DEPARTMENT OF NATURAL RESOURCES

Ecological and Water Resources - Groundwater Technical Analysis

Aquifer Test Technical Review

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Subject: 2020-2578, Riverview Dairy, Twelvemile

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PROFESSIONAL GEOLOGIST

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Geologist under the Laws of the State of Minnesota.

License No: *30303* *Signature:* ______________________________

Executive Summary

An aquifer test was conducted at the proposed Twelvemile Dairy site to evaluate the capacity of a deep aquifer to meet the long-term water production demands for the proposed facility. Initial analysis of the results suggests that the deep aquifer can sustainably meet the needs for the proposed plant in the immediate term because the aquifer draws groundwater from the shallower aquifer and from the surrounding lower permeability matrix. However, the dataset as a whole shows that using the aquifer at this rate will not be sustainable over the lifetime of the project and is likely to result in mining groundwater. Reasons for this include that: we suspect the 30-day aquifer test was not long enough for aquifer limits to be measured; the deep aquifer is very small; the aquifer is slow to recharge and recover, as indicated by slow water level recovery; water levels at the nearby Dollymount Dairy continue to decline and have not yet stabilized; and the potential for regional groundwater production is limited as indicated by significant lag times at distant wells in response to the pumping. Additionally, aquifers in this region typically cannot be pumped at a high rate for the long-term.

We recommend at an alternate primary source of water be used and that, if a permit is to be issued for the proposed facility, it is only as a backup supply to be used on a temporary basis. If it is permitted as such, it is strongly recommended that 1) an observation well nest be installed between the Dollymount Dairy and proposed Twelvemile facility; 2) a comprehensive long-term monitoring plan for water use and groundwater levels be implemented; 3) a contingency plan be submitted that addresses how an alternative water source would be used when the 50-percent and 25-percent safe-yield thresholds are breached as a result of pumping; 4) pumps be lowered in the four private wells determined to be at high risk; 5) private domestic wells lacking construction information be inspected to determine the height of the column of water above the pump or whether they have been abandoned; and 5) Dollymount Dairy's permit (2007-0361) be re-evaluated for compliance to permit conditions.

Introduction

An aquifer test was conducted on a high capacity well that was installed for livestock watering at a proposed Riverview LLP (Applicant) dairy operation, Twelvemile Dairy (Site), approximately 4.7 miles southeast of Dumont in Traverse County, as illustrated on Figure 1. The Applicant retained LRE Water (Consultant) to conduct the aquifer test and analyze the results. The objective of the analysis was to evaluate the potential to pump a maximum combined rate of 325 gallons per minute (gpm), and an annual withdrawal of 153 million gallons per year (MGY) at the Site, as requested in the Applicant's appropriation permit application (2020-2578). This review evaluates the results of that test and the resulting aquifer test report that the Consultant prepared dated April 19, 2021 (LRE Water, 2021).

Onsite Well Information

Three wells associated with the permit application have been installed onsite. Table 1 summarizes construction details for these wells. Production Well PW-1 and Observation Well OW-1 both appear to be screened in the same deep aquifer, which is interpreted to be comprised of sandy Cretaceous sediments. Therefore, this report subsequently refers to this unit as the Cretaceous aquifer. Although Observation Well OW-2 was installed between wells PW-1 and OW-1, it is screened at a shallower depth in an overlying Quaternary Buried Artesian Aquifer (QBAA) that is separated from the Cretaceous layer by tighter glacial till deposits.

Table 1. On-site well construction information

Unique Well No.	UTME (m)	UTMN [1] (m)	Ground Elevation (ft) [2]	Depth (ft)	Diameter (in)	Penetrated aquifer	Screened interval (ft BGS) [3]	Static water level (ft BGS) [3]
PW-1 (850332)	239480.8	5063869.6	1055.1	331	12	Cretaceous	301 – 331	17.9
OW-1 (852336)	239494.7	5064177.0	1054.3	300	4	Cretaceous	220 – 300	12.4
OW-2 (852337)	239484.3	5063945.1	1054.6	149	4	QBAA [4]	139 – 149	12.2

[1] UTM locations are in NAD83, Zone 15N
[2] Ground elevation is relative to NAVD88
[3] BGS: Below Ground Surface
[4] QBAA: Quaternary Buried Artesian Aquifer

The Applicant has submitted an application for groundwater appropriation from the deep Cretaceous aquifer for watering livestock for the proposed dairy operation as summarized in Table 2. The Applicant has requested a maximum pumping rate of 325 gallons per minute (gpm) and a total volume of 153 million gallons per year (MGY), which equates to an annual average pumping rate of 291 gpm.

Table 2. Appropriation permit application details

Permit application no.	Requested pumping rate (gpm) [1]	Proposed volume (MGY) [2]	Proposed use
2020-2578	325	153	Livestock Watering

[1] gpm: gallons per minute
[2] MGY: million gallons per year

Setting

Geology

The Groundwater Technical Review (Evans and Rose, 2020) characterizes the regional geology as comprised of a complex of unconsolidated Quaternary sediments deposited primarily on top of Precambrian crystalline bedrock with discontinuous occurrences of Cretaceous sandstones and shales occurring stratigraphically between the two. The surficial geology at the site is typically comprised of Quaternary nearshore sediments deposited by Glacial Lake Agassiz consisting of moderately to well-sorted sand, silt, and clay. These surficial deposits overlie a thick sequence of glacial drift materials, with the total thickness of these deposits ranging from approximately 200 to 300 feet in the area. Tight glacial tills predominate the Quaternary unconsolidated deposits, interspersed with occurrences of glacio-fluvial sand and gravel deposits.

Hydrogeology

In Traverse County, groundwater is typically only available in isolated aquifers and, consequently, is limited for high-capacity users (Evans and Rose, 2020). Groundwater is produced from aquifers in the area comprised of Quaternary sand and gravel deposits of limited extent and undifferentiated Cretaceous sandstones, which are also discontinuous. However, data in the area is limited for reliably mapping the extents of both the Quaternary and Cretaceous aquifers.

Geologic cross-sections presented in the Groundwater Technical Report (Evans and Rose, 2020) illustrate the highly variable, irregular, and discontinuous nature of the aquifers near the site. Production Well PW-1 is screened in a thick deep sand aquifer that that occurs from 191 to 331 feet below ground surface (BGS). Although the well log for PW-1 does not provide sufficient geologic information to differentiate whether this unit is Quaternary or Cretaceous, the bedrock surface mapped in Jirsa et al. (2010) correlates closely with the top of the sand interval, indicating that it appears to be Cretaceous in age as noted in the Groundwater Technical Report (Evans and Rose, 2020). Therefore, that aquifer is interpreted to be Cretaceous in age and is referred to as such in this report. The north-south cross-section in the Groundwater Technical Report indicates that the source aquifer to be thickest (75 to 142 feet) in a north to south orientation extending at least 3,800 feet. However, other geologic cross-sections in the report constructed from available logs in the area indicate that this aquifer either pinches out or dramatically thins (16 feet or less) immediately to the east and west of Production Well PW-1. The Groundwater Technical Report further states that shallower Quaternary sand and gravel aquifers mapped in this area are also limited in extent.

Observation Well 1 (852336) is screened in this deep aquifer approximately 1,000 feet north of the production well, as illustrated in Figure 2. Observation Well 2 (852337) was also installed for water level monitoring for the project, but was screened in a shallower QBAA approximately 250 feet north of Production Well PW-1 (Figure 2). Since these wells are found within the areal extent of the deep Cretaceous aquifer, aquifer test data from these two wells are expected to most reliably characterize the hydraulic properties associated with the deep aquifer from which the Applicant proposes to pump. All other wells monitored for the aquifer test are screened in units that are either not laterally continuous with the deep aquifer or that have dramatically thinned.

Nearby Groundwater Appropriation Permits

The closest permitted high capacity wells belong to Riverview LLP dairy operation (Dollymount, 2007-0361), approximately 4.7 miles to the north, and the City of Dumont municipal supply wells (1984-1161), approximately 4.7 miles to the northwest (Evans and Rose, 2020). Table 3 summarizes the permit requirements and information pertaining to the active wells under each permit. Wells at both locations produce water from unconsolidated QBAAs that are shallower than the production well at the proposed Twelvemile Dairy (Evans and Rose, 2020).

An aquifer test was conducted in 2007 on the shallower wells (120 to 125 feet deep) at the Dollymount site. However, Walker (2019) determined that the data were questionable and could not be used to produce reliable results for aquifer parameters. Walker (2019) instead analyzed specific capacity data for three deep production wells, and estimated the transmissivity to range from 1000 to 1300 feet^2/day, equating to a hydraulic conductivity value of 20 to 24 feet/day, which is typical for fine to medium sands. Although it was not possible to estimate a storativity value from the data, Walker (2019) concluded that a value of 0.001 would be reasonable.

Table 3. Nearby Groundwater Appropriation Permits

Location/Name	Unique Well No.	Appropriations Permit No.	Appropriation Annual Volume (MGY)	Appropriation rate (gpm)
Riverview/Dollymount	819407, 819415, 819416	2007-0361	86.5	250 (each well), total may not exceed 500 gpm
City of Dumont	240743, 772149	1984-1161	6.0	50 (each well)

* gpm: gallons per minute; MGY: million gallons per year

Regional Groundwater Level Monitoring

The nearest observation well (observation well 75031, unique number 8406640) found in DNR's observation well network (Minnesota Department of Natural Resources, 2021) is over 6 miles to the northeast and is screened in a QBAA. Since water level monitoring in this well began in 2020, it cannot be used to evaluate regional long-term water level trends.

Riverview LLP has been monitoring groundwater levels at its nearby Dollymount Dairy (Figure 1) in two dedicated monitoring wells to comply with permit conditions. Although one well (798446) is screened at an elevation approximately 50 feet higher than the other well (819402), both are interpreted to be screened in the same aquifer owing to the similar hydraulic responses to pumping. The hydrographs presented for these wells in Figure 3 represent the historical water level record for each. Additionally, this graph illustrates groundwater use associated with the Dollymount Dairy, which began operation during the summer of 2017. This figure readily shows that the water levels in each of the wells respond to variations in pumping, as evidenced by sudden decreases in water level in response to increased water use. Moreover, the hydrographs show a clear downward trend in the water levels as pumping has increased over that same period. The decreasing water levels have not yet shown any signs of stabilizing. Although the water levels have decreased a minimum of 20 feet, they still remain approximately 30 feet higher than the 50-percent drawdown threshold for that aquifer.

Aquifer Test

The aquifer test was conducted by pumping Production Well PW-1 at an average discharge rate of 313 gpm from November 30, 2020 through December 29, 2020. Water levels were monitored for background prior to pumping and during the pumping and recovery phases of the test in the pumped Well PW-1, Observation Wells OW-1 and OW-2, and five private domestic wells (Tritz Ab North, 821979 Tritz, Tritz Ab South, 714966 Ringger, and Lichtsinn) (locations shown in Figure 2). Drawdown in response to pumping PW-1 was observed in all seven observation (non-pumped) wells, as shown on Figure 4, which shows displacement during the pumping and recovery phases of the test. The Consultant used results from Wells PW-1, OW-1, OW-2, Tritz Ab North, Tritz Ab South, and Lichtsinn, and applied several analytical methods and various boundary scenarios to determine hydraulic parameters using the aquifer hydraulics analysis software AQTESOLV (Duffield, 2007). They concluded that the transmissivity ranged from 600 to 5600 feet^2/day with a geometric mean of 2200 feet^2/day, while acknowledging that the complex glacial geology could be problematic in developing a model that provides a consistent match for the data from all the wells. They estimated storativity values to range from 0.00029 to 0.022, attributing the higher values to wells completed in the QBAA. Values of hydraulic conductivity were estimated for each well based on the results and aquifer thickness at each location, and yielded a geometric mean value of 22 feet/day.

DNR Analysis

Clearly, a hydraulic connection exists in the formations between Production Well PW-1 and all the other wells that were monitored. Since the Applicant is proposing to use the deep Cretaceous aquifer as the water supply source for its proposed facility, it seems reasonable to analyze only those data from locations located within the areal extent of the Cretaceous aquifer and hydraulically connected to that aquifer to determine the most relevant hydraulic parameters. DNR staff used AQTESOLV to analyze the data for this purpose. Data from Well OW-1 were analyzed since the well is screened in the same deep aquifer as Well PW-1. Additionally, data from Well OW-2 were also used to help evaluate the hydraulic characteristics of the leaky aquifer system since it is located between the two deep wells and screened in an overlying aquifer that is separated from the deep aquifer by an aquitard. The aquitard is comprised of glacial till and was measured to be 40 feet thick at Well PW-1.

Data from any of the other wells that were monitored were not included in this analysis because the hydrogeologic conceptual model indicates that they are located outside the extent of the deep aquifer or are screened in a vastly thinned portion of the unit. An attempt to include these data in the analysis corroborated this conclusion since we could not find a good fit to the model developed solely for the deep Cretaceous aquifer and overlying QBAA. The measured drawdown in these wells was greater than that predicted by the model for the Cretaceous aquifer. Although hydrogeologic heterogeneity does not allow analysis of these data in a meaningful way to characterize hydraulic parameters, the data can be qualitatively used to provide useful insights on the hydrogeologic system. Additionally, given that good data were collected from the two non-pumped wells, data from Production Well PW-1 were not used in the analysis since drawdown tends to be exaggerated through well inefficiency.

Figure 5 shows the drawdown in Wells OW-1 and OW-2 during the pumping phase of the aquifer test, as well as the derivative for each curve. The derivative for the drawdown curve of Well OW-1 is characteristic of that for a permeable channel aquifer embedded in a lower permeability matrix (Butler and Liu, 1991). This is consistent with the conceptual model that we developed based on the geology and drawdown response observed in the private domestic wells. Consequently, a number of potential no-flow boundaries were evaluated in AQTESOLV to approximate this model. Figure 6 illustrates the locations of four potential no-flow barriers. All were evaluated by applying them to the solution in AQTESOLV in various combinations. Ultimately, it was found that the no-flow boundary on the west side of the pumping wells (defined by Points A and D) provided the best solution fit. Although we know the hydrogeology is much more complicated than this representation, it provided the best empirical fit to the drawdown data for both wells.

Since the analysis involves a two-aquifer system separated by an aquitard, the Neuman and Witherspoon (1969) method was used to analyze the data. Figure 7 presents both drawdown and recovery data for Wells OW-1 and OW-2, and the analytical results using the Neuman and Witherspoon (1969) method with the inclusion of the western no-flow boundary. Later drawdown data as well as recovery data appear to show a good fit to the solution curves. However, to reduce the graphical distortion that occurs from using log-log axes, the data and solutions were also plotted using linear axes, as shown in Figure 8, which shows very tight agreement between the data and analytical model. This approach yielded a transmissivity of 730 feet^2/day and a storativity of 8.1E-5 for the deep aquifer has. Similarly, the shallow aquifer was estimated to have a transmissivity of 1600 feet^2/day and a storativity of 0.0039. Additionally, this analysis estimates the vertical hydraulic conductivity of the aquitard that separates these two aquifers to be 0.050 feet/day. Table 4 summarizes these aquifer parameters, and also includes aquifer parameters estimated for the QBAA at the Dollymount Dairy site (Walker, 2019) and the Cretaceous aquifer parameters estimated by the Consultant (LRE Waters, 2021) for the proposed Twelvemile site to allow for ready comparison. Overall, the parameters estimated for the QBAA at the Dollymount site are consistent with those that DNR determined for the QBAA at the Twelvemile site. Similarly, LRE Water's (2021) values for the Cretaceous aquifer at the Twelvemile site are generally consistent with DNR's values for that aquifer, with the exception of the storativity value. The upper range determined by LRE Water (2021) likely overestimates the storativity for a confined aquifer, and DNR's estimate appears to underestimate the value considered normal for a confined aquifer (Freeze and Cherry, 1979).

Table 4. Summary of Aquifer Parameters

Aquifer Parameter	Dollymount Dairy Site (Walker, 2019)	Twelvemile Site (LRE Water, 2021)	Twelvemile Site (DNR)
QBAA Thickness (feet) from Well OW-2	--	--	34
Transmissivity QBAA (feet^2/day)	1000 - 1300	--	1600
Hydraulic Conductivity QBAA (feet/day)	20 - 24	--	47
Storativity QBAA	0.001	--	0.0039
Aquitard Thickness (feet) from Well PW-1	--	--	40
Vertical Hydraulic Conductivity Aquitard (feet/day)	--	--	0.050
Cretaceous Thickness (feet) from Well PW-1	--	140	140
Transmissivity Cretaceous (feet^2/day)	--	600 - 5600	730
Mean Transmissivity Cretaceous (feet^2/day)	--	2200	--
Hydraulic Conductivity Cretaceous (feet/day)	--	--	5.2
Mean Hydraulic Conductivity Cretaceous (feet/day)	--	22	--
Storativity Cretaceous	--	0.00029 – 0.022	0.000081
Mean Storativity Cretaceous	--	0.0017	--

The drawdown and recovery response in the shallow aquifer is notably similar to that in the deep aquifer, with the water levels generally being within 1 foot of each other, indicating strong vertical hydraulic communication between the aquifers. The similar response in each well is also a function of the close proximity of Well OW-2 to Well PW-3. Leakage will be greatest near the pumping well, decreasing with radial distance. As a consequence of the focused leakage near Well OW-2, hydraulic impacts would be more readily propagated to the QBAA aquifer, resulting in greater drawdown in Well OW-1.

Water Use Sustainability and Potential Impacts

This section addresses uncertainties and potential impacts from long-term operation of the proposed production well. Specifically, it evaluates long-term aquifer productivity and safe yield, potential for long-term cumulative impacts with the Dollymount facility to the north, and the potential for domestic well interference.

Safe Yield and Projected Water Levels

To evaluate whether an aquifer can be sustainably pumped for a proposed project, DNR typically applies the results of the AQTESOLV aquifer test analysis to estimate drawdown over the life of the project. These results are then applied to conduct safe-yield analysis for the confined aquifer(s) and determine whether long-term pumping for facility operation would decrease groundwater levels below drawdown thresholds based the available head above the confined aquifer(s). LRE Water (2021) conducted this analysis for the Twelvemile site and concluded that overall that the long-term pumping proposed for the facility was not likely to result in decreased water levels below the established drawdown thresholds for the Cretaceous aquifer. Similarly, DNR also conducted this type of analysis based on the hydraulic parameters it determined for the deep Cretaceous aquifer with results indicating that long-term pumping at the facility could be sustainable. However, this analysis is based on the fundamental assumptions that are used in the aquifer test analysis. A key assumption that is critical to this analysis is that the aquifer is homogeneous and extends infinitely in all directions. As previously discussed, the deep Cretaceous aquifer is very limited in its lateral extent and cannot approximate an infinite aquifer on the scale of the analysis being conducted. The aquifer test results indicate that water is being supplied by the shallower QBAA aquifer, as evidenced by almost identical drawdown and recovery curves, and laterally from the less permeable matrix as indicated by the derivative curve diagnostics. In addressing the QBAA, LRE's analysis concludes that water levels in the Western aquifer (QBAA) could potentially exceed the 50 percent drawdown threshold (LRE Water, 2021). Given the complexity of the Quaternary hydrogeology, the limited lateral extent of the deep aquifer, and previous observations regarding the long-term performance of aquifers in this region, these results cannot be applied with any degree of confidence. Therefore, further qualitative analysis is conducted to provide a better understanding of the long-term impacts to the aquifer(s) from the proposed pumping of the facility.

Water Level Recovery

As previously noted, there is also strong lateral hydraulic connection between the pumped deep aquifer and private domestic wells located up to 1.6 miles away from Production Well PW-1, as evidenced by the drawdown response seen during pumping (Figure 4). Water level recovery was evaluated as a qualitative indicator of how readily the hydrogeologic system is recharged. Table 5 summarizes the maximum recovery that was initially measured in each of the wells as part of the aquifer test, including Production Well PW-1.

Table 5. Initial Water Level Recovery Following Aquifer Test

Well	Measurement Type	Maximum Drawdown Displacement (feet)	Last Measured Residual Displacement Following Pump Shutdown (feet)	Time Elapsed Since Pumping Ceased When Recovery Measurement Made (days)	Percent Recovery
PW-1	Logger	17.0	3.0	29.0	82.2
OW-1	Logger	14.3	4.1	16.5	71.4
OW-2	Logger	13.9	4.1	16.4	70.1
821979 Tritz	Manual	6.4	2.6	28.9	59.3
Lichtsinn	Manual	4.5	2.9	29.0	36.6

Well	Measurement Type	Maximum Drawdown Displacement (feet)	Last Measured Residual Displacement Following Pump Shutdown (feet)	Time Elapsed Since Pumping Ceased When Recovery Measurement Made (days)	Percent Recovery
Tritz South	Logger	5.0	3.2	16.4	36.5
714966 Ringger	Manual	3.4	2.5	22.9	26.6
Tritz North	Logger	2.5	2.4	16.5	6.4

There was a high level of variation in the percentage of recovery, which is consistent with the conceptual model that the glacial materials outside the Cretaceous aquifer are highly heterogeneous. Although the water level in Well PW-2 appears to have recovered 82 percent after 29.0 days, this likely overestimates the recovery since it reflects the greater measured drawdown within the well as it was pumping than would be measured in the aquifer immediately outside the screen. The slow recovery observed after the pumping ceased may be an issue of concern regarding overall sustainability of the aquifer. This is especially pronounced in Wells Tritz North and 714966 Ringger.

Typically, DNR requires that monitoring of the recovery phase be continued for a duration as long as the pump was on or until water levels in all monitored wells recover 95 percent, whichever is longer. As indicated in Table 5, none of the wells were monitored for more than 29 days after the pump was shut down during the aquifer test. DNR requested subsequent water level data from the Applicant to be able to better evaluate the nature of aquifer recovery, which is an indicator of recharge occurring to the aquifer. Long-term data were provided only for Observation Wells OW-1 and OW-2. Water level data, plotted as depth to water, for Wells OW-1 and OW-2 from before the beginning of the aquifer test through March 28, 2022, are presented in Figures 9 and 10, respectively. Figure 9 show that water levels in the deep Cretaceous aquifer took approximately 4 months to achieve 95 percent recovery, and Figure 10 shows that water levels in the overlying QBAA took approximately 9 to 10 months to reach 95 percent recovery. Recovery times are summarized in Table 6. Water levels in both wells experienced a slight downward deflection during the summer of 2021, which is likely attributable to increased water use at the nearby Dollymount Dairy or irrigation demand. However, full water level recovery did not occur in either well until over an entire year had elapsed, indicating that recharge is very limited and not likely to be sufficient to sustain long-term operation of the proposed facility.

Table 6. Long-Term Water Level Recovery Following Aquifer Test

Well	Measurement Type	Time Elapsed for 95 Percent Recovery (months)	Time Elapsed for Full Recovery (months)
OW-1	Logger	4	14
OW-2	Logger	9 - 10	15

Another phenomenon occurred during the aquifer test that indicates limited transmission of groundwater and propagation of hydraulic effects outside the extent of the Cretaceous aquifer. There was a lag between the time that pumping ceased to when the maximum displacement was measured in the five private domestic wells not screened directly in the Cretaceous aquifer. This time lag was approximately 3.5 hours in wells 821979 Tritz and Lichtsinn, 2 days in Tritz South, 9 days in 714966 Ringger, and over 11 days in Tritz North. This indicates lower hydraulic diffusivity values for some of the glacial materials than the Cretaceous aquifer. This limits how much water can be produced from the surrounding glacial drift materials, an effect that would likely become more pronounced over the long term. This further corroborates the analysis that indicates that groundwater supplies are limited in the area.

Potential Cumulative Impacts

As previously indicated, there are two other high-capacity appropriators in the area—the Riverview Dollymount Dairy (2007-0361) and the City of Dumont (1984-1161) to the north and northwest, respectively. No discernible drawdown impacts were observed in the monitoring wells at the Dollymount site during the Twelvemile aquifer test. Since the Dollymount Dairy is permitted for 86.5 MGY and Dumont only for 6 MGY, cumulative impacts from Dollymount are of the most concern. This facility only began pumping in 2017, and it extracted in excess of 71 MGY in 2018 and 2019, and exceeded its permitted volume in 2020 and 2021 with total volumes of 91.7 MG and 99.2 MG, respectively. However, there appears to be a downward trend in water levels in in the deep (819402) and shallow (798446) observation wells at the site since pumping began in 2017 as previously discussed and illustrated in Figure 3. Continued monitoring is required to determine whether this is the start of a long-term trend or if water levels will stabilize. Given the site's proximity to the proposed Twelvemile site, the limited extent of aquifers in the regions, and the large volumes of water that both sites would pump, it seems likely that pumping at the Twelvemile facility as proposed would exacerbate long-term cumulative impacts.

Potential Well Interference

Table 7 of the Aquifer Test Report (LRE Water, 2021) identified 19 private domestic wells within 2 miles of Production Well PW-1, and appears to be complete. Given that significant drawdown was observed during the aquifer test at a distance of over 1.6 miles away, DNR expanded the radius around Well PW-2 to 2.5 miles to evaluate the risk of domestic well interference for evaluating domestic well interference at the proposed Twelvemile site. This approach, which is also consistent with that used by Walker (2019) for the Dollymount site, resulted in the identification of 32 wells, as listed in Table 7 (placed after the text of this report due to its size) and shown on Figure 11.

Of the 32 wells identified, two have been abandoned (Wells Tritz Ab North and Tritz Ab South), so impacts are not an issue, leaving only 30 wells to be evaluated. Although some of the well logs in CWI lacked construction information, consultation with a local driller, Reinart Well Drilling, was able to furnish the information for a number of wells. However, nine of the wells still lack the construction information necessary to evaluate the risk of going out of water as a result of long-term pumping at the facility, so the impacts cannot be evaluated and are unknown. Additionally, three of the wells, Wells 276656, 276646 (also one of the wells without construction information), and 630979, have unverified locations in the County Well Index.

To evaluate whether domestic wells could be impacted by the lower water levels from long-term pumping at the facility, it is important to know the height of the water column above the pump anticipated in each as a result of pumping. In evaluating the risk to wells, the DNR generally classifies the risk of well impacts to wells according to the height of water above the pump as follows based on estimated water level response:

- High risk—less than 10 feet above pump intake;
- Moderate risk—10 to 20 feet above pump intake; and
- Low risk—greater than 20 feet above pump intake.

Since the complex aquifer hydraulics of the area do not allow us to reliably predict drawdown at the domestic wells, a conservative approach was taken using the predictive model that DNR developed based on the initial aquifer test analysis for the deep Cretaceous aquifer. Although the model cannot be reliably applied to predict long-term drawdown, it was used to help identify which domestic wells would have the highest potential to be impacted by long-term pumping at the Twelvemile site. As previously indicated, this model underestimates the drawdown in all the domestic wells from pumping Well PW-1. Modeling results indicated that water levels in Well OW-1 would decrease approximately 38 feet after 30 years of pumping at 313 gpm. To evaluate the potential risk for domestic water supply wells, a worst-case drawdown scenario was evaluated based on the assumption that the domestic wells would also undergo the maximum drawdown of 38 feet.

Based in this worst-case scenario of drawdown of 38 feet, 16 of the 30 wells within 2.5 miles of Pumping Well PW-1 do not appear to be at risk of going out of water during 30 years of pumping at the proposed facility. One well was determined to have a moderate risk of going out of water, and four wells were determined to be at high risk. Risk for the remaining nine wells could not be determined. These wells should be inspected to determine 1) whether they have been abandoned, and, if not, 2) the height of the column of water above the pump.

However, note that this analysis is only used to identify domestic wells with the potential to be at the greatest risk of impact, and should not be used as a predictive tool for actual water level impacts.

Conclusion and Technical Recommendations

The Applicant conducted an aquifer test in support of its application for an appropriation permit to pump water from what is interpreted as a deep Cretaceous aquifer to supply water to the proposed Twelvemile Dairy at a combined rate of 325 gpm, and an annual withdrawal of 153 MGY. The aquifer is laterally limited in extent and is overlain and surrounded by a complex sequence of unconsolidated Quaternary glacial deposits.

The Applicant proposes to extract water from the deep Cretaceous aquifer which was pumped during the aquifer test. A number of wells were monitored during the aquifer test, including several private domestic wells. Although all of the wells showed drawdown in response to pumping, only two were located within the areal extent of the Cretaceous aquifer—Well OW-1, screened in the Cretaceous aquifer, and Well OW-2, screened in an overlying QBAA. The results from these wells were analyzed separately to characterize hydraulic parameters of the Cretaceous aquifer and the overlying leaky aquifer system. Good curve matches were achieved by analyzing the results of both wells using the analytical method developed by Neuman and Witherspoon (1969) for leaky aquifer systems. This analysis estimated that the transmissivity and storativity values, respectively, to be 730 feet^2/day and 8.1E-5 for the deep Cretaceous aquifer, and 1600 feet^2/day and 0.0039 and the shallower QBAA. Additionally, this analysis estimated the vertical hydraulic conductivity of the aquitard that separates these two aquifers to be 0.050 feet/day.

The drawdown response observed in the remaining private domestic wells that were monitored qualitatively indicate that the hydrogeologic system is hydraulically connected, but could not be analyzed in a meaningful way because of the very heterogeneous nature of the unconsolidated Quaternary deposits and the limited extent of the Cretaceous aquifer.

A forward solution model can be run based on the parameters determined for the deep Cretaceous aquifer to predict water levels from pumping as proposed over the life of the facility. However, this approach was determined to be flawed for the following reasons:

1. The aquifer test analysis is based on the assumption that the aquifer is infinite in extent. However, the Cretaceous aquifer, which is the proposed water source, has a very limited areal extent and is overlain and surrounded by complex glacial terrane that provides an undefined network of hydraulically connected

materials that provide recharge to the aquifer; the extent of this network is unknown, and it is likely to be bounded at some distance;

2. The pumping phase of the test was 29 days, a duration that may not be long enough to detect no-flow boundaries at distance;
3. Overall, groundwater levels were slow to recover once the pump was turned off, indicating that the aquifer is slow to recharge. The greatest recovery was observed in wells screened in the Cretaceous aquifer. Water levels in Production Well PW-1 appeared to recover 82.2 percent after 29 days. Water levels in Wells OW-1 and OW-2 recovered 71.4 and 70.1 percent, respectively after about sixteen and a half days. Long-term monitoring of recovery indicated that full recovery did not occur within the duration of one year after pumping ceased;
4. It took an unexpectedly long time for the hydraulic impacts of pumping to propagate to wells outside the Cretaceous aquifer, as evidenced by the time lag between when pumping stopped and the time at which the maximum drawdown was measured;
5. Since production began at the nearby Dollymount Dairy over four years ago, groundwater levels have decreased each year and have not yet shown signs of stabilizing; and
6. In general, aquifers in western Minnesota tend to be very limited in their areal extent. Groundwater resources are typically meager in this geography, as evidenced by the difficulties historically encountered in trying to supply high-capacity wells over the long term.

The hydrogeology at the site is complicated, particularly beyond the limits of the Cretaceous aquifer. The Cretaceous aquifer appears to be productive initially because it relies on vertical leakage from the overlying shallower aquifer and lateral leakage from the lower permeability matrix that surrounds it. It does not ensure that the system can be sustainably pumped over the life of the project, given the complexity of the site and the uncertainty associated with the issues discussed above.

In light of the conclusions presented above, we recommend that an alternate primary water source be used. If the deep Cretaceous aquifer is to be used at all, it should only be used as a contingency for temporary backup purposes since sustained pumping as proposed will likely lead to a case of groundwater mining. It could take years to decades to recharge it to current conditions. If it is permitted for water use as a temporary backup supply, we further recommend the following regarding the use of groundwater at the proposed facility:

1. An additional observation well nest should be installed roughly midway between the proposed facility and the Dollymount Dairy for regional long-term monitoring of water levels. First, a borehole should be advanced at that location to crystalline bedrock with continuous sampling to define the hydrostratigraphy at that location. This information will be used in consultation with DNR to determine the number of observation wells in the nest, and the depths at which they should be screened. The observation wells shall be constructed according to Minnesota well code and have a screen that is 5 to 10 feet in length and a nominal diameter of 2 or 4 inches.
2. An accurate flow meter shall be installed on each pumped well in accordance with the manufacturer's specifications that allows cumulative volume readings with a totalizer meter as well as instantaneous discharge rate readings. The total volume pumped for each production well shall be recorded at a minimum frequency of once per month.

3. Transducer data loggers shall be set to read depth to water (feet below the measuring point) at least once every hour year round in specified observation wells (see below). Additionally, manual groundwater level measurements shall be taken once per month in each of the observation wells. Data loggers should be downloaded concurrently with manual measurements. Long-term monitoring of water levels as described should occur in the following wells:
    a. Observation Wells OW-1 (deep Cretaceous) and OW-2 (shallow QBAA) at the proposed Twelvemile facility;
    b. Observation Wells 819402 (deep) and 798446 (shallow) at the Dollymount facility; and
    c. In the wells of the observation well nest to be installed between the two facilities.
4. Permit holder monitoring data, including water levels and volumes pumped, shall be reported in electronic format to the DNR on an annual basis or upon request. DNR and Riverview shall review data annually.
5. A licensed well contractor should lower the pumps in the four wells determined to have the highest potential of going out of water during facility operation;
6. The nine private domestic wells lacking construction information should be inspected by a licensed well contractor to determine 1) the height of the column of water above the pump, or 2) whether they have been abandoned.
7. Permitting staff should communicate with the City of Dumont and keep them apprised of developments regarding groundwater withdrawal at the Riverview facilities, and identify any issues or concerns that the city may have.
8. Amend the appropriation permit for the Dollymount Dairy (2007-0361) to include conditions based on the drawdown thresholds that have been determined for that facility.

Additionally, given that the Dollymount Dairy exceeded its permitted volume in 2020 and 2021, it must either implement measures that will keep its water use within the permitted volumes, or apply for a permit amendment (2007-0361) to increase the annual maximum allowable volume of water pumped. This may result in additional investigation, and does not provide assurance that a permit amendment will be granted.

Given the concerns regarding the ability to supply groundwater to both the Dollymount and proposed Twelvemile facilities, it is important that a reliable long-term source of water is used and the groundwater resource is protected if an appropriation permit is issued for backup purposes for the proposed Twelvemile facility.

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Table 7

Table 7. Potential Domestic Well Risk

Unique Number	Well Owner	UTME (m)	UTMN (m)	Distance from Pumped Well (miles)	Well Depth (feet)	Static Water Level (feet below ground surface)	Drop Pipe Length (feet below ground surface)	Water Above Pump Intake (feet)	Water Above Pump Intake after 38 feet Drawdown Subtracted (feet)	Interference Risk
Unknown	Randal and Melissa Tritz (Ab North)	238576	5063051	0.8	128	14	None	Not Applicable	Not Applicable	Not Applicable
Unknown	David and Janelle Tritz	240288	5064787	0.8	255	30	80	50	12	Moderate
Unknown	Alan and Katherine Behrens	240601	5064607	0.8	75	14	54	40	2	High
Unknown	Kevin Lichtsinn	240491	5065818	1.4	268	11	120	109	71	Low
214348	Todd and Valerie Tritz	239985	5061729	1.4	262	20	140	120	82	Low
821979	Joanne and Milo Tritz	240117	5061687	1.4	264	19	100	81	43	Low
Unknown	Melissa Tritz (Ab South)	238629	5061655	1.5	265	20	None	Not Applicable	Not Applicable	Not Applicable
714966	Robert and Margaret Ringger	241978	5063058	1.6	239	16	160	144	106	Low
244468	Vernon Behrens	241643	5062197	1.7	242	15	90	75	37	Low
546473	Randy Behrens	241651	5062174	1.7	241	35	100	65	27	Low
276646	V.J. Behrens	241591	5062119	1.7	76	15	Unknown	Unknown	Unkown	Unknown
Unknown	Thomas Tritz	238016	5061652	1.7	119	35	100	65	27	Low
1000013924	Craig Lichtsinn	240155	5066626	1.8	150	8	110	102	64	High, if jet pump
276656	Donald Tritz	236459	5064099	1.9	315	30	180	150	112	Low
214350	Don Tritz	236448	5064066	1.9	387	30	180	150	112	Low

Unique Number	Well Owner	UTME (m)	UTMN (m)	Distance from Pumped Well (miles)	Well Depth (feet)	Static Water Level (feet below ground surface)	Drop Pipe Length (feet below ground surface)	Water Above Pump Intake (feet)	Water Above Pump Intake after 38 feet Drawdown Subtracted (feet)	Interference Risk
411972	Adam Lichtsinn	240321	5066919	2.0	154	21	90	69	31	Low
630979	Craig Lichtsinn	240355	5067014	2.0	124	20	100	80	42	Low
517046	James Schwebach	240198	5060745	2.0	105	12	60	48	10	High
196981	Tom Schwebach	240167	5060665	2.0	116	20	60	40	2	High
744970	Ryan Pederson	242910	5062959	2.2	128	12	120	108	70	Low
744956	Tom Tritz	236218	5062585	2.2	119	20	100	80	42	Low
197484	Tom Tritz	236220	5062575	2.2	147	14	126	112	74	Low
546483	Gerald Frisch	242633	5065411	2.2	235	16	160	144	106	Low
727140	Ryan Pederson	243034	5062947	2.3	233	24	Unknown	Unknown	Unknown	Unknown
517036	Loren Pederson	243092	5062875	2.3	233	24	Unknown	Unknown	Unknown	Unknown
255340	Pat Leonard	243104	5062873	2.3	228	22	Unknown	Unknown	Unknown	Unknown
Unknown	Pearl Behrens	243133	5064461	2.3	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Unknown	Orval Rinke and Sara Lee	239824	5067532	2.3	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Unknown	John and Shirley Tritz	235741	5064642	2.4	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
247582	Loren Pederson	243254	5062888	2.4	265	0	Unknown	Unknown	Unknown	Unknown
823620	Randy Tritz	240151	5060038	2.4	204	25	160	135	97	Low
Unknown	Behrens	243495	5064661	2.5	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

Figures

Figure 1. Location of Proposed Twelvemile Dairy

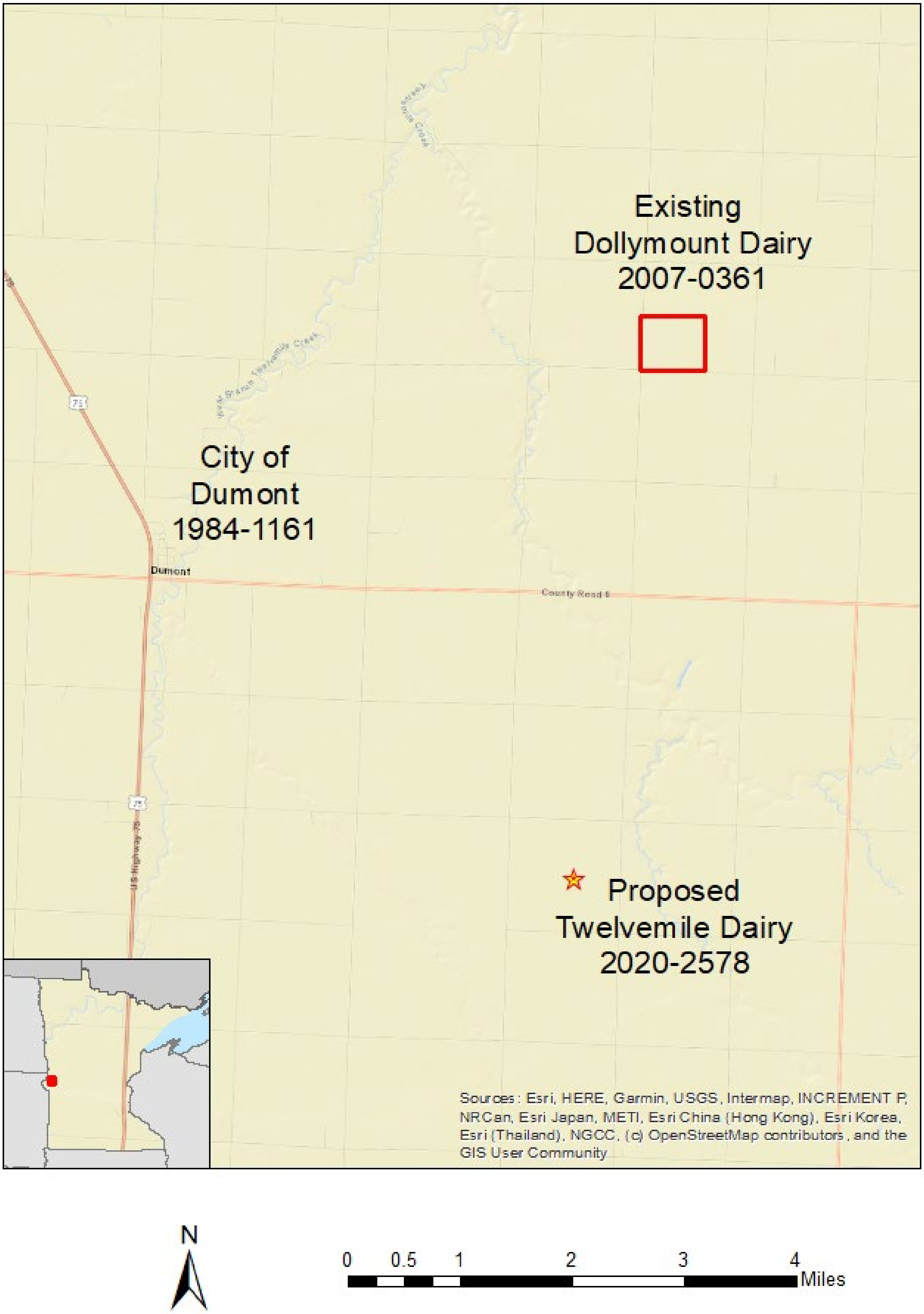

Figure 2. Location of Aquifer Test Wells

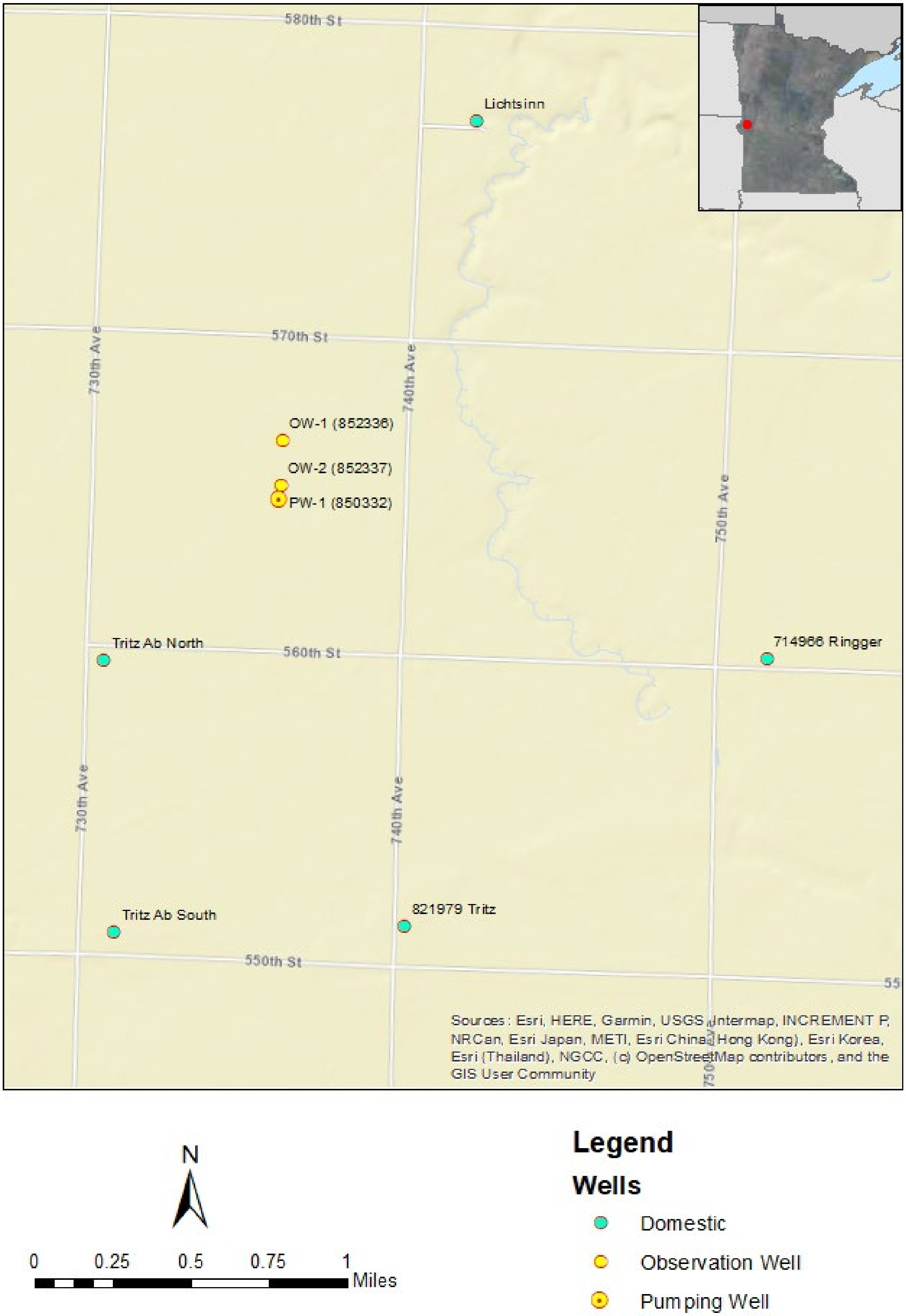

Figure 3. Groundwater Use and Groundwater Levels at Dollymount Dairy

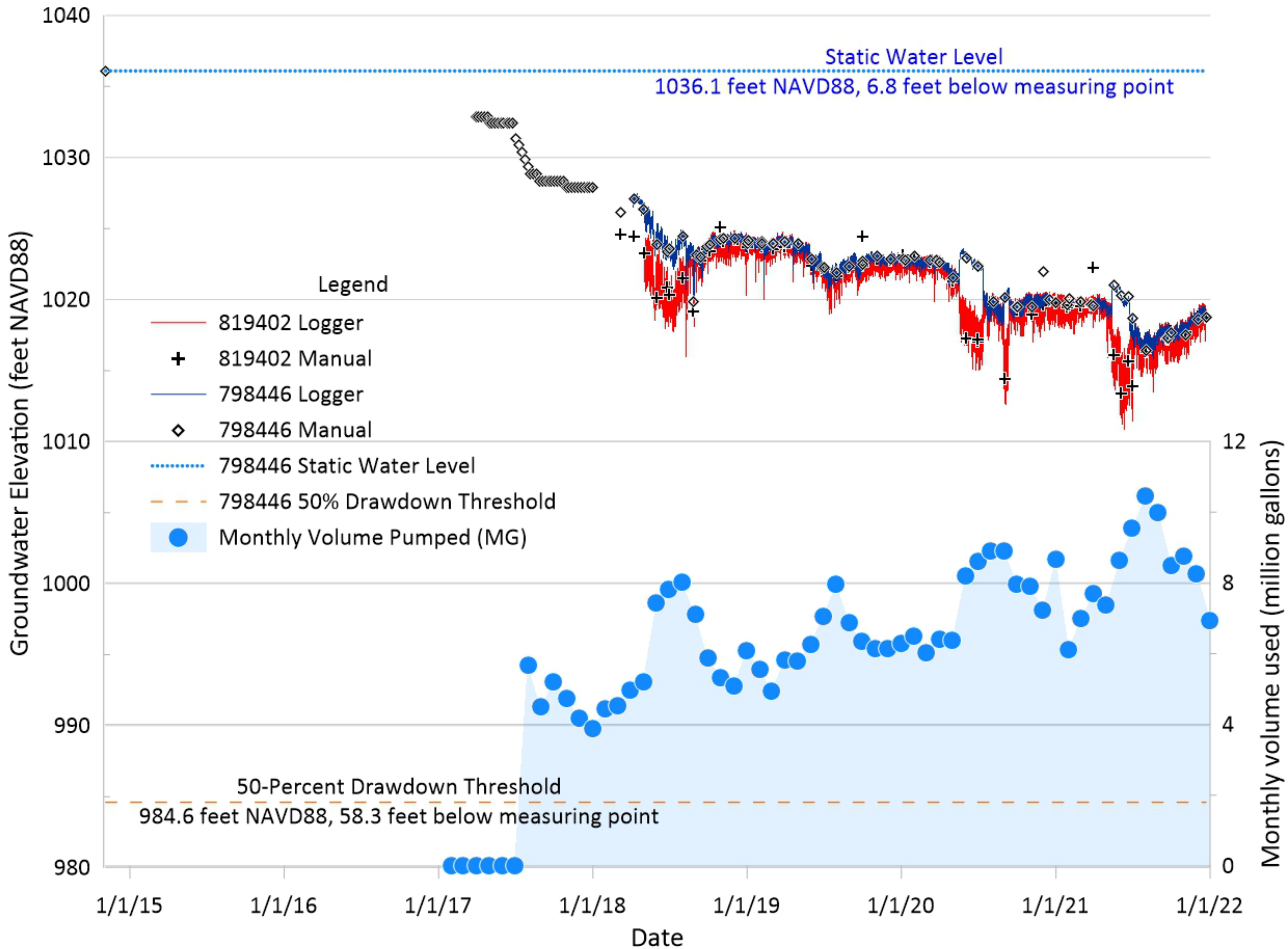

Figure 4. Water Level Displacement for All Wells Monitored during Aquifer Test

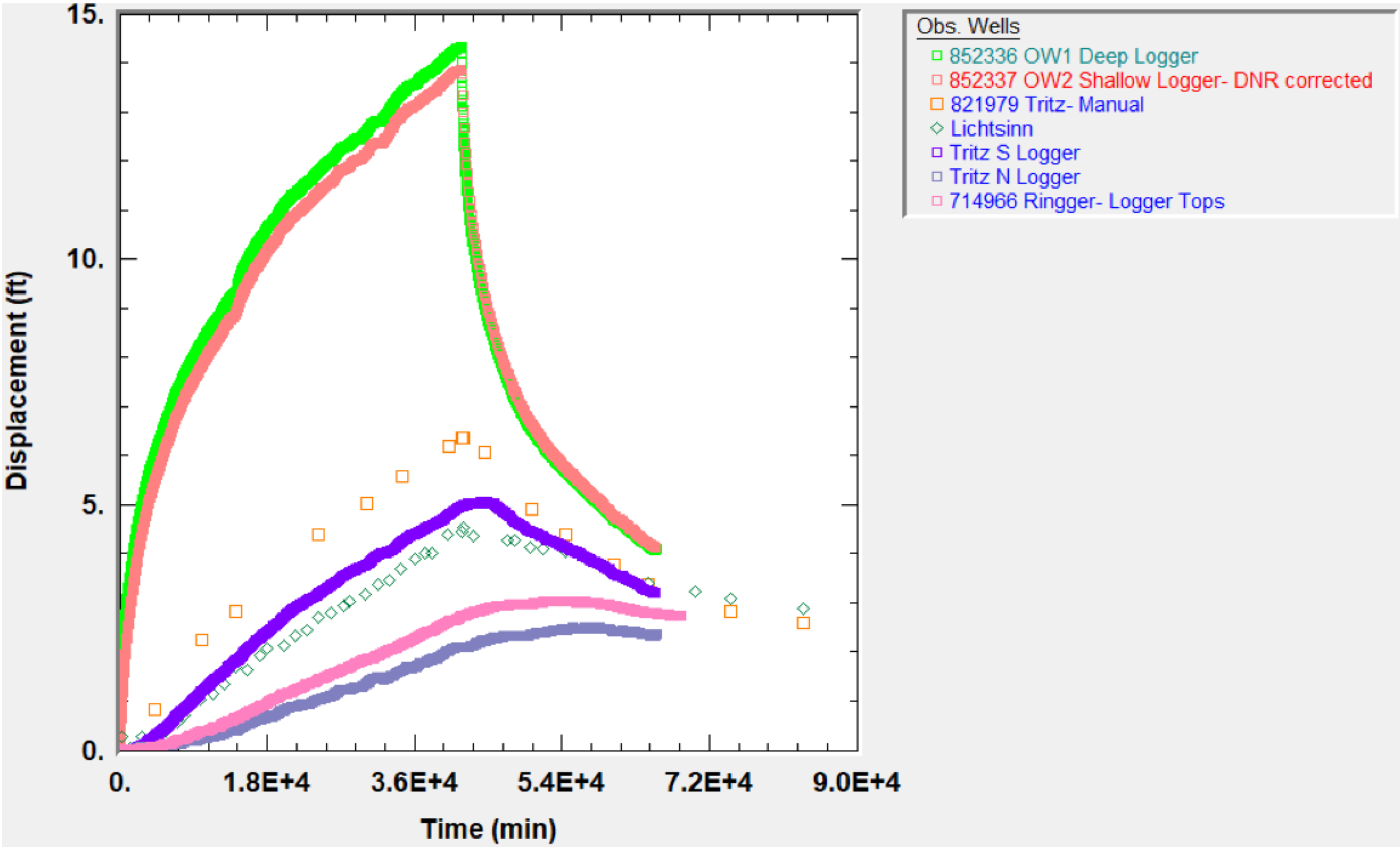

Figure 5. Drawdown Displacement and Derivatives for OW-1 and OW-2

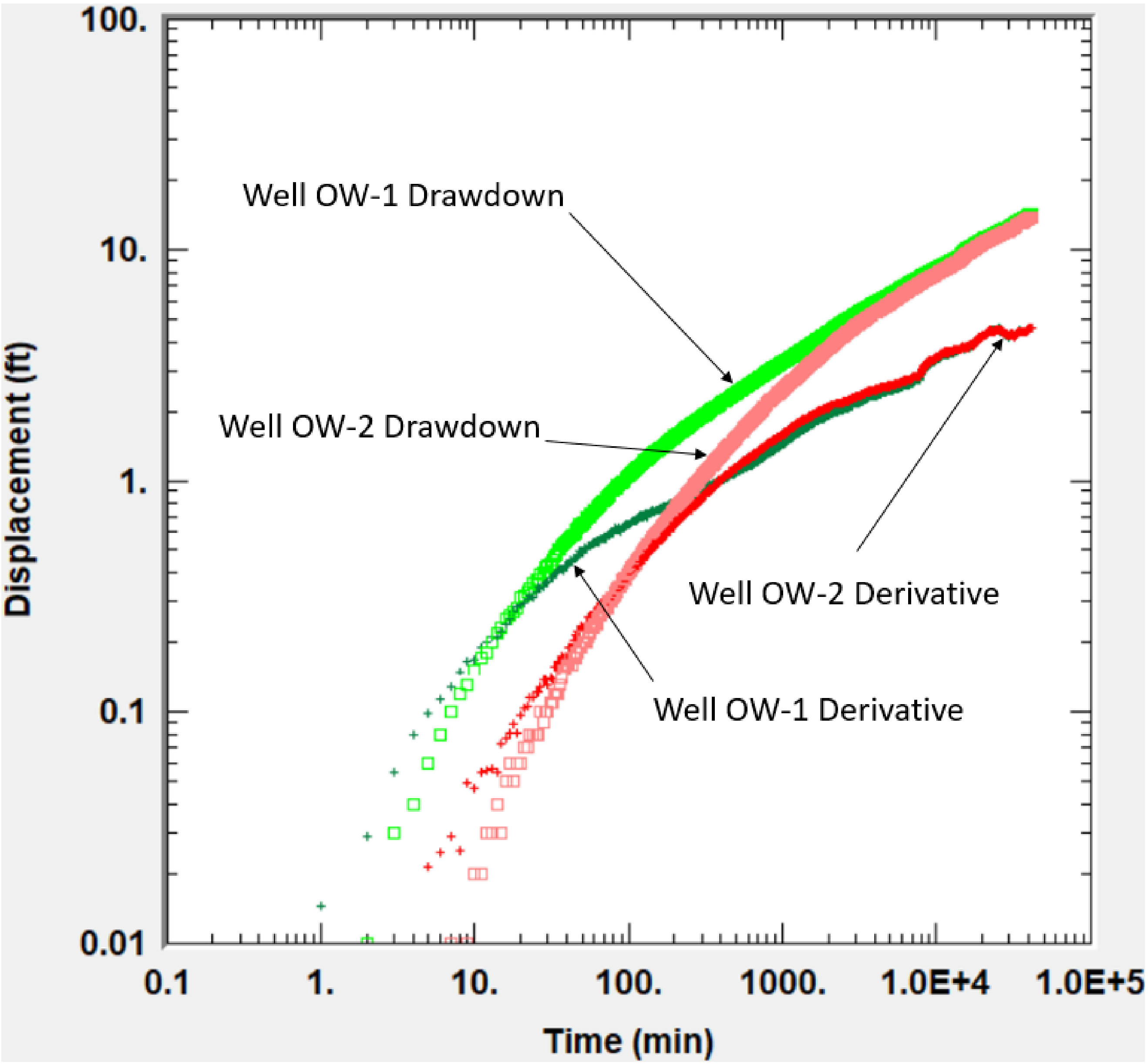

Figure 6. Potential No-Flow Boundaries in Analysis

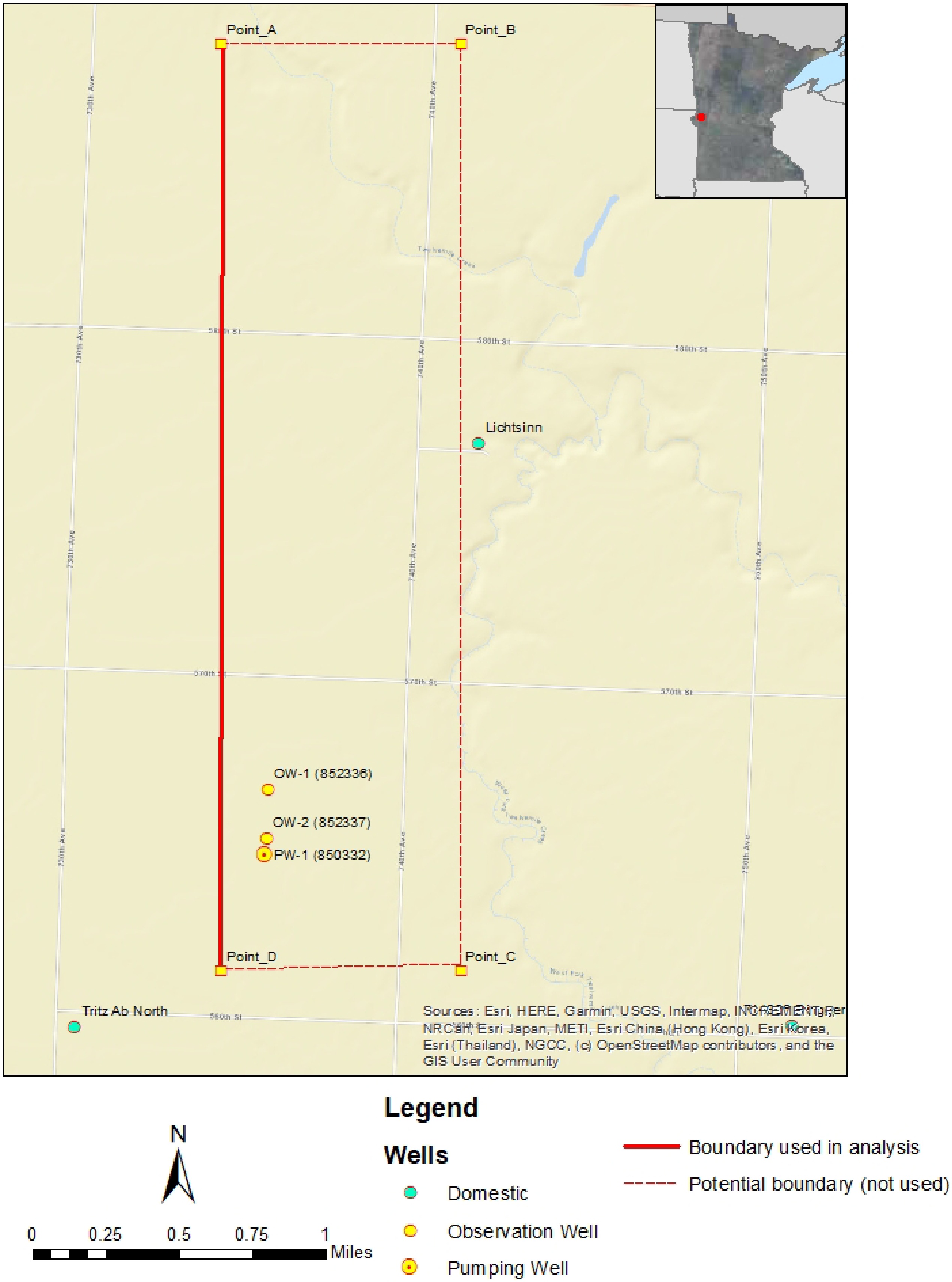

Figure 7. Aquifer Test Results (log-log axes) Using Neuman and Witherspoon (1969)

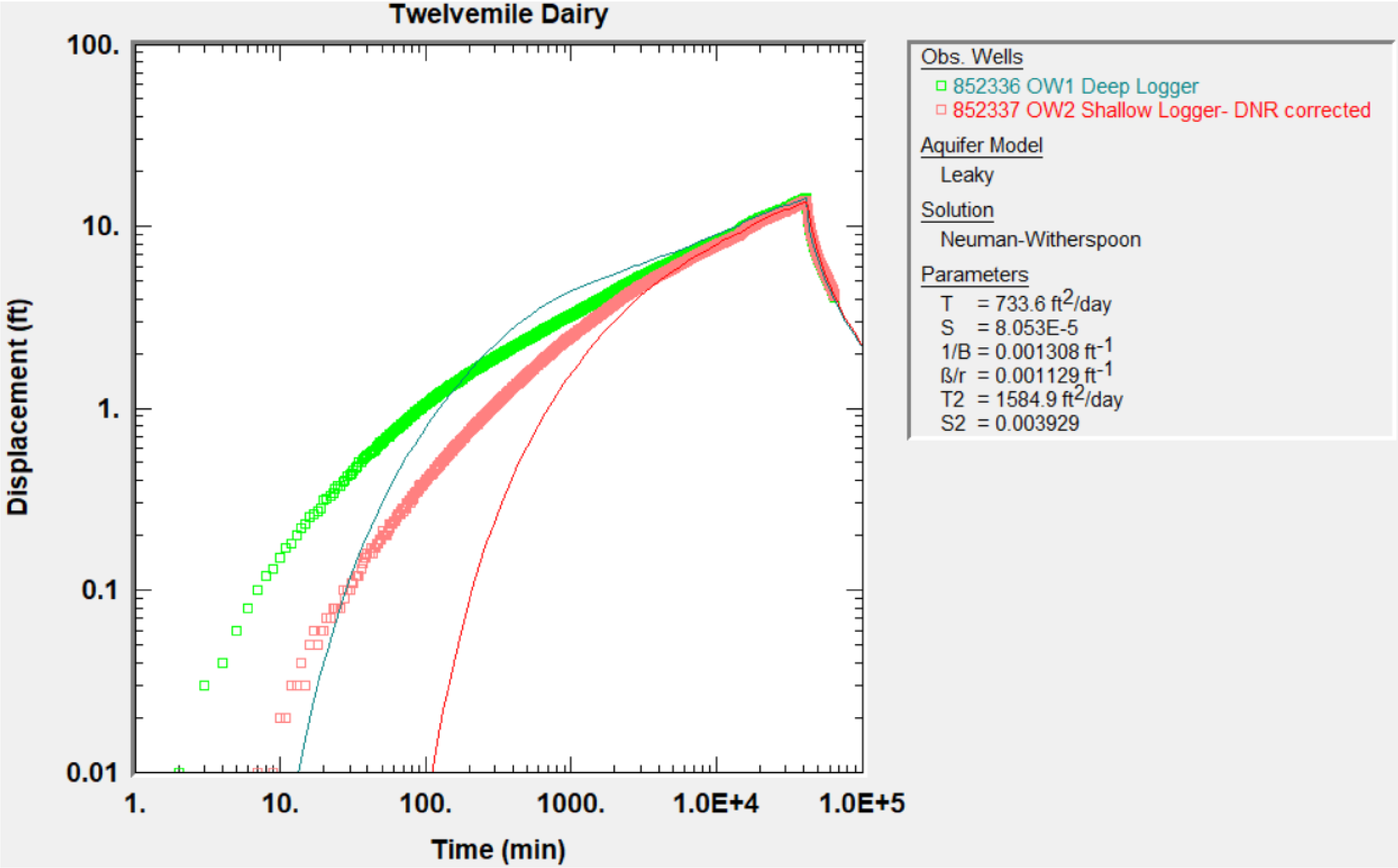

Figure 8. Aquifer Test Results (linear axes) Using Neuman and Witherspoon (1969)

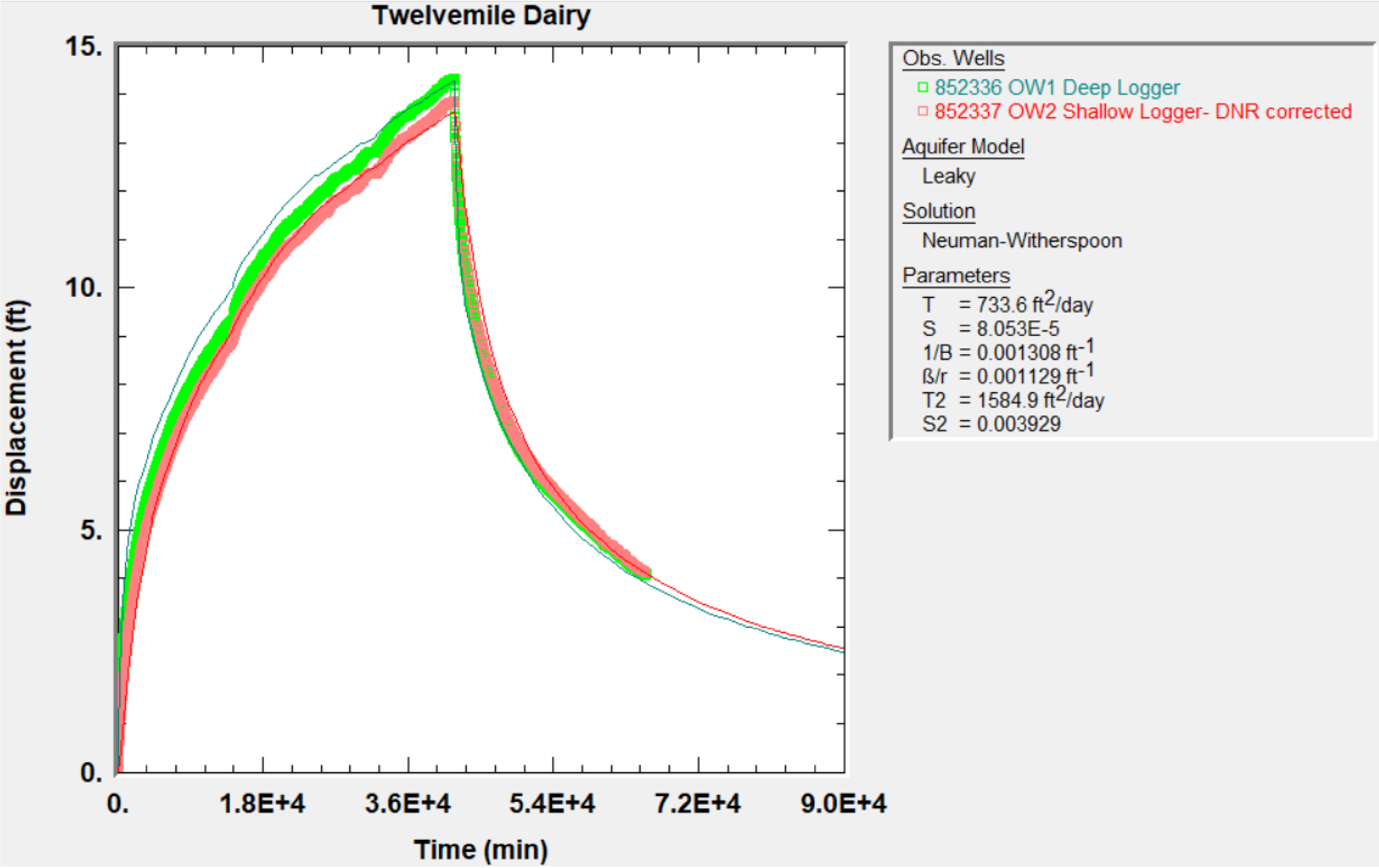

Figure 9. Long-Term Water Level Recovery in Well OW-1

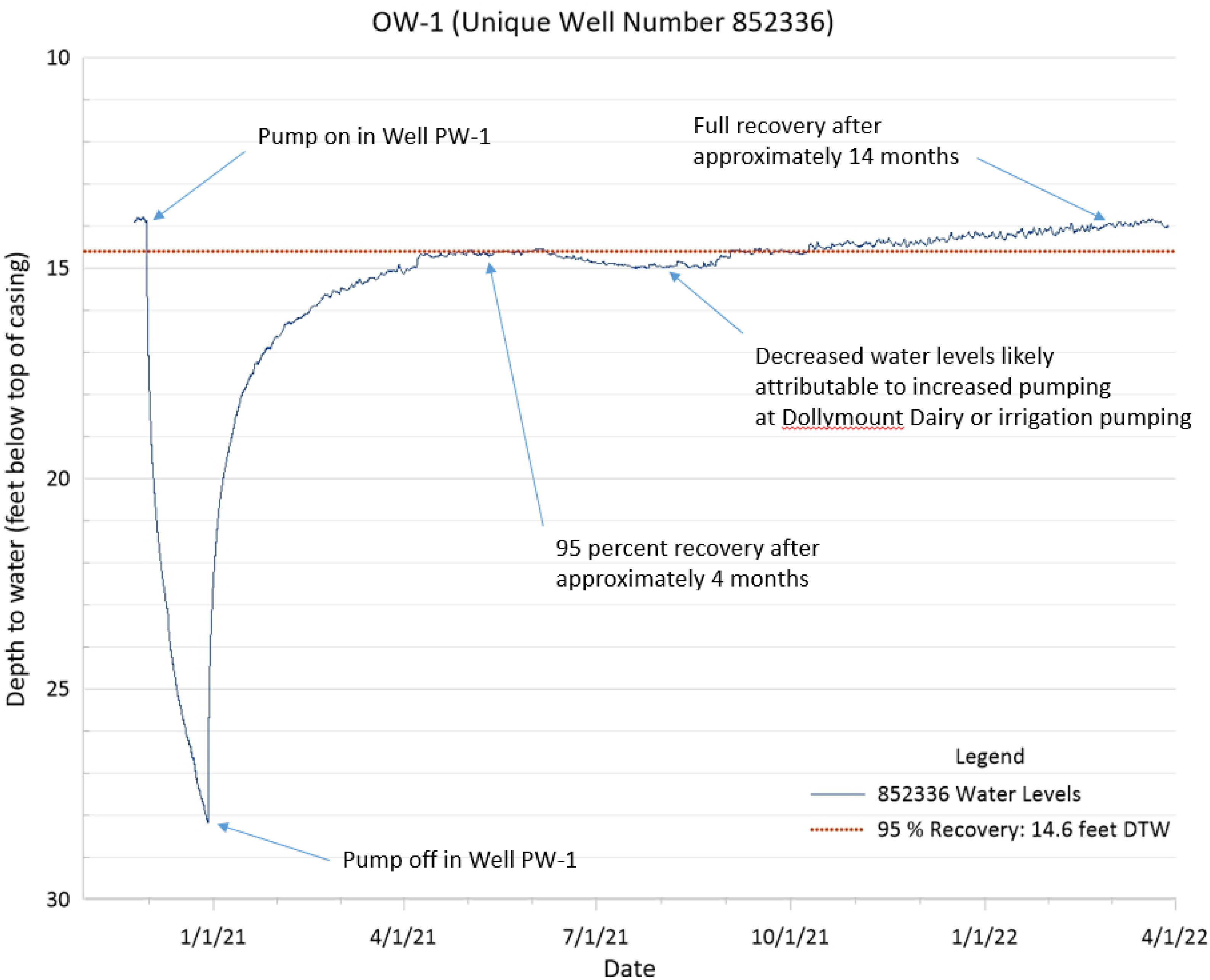

Figure 10. Long-Term Water Level Recovery in Well OW-2

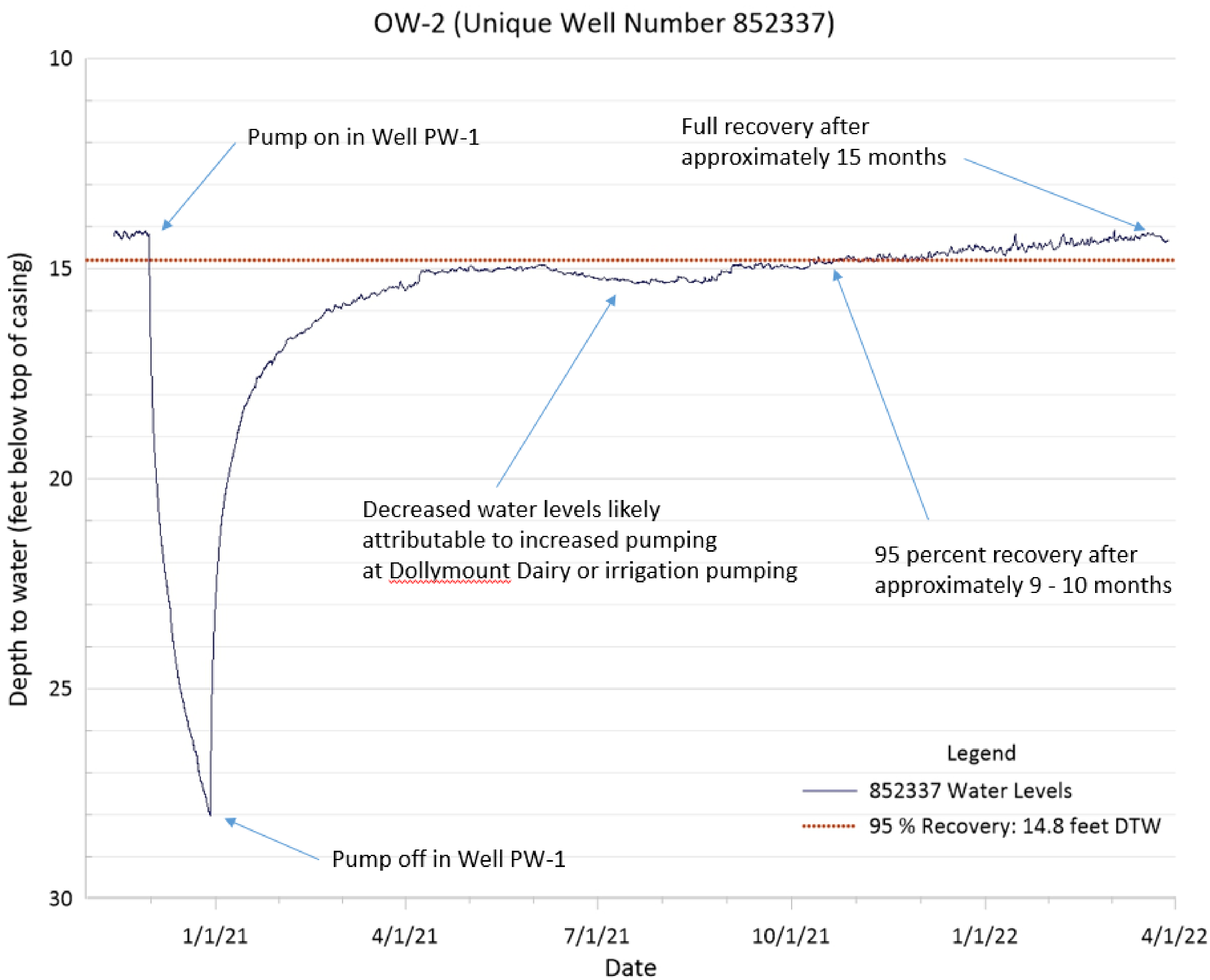

Figure 11. Domestic Wells within 2.5 Miles of Production Well PW-1