Groundwater System Impacts on the US 63 Railway Underpass near Waterloo, Iowa

Final Report
April 2022

IOWA STATE UNIVERSITY
Institute for Transportation

Sponsored by
Iowa Department of Transportation
(InTrans Project 14-517)

About the Institute for Transportation

The mission of the Institute for Transportation (InTrans) at Iowa State University is to save lives and improve economic vitality through discovery, research innovation, outreach, and the implementation of bold ideas.

Iowa State University Nondiscrimination Statement

Disclaimer Notice

Iowa DOT Statements

The preparation of this report was financed in part through funds provided by the Iowa Department of Transportation through its "Second Revised Agreement for the Management of Research Conducted by Iowa State University for the Iowa Department of Transportation" and its amendments.

Technical Report Documentation Page

<table>
<tr><td>1. Report No.
InTrans Project 14-517</td><td>2. Government Accession No.</td><td colspan="2">3. Recipient's Catalog No.</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle
Groundwater System Impacts on the US 63 Railway Underpass near Waterloo, Iowa</td><td colspan="2">5. Report Date
April 2022</td></tr>
<tr><td colspan="2">6. Performing Organization Code</td></tr>
<tr><td colspan="2">7. Author(s)
Chris R. Rehmann (orcid.org/0000-0002-4740-557X), Michael A. Perez (orcid.org/0000-0002-0309-3922), and Loulou C. Dickey (orcid.org/0000-0003-4228-1640)</td><td colspan="2">8. Performing Organization Report No.
InTrans Project 14-517</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address
Institute for Transportation
Iowa State University
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664</td><td colspan="2">10. Work Unit No. (TRAIS)</td></tr>
<tr><td colspan="2">11. Contract or Grant No.</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Organization Name and Address
Iowa Department of Transportation
800 Lincoln Way
Ames, IA 50010</td><td colspan="2">13. Type of Report and Period Covered
Final Report</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code
NHSX-063-6(88)-3H-07</td></tr>
<tr><td colspan="4">15. Supplementary Notes
Visit https://intrans.iastate.edu for color pdfs of this and other research reports.</td></tr>
<tr><td colspan="4">16. Abstract
The Iowa Department of Transportation (DOT) replaced the existing railroad underpass on US 63 in Waterloo between Dane and Newell Streets with an overpass. The existing underpass was initially constructed below the water table; therefore, the Iowa DOT had to continuously use a groundwater dewatering system to prevent water from entering the underpass. With the overpass construction project, the Iowa DOT aimed to change the existing well system to avoid unknown impacts on the water table. However, groundwater level monitoring was required throughout construction to avoid endangering neighboring properties. The Iowa DOT used nine dewatering pumps to control the high water table in the area during overpass construction.

The work described in this report aimed to observe groundwater levels at and around the construction site and assess the effects of dewatering, which occurred between November 5, 2017 and March 25, 2019, and a groundwater suppression system (GSS), which began operation on October 15, 2019. Water levels were monitored in several observation wells and reported over 76 months that encompassed four periods: before dewatering, during dewatering, between dewatering and operation of the GSS, and during operation of the GSS.

Analysis of the time series of water levels and statistical analysis of the mean water levels and variances during the four periods provided a picture of the behavior of the water table and led to the following conclusions:

1. Water levels in wells farther from the overpass were not greatly affected by the operations at the site. This observation confirms previous findings.
2. Dewatering lowered the water table by a large amount around the construction area. The water levels rose quickly by the end of the dewatering period; mean water levels before and after dewatering (but before groundwater suppression) appeared similar, though the statistical analysis indicated that most mean levels were significantly different at the 5% level.
3. The GSS has lowered the water table by about 1 to 2 ft. Statistical analysis supports the observation by showing that water levels during suppression were significantly different from the levels in periods without suppression or dewatering.
4. The variance of the water levels was smallest during the period with groundwater suppression. This observation suggests that the GSS has stabilized the water levels near the overpass.</td></tr>
<tr><td colspan="2">17. Key Words
dewatering pumps—groundwater suppression system (GSS)—water table</td><td colspan="2">18. Distribution Statement
No restrictions.</td></tr>
<tr><td>19. Security Classification (of this report)
Unclassified.</td><td>20. Security Classification (of this page)
Unclassified.</td><td>21. No. of Pages
36</td><td>22. Price
NA</td></tr>
</table>

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

GROUNDWATER SYSTEM IMPACTS ON THE US 63 RAILWAY UNDERPASS NEAR WATERLOO, IOWA

Final Report
April 2022

Principal Investigator
Chris R. Rehmann, Joel A. and Judy Cerwick Professor
Civil, Construction, and Environmental Engineering, Iowa State University

Co-Principal Investigator
Michael A. Perez, Assistant Professor, Construction
Civil and Environmental Engineering, Auburn University

Research Assistant
Loulou Dickey

Authors
Chris R. Rehmann, Michael A. Perez, and Loulou C. Dickey

Sponsored by
Iowa Department of Transportation

Preparation of this report was financed in part
through funds provided by the Iowa Department of Transportation
through its Research Management Agreement with the
Institute for Transportation
(InTrans Project 14-517)

A report from
Institute for Transportation
Iowa State University
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
Phone: 515-294-8103 / Fax: 515-294-0467
https://intrans.iastate.edu

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

The authors gratefully acknowledge sponsorship for this project from the Iowa Department of Transportation (DOT).

EXECUTIVE SUMMARY

The Iowa Department of Transportation (DOT) replaced the existing railroad underpass on US 63 in Waterloo between Dane and Newell Streets with an overpass. The existing underpass was initially constructed below the water table; therefore, the Iowa DOT had to continuously use a groundwater dewatering system to prevent water from entering the underpass. With the overpass construction project, the Iowa DOT aimed to change the existing well system to avoid unknown impacts on the water table. However, groundwater level monitoring was required throughout construction to avoid endangering neighboring properties. The Iowa DOT used nine dewatering pumps to control the high water table in the area during overpass construction.

The work described in this report aimed to observe groundwater levels at and around the construction site and assess the effects of dewatering, which occurred between November 5, 2017 and March 25, 2019, and a groundwater suppression system (GSS), which began operation on October 15, 2019. Water levels were monitored in several observation wells and reported over 76 months that encompassed four periods: before dewatering, during dewatering, between dewatering and operation of the GSS, and during operation of the GSS.

Analysis of the time series of water levels and statistical analysis of the mean water levels and variances during the four periods provided a picture of the behavior of the water table and led to the following conclusions:

1. Water levels in wells farther from the overpass were not greatly affected by the operations at the site. This observation confirms previous findings.
2. Dewatering lowered the water table by a large amount around the construction area. The water levels rose quickly by the end of the dewatering period; mean water levels for the periods before and after dewatering (but before groundwater suppression) appeared similar, though the statistical analysis indicated that most mean levels were significantly different at the 5% level.
3. The GSS has lowered the water table by about 1 to 2 ft. Statistical analysis supports the observation by showing that water levels during suppression were significantly different from the levels in periods without suppression or dewatering.
4. The variance of the water levels was smallest during the period with groundwater suppression. This observation suggests that the GSS has stabilized the water levels near the overpass.

1. INTRODUCTION

The section of US 63 that passes through Waterloo, Iowa, and intersects with Canadian National Rail Road line 276 was constructed as an underpass in 1963. Although the underpass was built with a drainage system, ongoing issues with water intrusion and seepage onto the roadway caused significant safety concerns. Multiple efforts were made to remedy the drainage problems, including replacing underdrains and ongoing dewatering via groundwater pumping. None of these efforts eliminated flooding on the roadway, and the hazardous conditions persisted. In 2012, an evaluation was conducted to determine the best long-term solution for the traffic hazards caused by excess water.

After extensive investigation and monitoring, the Iowa Department of Transportation (DOT) determined that the best course of action was to remove the underpass and replace it with an overpass. However, a plume of trichloroethylene contamination discovered during the evaluation led to a goal of avoiding drastic alteration of groundwater levels during future activities because large changes could cause the plume to expand (CH2M Hill 2014). Also, groundwater modeling showed that changes to the drainage regime at the underpass could cause seepage and flooding in the basements of homeowners in the area (CH2M Hill 2014). Construction of a new overpass involved raising the grade and interrupting existing dewatering procedures at the site. Therefore, construction plans included the installation of a groundwater suppression system (GSS) to prevent adverse effects, along with extensive monitoring to detect changes in the groundwater level.

The objective of this study was to evaluate the effects of removing the existing railroad underpass on US 63 on groundwater near Dane and Newell streets in Waterloo, Iowa. This report summarizes the findings from groundwater monitoring that was conducted before, during, and after construction of the new US 63 overpass between Dane and Newell streets. Monitoring began in 2013 and concluded in 2020 after the overpass was completed. The groundwater elevation and other conditions were recorded over the construction period to identify trends in water levels and inform management of the performance of the drainage system at the overpass. Time series of water elevations in several observation wells were used to provide insight into the behavior of the water table, and statistical testing was performed to assess the differences between the phases.

2. METHODS

2.1 Observation Wells and Monitoring

Monitoring of groundwater levels occurred in several observation wells (Figure 1, Table 1). An initial report on this project (CH2M Hill 2014) involved one existing well (GW1) near the center of the underpass and 10 observation wells drilled in June 2013. Six of the wells were drilled around the underpass: MW1 to the north, MW2 and MW3 to the east, MW4 and MW7 to the south, and MW5 and MW6 to the west. Three of the wells (MWB1, MWB2, and MWB4) were installed outside the likely zone of influence of the pumping at the underpass. Simulations of the discontinuation of pumping with the groundwater model MODFLOW (CH2M Hill 2014) showed that indeed the MWB wells were beyond the influence of the pumping at the underpass.

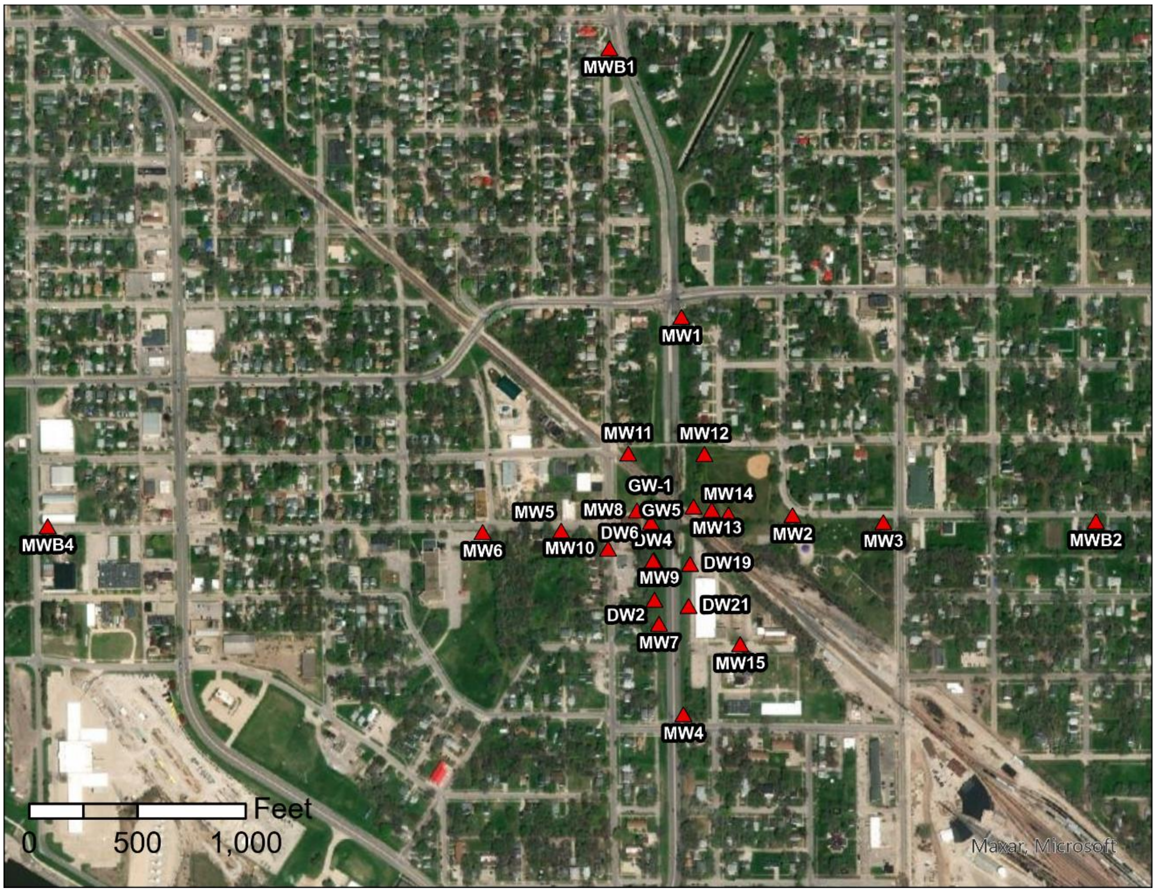


Figure 1. Observation wells used for monitoring groundwater levels

Table 1. Locations and ground elevations of the observation wells

Well	Year installed	Latitude (°)	Longitude (°)	Ground elevation (ft)
GW1	2013	42.51053032	-92.33704794	851.24
MW1	2013	42.5129283	-92.33365035	851.77
MW2	2013	42.51040184	-92.33462556	849.68
MW3	2013	42.51030455	-92.33307068	850.91
MW4	2013	42.50788786	-92.33652322	849.69
MW5	2013	42.5102298	-92.3385938	847.98
MW6	2013	42.51021889	-92.33994017	851.32
MW7	2013	42.50903956	-92.33369293	851.89
MWB1	2013	42.51634291	-92.3377014	852.60
MWB2	2013	42.51029439	-92.32942808	848.99
MWB4	2013	42.51033691	-92.34739397	854.54
GW5	Unknown	42.510522	-92.33632118	851.65
MW8	2015	42.51047894	-92.33729197	848.43
MW9	2015	42.50984903	-92.33700572	851.55
MW10	2015	42.50999657	-92.33779099	847.40
MW11	2015	42.51119939	-92.33743211	850.24
MW12	2015	42.51119144	-92.33612811	850.69
MW13	2015	42.51047896	-92.33600929	850.45
MW14	2015	42.51041958	-92.33572507	851.27
MW15	2015	42.50877169	-92.33355395	848.54
DW21	2014	42.509254	-92.336421	851.37
DW19	2014	42.509789	-92.336376	851.19
DW2	2014	42.50964124	-92.337045	851.00
DW4	2014	42.5099735	-92.337039	851.00
DW6	2014	42.510332	-92.337037	850.96

The wells installed in 2013 were drilled to a depth of about 10 ft below the observed water level (CH2M Hill 2014). Each of these wells had a 2 in. diameter polyvinyl chloride (PVC) casing and a 10 ft long screen with 0.01 in. slots. The screen was surrounded with medium coarse sand, while the rest of the casing was sealed with bentonite. The wells were developed by purging them with 30 gallons of water.

In 2014, a set of dewatering wells (DW2, DW4, DW6, DW19, and DW21) was installed near the construction site. These wells were designed for temporary groundwater pumping during construction of the overpass, and they were much deeper than the observation wells, with depths ranging from 31 to 49 ft below the ground surface. The wells consisted of 10 in. diameter PVC with 0.03 in. slotted screens ranging from 5 to 14 ft. Pumping capacity was designed to range from 100 to 200 gallons per minute (gpm), and the discharge was directed into Virden Creek. After construction was completed, these wells were converted into monitoring wells by removing the pumps and capping the outlets.

Eight more wells (MW8, MW9, MW10, MW11, MW12, MW13, MW14, and MW15) were installed by Olsson Associates in 2015 in a similar fashion to the 2013 wells. These wells ranged from 18 to 25 ft in depth below the ground surface, and they were constructed from 2 in. diameter PVC with 15 ft of 0.01 in. slotted screening. Filter sand encasements and bentonite caps were also used in these wells.

Each monitoring well was equipped with a pressure transducer (Solinst 3000 Levelogger) to measure groundwater level, while two wells (MWB2 and MWB4) also included an additional transducer to measure barometric air pressure (Solinst 300 Baro Loggers). The pressure transducers were set to collect measurements of head and temperature every 20 minutes. Data were collected periodically throughout the study period by retrieving the devices from each well and downloading the data. Water level was derived from the measurements at each well by normalizing for atmospheric pressure and the elevation of the transducer. Water level was also measured by hand when collecting the data so that the pressure transducers could be calibrated for instrument error. Although some of the measuring devices were replaced due to malfunction or battery depletion, the same monitoring protocol was maintained over the entire study period.

2.2 Analysis

Groundwater data were analyzed using time series of the water levels in each well and statistics of the water levels in the wells on a west-east line through the construction site. The water levels in the wells were averaged over each day, and the time series were analyzed in four periods: (1) before dewatering; (2) during dewatering, which occurred between November 5, 2017 and March 25, 2019; (3) between dewatering and operation of the GSS; and (4) after the GSS started operating on October 15, 2019. To provide context and help explain variations in the water levels in the wells, daily precipitation depths were collected from the Waterloo Regional Airport, and the daily elevation of the water surface in the Cedar River was collected from U.S. Geological Survey gaging station 05464000, which uses the National Geodetic Vertical Datum of 1929.

To evaluate how dewatering and the GSS affected the water table, the water levels were separated by the four periods and presented with box and whisker plots. These plots show the median water level along a west-to-east transect and indicate the variation by presenting the 25th and 75th percentiles and the full range during the period. For context, the ground elevation was obtained from a digital elevation model derived from lidar measurements (Figure 2), and the elevations of the water table were compared to the alert level of 836.5 ft. When the water reached that level in well GW1, Iowa DOT personnel were to check whether the GSS was operating correctly.

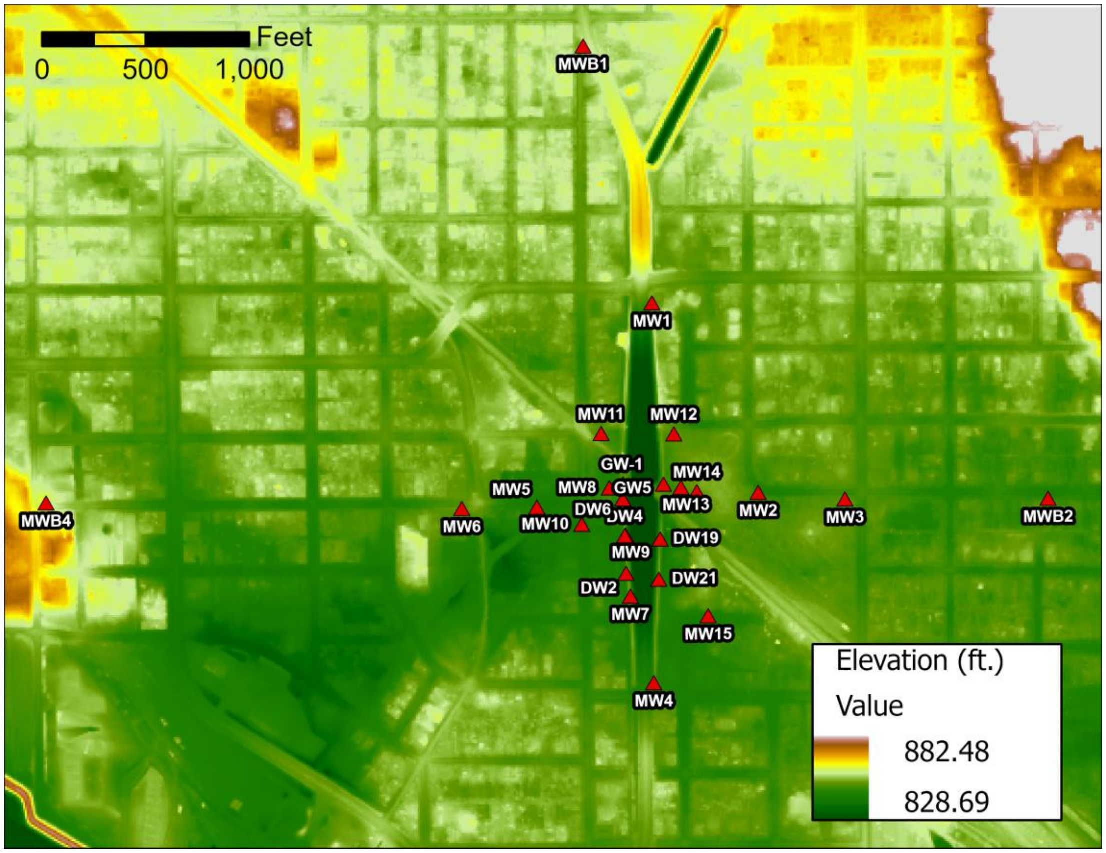


Figure 2. Location of groundwater wells shown with ground elevations from a digital elevation model derived from lidar

Statistical analysis was conducted to test the hypothesis that mean water levels were significantly different during different phases of the overpass construction. Paired t-tests were performed on the water level data from each well over the four time periods during construction. Any dataset with fewer than 10 observations in the respective time period was excluded from the analysis. An alpha level of 0.005 was used to determine statistical significance, and the data were assumed to come from populations with unknown and unequal variances.

3. RESULTS AND DISCUSSION

3.1 Time Series

Time series of precipitation and the elevation of the water surface in the Cedar River provide background information useful for interpreting the changes in water levels in the monitoring wells. Precipitation was usually highest between May and September; those periods in 2016, 2018, 2019, and 2020 had particularly large amounts of rain (Figure 3).

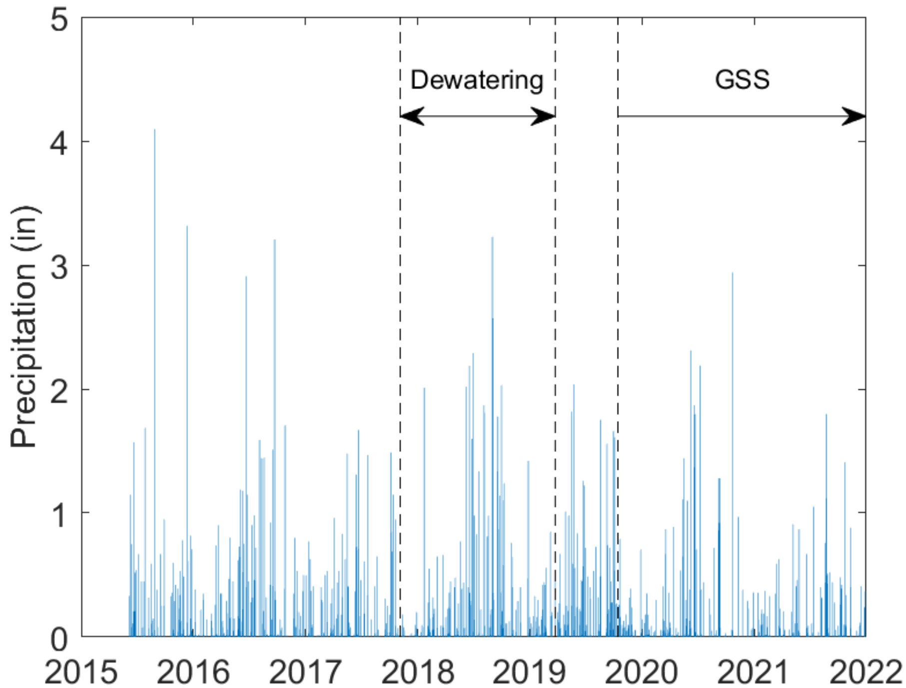


Figure 3. Daily precipitation at Waterloo Regional Airport during the study period, with vertical dashed lines indicating periods in which dewatering occurred and the GSS operated

As a result, flows in the Cedar River were high in those periods as well. The elevation of the water surface exceeded 838 ft in late September 2016, mid-June 2018, September/October 2018, March 2019, and June 2020 (Figure 4).

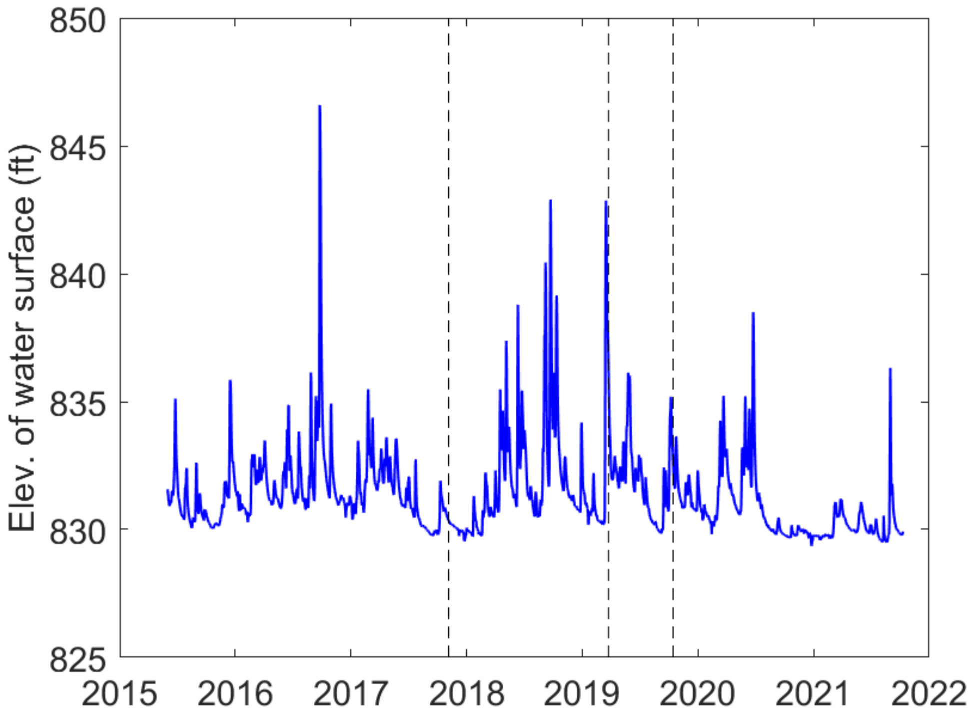
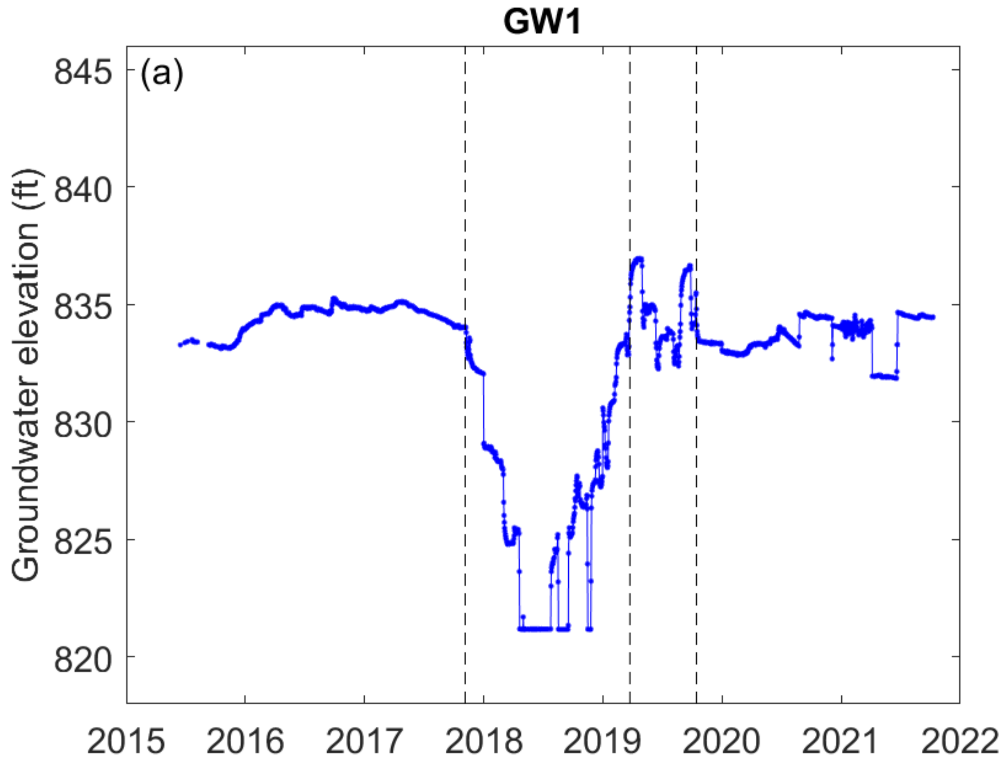
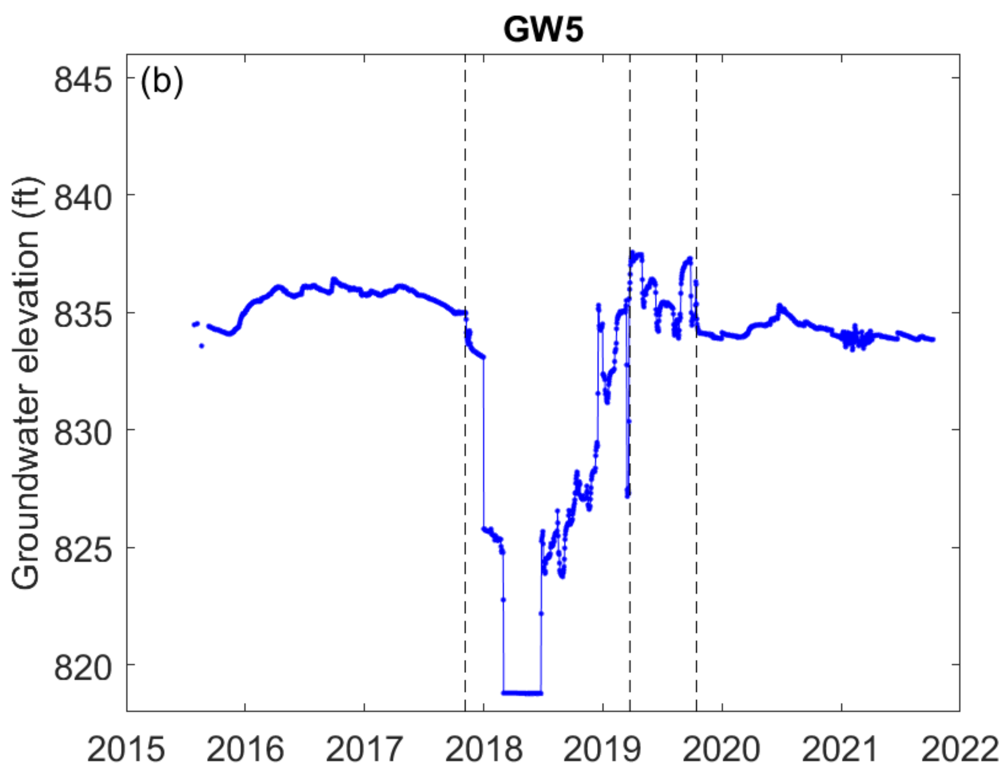
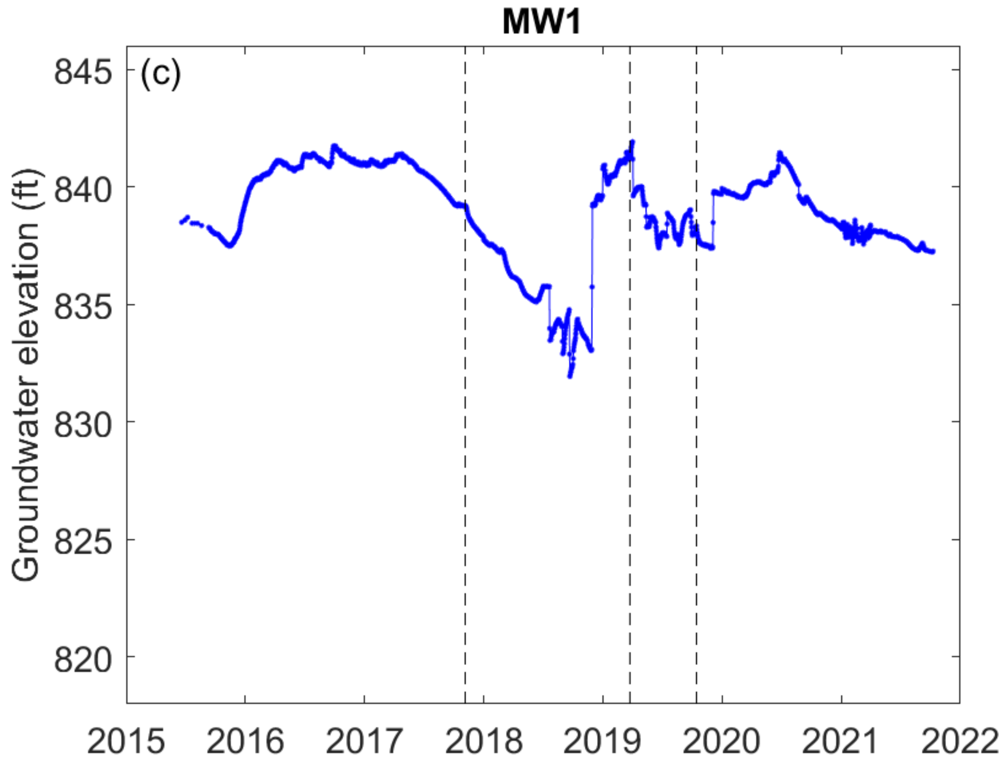


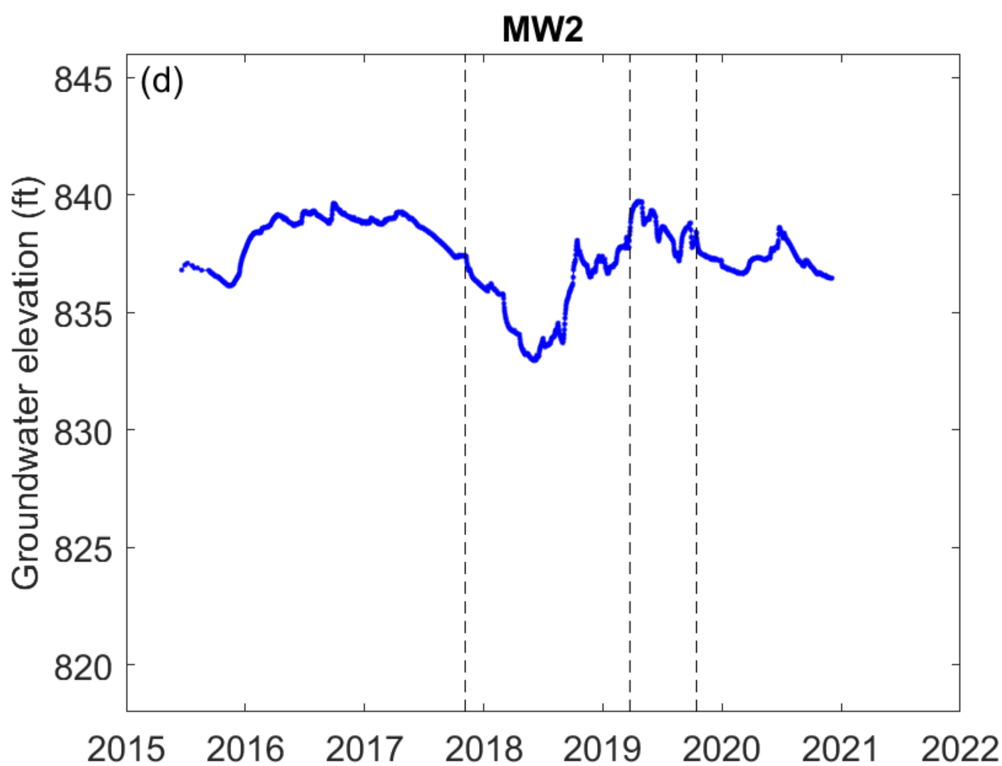
Figure 4. Elevation of the water surface of the Cedar River at U.S. Geological Survey station 05464000 (in reference to the National Geodetic Vertical Datum of 1929)

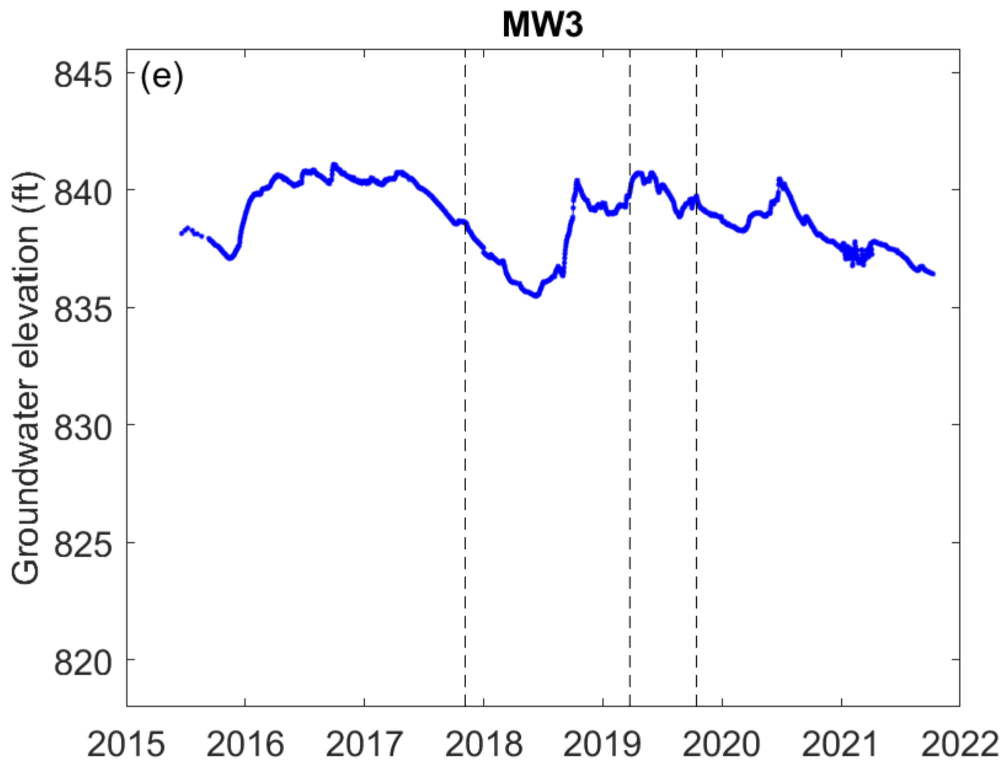
The time series of the groundwater elevations in the wells illustrate the effects of the dewatering and GSS (Figure 5).

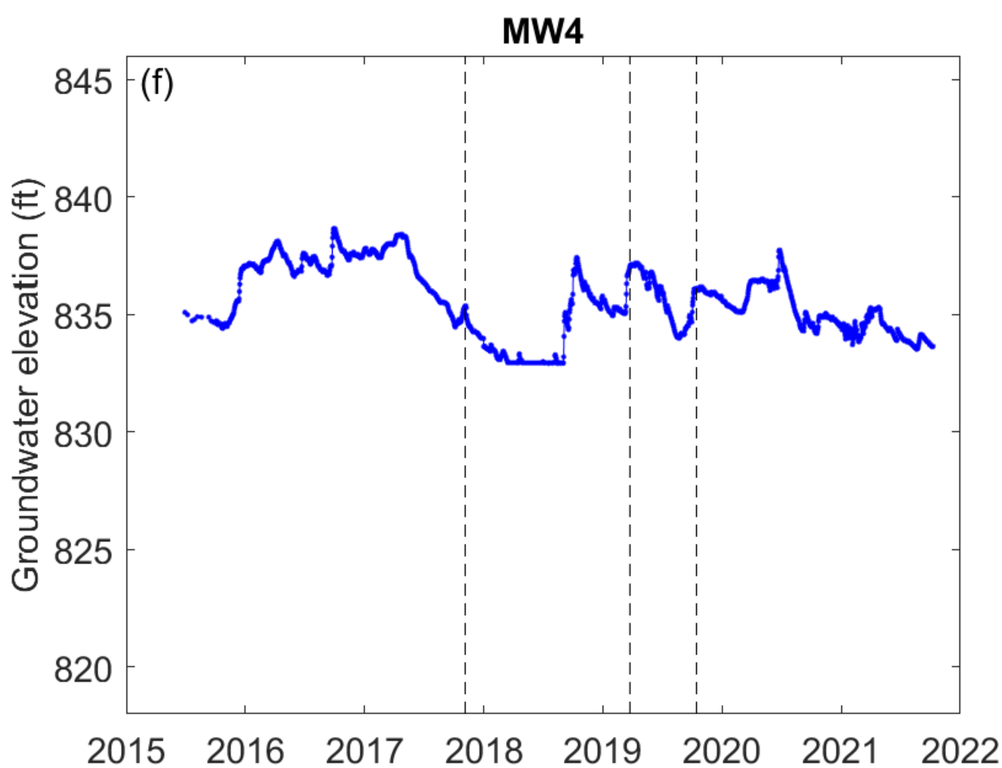

GW1
(a)
845
840
835
830
825
820
Groundwater elevation (ft)
2015
2016
2017
2018
2019
2020
2021
2022

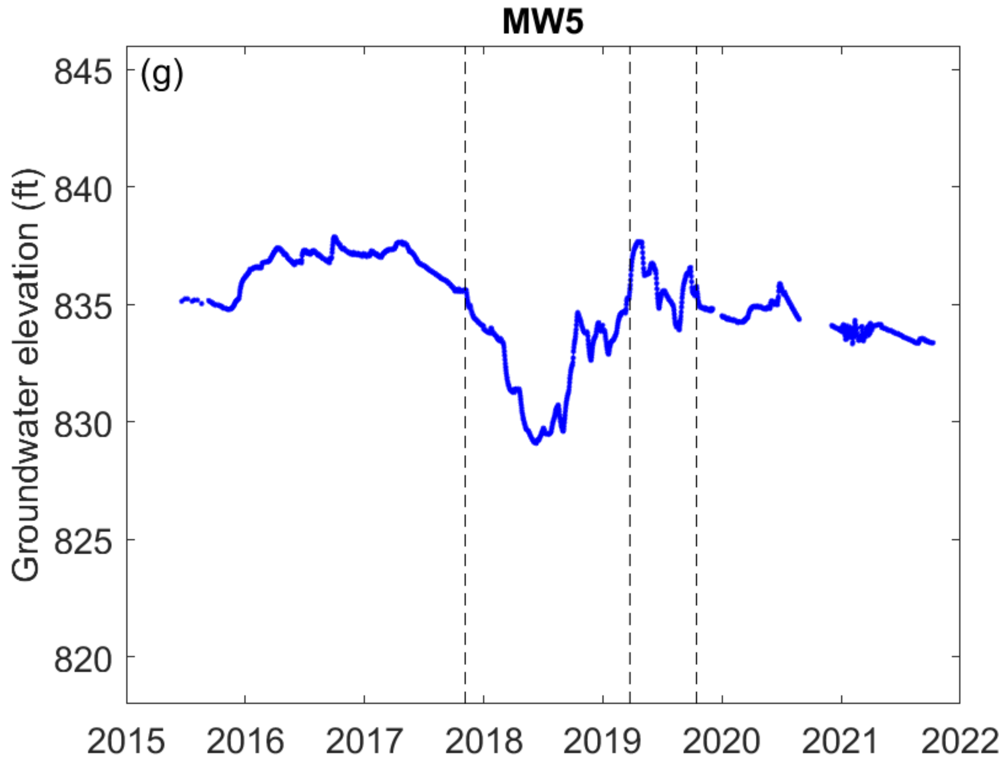

GW5
(b)
845
840
835
830
825
820
Groundwater elevation (ft)
2015
2016
2017
2018
2019
2020
2021
2022

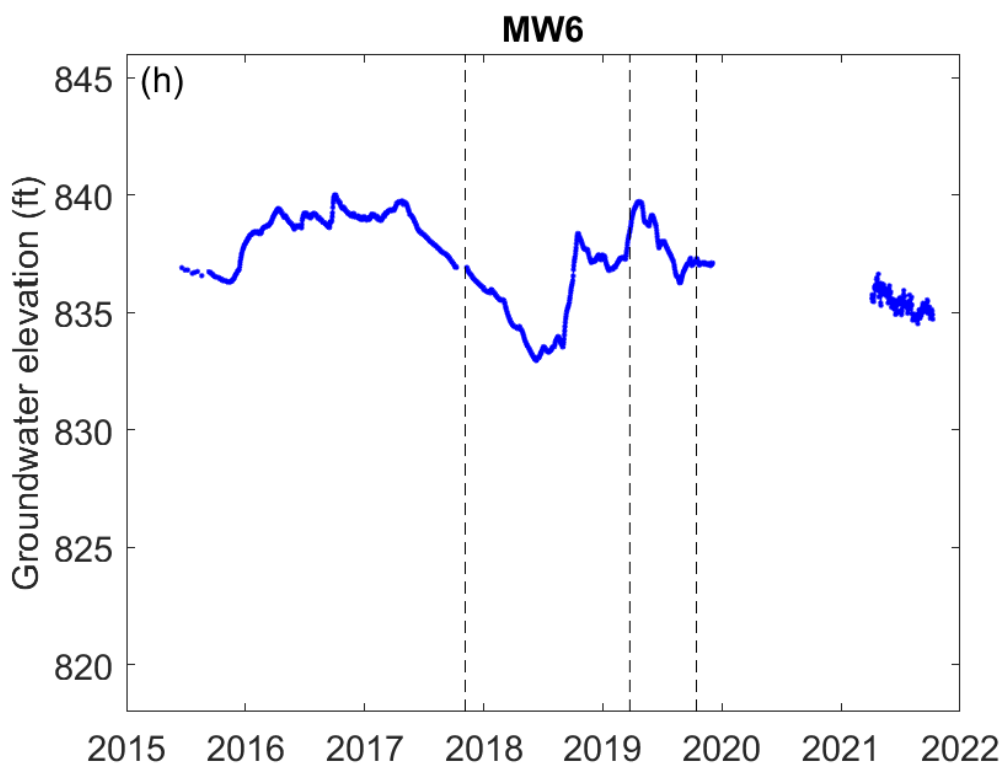

MW1
(c)
845
840
835
830
825
820
Groundwater elevation (ft)
2015
2016
2017
2018
2019
2020
2021
2022

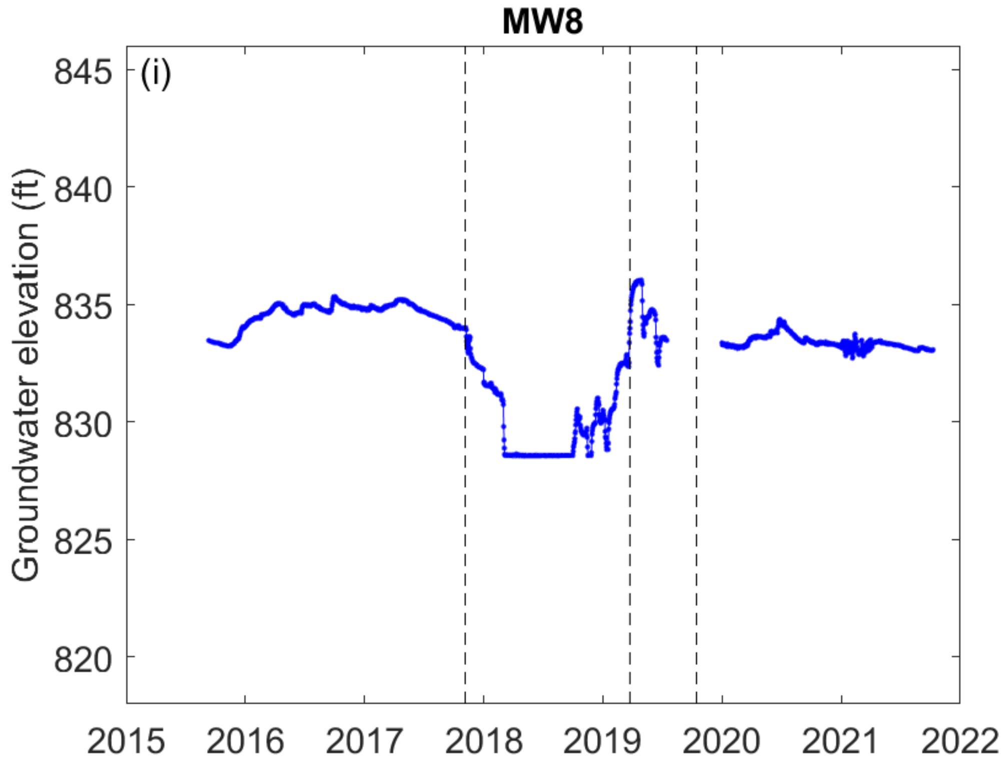

MW2
(d)
845
840
835
830
825
820
Groundwater elevation (ft)
2015
2016
2017
2018
2019
2020
2021
2022

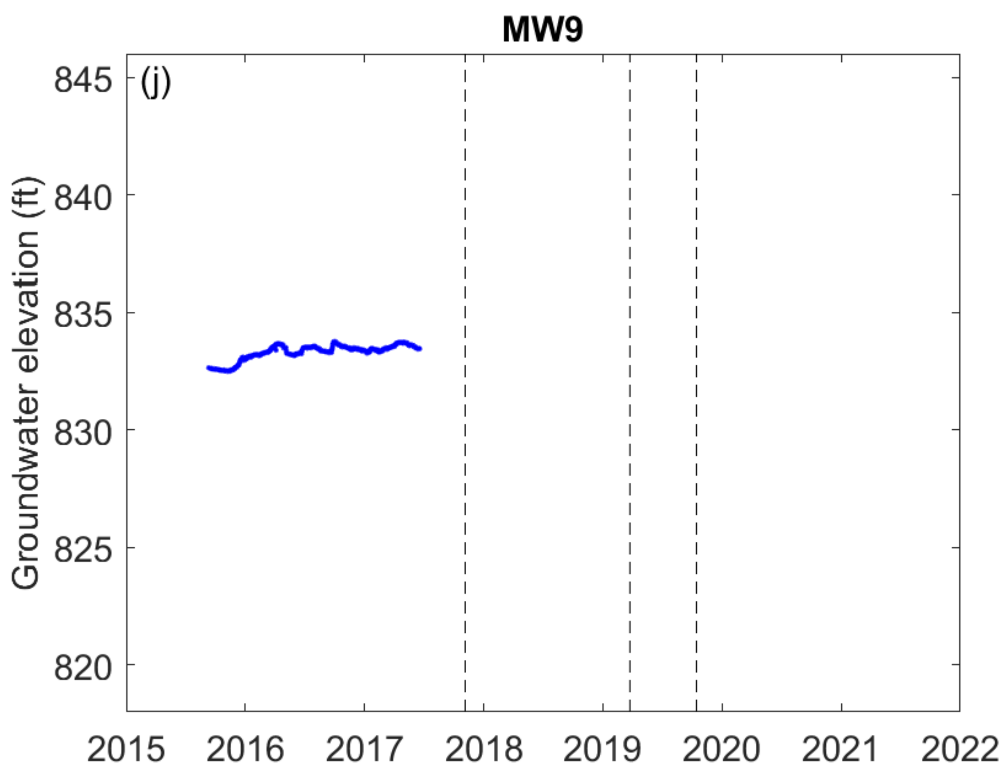

MW3
(e)
845
840
835
830
825
820
Groundwater elevation (ft)
2015
2016
2017
2018
2019
2020
2021
2022

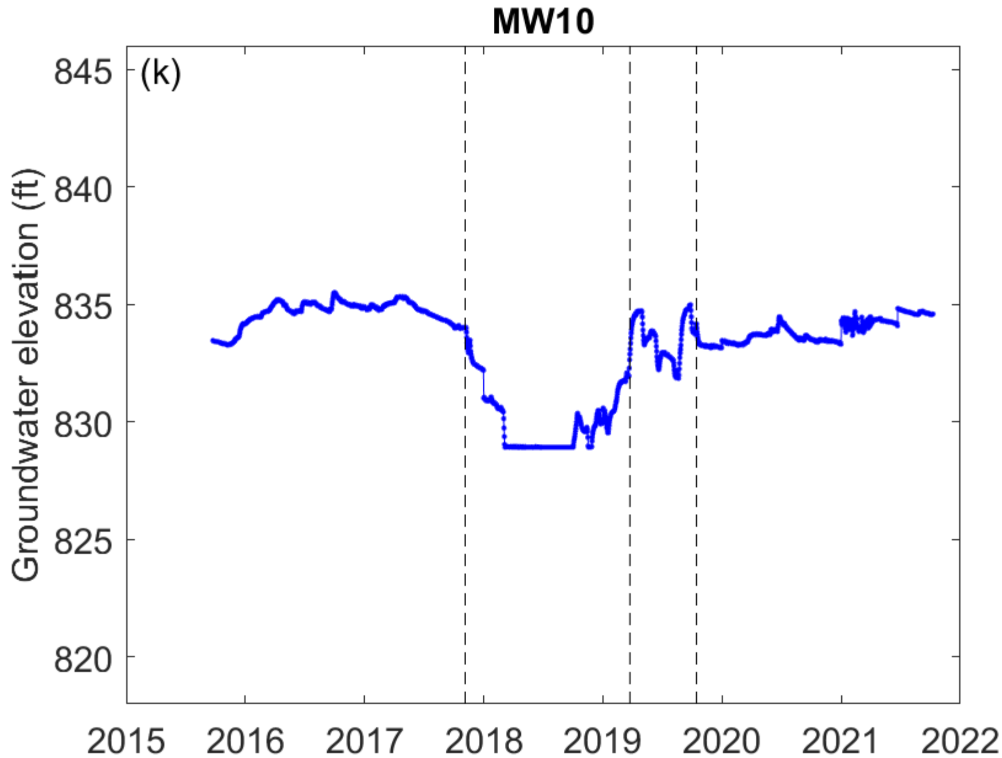

MW4
(f)
845
840
835
830
825
820
Groundwater elevation (ft)
2015
2016
2017
2018
2019
2020
2021
2022

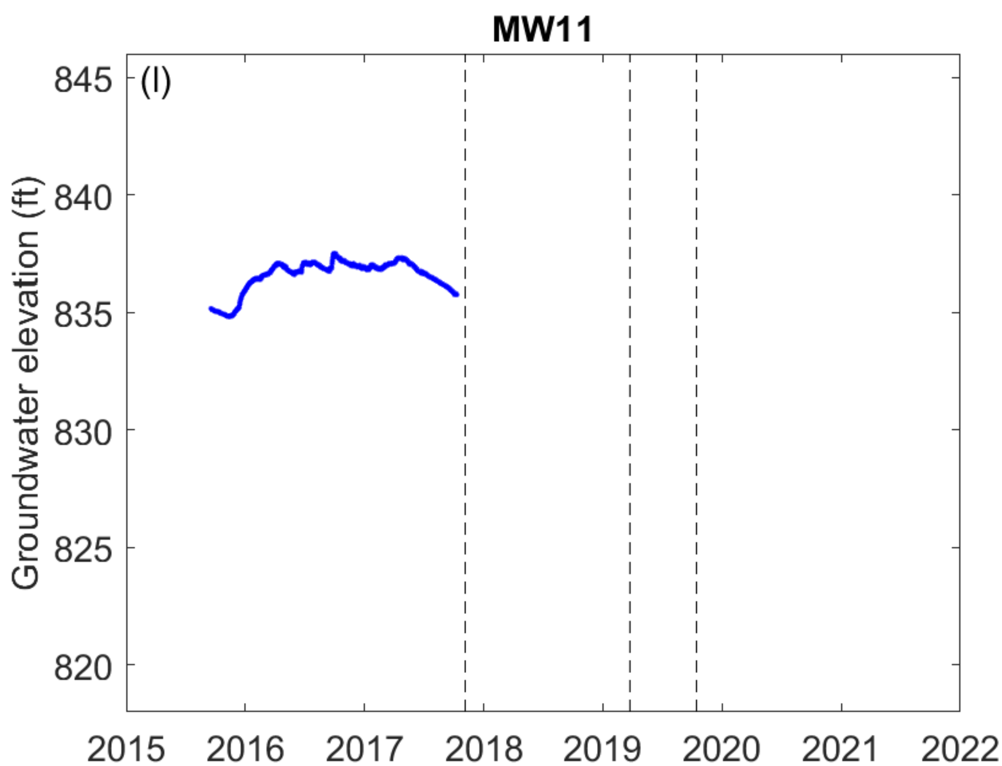

MW5
(g)
Groundwater elevation (ft)
845
840
835
830
825
820
2015
2016
2017
2018
2019
2020
2021
2022

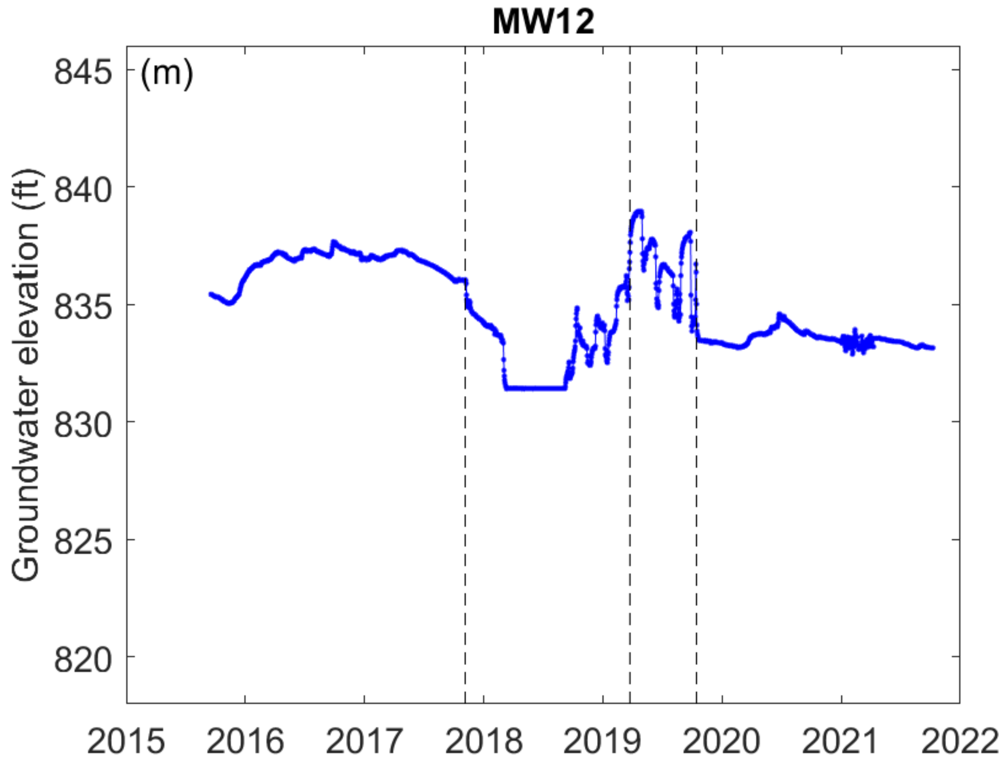

MW6
(h)
Groundwater elevation (ft)
845
840
835
830
825
820
2015
2016
2017
2018
2019
2020
2021
2022

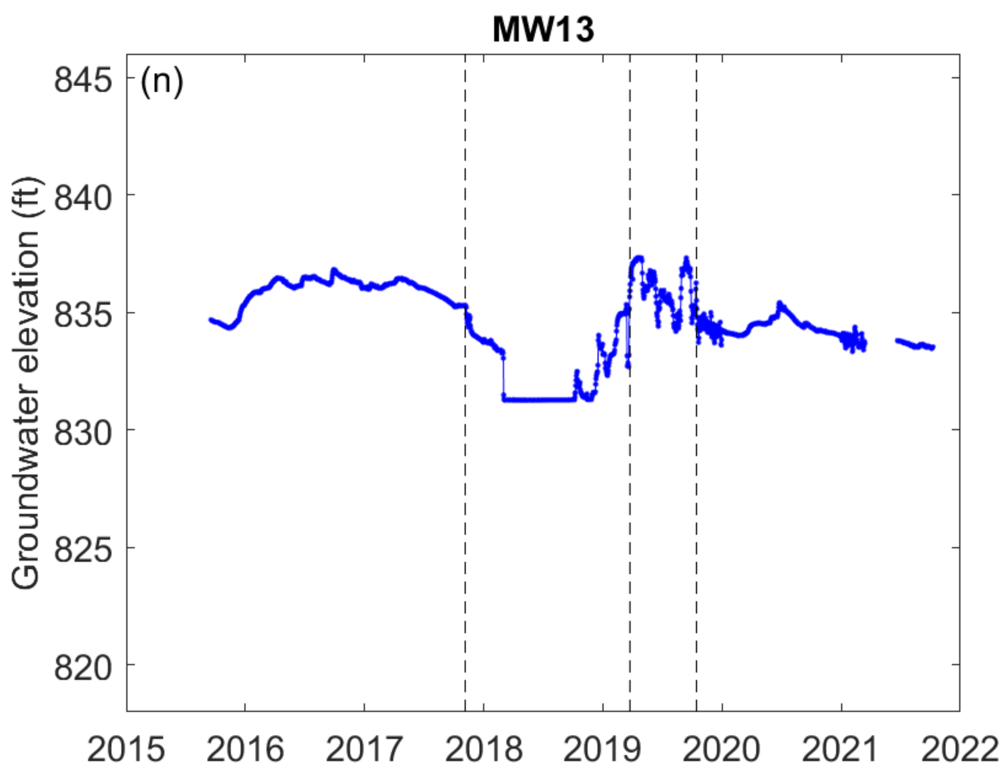

MW8
(i)
845
840
835
830
825
820
Groundwater elevation (ft)
2015
2016
2017
2018
2019
2020
2021
2022

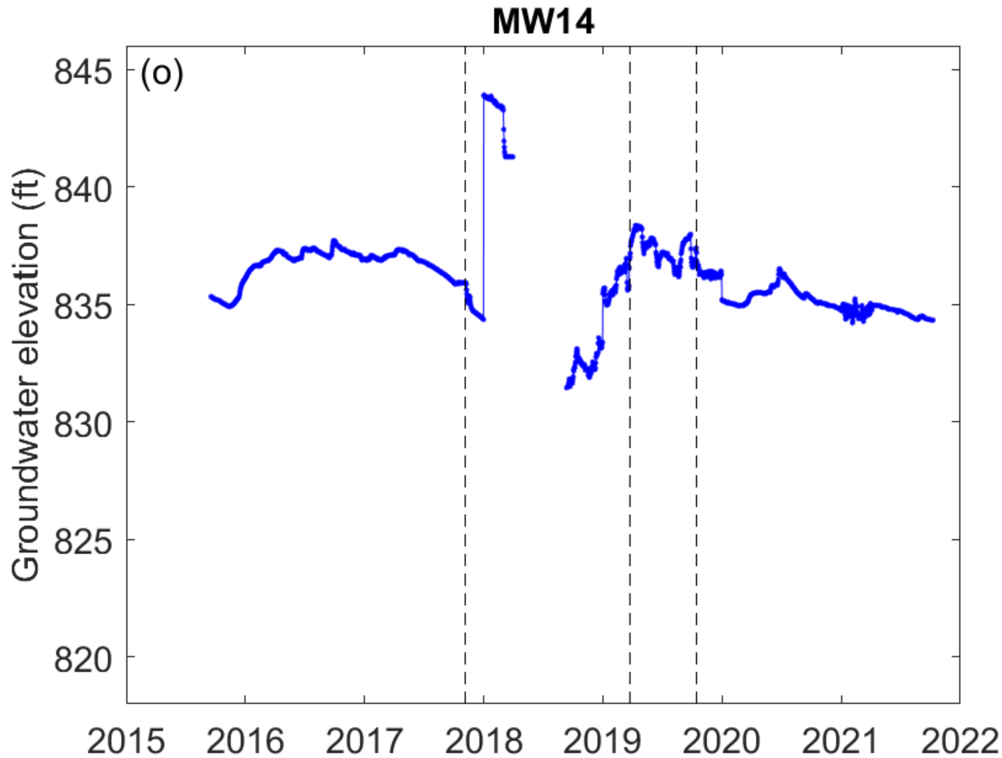

MW9
(j)
845
840
835
830
825
820
Groundwater elevation (ft)
2015
2016
2017
2018
2019
2020
2021
2022

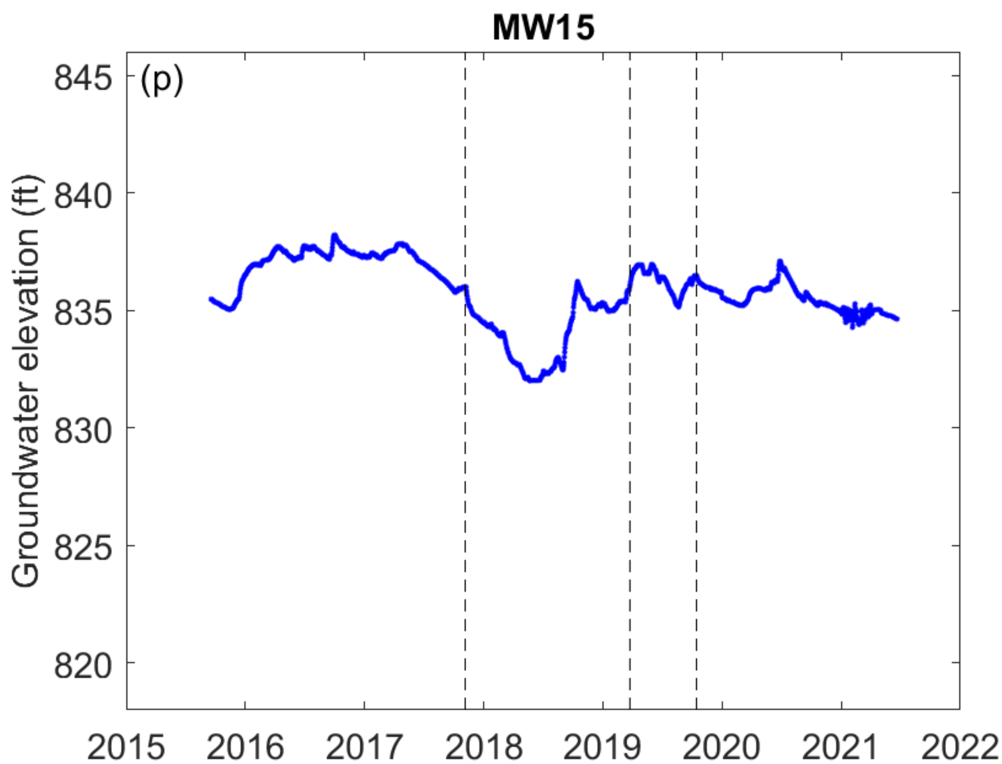

MW10
(k)
Groundwater elevation (ft)
845
840
835
830
825
820
2015
2016
2017
2018
2019
2020
2021
2022

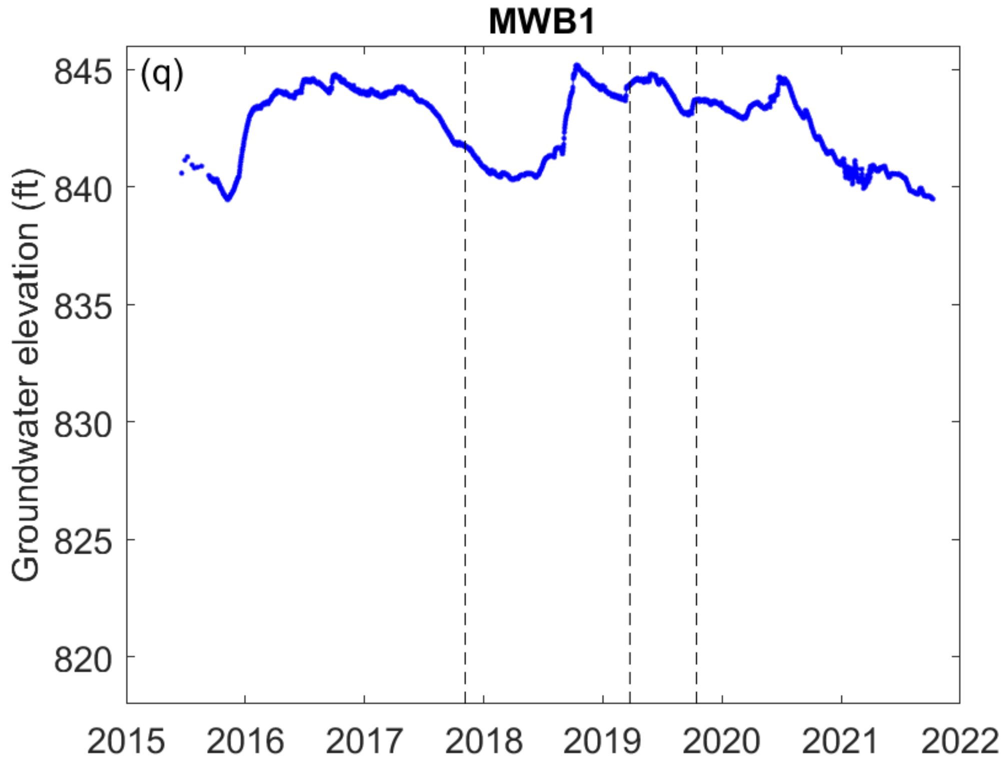

MW11
(l)
Groundwater elevation (ft)
845
840
835
830
825
820
2015
2016
2017
2018
2019
2020
2021
2022

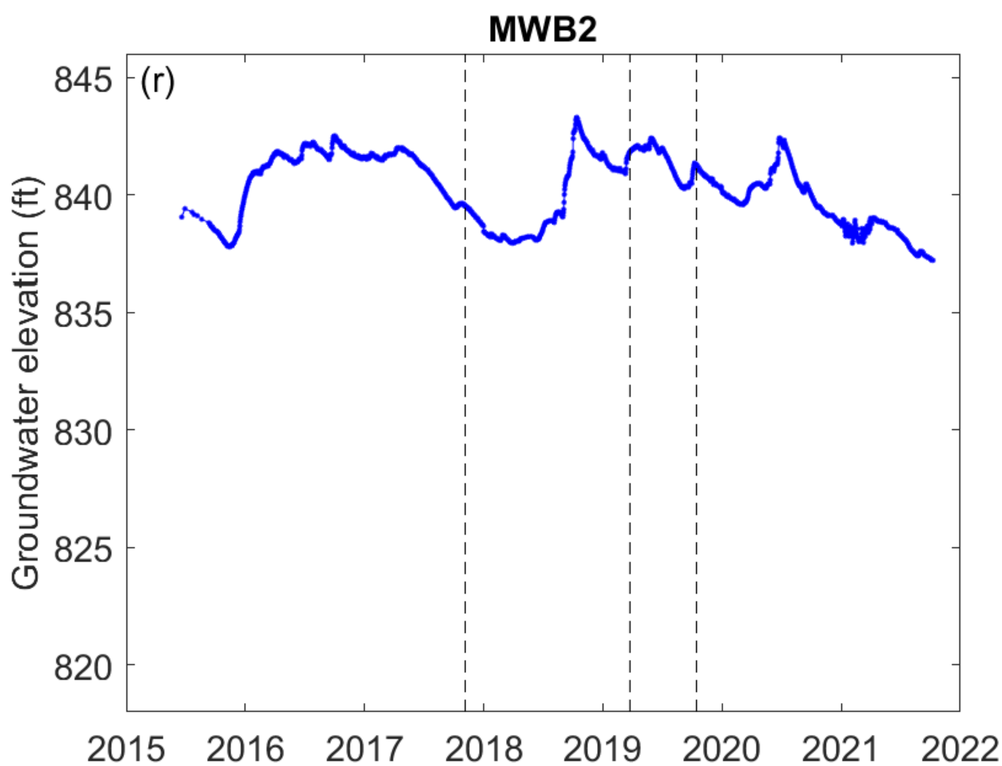

MW12
(m)
Groundwater elevation (ft)
845
840
835
830
825
820
2015
2016
2017
2018
2019
2020
2021
2022

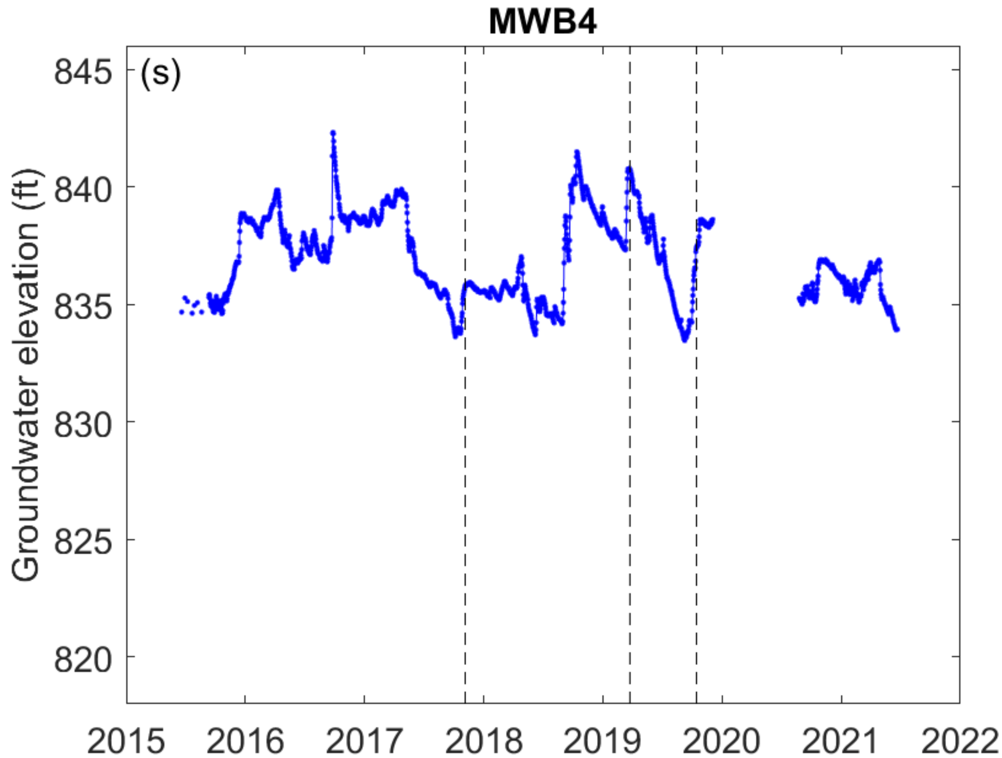

MW13
(n)
Groundwater elevation (ft)
845
840
835
830
825
820
2015
2016
2017
2018
2019
2020
2021
2022

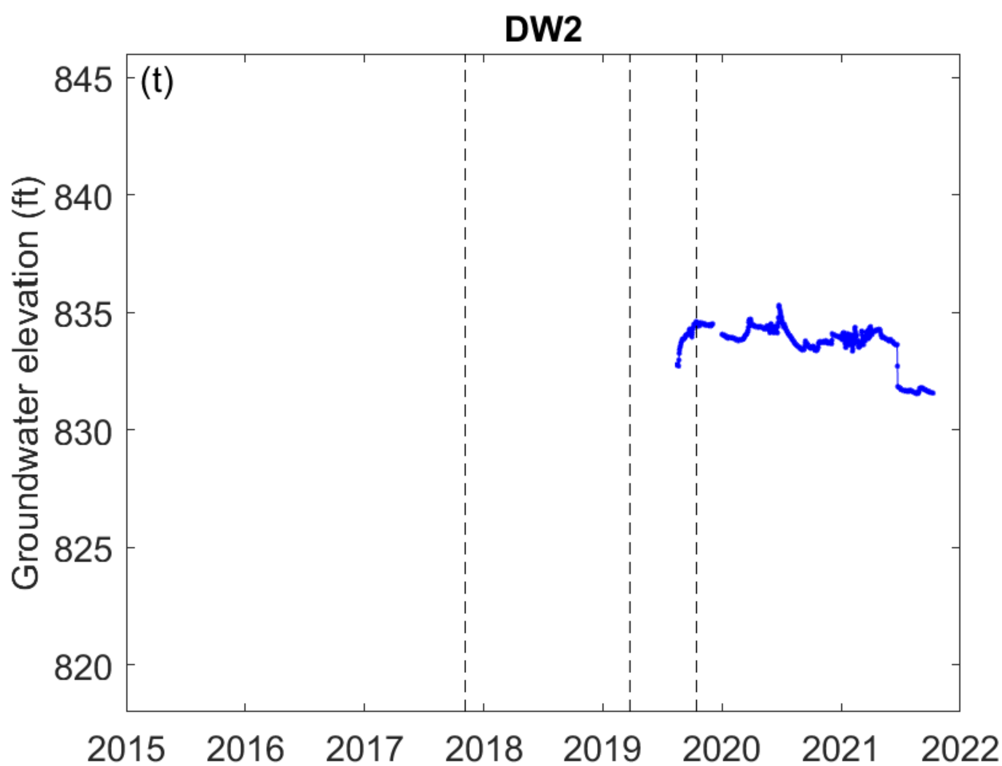

MW14
(o)
845
840
835
830
825
820
Groundwater elevation (ft)
2015
2016
2017
2018
2019
2020
2021
2022

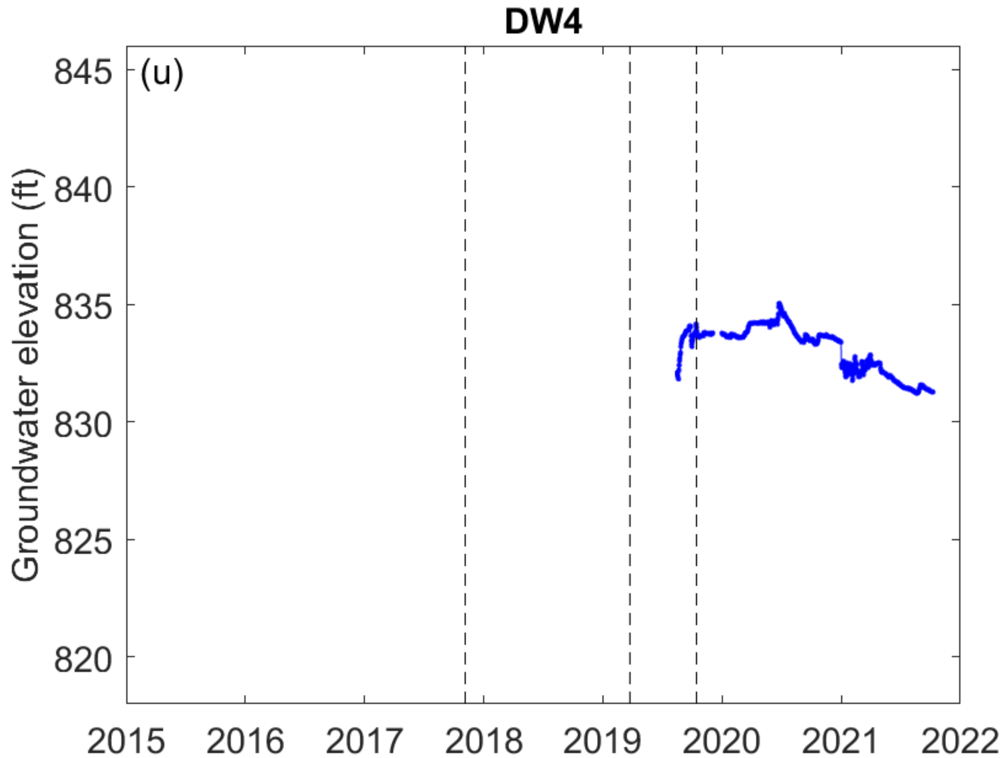

MW15
(p)
845
840
835
830
825
820
Groundwater elevation (ft)
2015
2016
2017
2018
2019
2020
2021
2022

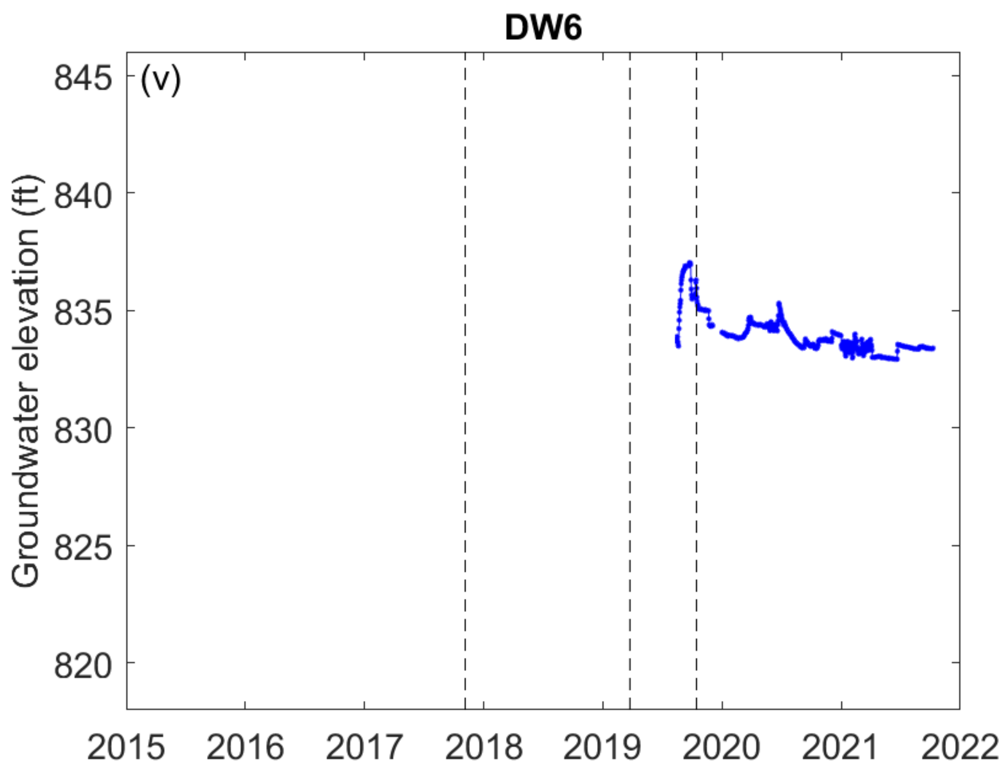

MWB1
(q)
Groundwater elevation (ft)
845
840
835
830
825
820
2015
2016
2017
2018
2019
2020
2021
2022


MWB2
(r)
Groundwater elevation (ft)
845
840
835
830
825
820
2015
2016
2017
2018
2019
2020
2021
2022


MWB4
(s)
Groundwater elevation (ft)
845
840
835
830
825
820
2015
2016
2017
2018
2019
2020
2021
2022


DW2
(t)
Groundwater elevation (ft)
845
840
835
830
825
820
2015
2016
2017
2018
2019
2020
2021
2022


DW4
(u)
845
840
835
830
825
820
Groundwater elevation (ft)
2015
2016
2017
2018
2019
2020
2021
2022


DW6
(v)
845
840
835
830
825
820
Groundwater elevation (ft)
2015
2016
2017
2018
2019
2020
2021
2022

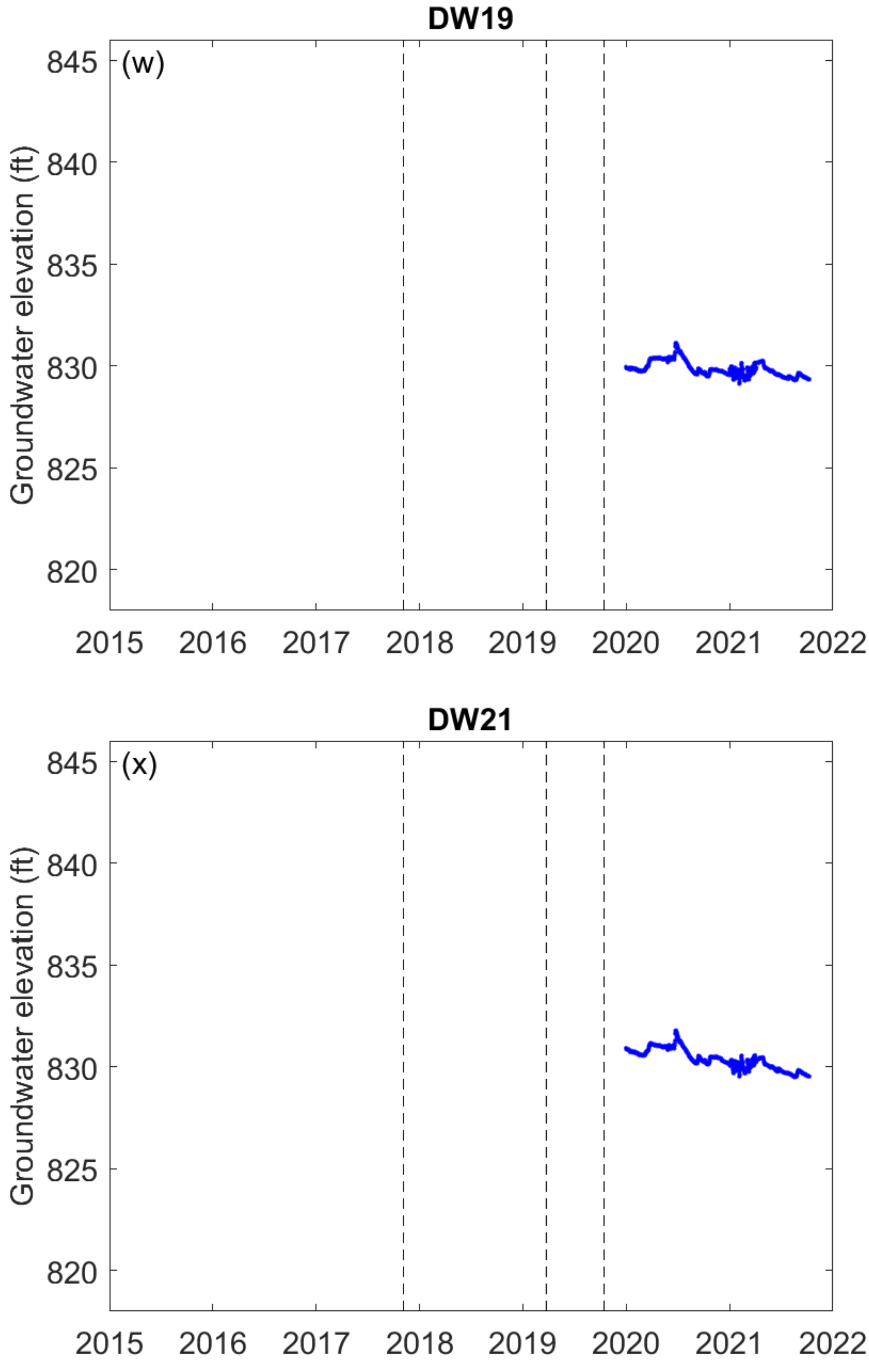


Figure 5. Time series of water elevations in the monitoring wells, with vertical dashed lines indicating periods in which dewatering occurred and the GSS operated

Before the dewatering began on November 5, 2017, the water levels in all wells showed similar behavior. After a small dip near the beginning of sampling, water levels increased to a near-constant level and decreased slightly before dewatering. The variation in water levels during this period was smallest close to the overpass (about 2 ft) and larger farther from the site (3 to 4 ft). The water level in well MWB4, which is closest to the Cedar River, varied over a range of about 8 ft. It clearly showed the effect of the river; for example, the sharp rise in late September 2016 reflected the high flow in the river at that time (Figure 4).

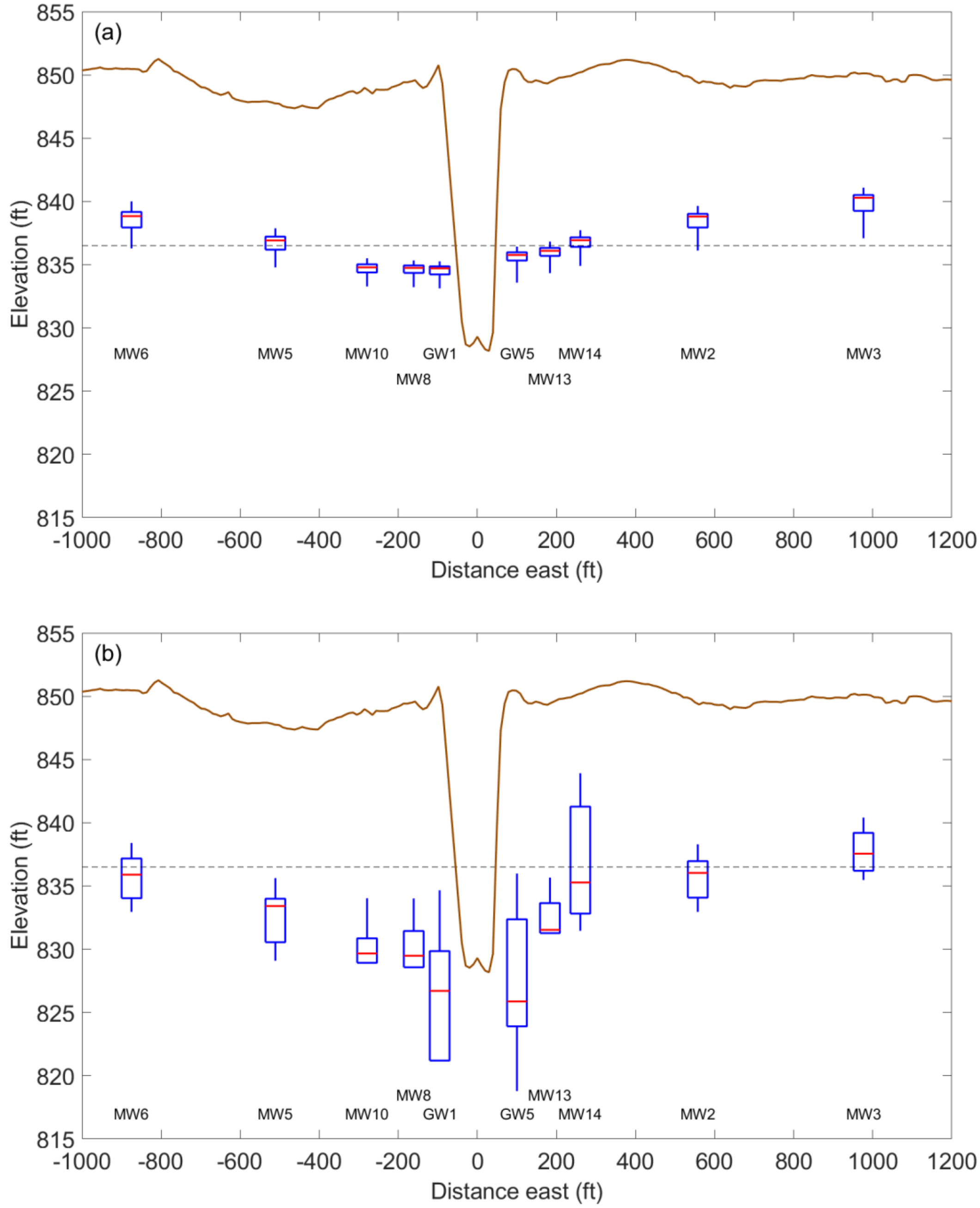
During the dewatering period, the water levels in the wells closest to the construction site (GW1 and GW5, Figures 5a, 5b) experienced the largest decreases: about 13 ft and 17 ft, respectively. Large drawdowns of 6 to 7 ft occurred at wells MW1, MW5, and MW8 (Figures 5c, 5g, 5i) and decreased with distance. Although the drawdown reached about 1.5 ft in background wells MWB1 and MWB2 (Figures 5q, 5r), the effect of the dewatering was not apparent in the remaining background well, MWB4 (Figure 5s). The maximum drawdown was reached in several wells in late April 2018; water levels in wells GW1, GW5, MW4, MW8, MW10, MW12, and MW13 reached a clear and sustained minimum, whereas the levels in other wells did not. (The sharp increase in the water level in well MW14 is likely due to a malfunctioning sensor.) Even with the dewatering, water levels increased in early September 2018 when high flows in the Cedar River occurred (Figure 4) after a wet summer (Figure 3).

Between the end of dewatering on March 25, 2019 and the start of GSS operation on October 15, 2019, the water levels varied between 1 and 5.5 ft in all wells except for MWB4, whose water level varied by 8 ft. Just before this interlude, the stage in the Cedar River reached the third highest level of the 76-month period of sampling. The water levels in wells GW1, GW5, MW12, and MW13 followed a similar pattern: they increased and decreased four times. At the same time, rainfall of 0.5 in. or more occurred. This pattern was not observed in other wells.

For most wells, the range of variation in water levels was smaller while the GSS was operating than in the period immediately before. For example, the ranges for wells GW1 and GW5 were about 2 ft smaller after the GSS started, despite a few periods of relatively heavy precipitation (Figures 5a, 5b). The level in well GW1 increased by about 1 to 2 ft, while the level in well GW5 remained constant. In a similar way, the water level in well MW10 increased slightly, and the levels in wells MW8, MW12, MW13, and MW15 varied little overall. In the remaining wells (MW1 through MW6 and MW14), water levels decreased; that decrease led to ranges of variation after the GSS started that were larger or similar to the ranges between the end of dewatering and the start of the GSS. Although the level in well DW19 remained nearly constant while the GSS operated (Figure 5w), the levels in the other dewatering wells decreased (Figures 5t, 5u, 5v, 5x).

3.2 Water Table

The observations for individual wells can be collected to investigate the behavior of the water table during this period (Figure 6).


(a)
Elevation (ft)
Distance east (ft)
MW6
MW5
MW10
GW1
GW5
MW14
MW2
MW3
MW8
MW13
(b)
Elevation (ft)
Distance east (ft)

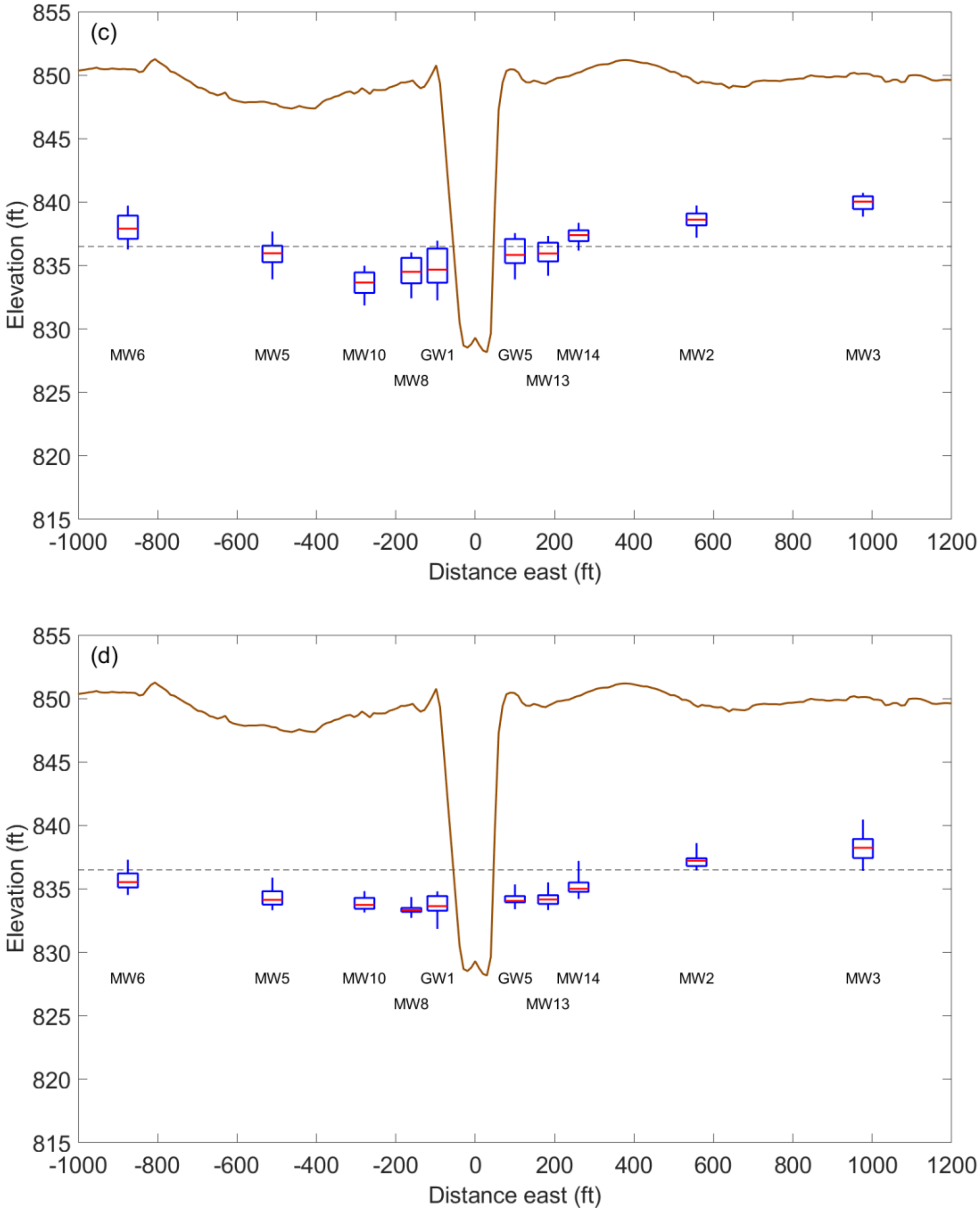


Figure 6. Box and whisker plots of the groundwater elevation in wells roughly along a west-east axis, with statistics computed for the following time periods: (a) before dewatering from June 15, 2015 to November 5, 2017 and (b) during dewatering from November 5, 2017 to March 25

Before the dewatering began, the water table showed a clear dip near the construction area; the median water level at well GW1 during this period was about 5 ft less than the median level at well MW14 (Figure 6a). The box plots reflect the observations from Section 3.1: the variation in water levels was small near the underpass and larger farther away. During the dewatering period, the water table dropped across the west-east section (Figure 6b). At all wells, the median water levels were smaller, and the range of variation was larger. After dewatering stopped, the water table rose, returning approximately to the levels observed before dewatering (Figure 6c). The GSS lowered the water table by about 1 to 2 ft over the west-east section (Figure 6d).

Plotting the mean elevations of the wells in a west-east line over each of the time periods illustrates the behavior of the water table (Figure 7). As in the box and whisker plots of Figure 6, the effect of pumping on the water table is apparent; a depression in the water table near the construction site is clearly visible. The other time periods had similar water table profiles; the period during GSS operation had lower mean values than the period before dewatering and the period between dewatering and GSS operation. The water tables were qualitatively most similar in the first and third periods.

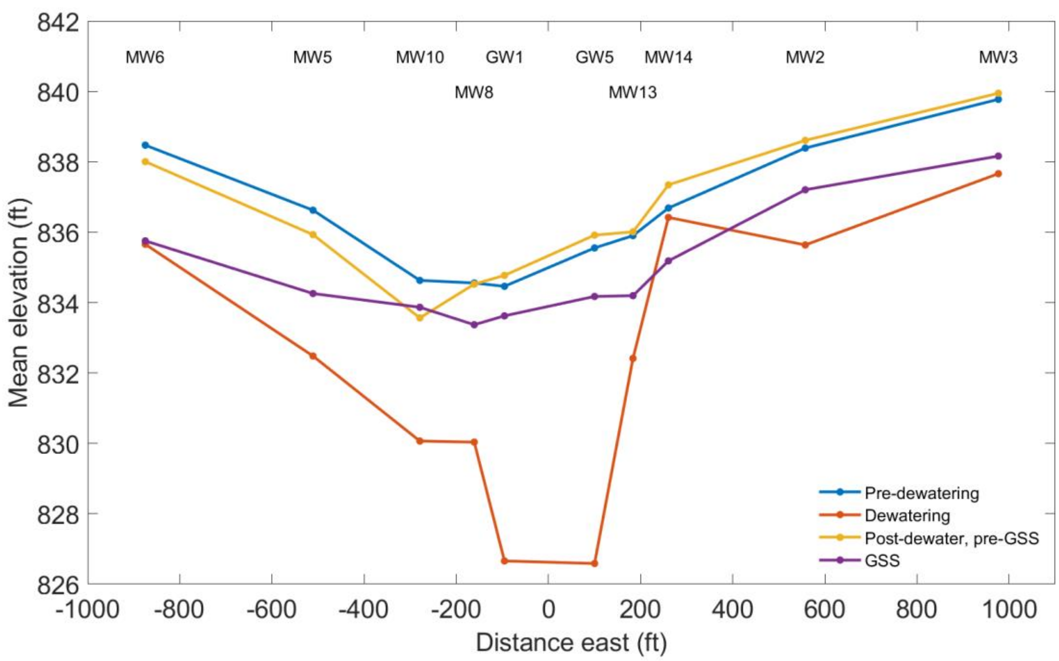


Figure 7. Mean elevation of the water table elevation in wells roughly on a west-east line during the four periods

3.3 Statistical Comparison

The statistical analysis showed that most of the water levels averaged over the each of the four periods differed from the mean water levels in the other periods at the same well. Wells MW8 and MW13 had no significant difference in mean values for the first and third periods ($p = 0.79$ and $p = 0.11$, respectively). However, in most cases (92%), the mean water levels were significantly different ($p < 0.05$) among the four periods. Almost all mean water levels during GSS operation were significantly different from the means in the first and third periods. Only the means for periods 3 and 4 in well MW1 were not significantly different, and that well is relatively far from the construction area.

Comparing the average variance in water levels of all wells in different time periods gives insight into the efficacy of the dewatering and groundwater suppression systems. This analysis further quantifies the description of the time series in Figure 5 and the box and whisker plots in Figure 6. The dewatering period has the highest variance (Table 2), as would be expected from a system designed to alter water levels. The second highest variance occurred during the third period (between dewatering and GSS operation), corresponding to typical groundwater behavior where levels are influenced by precipitation and surface water. The periods before dewatering and during GSS operation had the lowest variances in water levels (0.87 and 0.66 ft, respectively).

Table 2. Variance during each construction period averaged across all wells.

Period	Average variance (ft)
Before dewatering	0.87
Dewatering	6.11
After dewatering and before GSS operation	1.01
During GSS operation	0.66

The small variance during the period during GSS operation suggests that the system is functioning correctly and reducing variability in the water levels. This stabilization was strongest near the overpass, as observed in wells MW8 and MW12 (variances of 0.08 and 0.10 ft, respectively), and the effect is smaller (i.e., variances increase) as the distance from the overpass increases. For example, background wells MWB1 and MWB2 had the highest variances of all wells in the period during GSS operation (2.39 and 1.53 ft, respectively). Therefore, whereas the GSS stabilizes water levels nearby, it does not appear to affect the natural groundwater regime in the larger region.

4. CONCLUSIONS

Monitoring water levels in several observation wells over a 76-month period provided a picture of the behavior of the water table during the construction of the overpass on US 63. The following conclusions can be stated:

1. Water levels in wells farther from the overpass were not greatly affected by the operations at the site. This observation confirms previous findings (CH2M Hill 2015).
2. Dewatering lowered the water table by a large amount around the construction area. The water levels rose quickly by the end of the dewatering period; mean water levels for the periods before and after dewatering (but before groundwater suppression) appeared similar, though the statistical analysis indicated that most mean levels were significantly different at the 5% level.
3. The GSS has lowered the water table by about 1 to 2 ft. Statistical analysis supports the observation by showing that water levels during suppression were significantly different from the levels in periods without suppression or dewatering.
4. The variance of the water levels was smallest during the period with groundwater suppression. This observation suggests that the GSS has stabilized the water levels near the overpass.

A caveat to these conclusions is that the statistical analysis does not ascribe a cause to the observations. Further understanding of the groundwater dynamics in the area would require modeling similar to that done by CH2M Hill (2014).

REFERENCES

CH2M Hill. 2014. *Phase II Interim Groundwater Study at the US 63 Underpass Dane Street N. to Newell Street, Black Hawk County, Waterloo, Iowa*. Project # 424101. CH2M Hill, Englewood, CO.

Olsson Associates. 2015. *Piezometer Installation Log*. Project # 015-0920 103/103001. Olsson Associates, Lincoln, NE.

THE INSTITUTE FOR TRANSPORTATION IS THE FOCAL POINT FOR TRANSPORTATION AT IOWA STATE UNIVERSITY.

InTrans centers and programs perform transportation research and provide technology transfer services for government agencies and private companies;

InTrans contributes to Iowa State University and the College of Engineering's educational programs for transportation students and provides K–12 outreach; and

InTrans conducts local, regional, and national transportation services and continuing education programs.