technical memo

Project Name	BCWD Groundwater Coordination	**Date**	3/2/2023
To / Contact info	BCWD Board of Managers		
Cc / Contact info	Karen Kill; Camilla Correll		
From / Contact info	Stu Grubb, PG ,Matt Hegland, GIT;		
Regarding	Groundwater pumping wells near Brown's Creek		

Background

BCWD has for many years questioned whether high capacity pumping wells near Brown's Creek have an effect on the hydrology of the creek, particularly base flow. Base flow supported by groundwater coming into the creek is critical to maintaining the cold water fishery, particularly during hot summer months. Oak Glen golf course has two high capacity irrigation wells near Brown's Creek (Figure 1).

In 2022 the BCWD Board authorized EOR to develop a plan for a groundwater pump test in the area of Oak Glen Golf Course and Brown's Creek. A pump test involves pumping water from a well for an extended period of time (usually 24 to 72 hours) and measuring the water level drawdown in nearby wells. The resulting data can be analyzed to determine aquifer properties such as permeability and delayed yield (storativity). These parameters are critical for calculating groundwater flow and developing computer models to be used for watershed management. The Board intended to review the plan, the estimated costs, and the likely outcomes/benefits to decide whether to proceed with the pump test.

In the process of reviewing geologic and groundwater data, EOR discovered some important relationships between the golf course irrigation wells and water levels in nearby observation wells. Further analysis of the data led to a better understanding of the local geology and groundwater flow, which will then be used to refine the pump test design. This memo describes the local geology, the irrigation wells and pumping wells, our current understanding of groundwater flow, and recommendations for further study.

Geology

A geologic cross section of the area is located on Figure 1 and shown on Figure 2. BCWD lies on the eastern edge of the so-called Twin Cities basin. The bedrock units are tilted and rise to the east. The surface topography generally dips toward the Saint Croix River. These two factors combined mean that lower geologic formations that are deeply buried in other parts of the Twin Cities are close to the surface in BCWD. The geologic formations are described below from top to bottom.

<u>Quaternary (Glacial) Deposits</u>

Quaternary deposits are the most recent formation and consist primarily of sediment deposited by glaciers. The deposits are an unconsolidated mixture of sand silt and clay. Varying thicknesses of quaternary deposits overlay the bedrock in almost all parts of BCWD.

Oneota Dolomite

The Oneota Dolomite is the lower member of the Prairie du Chien Group formation that extends throughout the Twin Cities area. It is predominantly a yellowish-gray to light brown, medium- to thick-bedded dolostone.

Jordan Sandstone

The Jordan sandstone is dominantly a white to yellow, very fine- to coarse- grained quartz sandstone. It can vary from 65 to 80 feet thick.

Saint Lawrence Formation

The Saint Lawrence formation is principally light gray to yellowish-gray and pale yellowish-green siltstone with interbedded, very fine-grained sandstone and shale. The formation is 35 to 45 feet thick.

Tunnel City Group

The Tunnel City Group is primarily sandstone and shale, but features can vary throughout the area. It ranges from 160 to 180 feet thick.

Wonewoc Sandstone

The Wonewoc Sandstone is composed mostly of fine- to coarse-grained, light gray, cross-stratified, quartz sandstone. The thickness of the formation is 45 to 75 feet.

Eau Claire Formation

The Eau Claire Formation is composed of yellowish-gray to pale olive-gray, fine- to very fine-grained, sandstone, siltstone, and shale. The formation ranges from 80 to 100 feet thick.

Mount Simon Sandstone

The Mount Simon Sandstone is a pale yellowish-brown to light gray, medium- to coarse- grained, quartz sandstone. It has a maximum thickness of about 280 feet.

Aquifers

Aquifers are geologic formations or groups of formations that contain usable amounts of groundwater. Aquifers can be divided into three basic types:

- *Unconfined* aquifers do not have an impermeable layer above them. For this study, this is also the uppermost or water table aquifer.
- *Confined* aquifers have an impermeable layer above and below.
- *Leaky confined* aquifers have confining layers that are mostly impermeable but also leak some water into the aquifer.

The aquifers considered for this study are, from top to bottom:

Quaternary (Glacial) Aquifer

The glacial aquifer varies in thickness throughout the project area. It is the uppermost or water table aquifer, so it is in contact with Brown's Creek and other groundwater dependent natural resources.

The hydraulic connection to lower bedrock aquifers likely varies from place to place. Some areas may have thick clay layers that act as lower confining units, while some areas without clay layers may have a good hydraulic connection to the bedrock.

Jordan Aquifer

The Jordan aquifer is one of the most heavily used aquifers in the Twin Cities area. It is confined above by the Oneota dolomite, where present, and it is confined below by the Saint Lawrence Formation. The Saint Lawrence Formation is a leaky confining layer and is even considered part of the Jordan aquifer in some areas.

Tunnel City/Wonewoc

The Tunnel City and Wonewoc Formations are generally considered to be hydraulically connected. This is a widely used aquifer for drinking water, but it is generally not used where the shallower, more productive aquifers are present. The Tunnel City/Wonewoc is a leaky confined aquifer, bounded on the top by the Saint Lawrence Formation and on the bottom by the Eau Claire Formation. Where the Saint Lawrence Formation is not present, the Tunnel City/Wonewoc likely has a hydraulic connection to the glacial aquifer.

Mount Simon

The Mount Simon aquifer is an important regional drinking water source. It is too deep to have a significant influence on this study.

Wells

The Oak Glen Golf Course has two irrigation wells onsite. Well No. 1 draws water from the Jordan Aquifer and Well No. 2 draws water from the Tunnel City/Wonewoc Aquifer. Note that both wells have solid casings from the ground surface to the top of the aquifer, so that they only draw water from one aquifer each. See Figure 1 for the locations of the wells and Table 1 for the relevant well data.

Table 1 - MPARS Well Data

Well	Permit Number	Well Number	Permit Total Volume (MGY)	Installation Pumping Rate (GPM)
No. 2	1986-6106	151581	30	400
No. 1	1986-6107	151580	30	275

The golf course wells are operated manually by a switch in each pump house. Maintenance staff turn on one well when they notice that the water level in the irrigation pond is getting low. They have only used Well No. 2 for the last several years. Each pump has an inline meter that records the total amount pumped but does not record the time that the pump turned on or off. The total amount pumped is read once per month and reported annually to the DNR, along with the pumping rate, as required by their water appropriations permit.

The Minnesota Department of Natural Resources (DNR) has several groundwater observation wells within the BCWD. The wells of interest to this study are located within Brown's Creek Park. The deep well is named *BC Park – Deep* and is finished within the Tunnel City Aquifer. See Figure 1 for a location map showing the well. Two nearby shallower wells, *BC Park – Shallow* and *BC Park – Middle*, are completed in the glacial aquifer.

Observed Water Levels

When water is pumped from a well, it decreases the water level or the hydraulic head in the well and the surrounding aquifer. The pattern of water level decrease or drawdown around the well is known as a cone of depression, and is illustrated on Figure 3. The cone of depression can extend for long distances depending on the pumping rate, time since pumping began, aquifer permeability, and other aquifer characteristics. When the pumping stops, the groundwater level rises and eventually returns to pre-pumping levels.

EOR downloads and reviews water levels from the DNR observation wells as part of the BCWD groundwater monitoring program. A record of groundwater levels recorded at the *BC Park – Deep* well is shown on Figure 4. The data from 2007-2016 is not available as the well had partially collapsed, but it was later repaired.

EOR noted frequent, short drawdowns of groundwater levels at the *BC Park – Deep* well of about 4-6 feet. Upon further inspection, the drawdown data had characteristics of being caused by brief periods of pumping by a nearby well. Figure 5 shows a small subset of the water level data from the *BC Park – Deep* well where the effects of pumping are clearly evident. Multiple high-capacity wells were suspected of causing the drawdown, but the culprit could not be identified because of the lack of short-term pumping records.

While doing research for this study, we noted that Oak Glen golf course did not operate Well No. 2 during the years 2019-2020, as shown on Figure 4. Not coincidentally, the frequent, short drawdowns at the *BC Park - Deep* well also stopped during that time period. The pumping and the drawdowns resumed in 2021. We consider this to be strong evidence that Well No. 2 caused the drawdown of groundwater levels in the area of the *BC Park – Deep* well. Note that both these wells are completed in the Tunnel City/Wonewoc aquifer. The drawdowns in the observation well also only occurred during warm weather months, further suggesting a connection to the golf course wells.

A comparison of the groundwater levels in the three BC Park observation wells is presented on Figure 6. It is important to note that no drawdown was observed in the shallower wells, *BC Park - Medium* and *BC Park – Shallow* completed in the glacial aquifer. This implies that a confining layer separates the Tunnel City/Wonewoc aquifer from the glacial aquifer. Because Brown's Creek is only in direct contact with the uppermost aquifer (glacial aquifer), we can further conclude that pumping from Well No. 2 does not affect Brown's Creek in the area of Brown's Creek Park. However, it is important to note that aquifer conditions may be very different downstream and upstream from this area.

Calculated Drawdown Effects in other Areas

This discovery presented an opportunity to develop a simple groundwater model to estimate the groundwater drawdown caused by the golf course wells in other locations along Brown's Creek. The first step was to calculate the hydraulic conductivity and storativity of the Tunnel City/Wonewoc aquifer in the area of Brown's Creek Park based on the following parameters:

- Aquifer thickness, as recorded in well logs (77 ft)
- Pumping rate of Well No. 2, as reported to DNR by Oak Glen golf course (400 gpm)
- Drawdown data observed in the *BC Park- Deep* well
- Distance between the two wells.

The Hantush (1964) Method was used for a leaky aquifer with no aquitard storage. The hydraulic conductivity (permeability) of the aquifer was determined to be 19.54 ft/day with a storativity of 6.928E-5. These are comparable two parameters reported for the Tunnel City/Wonewoc aquifer in other parts of the Twin Cities.

Next, we calculated the drawdown that occurs in the Tunnel City/Wonewoc aquifer at other locations along Brown's Creek. The calculations were based on the assumption that the aquifer thickness and the hydraulic conductivity are the same everywhere. The aquifer was assumed to be confined where the Saint Lawrence formation was present and unconfined where it was not present. The calculations simulated continuous pumping of Well No. 2 for 24 hours.

Finally, we calculated the drawdown that likely occurs in the Jordan aquifer when Well No. 1 is pumped for 24 hours. No observation data was available as it was for Well No. 2. Instead, we used the following values:

- Hydraulic conductivity (43.3 ft/day) that had been developed for the Twin Cities Metro Model (Met Council, 2014).
- Storativity (6.928E-5) was assumed to be the same as was calculated for the Tunnel City/Wonewoc aquifer.
- Pumping rate (300 gpm) reported to DNR in the past when the well was operational.
- Aquifer thickness (77 ft) as reported in well logs.

Again, we assumed that the aquifer thickness and hydraulic conductivity were the same everywhere. The Jordan aquifer was assumed to be confined where the Oneota Dolomite was present and unconfined everywhere else.

Model Results

Model results are shown on Figure 7 and Figure 8. The underlying geologic maps show the uppermost bedrock layer encountered below areas of BCWD. Figure 5 shows the calculated drawdown in the Tunnel City/Wonewoc aquifer created by pumping Well No. 2 at different points along Brown's Creek. The aquifer was assumed to be unconfined in areas where the Tunnel City Group formation is the uppermost bedrock. In other areas, the aquifer was assumed to be confined, which resulted in greater calculated drawdown. **Calculated drawdowns range from 1.7 feet in the area of the St. Croix River, to 17.7 feet closer to the well.**

Similarly, Figure 6 shows the calculated drawdown in the Jordan aquifer created by pumping Well No. 1. Figure 6 has fewer points because the Jordan aquifer is not present in all areas, as indicated by the geologic map. The aquifer was assumed to be unconfined in all areas. **Calculated drawdowns ranged from 3.7 to 5.1 feet.**

Discussion

The constant inflow of groundwater into Brown's Creek is important for maintaining cooler temperatures, addressing thermal loading, and improving the coldwater assemblage for fish and macro-invertebrates. Monitoring data has shown that Brown's Creek actually loses water in the area of the lower gorge under some conditions, usually late in the summer. Brown's Creek flow monitoring data has shown decreasing discharge further downstream in the area of the gorge. In addition, monitoring using in-stream piezometers has shown that lower reaches in the Creek lose water to groundwater during certain times of the year.

The findings of this evaluation suggest that groundwater pumping from nearby wells could increase the rate of loss from the Creek. The calculated values of drawdown in the Tunnel City/Wonewoc and Jordan aquifers are a cause for concern that the wells are drawing water away from Brown's Creek. Drawdown, or reduction in the hydraulic pressure within an aquifer, potentially reduces the contribution of an aquifer to a stream.

A hydraulic connection between the bedrock aquifers (i.e. Jordan and Tunnel City/Wonewoc) and Brown's Creek has not been positively identified. In fact, shallow wells in Brown's Creek Park are not affected by the pumping of Oak Glen Well No. 2 from the Tunnel City/Wonewoc aquifer. This is evidence that the Creek is not hydraulically connected to the bedrock aquifer in this area and is "protected" by clay layers in the glacial aquifer. However, a connection appears likely in other areas because bedrock has been observed at ground surface or just below ground surface throughout the lower gorge.

The analysis presented here provides useful insight into groundwater flow in a limited area around Brown's Creek. To better understand how pumping affects the quantity of baseflow contributions (how much water is being lost from the system due to pumping) the BCWD would need to develop a more robust groundwater model which requires more accurate input parameters (i.e., local hydraulic conductivity measurements). All groundwater models need to be calibrated to actual field data in order to be considered accurate.

We do not yet have enough data to develop a more sophisticated groundwater model of the area, which could be used to support management decisions, or regulate groundwater use in other areas around Brown's Creek. A well-designed pump test would provide groundwater modeling data for other areas and answer key questions such as:

- Are the area aquifers homogeneous or do they have variable characteristics? This would help us understand the effect of pumping on different parts of the Creek. It would also be important for developing future groundwater models in other areas.
- Is there a hydraulic connection between the bedrock aquifers, the glacial aquifer, and Brown's Creek?
- Does pumping from the golf course wells affect the discharge (baseflow) of Brown's Creek through the lower gorge?

Recommendations

BCWD and EOR should continue to develop a methodology and cost estimate for a pump test using the pumping wells at Oak Glen Golf Course. One significant finding of this investigation is that short-term pumping of an irrigation well will produce drawdown in the area of Brown's Creek. Because the pump test does not need to run for a long time, the golf course irrigation pond has sufficient capacity to accept the discharge from the pump test, and the water does not need to be "wasted".

The pump test would involve:

- New shallow observation wells installed near Brown's Creek to measure changes in groundwater level in the water table aquifer.
- Instream piezometers installed in Brown's Creek to directly measure changes in the groundwater levels just below the Creek.
- Two independent pump tests, one for each irrigation well.
- Pump test runtime of 24-48 hours.

A pump test would ideally be conducted in late summer when the discharge of Brown's Creek is close to base flow levels.

References

Hantush 1964. Hydraulics of Wells. Advances in Hydroscience. Vol. 1, pp. 281-432.

Metropolitan Council, 2014. Twin Cities Metropolitan Area Groundwater Flow Model Version 3. :83.

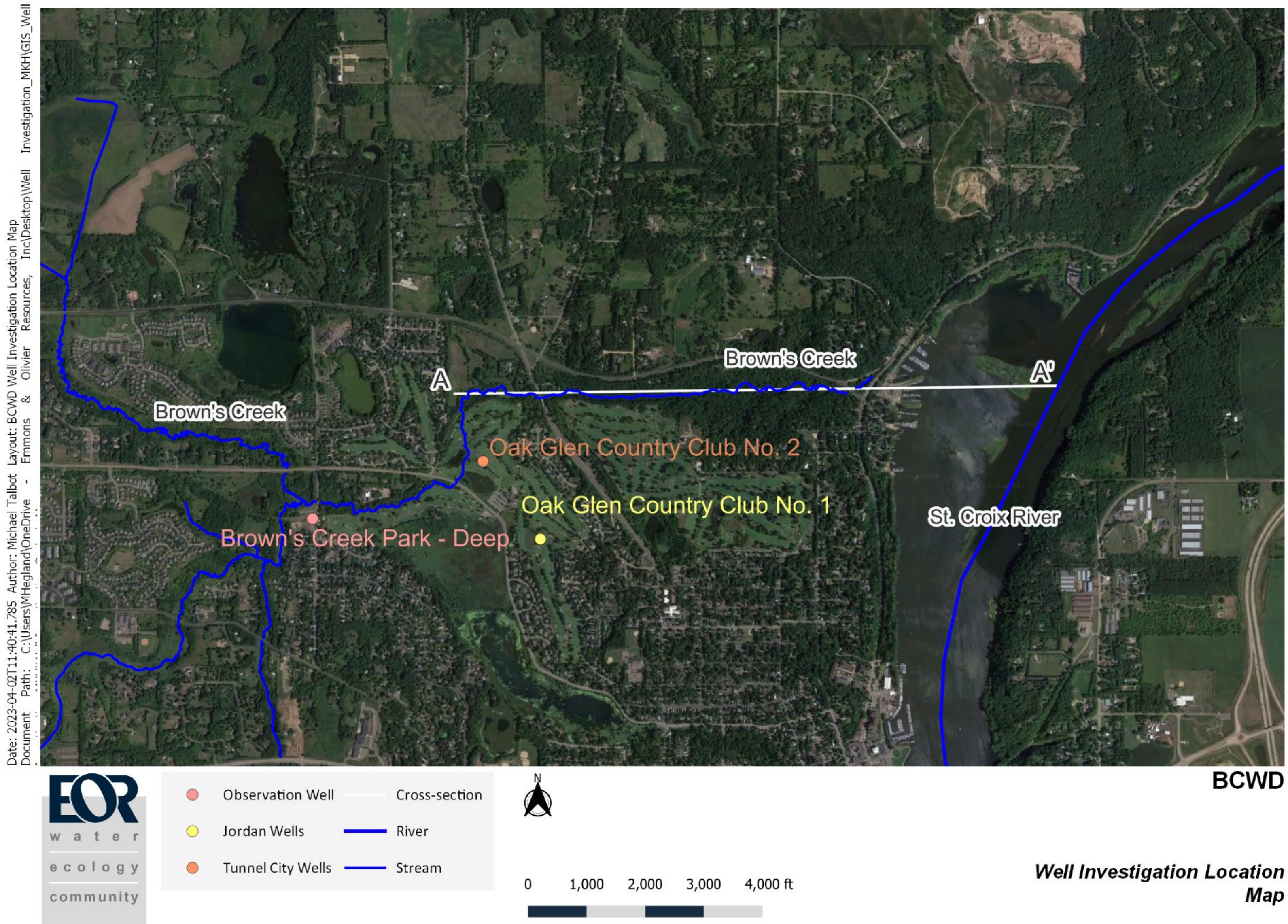

Figure 1 - Location Map

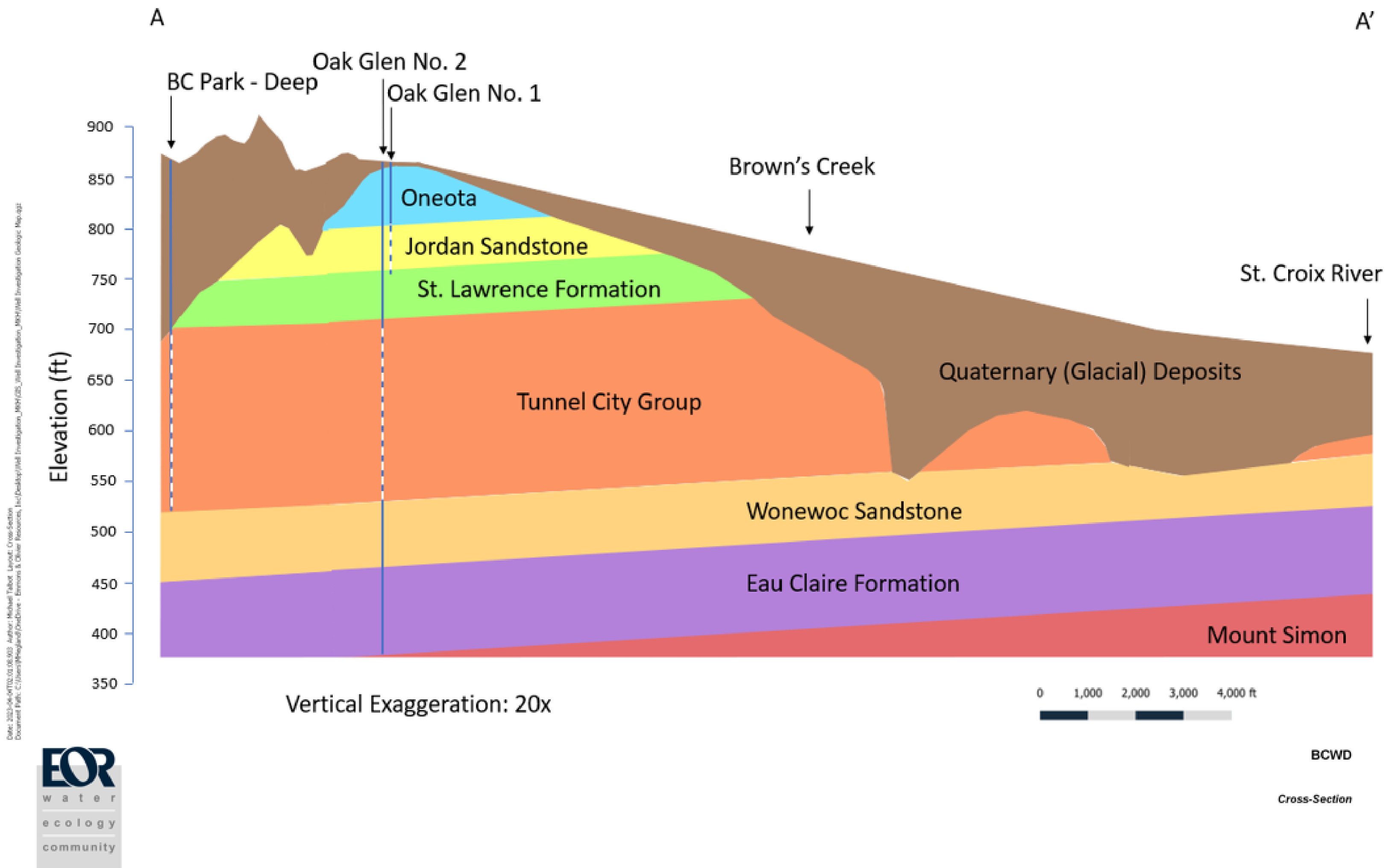

Figure 2 – Geologic cross-section A-A'

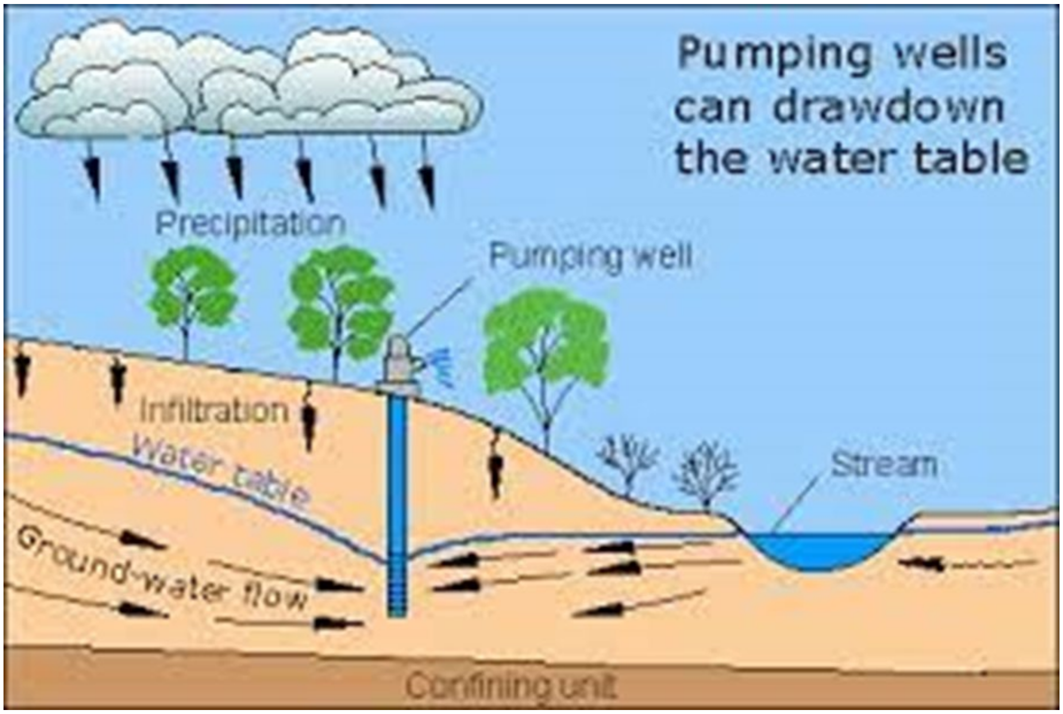

Figure 3. Cone of depression created by a pumping well

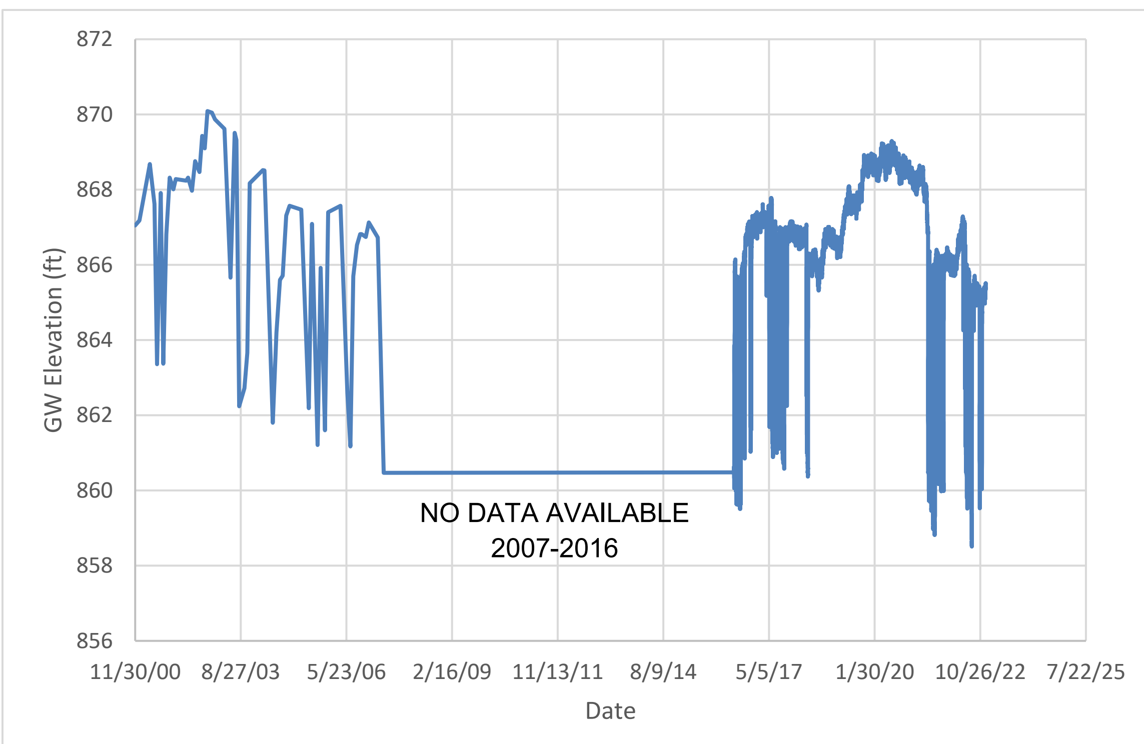

Figure 4. Groundwater Elevation at BC Park – Deep

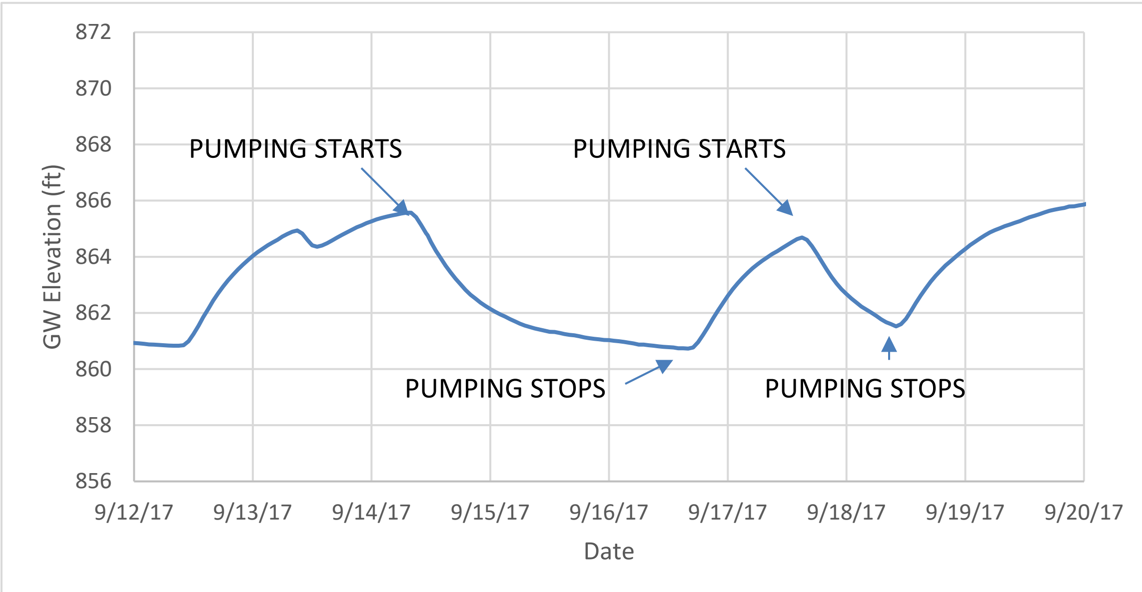

Figure 5. Influence of pumping on *BC Park - Deep* well

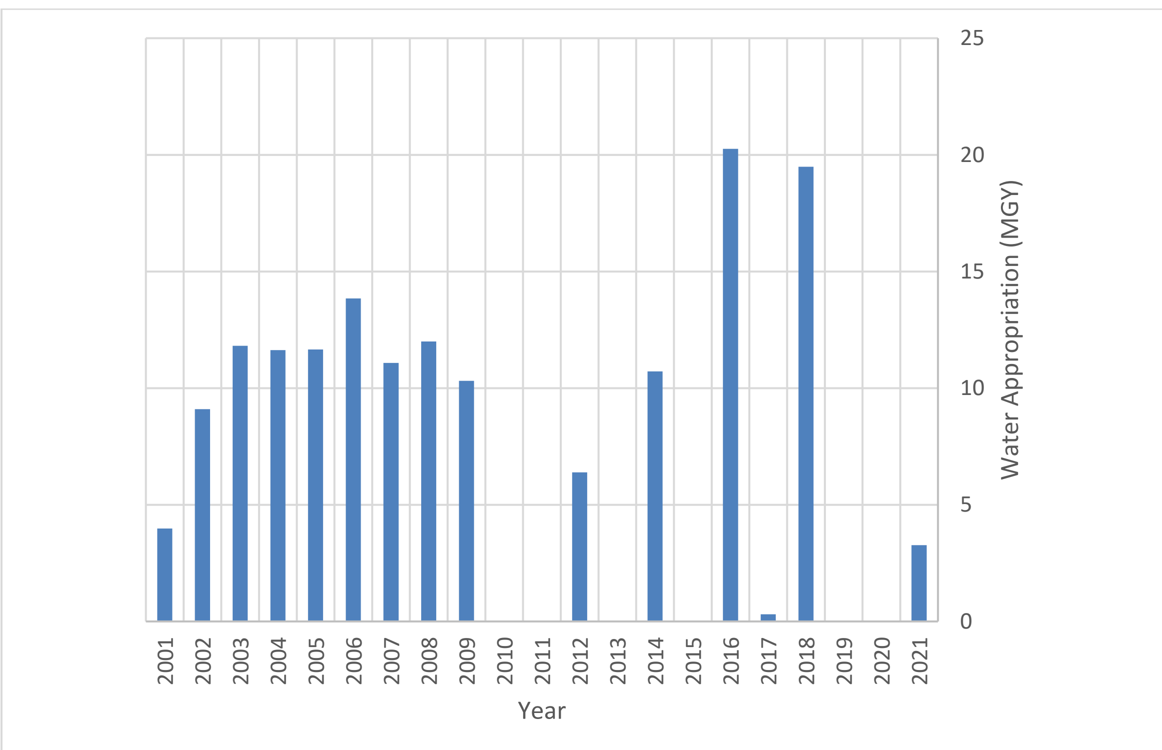

Figure 4 - Water Appropriation for Oak Glen Golf Course Well No. 2

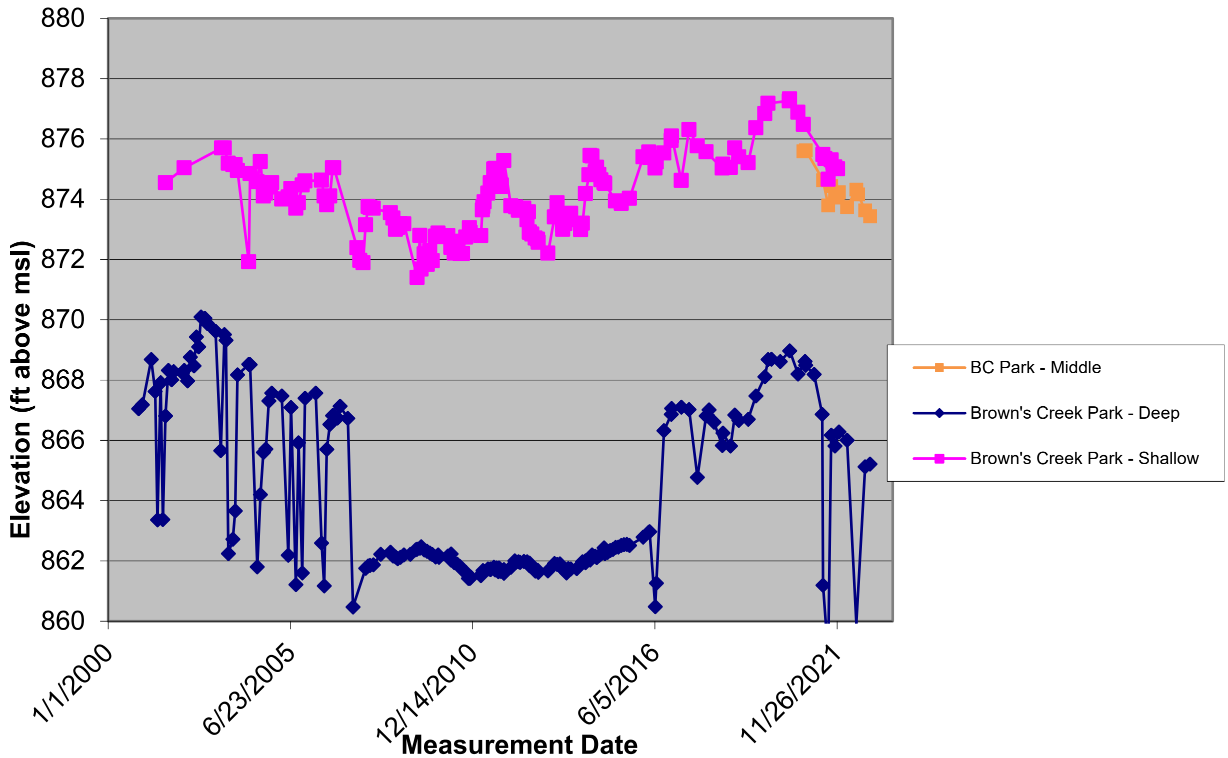

Figure 6. Comparison of groundwater levels in BC Park observation wells

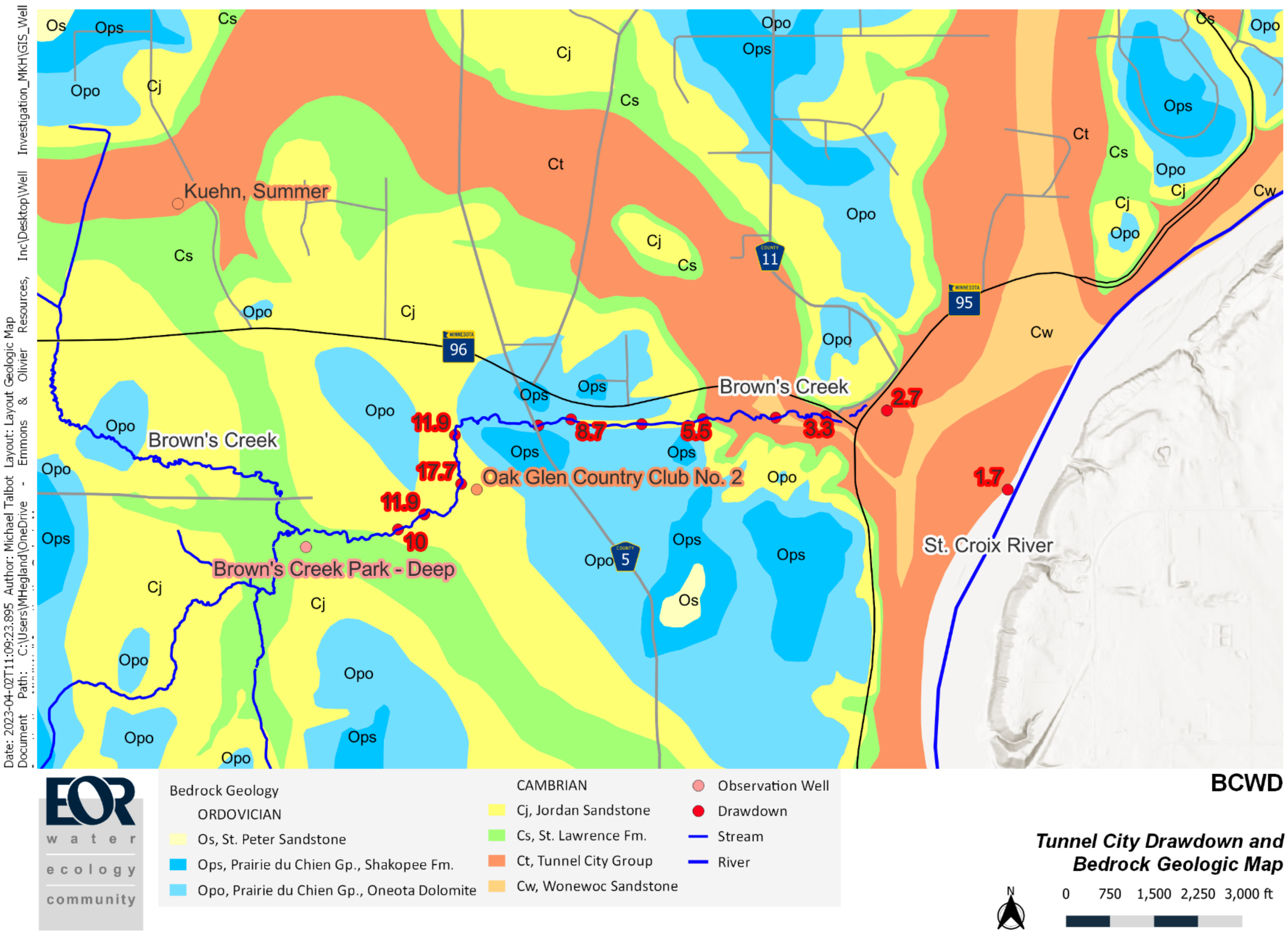

Figure 7 - Geologic Map of the Study Area showing calculated groundwater drawdown in the Tunnel City Group aquifer

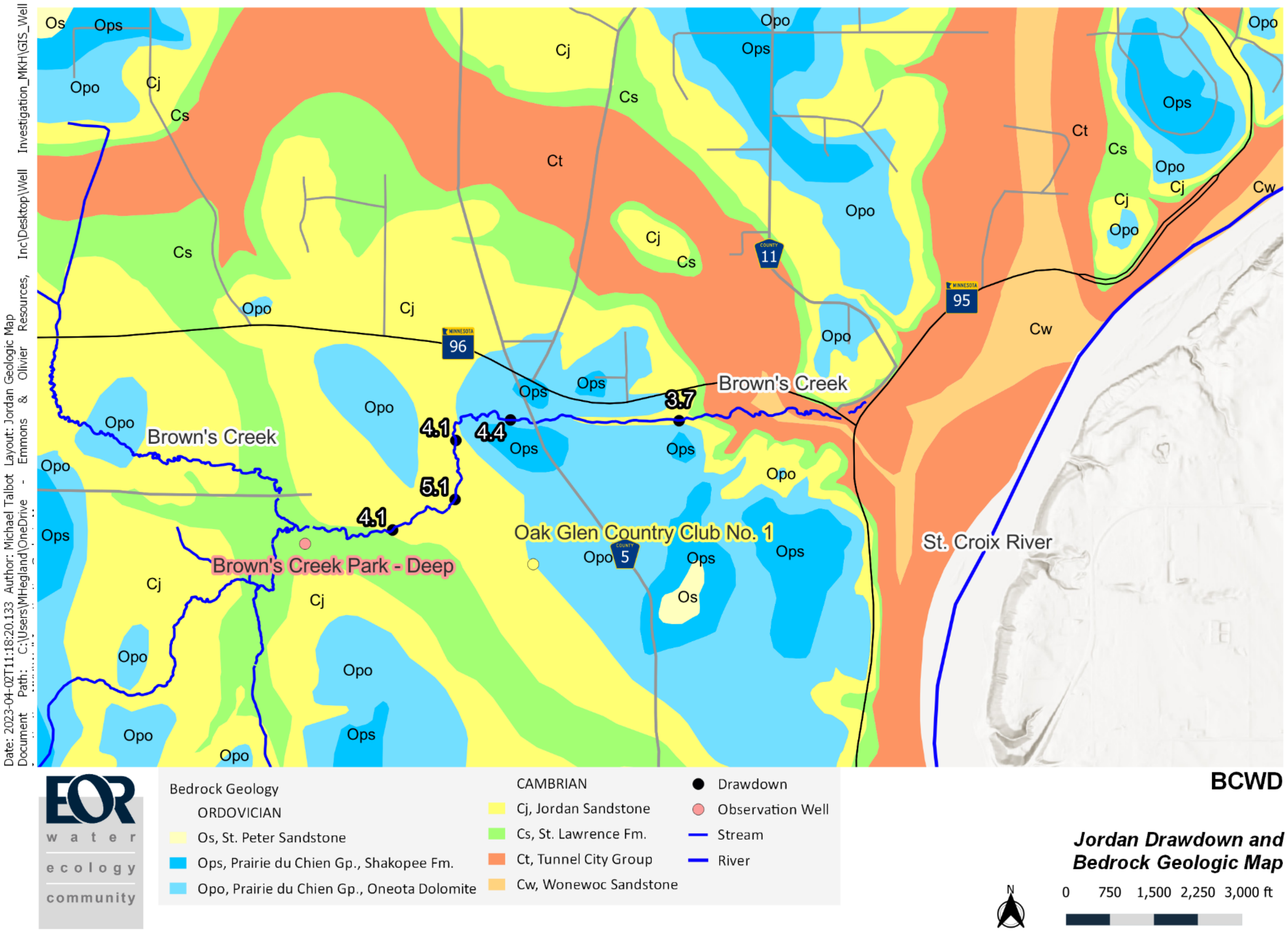

Figure 8 - Geologic Map of the Study Area showing calculated groundwater drawdown in the Jordan aquifer