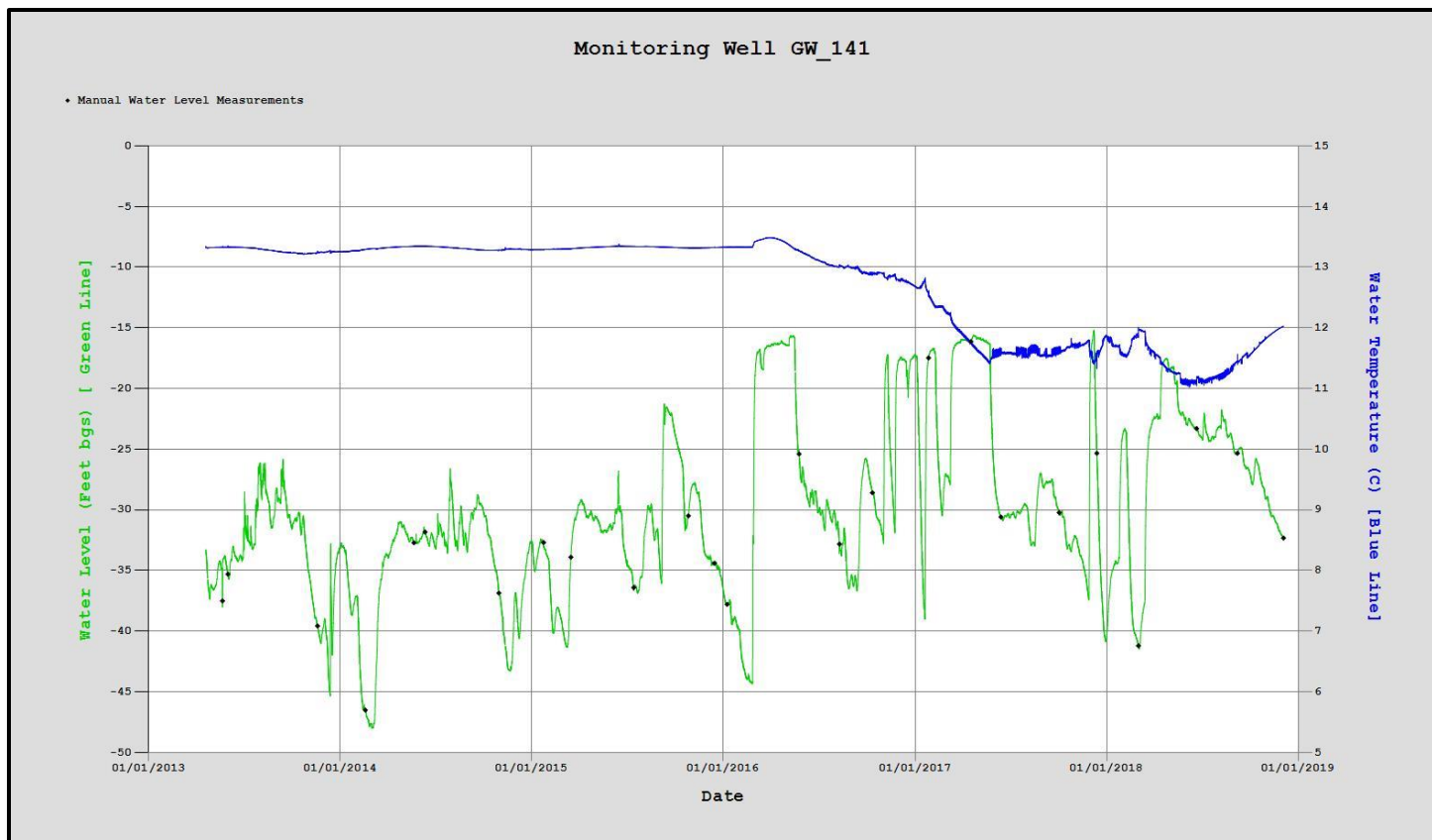


Figure 33. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_141 located in the WWBWC's Shallow Aquifer Monitoring Network.

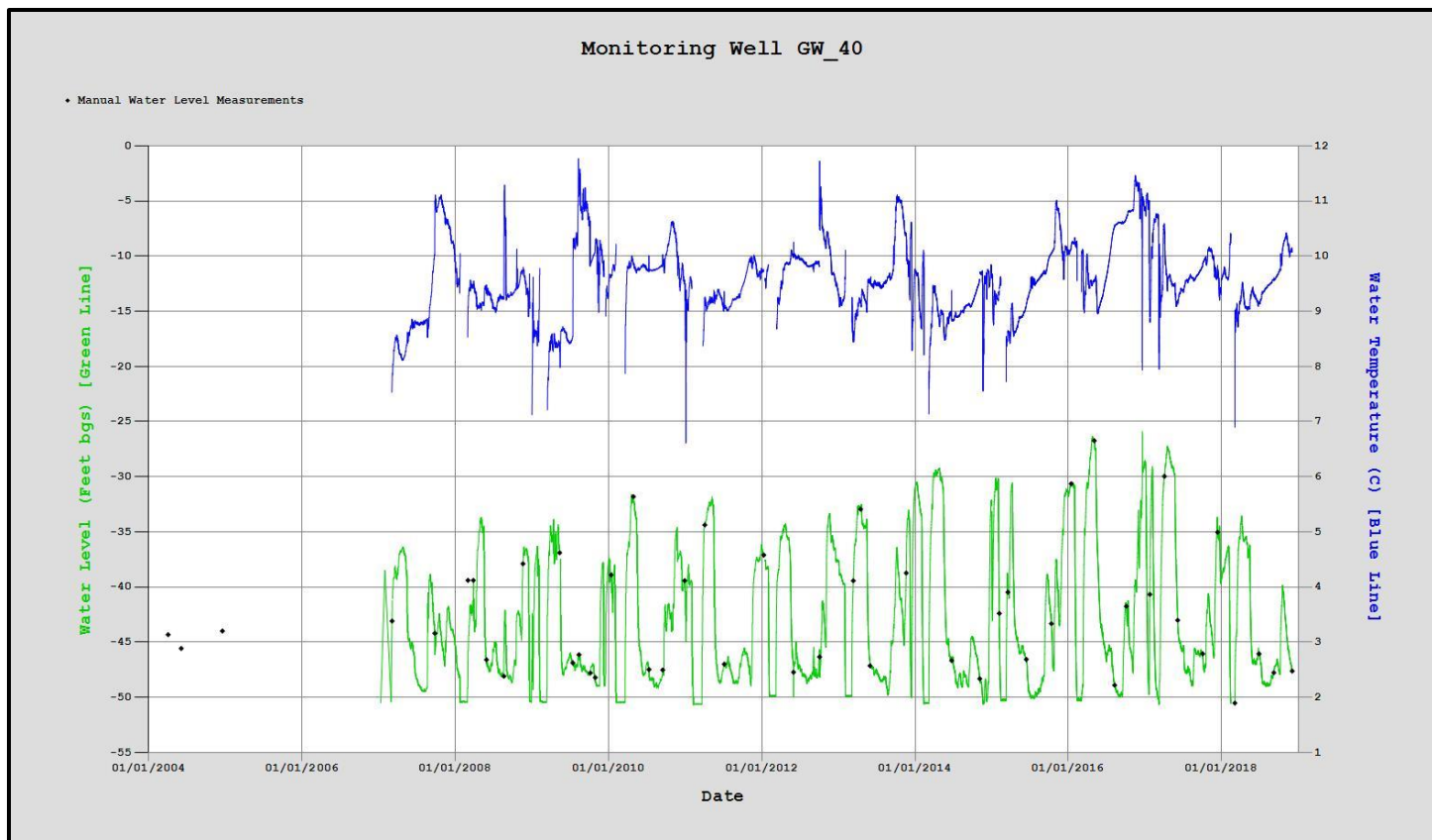


Figure 34. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_40 located in the WWBWC's Shallow Aquifer Monitoring Network.

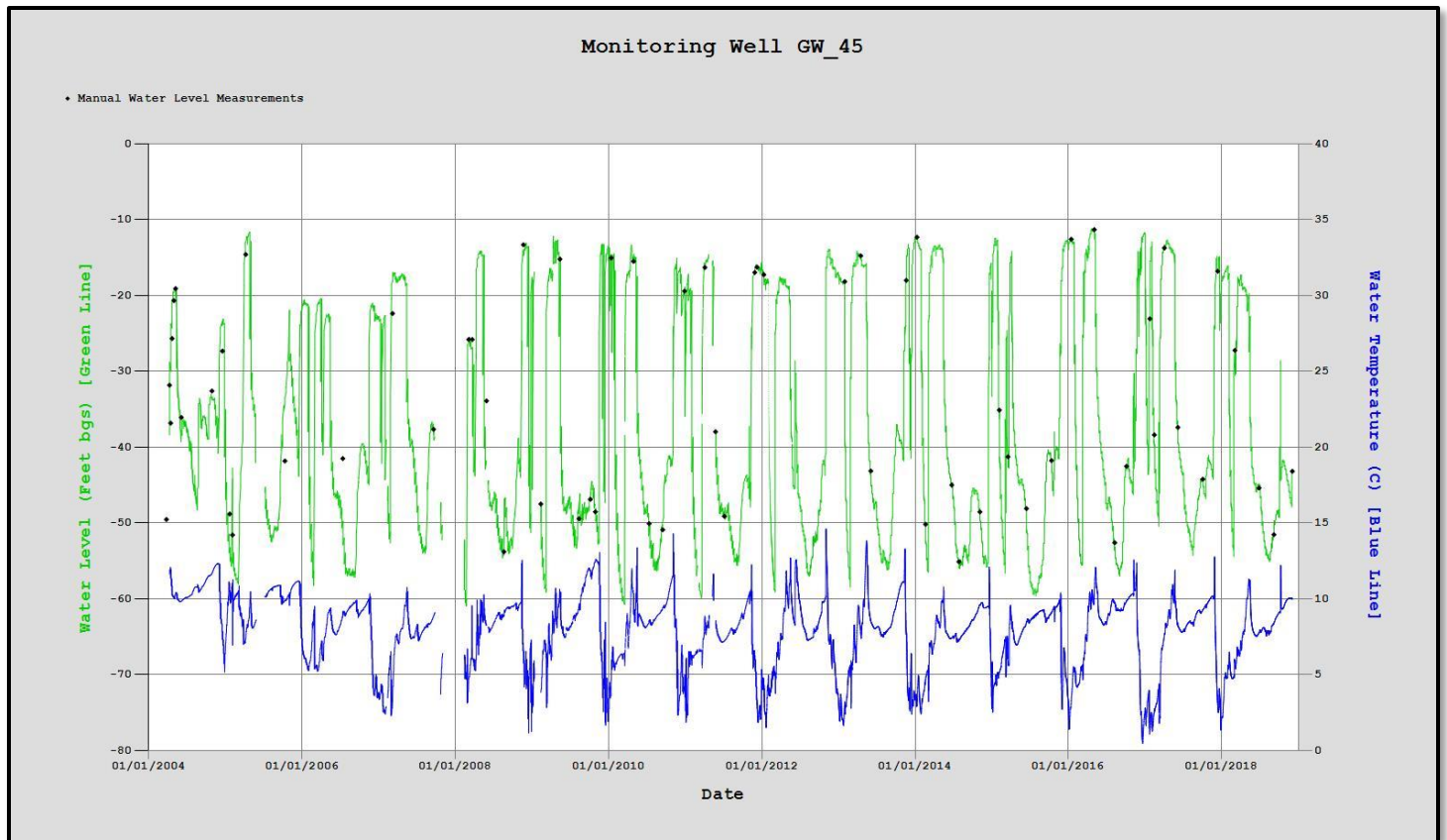


Figure 35. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_45 located in the WWBWC's Shallow Aquifer Monitoring Network.

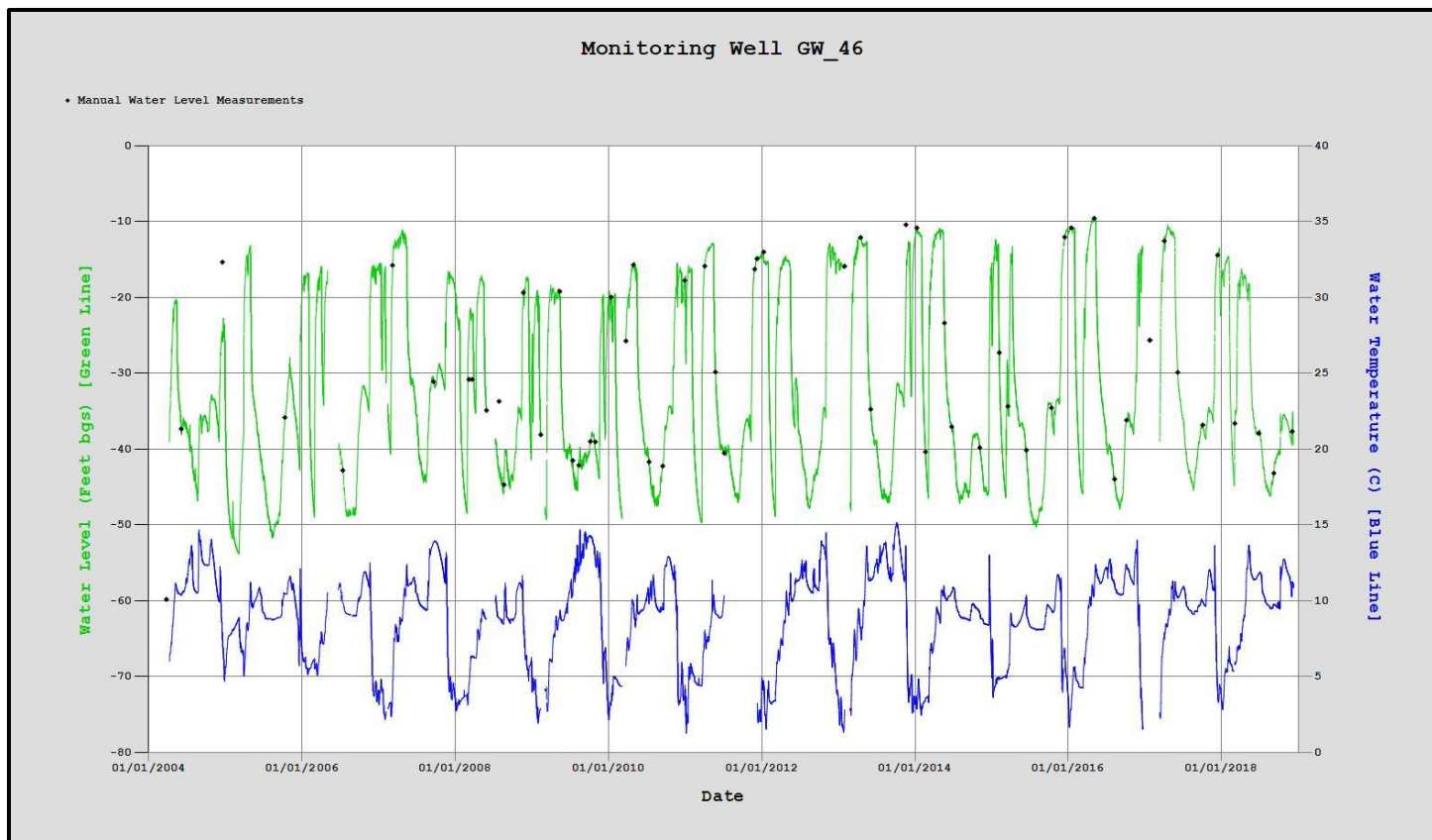


Figure 36. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_46 located in the WWBWC's Shallow Aquifer Monitoring Network.

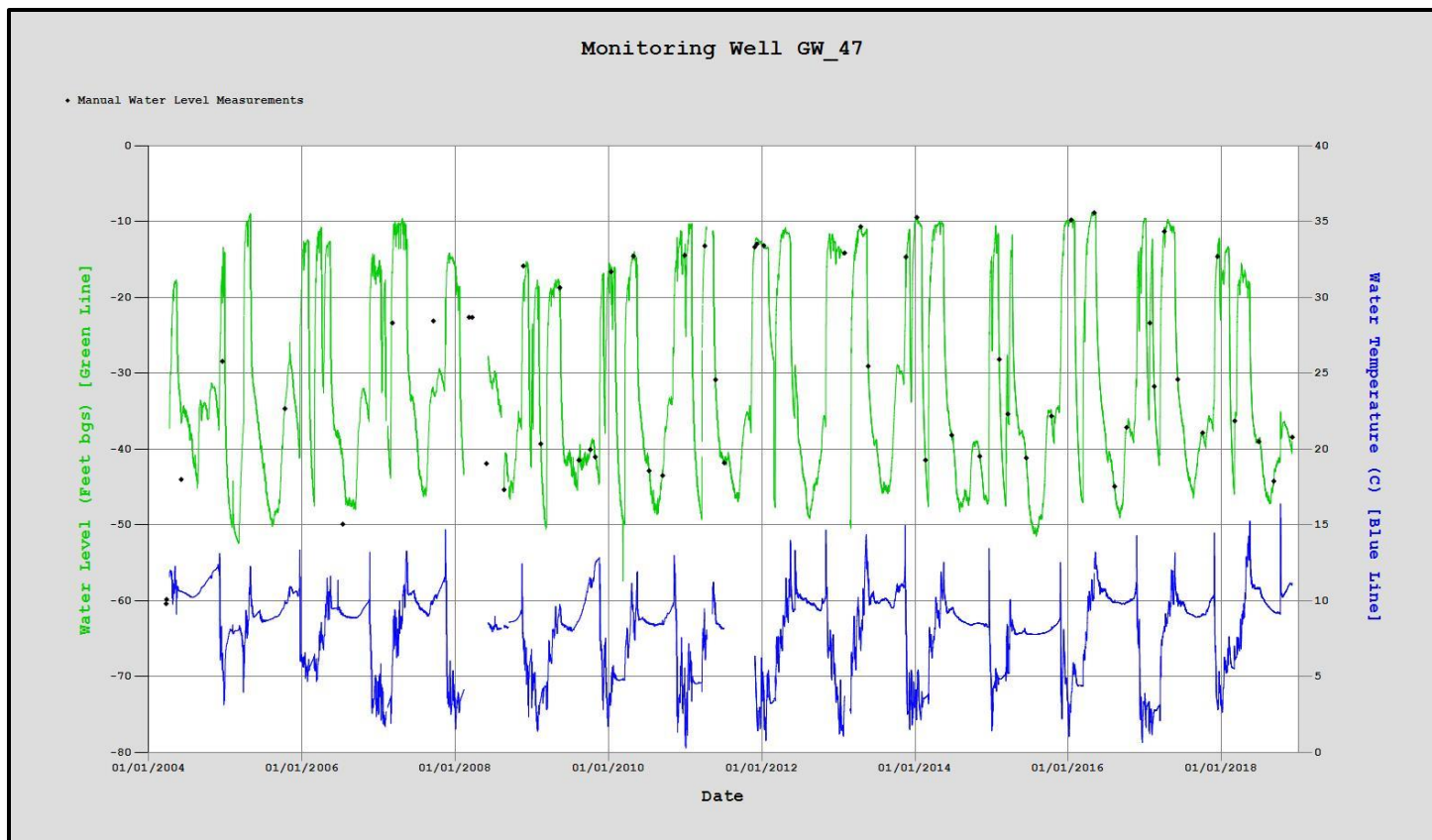


Figure 37. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_47 located in the WWBWC's Shallow Aquifer Monitoring Network.

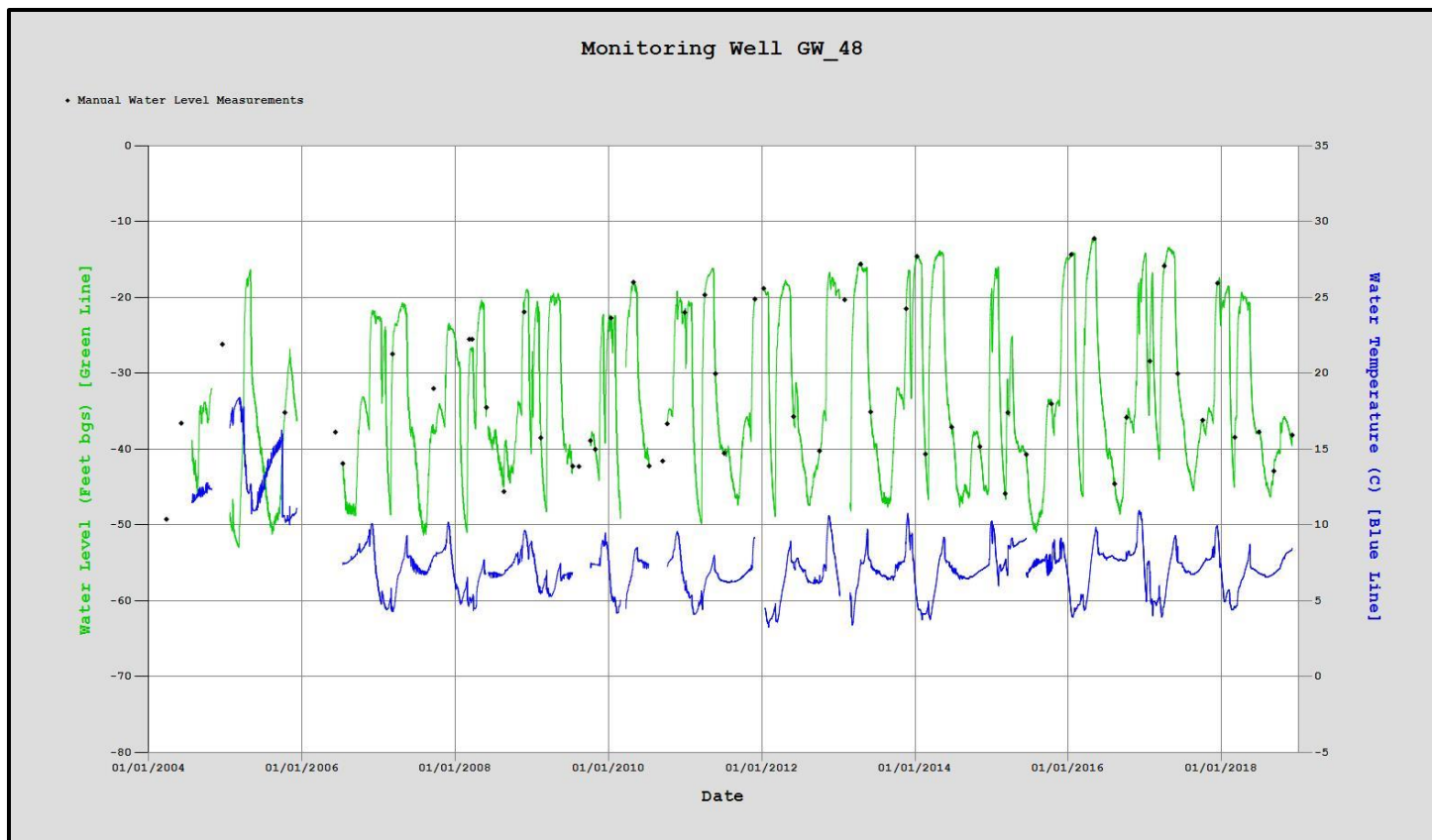


Figure 38. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_48 located in the WWBWC’s Shallow Aquifer Monitoring Network.

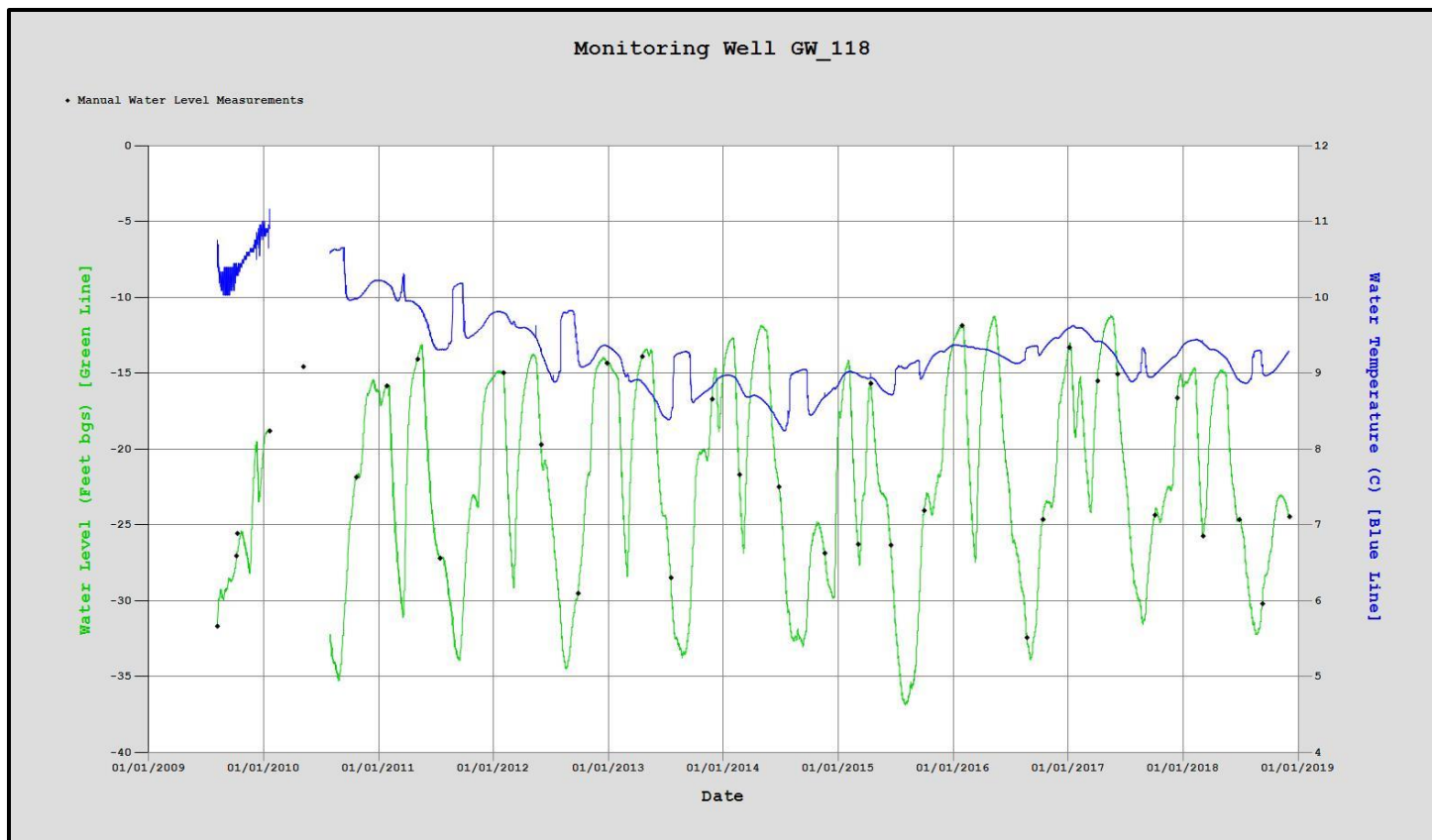


Figure 39. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_118 located in the WWBWC's Shallow Aquifer Monitoring Network.

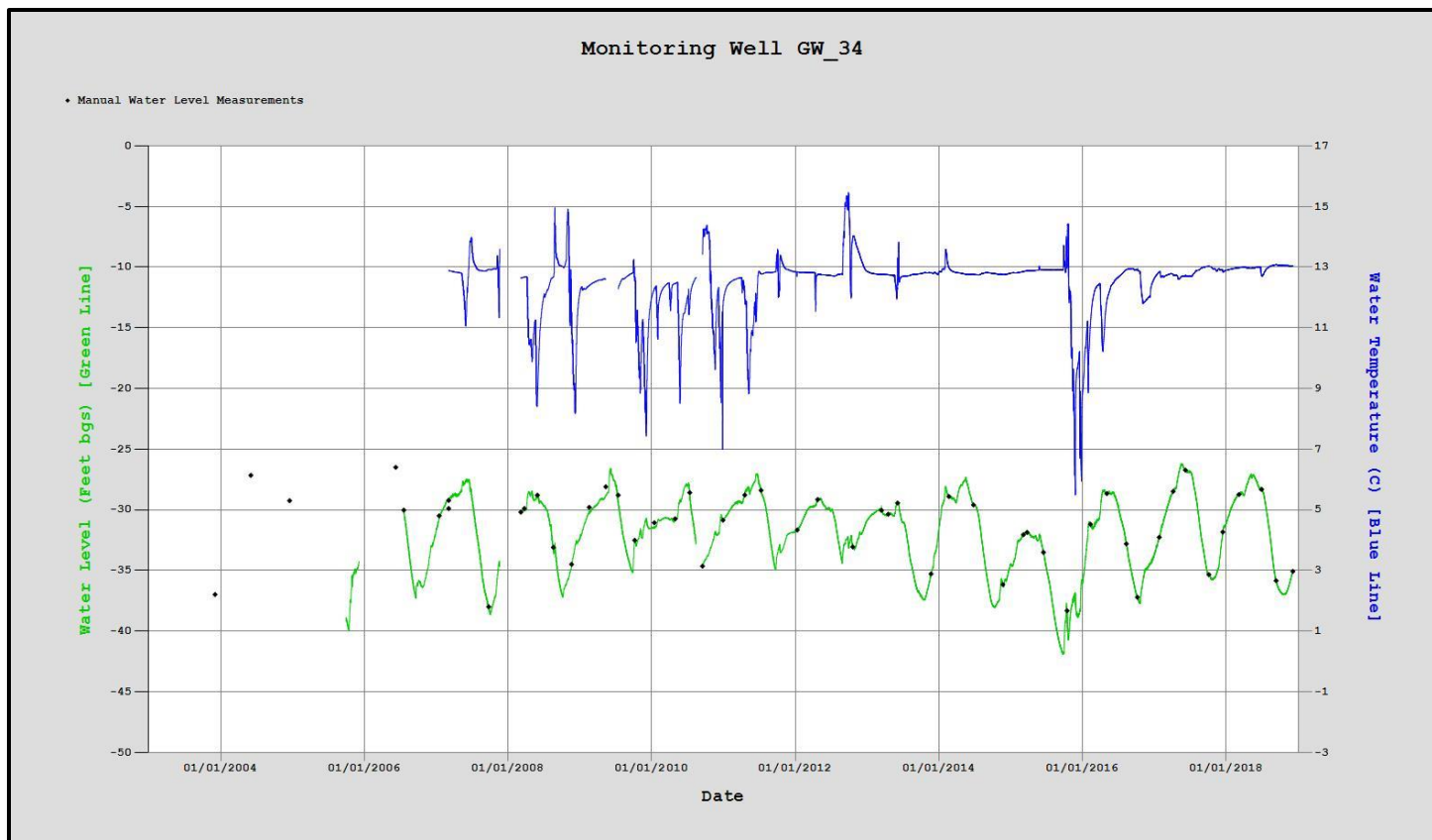


Figure 40. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_34 located in the WWBWC's Shallow Aquifer Monitoring Network.

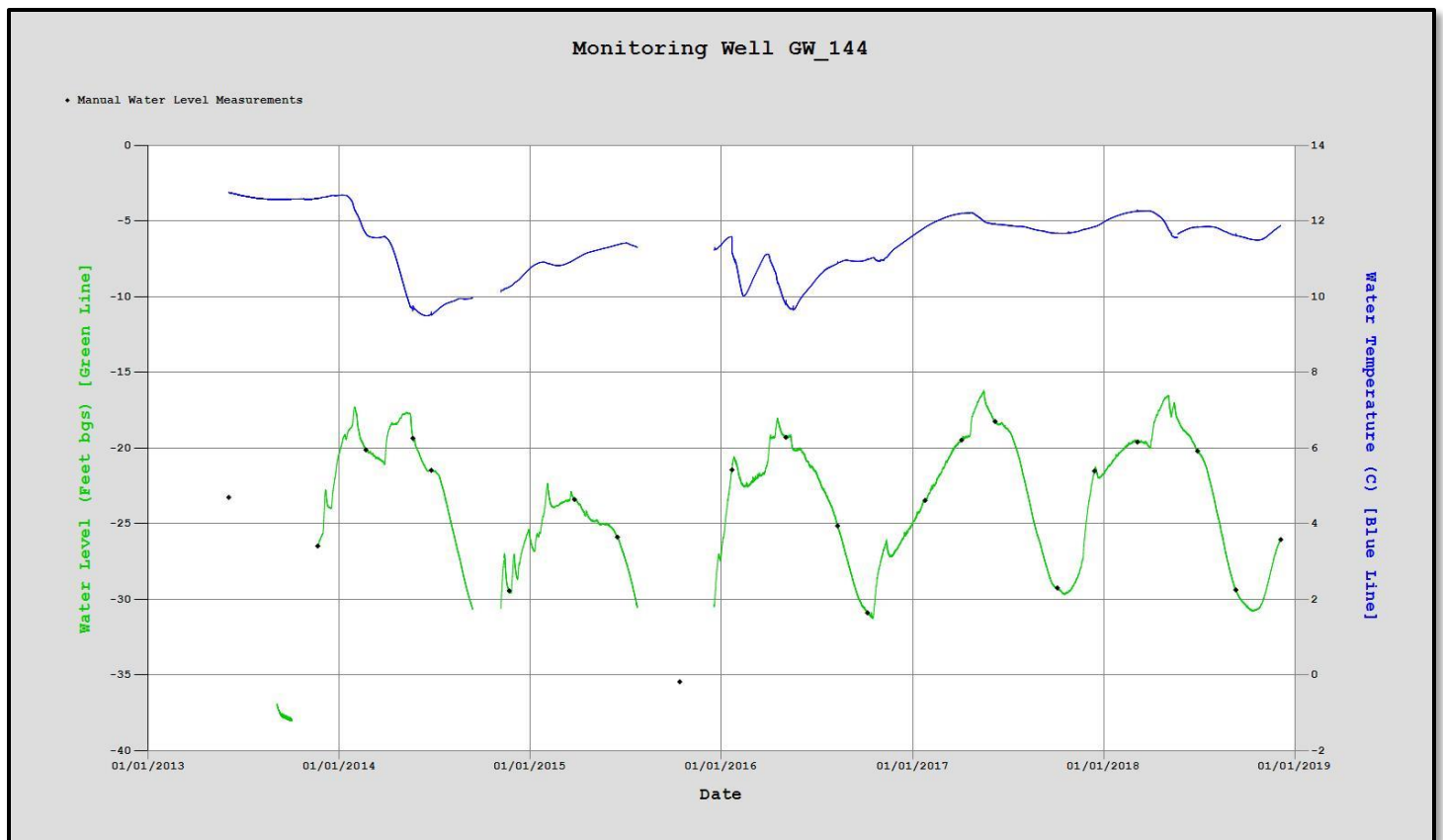


Figure 41. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_144 located in the WWBWC's Shallow Aquifer Monitoring Network.

APPENDIX B

GPS coordinates for wells currently monitored in the Walla Walla Basin Shallow Aquifer.

Note: GPS coordinates are in UTM (Datum = NAD83 and NAVD88 for Elevation)

WELL_ID	Easting	Northing	Well Elevation in Meters	Well Elevation in Feet	Horizontal Confidence in Meters	Vertical Confidence in Meters
GW_03	393477.08	5091165.361	273.745	898.114	0.016	0.012
GW_05	393764.617	5094403.253	248.064	813.920	0.022	0.015
GW_06	392664.181	5092403.474	262.960	867.425	0.015	0.011
GW_07	392787.583	5091551.116	271.717	891.460	0.012	0.012
GW_09	392658.605	5088806.697	306.631	1006.007	0.014	0.01
GW_10	392132.402	5091372.824	273.696	897.950	0.022	0.019
GW_13	390667.86	5093232.622	250.852	823.004	0.013	0.015
GW_14	392157.683	5089568.006	295.488	969.449	0.012	0.009
GW_15	388945.465	5089304.752	272.057	892.575	0.003	0.003
GW_18	386647.989	5093698.759	225.360	739.367	0.005	0.006
GW_19	391225.116	5092022.761	265.289	870.369	0.014	0.018
GW_20	393114.775	5092400.73	264.392	867.428	0.096	0.101
GW_23	390432.546	5088757.822	292.342	959.125	0.006	0.007
GW_27	391245.146	5088811.531	298.777	980.239	0.008	0.009
GW_28	390083.217	5090403.42	274.565	900.803	0.005	0.004
GW_31	385163.051	5093209.972	218.535	716.976	0.006	0.007
GW_33	387947.465	5093853.935	230.034	754.702	0.008	0.006
GW_34	383288.818	5093418.243	201.734	661.855	0.011	0.008
GW_36	384946.272	5091616.019	220.534	723.534	0.01	0.012
GW_37	384227.715	5092519.703	208.416	683.780	0.008	0.01
GW_38	392985.262	5094932.606	248.083	812.122	0.021	0.014
GW_39	388823.228	5090045.31	266.394	873.993	0.004	0.002
GW_40	388846.149	5089945.789	266.979	875.913	0.004	0.002
GW_41	388830.34	5090133.816	265.537	871.182	0.004	0.002
GW_45	388555.543	5090167.255	262.553	861.394	0.003	0.003
GW_46	388325.733	5090362.964	259.118	850.123	0.004	0.002
GW_47	388335.675	5090331.38	259.507	851.400	0.003	0.002
GW_48	388432.429	5090413.757	259.608	851.732	0.004	0.002
GW_58	387261.534	5091269.173	245.655	805.953	0.005	0.004
GW_60	388039.791	5090041.577	257.473	844.726	0.003	0.003
GW_61	387730.609	5089747.583	255.862	839.440	0.003	0.003
GW_62	389834.806	5089059.234	283.305	929.478	0.006	0.004
GW_63	383280.245	5091893.17	203.980	669.226	0.014	0.01
GW_64	383657.595	5091641.274	208.550	684.218	0.011	0.013
GW_65	387239.855	5090936.276	246.133	807.520	0.005	0.003
GW_66	384016.598	5091700.048	209.851	688.485	0.014	0.01
GW_67	378968.413	5093403.081	175.056	574.330	0.019	0.02

GW_68	379255.547	5092242.311	181.305	594.831	0.022	0.018
GW_69	383991.427	5091254.854	212.394	696.829	0.013	0.013
GW_73	390621.47	5095033.16	232.761	763.651		
GW_74	390649.10	5094642.92	234.943	770.811		
GW_75	390474.91	5095093.45	230.702	756.897		
GW_92	372892.083	5095185.179	170.620	559.775	0.017	0.016
GW_98	388276.158	5089528.166	263.425	864.255	0.021	0.014
GW_115	392743.234	5086919.977	326.984	1072.780	0.072	0.106
GW_116	391304.129	5091322.097	272.050	892.550	0.022	0.015
GW_117	389825.547	5090864.475	268.409	880.607	0.004	0.004
GW_118	387655.395	5090858.899	250.210	820.898	0.004	0.003
GW_119	384949.15	5092104.046	217.173	712.508	0.01	0.011
GW_120	380094.16	5094289.865	172.605	566.289	0.019	0.013
GW_135	390848.356	5088932.953	294.177	965.146	0.01	0.01
GW_140	388116.677	5092574.411	243.582	799.154	0.006	0.007
GW_141	390842.948	5088970.697	293.484	962.874	0.011	0.01
GW_142	388923.795	5091216.075	258.721	848.822	0.003	0.003
GW_143	388395.621	5091633.293	252.996	830.039	0.005	0.003
GW_144	383287.34	5092945.899	200.103	656.506	0.012	0.018
GW_150	389352.667	5089573.785	274.086	899.232	0.003	0.003
GW_151	389744.387	5094445.287	234.767	770.233	0.015	0.009
GW_152	393286.724	5089571.48	296.604	973.110	0.015	0.011
GW_160	393147.417	5089956.004	290.045	951.591	0.003	0.003
GW_161	393734.325	5090589.237	278.018	912.133	0.003	0.004
GW_162	393090.749	5090347.905	284.768	934.278	0.003	0.003
GW_163	393084.789	5090347.965	284.814	934.429	0.003	0.003
GW_164	386472.034	5092250.3	230.158	755.112	0.01	0.006
GW_165	387848.965	5091049.631	251.695	825.771	0.004	0.002
GW_166	386644.834	5090448.375	243.503	798.894	0.006	0.004
GW_167	386674*	5090444*	244*	801*	*	*
GW_168	386698*	5090444*	244*	802*	*	*
GW_169	390001.583	5088453.461	290.135	951.887	0.006	0.006
GW_170	389307.391	5092050.988	255.411	837.963	0.007	0.004
GW_171	388106.856	5094086.999	228.983	751.257	0.013	0.008

* Well locations not yet surveyed. Values shown here were obtained from Google Earth.

Appendix C

Explanation of Data Gaps during the 2018 Water Year

Well ID	Gap Dates	Explanation
GW_33	11-22-17 to 12-15-17	Cows interfered with data logger
GW_33	12-16-17 to 1-13-18	Cows interfered with data logger
GW_33	7-2-18 to 9-11-18	Logger failure Couldn't communicate.
GW_40	2-16-18 to 3-5-18	Water dropped below level of datalogger. Dry data were deleted
GW_58	7-19-17 to 10-31-17	Water dropped below level of datalogger. Dry data were deleted
GW_58	3-7-18 to 3-27-18	Water dropped below level of datalogger. Dry data were deleted
GW_58	7-21-18 to 12-11-18	Water dropped below level of datalogger. Dry data were deleted
GW_60	3-2-18 to 3-6-18	Water dropped below level of datalogger. Dry data were deleted
GW_60	6-15-18 to 10-10-18	Water dropped below level of datalogger. Dry data were deleted
GW_62	12-18-17 to 3-2-18	Water dropped below level of datalogger. Dry data were deleted
GW_62	3-2-18 to 6-21-18	Logger failure Couldn't communicate.
GW_63	3-5-18 to 6-29-18	Logger failure Couldn't communicate.
GW_65	6-14-18 to 6-20-18	Water dropped below level of datalogger. Dry data were deleted
GW_65	8-8-18 to 9-10-18	Water dropped below level of datalogger. Dry data were deleted
GW_92	12-22-17 to 1-28-18	Water dropped below level of datalogger. Dry data were deleted
GW_92	1-28-18 to 2-5-18	Water dropped below level of datalogger. Dry data were deleted
GW_92	8-13-18 to 9-3-18	Water dropped below level of datalogger. Dry data were deleted
GW_92	10-4-18 to 10-29-18	Water dropped below level of datalogger. Dry data were deleted
GW_115	9-6-18 to 12-3-18	Logger failure. Couldn't communicate.
GW_142	3-2-18 to 3-17-18	Water dropped below level of datalogger. Dry data were deleted
GW_142	8-11-18 to 8-27-18	Water dropped below level of datalogger. Dry data were deleted
GW_150	10-16-17 to 10-18-17	Water dropped below level of datalogger. Dry data were deleted
GW_150	11-22-17 to 3-9-18	Water dropped below level of datalogger. Dry data were deleted
GW_150	5-24-18 to 5-27-18	Water dropped below level of datalogger. Dry data were deleted
GW_150	8-12-18 to 8-21-18	Water dropped below level of datalogger. Dry data were deleted
GW_150	11-24-18 to 12-4-18	Water dropped below level of datalogger. Dry data were deleted
GW_152	12-14-17 to 1-4-18	Data not logged due to inadequate power availability.
GW_152	9-16-18 to 9-25-18	Data not logged due to inadequate power availability.
GW_163	9-18-17 to 1-2-18	Water dropped below level of datalogger. Dry data were deleted
GW_163	9-25-18 to 12-3-18	Water dropped below level of datalogger. Dry data were deleted
GW_169	3-4-18 to 4-11-18	Water dropped below level of datalogger. Dry data were deleted