Wells 18 and 19 Siting Evaluation

Prepared for
City of Blaine, Minnesota

December 2012

BARR

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4700 West 77th Street
Minneapolis, MN 55435-4803
Phone: (952) 832-2600
Fax: (952) 832-2601

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I hereby certify that this evaluation 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.

John C. Greer Date: 12/28/2012
John C. Greer, P.G. (license no 30347)

1.0 Introduction

The City of Blaine (the City) currently operates 16 municipal water supply wells. Well locations are shown on Figure 1. As the city continues to grow additional water supply will be needed to meet demands. The City reviewed land that might be available for future well fields and identified sites in the northeast corner of the city. The collection of sites is called the Northeast Well Field. The purpose of this report is to assist the City of Blaine in planning out future well locations in this well field so that a series of wells can be drilled to meet water demands as the City grows. Preferred and alternate sites for wells are shown on Figure 2. The City also intends to transition Well 7 from seasonal use to emergency use and augment current supply with Wells 18 and 19, which would be located in the Northeast Well Field that is the subject of this report. Following the installation of Wells 18 and 19 the City plans to install additional wells in the Northeast Well Field until it can supply approximately 6,000 gpm. Current plans call for water pumped from the Northeast Well Field to be fed to a new water treatment plant that would be constructed in the vicinity of the Northeast Well Field.

1.1 Study Objectives

The objectives of the study discussed in this report are as follows:

1. Identify locations for Wells 18 and 19 so that the design of the wells can begin.
2. Identify which aquifer should be targeted for Wells 18 and 19 and future wells in the proposed Northeast Well Field.
3. Provide a qualitative assessment of the total capacity of the Northeast Well Field to see if it can likely produce the desired amount of water for the new treatment plant.
4. Identify potential sources of contamination that might affect the siting of wells in the proposed Northeast Well Field area.
5. Estimate the impacts of the proposed wells and Northeast Well Field on nearby existing wells.
6. Estimate the impact of pumping in the proposed Northeast Well Field on water levels beneath nearby wetlands and surface water body features.
7. Provide a recommended path forward to reduce risk and uncertainty by filling gaps in the data needed to resolve unanswered questions.

1.2 Previous Work

During 2003 – 2004, Barr Engineering conducted a preliminary well field siting and aquifer yields evaluation for new wells open to the Quaternary glacial drift aquifer and the Tunnel City Group – Wonewoc Sandstone (TCW) aquifer in Blaine (Barr, 2003a,b; 2004). (Note: prior to July 2012, the Tunnel City Group and Wonewoc Sandstone were known as the Franconia Formation and Ironton/Galesville Sandstones, respectively, in Minnesota.) The results of the preliminary evaluation identified areas in the northeastern and southeastern portions of Blaine as potential areas for future well fields and served to guide the city in its early search for a well field location and this study as well.

2.0 Study Approach

The general approach to this study was to use groundwater flow modeling to meet project objectives by estimating well field yield and the impacts of various well field configurations on existing wells and environmental features. This was done by creating a baseline condition that represents approximate water levels in each of the aquifers of interest as they are today and comparing them to those created by a number of alternate well field configurations. The alternate well field configurations have increased total pumping as compared to the baseline. This is intended to represent the demand that will be added to the wells as Blaine grows to full build out. Results are depicted on a series of figures that show lines of equal additional drawdown created by the new well configuration as compared to today's levels in each aquifer of interest. Modeling was also performed to estimate the additional drawdown created by a drought scenario where all wells would be operated at full capacity for a period of four weeks.

The two aquifers targeted for evaluation in this study in the northeastern portion of Blaine were identified during the previous work noted above. This work builds on that study to by providing more detail to the well fields under consideration, identifying data gaps that lead to uncertainty regarding the results, and then suggesting a path forward that would allow the City to move into plans and specifications for the wells with some assurances regarding how the regulatory agencies will respond to the required well permit applications. The targeted aquifers are: 1) the unconsolidated glacial drift aquifer composed of Quaternary sand and gravel deposits and 2) a bedrock aquifer comprised of the Tunnel City Group (formerly known as the Franconia Formation) and the Wonewoc Sandstone (formerly known as the Ironton and Galesville Sandstones). These two aquifers are the uppermost aquifers underlying Blaine. Both are currently being used successfully in the City for water supply.

Groundwater modeling for this study was done using a local-scale model extracted from the regional-scale Metro Model 2 that Barr Engineering constructed for the Metropolitan Council. Metro Model 2 is described in detail in another report (Metropolitan Council, 2009).

The environmental features of concern include wetlands, scientific and natural areas (SNAs) and naturally occurring and manmade lakes. Among those that are nearest to the proposed well sites or that have been specifically identified by the Minnesota Department of Natural Resources (MnDNR) (see Appendix B) as highly valued are:

- Pioneer Park located northwest of the preferred site on the north site of 125th Avenue
- An Anoka County wetland bank location east of the alternate site
- An unnamed wetland area located southwest of the preferred site
- Blaine Airport Rich Fen SNA
- Blaine Preserve SNA
- Several lakes and stormwater ponds that were constructed as part of the Lakes Development
- A lake north of 125th and east of Lexington and
- A pond south of 125th and east of Lexington

These features are shown on Figure 1.

2.1 Geology/Hydrogeology

2.1.1 Quaternary Glacial Drift Aquifer and Aquitard

The City of Blaine sits atop a relatively large regional sand and gravel deposit known as the Anoka Sand Plain. The Minnesota Geological Survey (MGS) worked in conjunction with Metropolitan Council Environmental Services (MCES) to define the Quaternary hydrostratigraphy in the Twin Cities metropolitan area (see Meyer and Tipping, 2007). Results from Meyer and Tipping (2007) show that in the Blaine area a surficial sand unit overlies a complex sequence of discontinuous clayey till layers and deeper sand bodies. Geologic cross sections through the northern and eastern portions of Blaine that abut the proposed Northeast Well Field location were prepared using geologic information from well records stored in the MGS' County Well Index (CWI). Locations of these cross sections are shown on Figure 2. Figures 3and 4 show the interpreted Quaternary glacial drift stratigraphy along the two geologic cross sections.

The shallowest portions of the glacial drift aquifer, often referred to as the water table aquifer, may be in relatively good connection with local wetlands, streams and lakes. Recharge of this shallow aquifer is primarily by infiltrating precipitation. Discharge is to streams, lakes, and leakage to underlying aquifers. In some places wetlands and water bodies are likely the exposed surface of the groundwater (i.e., the water table) meaning that water levels in them will fluctuate along with groundwater levels. In other cases wetlands and water bodies may be separated from the water table by clay or organic layers that have accumulated on the bottom of the specific feature.

It is important to note that well logs in this area identify a clay layer that may be relatively continuous and may separate the glacial drift aquifer into upper and lower sand units that may not be well connected to each other (e.g., see Figures 3 and 4). The continuity and thickness of this clay layer is not fully documented but it appears to be present in the majority of the well logs reviewed as part of this and previous work. The spatial continuity of this clay layer plays an important role in determining the magnitude of impacts well pumping in the proposed Northeast Well Field would have on surface water bodies and wetlands in the area.

Glacially deposited sediment, including clay layers, can have very complex and unpredictable hydrostratigraphy. The modeling of discrete zones of saturation in glacial deposits is typically not possible unless a large amount of reliable data on stratigraphy, hydraulic characteristics, and hydraulic head is gathered. In many areas, the existing data are sparse or so complex that the entire thickness of glacial deposits must be treated as a single aquifer with homogeneous characteristics in any modeling effort, even though clay layers exist that may act as local aquitards or barriers to flow. It was beyond the scope of this study to modify Metro Model 2 to replicate the clay layer noted above in the model used for this preliminary siting evaluation effort. Because of this, impacts to water levels in the glacial sediments are shown as drawdowns at the groundwater surface (i.e., at the water table). If the clay layer is spatially continuous and its hydraulic characteristics such that it acts as an aquitard, pumping in the deeper sand unit would NOT necessarily show up as a drawdown at the water table.

2.1.2 Tunnel City Group

In the study area, the Tunnel City Group is generally the uppermost bedrock unit. The Tunnel City Group is composed of fine- to coarse-grained, dolomite-cemented, quartz sandstone in northern Washington, Anoka, and Hennepin counties. (In the southern and central part of the Twin Cities metro area the Tunnel City Group consists of glauconitic and feldspathic sandstone.) The lower part of the formation consists of interbedded shale, siltstone and lesser amounts of very fine grained feldspathic sandstone. The contact with the underlying Wonewoc Sandstone is sharp (Mossler and Tipping, 2000).

The Tunnel City Group and Wonewoc Sandstone are often considered to be a single aquifer (referred to hereinafter as the TCW aquifer). For this study the Tunnel City Group was modeled as a separate aquifer unit from the Wonewoc Sandstone.

2.1.3 Wonewoc Sandstone

The Wonewoc Sandstone immediately underlies the Tunnel City Group. The Wonewoc Sandstone ranges from a medium to very coarse-grained, quartzose sandstone to a very-fine to fine-grained feldspathic sandstone with scattered thin beds of shale (Mossler and Tipping, 2000). The Wonewoc

Sandstone aquifer has not been highly utilized in the central and southern Twin Cities metro area because sufficient water supplies can be obtained from shallower units, such as the Prairie du Chien Group and Jordan Sandstone. In the northern parts of the Twin Cities metro area where the Prairie du Chien Group and the Jordan Sandstone are eroded away this unit has been successfully utilized as a source of water.

Recently, the Wonewoc Sandstone aquifer (along with the Tunnel City Group aquifer) has undergone greater evaluation by the Minnesota Geological Survey, particularly in the northwestern portion of the Twin Cities metropolitan area where the Prairie du Chien Group and Jordan Sandstone aquifers are not present. In the northwest metro area, where the Tunnel City Group or the Wonewoc Sandstone is the uppermost bedrock unit, these formations are more highly fractured and, thus, more permeable. Where these units are overlain by other bedrock units (e.g. the St. Lawrence Formation) the fracturing is much more poorly developed and the ability to produce usable quantities of water is substantially reduced. The fracturing appears to be associated with "lithostatic pressure relief" – the fractures develop where the weight of the overlying bedrock had been removed (e.g., see Runkel et al., 2003).

2.2 Potential Well Construction Parameters

2.2.1 Glacial Drift Aquifer

Available information indicates the unconsolidated glacial drift varies in thickness from as little as approximately 200 feet in the vicinity of the northern and western sides of the proposed Northeast Well Field to as much as approximately 350 feet thick in the vicinity of the southern boundary of the area under consideration. The thickness of the sand units within the glacial drift also varies. As shown on Figures 3 and 4, significant amounts of clay are identified on both cross sections near the proposed Northeast Well Field. A well planned site investigation is recommended to determine if it is feasible to construct a well in the glacial drift sediments since there is the possibility that deeper sand units, if present, are separated from surficial and other deeper sand units by clay and may not be well recharged and, therefore, unable to produce the volume of water desired by the City. If a deeper sand unit is present, wells drilled into this formation would likely be between 200 and 350 feet deep and screened over the bottom 40 to 80 feet depending on well-specific information gathered during drilling. The model will not show the site specific clay units that may significantly affect well yield in this area since it treats the entire unconsolidated unit as a homogeneous hydraulic unit.

2.2.2 Bedrock Aquifer

The surface of the bedrock varies in depth from approximately 200 feet in the vicinity of the northern and western sides of the area under consideration to as much as approximately 350 feet in the vicinity of the southern boundary of the area under consideration. As noted above, the Tunnel City Group is typically the uppermost bedrock unit in the vicinity of the proposed Northeast Well Field. Wells drilled into this formation would be cased off into the upper portion of the bedrock with an open hole likely constructed to a depth of about 400 to 450 feet. Based on available information, it appears that a clay unit is present at the surface of the bedrock in some of the areas near the proposed Northeast Well Field. Where present, this unconsolidated clay may act as an aquitard that hydraulically separates the glacial drift aquifer from the underlying TCW aquifer. It is, therefore, possible that this clay unit may limit vertical flow from the glacial drift aquifer into the TCW aquifer in this area which could affect well yield to some extent.

2.3 Groundwater Model

Metro Model 2 covers the entire seven county Twin Cities metropolitan area and has nine layers, generally representing the following geologic units:

- Layer 1: Quaternary sediments
- Layer 2: St. Peter Sandstone or Quaternary sediments if the St. Peter is absent
- Layer 3: Prairie du Chien Group or Quaternary sediments if the Prairie du Chien is absent
- Layer 4: Jordan Sandstone or Quaternary sediments if the Jordan is absent
- Layer 5: St. Lawrence Formation or Quaternary sediments if the St. Lawrence is absent
- Layer 6: Tunnel City Group or Quaternary sediments if the Tunnel City is absent
- Layer 7: Wonewoc Sandstone
- Layer 8: Eau Claire Formation
- Layer 9: Mt. Simon Sandstone

Since the Tunnel City Group is the uppermost bedrock unit in the vicinity of the proposed Northeast Well Field model Layers 1-5 all represent Quaternary sediments. The range in variation of the hydraulic properties of the Quaternary sediments was determined during the calibration of Metro Model 2. As more detail is learned about the clay layer mentioned above it is possible that the hydraulic conductivity of one or more of these model layers could be modified in the vicinity of Blaine to better approximate its effect on groundwater flow and response of the water table to pumping in the proposed Northeast Well Field. It was beyond the scope of this study to modify the hydraulic conductivity distribution in Metro Model 2 in the vicinity of Blaine. It is recommended that future efforts be undertaken to obtain data that will facilitate evaluation of the impact of the clay layer on drawdowns at the water table.

A smaller, local-scale model was extracted from the full, regional-scale Metro Model 2 using a process known as telescopic mesh refinement, or TMR. The TMR model boundary is shown in Appendix A and was chosen to center the proposed Northeast Well Field in an appropriately-sized grid. The grid cell size was reduced from 500 m by 500 m in the full Metro Model 2 to 100 m by 100 m in the TMR model. The grid was refined further to 25 m by 25 m cells in the Northeast Well Field area (see Appendix A). The outer boundary conditions of the TMR model were determined from the results of a simulation using the full Metro Model 2. For this study, constant fluxes were specified for the outer boundaries. Constant flux boundaries were chosen since many of the existing City wells are located near the model boundary. Constant head boundaries would provide an unlimited amount of water to the TMR model domain and, potentially, cause drawdown resulting from the simulation of new wells in the proposed Northeast Well Field to be under estimated. The TMR model was used to generate current baseline groundwater flow conditions and to evaluate yield and drawdown under future pumping scenarios.

A few modifications were made to the TMR model to better reflect conditions in and around Blaine:

- The coordinates of the City wells were updated using data obtained from the City and Well 17 was added to the model (Well 17 was not included in Metro Model 2 because of an insufficient pumping history for the well at the time Metro Model 2 was constructed). Table 1 identifies the model layers in which each of the Blaine municipal wells is simulated.
- Pumping rates for the City wells were updated to reflect the average steady state pumping rate (i.e., the annual average pumping rate) for each well during the period 2007-2011.
- Due to the size of the Metro Model 2, large portions of bedrock aquifer units are assigned homogeneous hydraulic parameters in order to achieve a stable and calibrated model over a large region. When a specific area of interest with the Metro Model 2 domain is identified additional detail is often added by modifying some of these hydraulic parameters based on site specific data in order to improve the accuracy of model results on a local level. In this case the hydraulic conductivity of the Tunnel City Group in the Blaine area in Metro Model 2 was modified to be more representative of site specific data. The hydraulic conductivity was set at 6.6 m/day for the Tunnel City Group. No other hydraulic parameter values in the vicinity of Blaine were changed from the values in Metro Model 2.

2.3.1 Modeling Scenarios

The TMR model was used in steady state mode to provide baseline hydraulic head conditions throughout the model domain, assess the capacity of the proposed Northeast Well Field and to estimate potential water table drawdown beneath nearby wetlands and surface water features due to long term pumping in the proposed well field created by Wells 18 and 19 only and the well field when fully developed to meet ultimate demand. Steady state scenarios use annual average pumping rates and model results essentially approximate the long term average impacts of a given pumping scenario. The TMR model was used in transient mode to evaluate potential water table drawdown resulting from pumping to meet short term, peak water demands and to assess the potential for well interference for Wells 18 and 19 only and when the well field is fully developed to meet ultimate demand. Transient model results essentially approximate the departure from the average impacts noted above at a specific point in time that result from a modification of the average pumping rates to those in the transient analysis; in this case the increased drawdown created by a short term peak pumping demand that might occur during an extended dry period. These are not steady state results, in other words drawdown might be greater if pumping were allowed to continue for a longer period of time than that included in the transient mode analysis.

Wells shown as pumping from the glacial drift aquifer are all assumed to be screened wells completed in the lower part of the aquifer below the clay layer discussed above. Wells shown as pumping from the TCW aquifer are assumed to be open hole wells completed in both the Tunnel City Group and the Wonewoc Sandstone.

2.3.1.1 Baseline Scenarios

Two steady-state model runs were performed to establish baseline hydraulic head conditions for use in calculation of drawdowns produced by the future pumping scenarios evaluated in this study. The first baseline run (referred to as “Baseline”) used annual average pumping rates for each of the City’s wells computed from 2007-2011 pumping data. The second baseline run, (referred to as “Modified Baseline”) takes into account the City’s plan to make Well 7 an emergency well. For the Modified Baseline run, Well 7 was turned off and the annual average 2007-2011 pumping rate for Well 7 was equally distributed among the remaining 15 wells. Table 1 shows the pumping rates for each well used in the Baseline and Modified Baseline scenarios.

2.3.2 Steady State Pumping Scenarios

2.3.2.1 Well 18 and 19 Scenarios

The proposed new Wells 18 and 19 were added to the model about one quarter mile apart in the preferred site location shown on Figure 1 southwest of the intersection of Lexington Avenue NE and 125th Avenue NE. Six total scenarios were modeled for the two wells. They are broken into two groups of three steady-state scenarios as shown below:

- Steady State Group 1 (results shown on Figure 6): Wells 18 and 19 in the TCW aquifer; pumping rate scenarios include: Wells 18 and 19 each pumping at 800 gpm, 1000 gpm, and 1250 gpm (Note that while a 1,250 gpm TCW aquifer well appears to be possible the Quaternary clay units beneath the proposed Northeast Well Field site may limit the upper end of yields by limiting vertical recharge at this location. Therefore, a site-specific aquifer test and related field evaluations of the site are recommended to determine if it would be possible to pump a well in the TCW aquifer at such a rate.)
- Steady State Group 2 (results shown on Figure 7): Wells 18 and 19 in the glacial drift aquifer; pumping rate scenarios include: Wells 18 and 19 each pumping at 800 gpm, 1000 gpm, and 1250 gpm (Note that based on the currently available well logs the extent of the lower sand unit in the glacial drift aquifer in the vicinity of the proposed Northeast Well Field is unclear. Therefore, a site-specific aquifer test and related field evaluations of the site are recommended to determine if it would be possible to construct productive wells in the glacial drift aquifer at this location.)

The pumping rates are intended to represent added demand as the City grows. Based on average day demand projections in the City's Comprehensive Plan Update (Bonestroo, 2009): Scenario 1 (800 gpm) is approximately equal to the increased demand over the 2007-2011 annual average anticipated in 2020, Scenario 2 (1000 gpm) is approximately equal to the increased demand over the 2007-2011 annual average anticipated in 2030, and Scenario 3 (1250 gpm) represents post-2030 build out.

2.3.1.3 Ultimate Capacity Scenarios

Since the City's target ultimate capacity for the proposed Northeast Well Field is 6,000 gpm, a series of steady-state runs were performed to simulate pumping of multiple wells in the Northeast Well Field with a total pumping rate of 6,000 gpm. Well locations were confined to the preferred and alternate sites shown on Figure 1, with preference given to the preferred site and a minimum spacing of approximately one-quarter mile between wells. Note that one-quarter mile was chosen for the well spacing because it is a typical spacing found in well fields in the Twin Cities area. Final well spacing should be based on the results of an aquifer test conducted in the aquifer of interest at the site that includes multiple observation points so that both well capacity and potential well interference can be evaluated. Cross section B-B' (Figure 4) indicates there is a substantial thickness of clay in the Quaternary sediments adjacent to the southern parcel of the preferred site so no wells were modeled in layers 1 through 5 (i.e., the Quaternary sediments) in that parcel. Six total scenarios were run this time broken into three groups:

- Steady State Ultimate Group 1 (results shown on Figures 8 and 9): All wells pumping from the TCW aquifer,
- Steady State Ultimate Group 2 (results shown on Figures 10 and 11): All wells pumping from the Quaternary aquifer,
- Steady State Ultimate Group 3 (results shown on Figures 12 and 13): A mix of TCW aquifer wells and Quaternary aquifer wells.

Two scenarios were run in each group. For the first scenario all existing City wells were assumed to be running at the Baseline rate and then 6 new wells were added in the Northeast Well Field pumping at 1000 gpm each. For the second scenario all existing City wells were again assumed to be running at the Baseline rate and then new wells were added in the Northeast Well Field pumping at rates that are based on current use patterns for that specific aquifer. This is the total existing annual average amount of water pumped from each aquifer divided by the number of wells constructed into that aquifer converted into a pumping rate of gallons per minute. For example, for the period 2007 – 2011 shown in Table 1, the maximum annual average rate pumped from each aquifer was 782.2 gpm for a TCW aquifer well, and 547.7 gpm for a glacial drift aquifer well. The net result of this scenario was that more wells were added to the Northeast Well Field to reach the 6,000 gpm total pumping rate. This spreads the demand out among more wells and reduces somewhat the maximum drawdown in the vicinity of the Northeast Well Field due to the withdrawal. The intent of this was to see if spreading the 6,000 gpm load out among more wells would reduce the impacts to nearby wells and environmental features. The final pumping rates for the latter group of scenarios were adjusted slightly so that the total pumping added up to 6000 gpm. Table 2 summarizes the details of the 6000 gpm scenarios.

2.3.3 Transient Pumping Scenarios

2.3.1.4 4-Week Maximum Pumping Scenarios

The 4-week maximum pumping scenarios are intended to simulate conditions in which the City would need to run most all of its wells at full capacity for a sustained period of time, such as during a summer drought. Unlike the previous model runs, the 4-week maximum pumping scenarios were transient runs in order to show the evolution of the drawdown at the water table with time over the 4-week pumping period. Projected ultimate system build out maximum daily demand presented in the City's Water Emergency and Conservation Plan (BlueStone, 2007) was used as the basis for determining pumping rates for each of the City's wells. Table 3 shows the capacities of the City wells and the projected maximum daily water demand. Two pumping configurations for the existing City wells were considered:

- Scenario Peak1 (results shown on Figures 14 and 15) – all existing wells except Well 7 pumping at capacity; a single new well (Well 18) is added to meet peak demands. This essentially shows the impacts of a maximum day scenario with pumping stress centered in the western part of the City across most of its existing wells.
- Scenario Peak2 (results shown on Figures 16 – 18) – Well 7 pumping but Wells 12 and 17 turned off; four new wells (Wells 18 – 21) added to meet peak demands. This essentially shows the impacts of a maximum day scenario with a significant part of the pumping stress shifted to the new Northeast Well Field.

Scenario Peak2 simulates a situation in which the two City wells with the highest capacities (see Table 3) are unavailable to be used and emergency Well 7 is utilized. For both scenarios Peak1 and Peak2, one or more additional wells are necessary to meet the projected demand. Table 4 shows the pumping rates of the new wells used in each pumping scenario. A capacity of 1000 gpm was assumed for each new well, though as Table 4 shows, the actual pumping rate assigned to each well depended on the amount of water required to satisfy the maximum demand. Scenarios were run with wells completed in either the TCW aquifer or the Quaternary glacial drift aquifer, or both. The suffixes "_T" and "_Q" were added to "Peak1" and "Peak2" to identify if the scenario included wells in the Quaternary glacial drift aquifer or just in the TCW aquifer. Note that in all of the transient model runs new well spacing is approximately ¼-mile. As noted above, this is a typical well spacing for a Twin Cities-area well field. This approach is reasonable for evaluating if the aquifers can supply the required water to the wells at the site, but site specific aquifer testing will be required to determine actual well capacity and if local well interference will dictate a greater separation to limit drawdown to a reasonable amount. This is especially true of wells drilled into the TCW aquifer, which has significant interference issues in some areas.

3.0 Results and Discussion

The modeled water level fluctuations in Layer 1 represent the behavior of the local water table; therefore, all model result figures referenced in this section show heads or drawdowns in Layer 1 of the model. It is important to remember that the glacial drift aquifer wells modeled are assumed be screened below the clay layer discussed earlier in the report and that the clay layer is not currently represented in the model due to insufficient data on its hydraulic properties and extent. What this means is that the drawdowns shown are those that would likely occur if the clay layer is NOT spatially continuous and pumping stresses are communicated all the way to the water table. If the clay layer is continuous, the drawdown at the water table would likely be substantially less; maybe even totally absent. TCW aquifer wells would also be finished below the referenced clay layer and likewise would not be likely to drawdown the water table if the clay layer is present.

3.1 Baseline Scenarios

Figure 5 shows head contours from the Baseline and Modified Baseline runs described in Section 2.2.1.1. These contours are nearly identical, indicating that redistributing Well 7's share of the annual average 2007-2011 pumping to the other Blaine wells makes little difference in modeled water table elevations within the model domain.

3.2 Steady State Pumping Scenarios

In order to simplify the analysis and reduce the number of figures in the report, only water table drawdowns relative to scenario Baseline were calculated for the steady state pumping scenarios discussed below. The figures are intended to show where wells were modeled in the scenarios analyzed. They are not intended to suggest that glacial drift aquifer wells could be constructed at any of the exact locations shown. There are significant clay deposits around all sites and site specific data will be needed to verify the presence of a viable sand unit that is recharged from infiltration or surrounding sand bodies before a glacial drift aquifer well can be recommended at any of the locations shown. In addition, the figures are also not intended to suggest that TCW aquifer wells could be constructed at the spacing shown. The presence of the TCW is almost certain at all locations but site-specific hydraulic conductivity and well interference needs to be determined from aquifer tests before a final well spacing can be recommended.

3.2.1 Well 18 and 19 Scenarios

Figures 6 and 7 show the results of pumping proposed Wells 18 and 19 each at 800, 1000, and 1250 gpm from the TCW aquifer and the Quaternary glacial drift aquifer, respectively. As one would expect, Figures 6 and 7, show that the modeled drawdown at the water table increases as pumping from either aquifer increases. A comparison of Figures 6 and 7 indicates that the model predicts there would be slightly more drawdown at the water table beneath the well field parcel close to proposed Wells 18 and 19 if the wells are pumping from the Quaternary glacial drift aquifer rather than the TCW aquifer while farther from the pumping wells modeled drawdown is virtually identical regardless of which aquifer is being pumped. This suggests that a portion of the water pumped from the TCW aquifer would be conveyed to the well horizontally from a distance rather than via infiltration from the glacial drift aquifer in the immediate vicinity of the well.

3.2.2 Ultimate Capacity Scenarios

Figures 8-13 show drawdown contours for well configurations in the proposed Northeast Well Field that deliver a total yield of 6000 gpm (the City's target ultimate capacity for the proposed Northeast Well Field). Modeled drawdowns in the vicinity of the proposed well field are significant for all scenarios; the predicted water table drawdowns beneath the northern of the two preferred site parcels range from approximately 24 to more than 26 feet. All of these scenario results show a 16-foot drawdown contour beneath the subdivision lake to the west of the well field. While the depth of this lake is not known, it is considered likely that water table drawdown on the order of 16 feet beneath this lake would have a deleterious effect on the lake level. It is likely that this drawdown would be mitigated almost completely if the clay layer previously discussed is continuous throughout the region.

3.2.3 Discussion of Steady State Scenarios

As discussed in Section 2 and Appendix B, the MnDNR has expressed concerns regarding the potential effects of drawdown from pumping in the proposed Northeast Well Field on sensitive wetlands and designated Scientific and Natural Areas (SNAs) in Blaine. The areas of concern identified by the MnDNR include:

- Pioneer Park located northwest of the preferred site on the north site of 125th Avenue
- An Anoka County wetland bank location east of the preferred site
- An unnamed wetland area located southwest of the preferred site
- Blaine Airport Rich Fen SNA
- Blaine Preserve SNA

In addition to the specific areas noted by the DNR there are several surface water body features, both manmade and naturally occurring, that could be impacted by pumping if they are in fact exposures of the groundwater table and if the clay layer is NOT spatially continuous. These features include:

- Several lakes and stormwater ponds that were constructed as part of the Lakes Development
- A lake north of 125th and east of Lexington
- A pond south of 125th and east of Lexington

Locations of the sensitive areas of concern identified by the MnDNR in Blaine are shown on Figure 1. Based on existing pumping data for the City's wells (e.g., see Table 1), it appears reasonable to assume that long term, average pumping rates for proposed Wells 18 and 19 are unlikely to exceed 800 gpm. Figure 14 shows the modeled water table drawdown for the steady state scenario with Wells 18 and 19 each pumping at 800 gpm from the TCW aquifer. The modeled drawdowns shown on Figure 14 beneath the areas of concern could potentially have adverse effects on these sensitive areas whose plant communities depend on access to shallow groundwater. In addition, the drawdowns could adversely impact water levels in the surface water bodies also noted in the area. Given the recent concern regarding White Bear Lake, the potential impact to levels in these lakes should not be ignored.

The modeled hydraulic conductivity field in model layers 1 – 5 that represent the Quaternary sediments in the vicinity of the proposed Northeast Well Field is fairly homogeneous and has relatively high conductivity: the highest horizontal hydraulic conductivity in the vicinity of the proposed well field is 36 m/day and the highest vertical hydraulic conductivity is 19 m/day. (See Appendix A for a hydraulic conductivity map.) These high conductivities, especially the high vertical conductivity, are a major reason for the large modeled drawdown at the water table resulting from high-capacity well pumping deeper in the aquifer system. However, as the geologic cross-sections on Figures 3 and 4 shows, available information suggests that a relatively continuous clay layer is present in the Quaternary sediments near the proposed Northeast Well Field that separates the shallow sand and gravel deposits from the deeper Quaternary glacial drift aquifer in which the proposed new wells might be screened. However, the hydraulic properties of this clay layer and its areal continuity are unknown. If present and continuous as shown on the cross sections, this clay layer would likely serve as a confining unit and lessen or eliminate the water table drawdowns induced by pumping deeper in the aquifer system. Additional information, including a pumping test and, ideally, additional geologic data for assessing continuity of the clay, would be needed to update the current TMR model to account for any hydraulic effects of the Quaternary clay layer. Therefore, the TMR model likely overestimates water table drawdowns from pumping deeper in the Quaternary glacial drift aquifer or in the TCW aquifer. This points to a key data gap that should be filled prior to moving forward with plans and specs for the new wells.

3.3 Transient Pumping Scenarios

Water table drawdowns for the transient pumping scenarios discussed below were calculated relative to scenario Modified Baseline to account for the City's plan to change Well 7 to an emergency backup well.

3.3.1 Four-Week Maximum Pumping Scenarios

Figures 15-19 show the results of the transient 4-week maximum pumping scenarios with snapshots of the modeled water table drawdown at the end of each week. The general pattern of the drawdown contours is consistent from week to week, and the magnitudes of the drawdowns increase steadily as expected. For scenarios Peak1_T and Peak1_Q, the choice of aquifer makes no discernible difference on the observed drawdowns. However, when it is assumed that Wells 12 and 17 are inoperable and four new wells are added, there is more water table drawdown in scenarios Peak2_Q and Peak2_TQ than in scenario Peak2_T due to the additional load on the aquifer from wells pumping from the Quaternary glacial drift aquifer in scenarios Peak2_Q and Peak2_TQ. The maximum water table drawdowns occur in the southwestern portion of the frames near Well 10; this is likely due to a combination of new pumping upgradient in the Northeast Well Field and the fact that Well 10 and the other nearby City wells are being pumped at much higher rates in the 4-week maximum scenarios than in the Modified Baseline scenario.

3.3.2 Discussion of Transient Pumping Scenarios

All of the 4-week maximum pumping scenarios show water table drawdowns in excess of 10 feet beneath most of the City. As indicated in Section 3.2.3, such large drawdowns, if realized, pose a potential threat to surface water bodies and also to sensitive wetlands.

Preliminary well interference calculations were performed using the results of Scenario Peak2_TQ at 4 weeks. This scenario and time represent a worst-case for modeled water table drawdown magnitudes, and includes wells completed in both the Quaternary glacial drift and TCW aquifers. Static water columns were calculated for wells in the Blaine area from data in the CWI by subtracting the measured depth to water below ground surface from the total well depth. Wells identified in the CWI as abandoned or sealed and wells denoted as monitoring wells were excluded from the calculations. The water column in each well was then compared to the modeled drawdown at that location. As shown on Figure 20, there are 30 wells in the model domain for which the modeled drawdown represented a 50% or greater reduction in water column height. These wells are located mainly in the western part of Blaine, though 4 are in Andover, 5 are in Ham Lake, 2 are in Lino Lakes, 1 is in Circle Pines, and 2 are on the border between Blaine and Coon Rapids. Figure 20 also shows other wells in the model domain in which the modeled drawdown is less than a 50% reduction in water column height. Note that Figure 20 should not be considered all-inclusive as not all wells in the CWI have water level data available, and there may be other wells in the area that are not included in the CWI. In addition, some wells are constructed in such a way that even small fluctuations in water levels can result in substantial impacts to well function. If a ten foot reduction in water level occurs in any residential well it is likely to be a problem that the MnDNR may make the City mitigate.

When a new well is installed and pumping from it impacts existing wells the MnDNR requires that the party who installed the new well mitigate the impact and make the existing well user whole. This is often in the form of lowering a pump setting or upgrading a well pump so that it can deliver approximately the same amount of water following the installation of the new well as it did before. In extreme cases it may mean drilling a whole new well. The MnDNR will respond to complaints from well owners when problems occur and if appropriate seek out parties responsible for the reduction in well performance. These problems usually manifest themselves during times of drought when high water use results in depressed water levels and impaired well function. The City should plan for costs to mitigate impacted wells. Note that some of the wells noted are in the shallower unit and may NOT be impacted by pumping in the deeper glacial sand unit or TCW aquifer if the clay layer discussed in this report is continuous across the region. However, in many cases the areal extent of the clay layer that has been discussed will not reduce the impact of well interference since many of the wells identified are completed below the clay layer.

3.5 Preliminary Wellhead Protection Area (WHPA)

A preliminary Wellhead Protection Area (WHPA) was prepared for Wells 18 and 19 following Minnesota Department of Health (MDH) guidelines. It was assumed that Wells 18 and 19 would both be completed in the Quaternary glacial drift aquifer at the locations shown on Figure 7 and would each be pumped at a rate of 1,000 gpm. Figure 21 shows the preliminary WHPA, which is centered on a point midway between the proposed Well 18 and Well 19 locations.

Figure 21 also shows contaminated site data from the Minnesota Pollution Control Agency's (MPCA) What's in My Neighborhood database. Diesel fuel spills were reported in 2002 at both the

Balfany Farm and the Leffingwell Farm to the west of the proposed Northeast Well Field. Underground storage tanks are located at the Leezer's Express gas station in the southeast corner of the intersection of Main St. NE and Lexington Ave. NE. No leaks have been reported to date at this site. Further information about the contaminated sites shown on Figure 21 can be found on the MPCA website – the web address to the What's in My Neighborhood database is included on Figure 21.

The completed MDH Preliminary WHPA worksheet is included in Appendix C. Also included are water main and sanitary sewer maps for Blaine and Lino Lakes to support question 2 in Part 2 of the WHPA form.

4.0 Summary and Recommendations

4.1 Summary

The City of Blaine is planning out future well locations in its proposed Northeast Well Field so that a series of wells can be drilled to meet water demands as the City grows. Preferred and alternate sites for the proposed Northeast Well Field have been identified near the intersection of 125th Avenue and Lexington Avenue NE. Current plans call for the City to install Wells 18 and 19 in the proposed Northeast Well Field in the near future. The ultimate system build out goal is for the Northeast Well Field to produce up to 6,000 gpm.

The objectives of this study include:

1. Identify locations for Wells 18 and 19 so that the design of the wells can begin.
2. Identify which aquifer should be targeted for Wells 18 and 19 and future wells in this well field.
3. Provide a qualitative assessment of the total capacity of the Northeast Well Field to see if it can likely produce the desired amount of water for the new treatment plant.
4. Identify potential sources of contamination that might affect the siting of wells in the proposed Northeast Well Field area.
5. Estimate the impacts of the proposed wells and Northeast Well Field on nearby existing wells.
6. Estimate the impact of pumping in the proposed Northeast Well Field on water levels beneath nearby wetlands and surface water body features.
7. Provide a recommended path forward to reduce risk and uncertainty by filling gaps in the data needed to resolve unanswered questions.

A local-scale groundwater model derived from the regional-scale Metro Model 2 for the Twin Cities metropolitan area was used to conduct evaluations required to meet the study objectives. Due to lack of complete hydrogeologic information regarding the continuity and hydraulic properties of a shallow clayey unit that may hydraulically separate the water table in the vicinity of the proposed Northeast Well Field from deeper portions of the groundwater system the groundwater model does not attempt to account for the clay unit. As a result, the groundwater model may overestimate predicted water table drawdown due to pumping from deeper portions of the groundwater system in the proposed Northeast Well Field.

The groundwater modeling results indicate that both the Quaternary glacial drift aquifer (where present) and the TCW aquifer are productive in the proposed Northeast Well Field area, and that a total yield of 6,000 gpm could likely be achieved. However, at these pumping rates the model shows significant water table drawdowns that may adversely affect surface water bodies and sensitive wetlands in the vicinity. Based on the City's ultimate system build out maximum day demand projection, it appears that the total instantaneous pumping rate from the proposed Northeast Well Field required to meet maximum day demand likely would be less than 6,000 gpm.

Objectives 1, 2 and 3: Based on available information, Wells 18 and 19 should be sited as part of a site specific aquifer characterization project. Well records for wells near the proposed well field indicate there is a significant amount of clay in the Quaternary sediments. Due to a lack of information on its hydraulic properties, this clay is not well represented in the model at this time and could impact the viability and productivity of the Quaternary glacial drift aquifer. Though it is likely that Wells 18 and 19 and the well field can produce the water desired, site specific work is needed to reduce uncertainty and risk. If significant clay is present and no glacial drift aquifer wells are possible then all wells would need to be constructed into the TCW aquifer. In this case well interference may become a concern. Again site specific investigation will be needed to better quantify hydraulic conductivity of the TCW aquifer and related well interference issues. Preliminary planning for Wells 18 and 19 should include site specific deep drilling of pilot holes to characterize the presence and continuity of any deep sand units that may be a viable water source. Until that information is available plans should include deeper wells into the TCW aquifer since clay may preclude Quaternary glacial drift aquifer wells at the Northeast Well Field.

Objective 4: There are potential contaminant sources within approximately 1.7 miles of the proposed Northeast Well Field. The closest potential contaminant source location is the Leezer's Express gas station located on the east side of Lexington Ave. NE several hundred feet from the preferred site for the Northeast Well Field. If a gasoline spill were to occur at this site it could, potentially, affect groundwater captured by wells pumping in the Northeast Well Field. Whether such contamination of the groundwater could occur depends in part upon the continuity and confining (or lack thereof) characteristics of the shallow clayey unit that may hydraulically separate the water table in the vicinity of the proposed Northeast Well Field from deeper portions of the groundwater system. The only data gap for this objective, other than the continuity and hydraulic properties of the clay layer, is the absence of site specific groundwater quality data. This should be gathered during any site investigation that includes construction of test wells and/or monitoring wells to validate the absence of contaminants of concern.

Objective 5: At least 30 wells are likely to be adversely affected by increased pumping in the proposed Northeast Well Field and other Blaine wells as the city grows. The wells are located in and near Blaine. The main data gap relative to this objective is again the spatial continuity and impact of local clay units on hydraulic characteristics of the glacial drift aquifer. This may reduce the impacts of pumping on some nearby wells that are completed in the shallower sand unit. Note that the total number of wells that may be impacted to a point where City mitigation is required could be significantly higher than 30.

Objective 6: As noted above, modeling suggests that if the discussed clay layer is not spatially continuous then impacts to local surficial water bodies and wetlands are likely. Discussions with MnDNR staff indicate that the Department would expect that an aquifer test be performed in the proposed Northeast Well Field to assess potential effects on nearby sensitive wetlands before the well field could be put into service. MnDNR staff have also indicated that they would expect to have a chance to review the work plan for the aquifer test before the test is conducted. Finally, they would also like to see the monitoring results for monitoring wells in Pioneer Park to determine if pumping in Well 17 has had any impact on a sensitive wetland in that location.

The MnDNR's stated concerns point to one of the bigger risks associated with this well siting effort. The MnDNR may not allow use of Wells 18 and 19 at their full capacity if it is determined that they have a negative impact on the valued environmental resources identified above. The City could spend the money to install two high capacity wells only to have their use limited by the MnDNR to mitigate impacts to local wetlands.

Objective 7 is addressed below in section 4.2.

4.2 Recommendations

It is recommended that before finalizing any well plans that additional study is undertaken to reduce risk and uncertainty.

The unknown continuity and hydraulic characteristics of the shallow Quaternary clayey layer as a protective unit to the water table should be addressed before proceeding with well field design and construction. The following recommended path forward outlines a stepwise approach to reducing uncertainty, and gives the City the option of deciding if and how to proceed after each step.

Step 1: Detailed Paper Study

Description of the work: Commission a paper study to identify additional data regarding Quaternary geology and hydraulic connection between upper and lower zones of the Quaternary glacial drift aquifer. The study should involve a detailed review of well logs in and around Blaine and a review of nearby pumping tests that may provide supporting data relative to the hydraulic connection of the deeper units to the shallower units. Using the data acquired, update the groundwater model and use it to better understand potential impacts to surface water bodies and wetlands. This is a relatively low cost initial step to gain more understanding of the Quaternary geology of the area and ensure that it is adequately represented in the model being used to analyze the well field.

Risks: The additional data may not be specific enough to resolve the issue of clay continuity. However it will likely be detailed enough to allow valuable model updates.

Step 2: Pumping Test with Existing Wells

Description of Work: Plan out a pumping test that would utilize existing City wells and existing and new monitoring wells. Install monitoring well nests at key locations near valued environmental features and in the proposed Northeast Well Field and run a pumping test using existing City well(s). Use the data gathered to update the groundwater model. This effort will help in several ways. Any new monitoring wells that are installed should be strategically sited to provide data on a pumping test but also help to better characterize the Northeast Well Field.

Risks: Location of the pumping center will not be at the proposed Northeast Well Field, and wetland impacts caused by future pumping from that location may not be captured

Step 3: Site-Specific Pumping Test

Description of Work: Drill several pilot holes into the bedrock around the Northeast Well Field. Using this data, characterize the site and select an aquifer for Well 18. Drill Well 18 and install any additional monitoring wells that may be needed if the ones installed in Step 2 are not sufficient to capture the needed data. Using Well 18, run a site-specific pumping test to evaluate impacts to environmental features of interest and determine well capacity.

Risks: The MnDNR may significantly limit the use of the production wells if surface water and wetland impacts are observed

The recommended path forward provides the opportunity after each step for the City to stop and reconsider what is the best way to proceed. If unfavorable results suggest that the clay layer is NOT continuous and that substantial negative impacts will occur as a result of installing Wells 18 and 19 in the proposed Northeast Well Field then the City can stop moving along this path an move to study an alternative water source such as a deeper aquifer. If, after each step, results are favorable then the City can proceed to the next step. In this way, the City can take incremental steps forward and limit its total out of pocket costs all the while building a greater understanding of the hydrogeologic setting and gain more insight into the likely response of regulators to the permit applications that will be required to construct and use the planned wells.

As a final note, it is recommended that the steps above should be communicated to the MnDNR as a first cut at the aquifer test plan to see if they approve of the direction proposed. They will then likely want to see a detailed plan associated with each step before the City proceeds with the work. The detailed plans should include monitoring well nest locations along with location of existing (Step 2) or new (Step 3) planned pumping wells and a description of the pumping rate(s) and duration of the test.

Barr would like to thank the City of Blaine for working with us to prepare this report. We acknowledge the input of key staff members in pulling together the data needed to complete this effort.

5.0 References

Barr Engineering Company (Barr), 2003a. City of Blaine Well Siting Study, Letter Report to Michael Ulrich, May 22, 2003.

Barr Engineering Company (Barr), 2003b. Results of Well Siting Study – City of Blaine, PowerPoint presentation by Ray Wuolo to City of Blaine, September 11, 2003.

Barr Engineering Company (Barr), 2004. Well Siting Phase 2 – Northeast and Southeast Areas, Technical Memorandum to Chuck Lenthe and Jean Keely, July 1, 2004.

BlueStone Engineering (BlueStone), 2007. Water Emergency and Conservation Plan – City of Blaine, approved by MDNR May 23, 2007.

Bonestroo, 2009. City of Blaine Comprehensive Plan Update, November 2009

Hansen, D.D. and J.K. Seaberg, 2000. Metropolitan Area Groundwater Model Project Summary: Lower Aquifers Model, Layers 4 and 5. MPCA report, 76pp.

Metropolitan Council, 2009. Twin Cities Metropolitan Area Regional Groundwater Flow ModelVersion 2.00: Technical Report in Support of the Metropolitan Area Master Water Supply Plan(Draft).

Meyer, G.N. and R.G. Tipping, 2007, Geology in support of ground-water management for the Twin Cities Metropolitan Area, Metropolitan Council Water Supply Master Plan Development - Phase I. Minnesota Geological Survey Open File Report OF07-02.

Minnesota Geological Survey (MGS), 2006. County Well Index, update November 3, 2006.

Mossler, J.H. and R.G. Tipping. 2000. Bedrock geology and structure of the seven-county Twin Cities metropolitan area, Minnesota. Miscellaneous Map Series M-104, Minnesota Geological Survey.

Runkel, A.C, R.G. Tipping, E.C. Alexander, Jr., and J.A. Green, 2003. Hydrogeology of the Paleozoic Bedrock in Southeastern Minnesota, Minnesota Geological Survey Report of Investigations 61, 105 p., 2 pls.

Tables

Table 1
Baseline Scenario Pumping Rates
Wells 18 and 19 Siting Evaluation
City of Blaine

Well	Unique Number	Open to Model Layers…	Total Pumping 2007-2011 (Mgal)[1]	Baseline Pumping Rate (2007-2011 average) (gpm)	Modified Baseline Pumping Rate (gpm)
1	208629	6-9	157.881	60.1	63.5
2	208628	5-9	115.444	43.9	47.3
3	208646	4-9	2055.543	782.2	785.5
4	208645	4-7	2033.963	774.0	777.3
5	208615	5-9	178.455	67.9	71.3
6	208634	6-9	1680.786	639.6	642.9
7	208616	6-8	133.088	50.6	0.0
8	208630	6-8	227.975	86.7	90.1
9	208618	6-8	148.519	56.5	59.9
10	208643	6-8	329.540	125.4	128.8
11	208633	6-9	1067.859	406.3	409.7
12	127264	5-6	1078.208	410.3	413.7
13	127270	6-9	1787.288	680.1	683.5
14	233109	7-9	286.109	108.9	112.2
16	151587	6-8	141.794	54.0	57.3
17	721815	5	1439.309	547.7	551.1

[1] From DNR Annual Water Use Reports provided by the City.

Table 2
Ultimate Capacity Scenarios
Wells 18 and 19 Siting Evaluation
City of Blaine

Scenario	Proposed Well	UTM E	UTM N	Aquifer	Pumping Rate (gpm)
6000_T1	18	487100	5004360	TCW	1000
	19	487099	5004770	TCW	1000
	20	486844	5004770	TCW	1000
	21	487152	5003780	TCW	1000
	22	486765	5004388	TCW	1000
	23	486812	5003766	TCW	1000
6000_T2	18	487100	5004360	TCW	750
	19	487099	5004770	TCW	750
	20	486844	5004770	TCW	750
	21	487152	5003780	TCW	750
	22	486765	5004388	TCW	750
	23	486812	5003766	TCW	750
	24	487948	5004740	TCW	750
	25	487950	5004040	TCW	750
6000_Q1	18	487100	5004360	Glacial Drift	1000
	19	487099	5004770	Glacial Drift	1000
	20	486844	5004770	Glacial Drift	1000
	21	486765	5004388	Glacial Drift	1000
	22	487948	5004740	Glacial Drift	1000
	23	487950	5004040	Glacial Drift	1000
6000_Q2	18	487100	5004360	Glacial Drift	545.45
	19	487099	5004770	Glacial Drift	545.45
	20	486844	5004770	Glacial Drift	545.45
	21	486765	5004388	Glacial Drift	545.45
	22	487948	5004740	Glacial Drift	545.45
	23	487950	5004390	Glacial Drift	545.45
	24	487950	5004040	Glacial Drift	545.45
	25	487410	5003964	Glacial Drift	545.45
	26	487588	5003630	Glacial Drift	545.45
	27	487516	5004750	Glacial Drift	545.45
	28	487516	5004390	Glacial Drift	545.45
6000_TQ1	18	487100	5004360	Glacial Drift	1000
	19	487099	5004770	Glacial Drift	1000
	20	486844	5004770	Glacial Drift	1000
	21	487152	5003780	TCW	1000
	22	486765	5004388	Glacial Drift	1000
	23	486812	5003766	TCW	1000
6000_TQ2	18	487100	5004360	Glacial Drift	550
	19	487099	5004770	Glacial Drift	550
	20	486844	5004770	Glacial Drift	550
	21	487152	5003780	TCW	760
	22	486765	5004388	Glacial Drift	760
	23	486812	5003766	TCW	760
	24	487948	5004740	TCW	550
	25	487950	5004040	TCW	760
	26	487410	5003964	TCW	760

Table 3
Well Capacities and Maximum Demand
Wells 18 and 19 Siting Evaluation
City of Blaine

Projected Maximum Demand 25,180,000 gpd

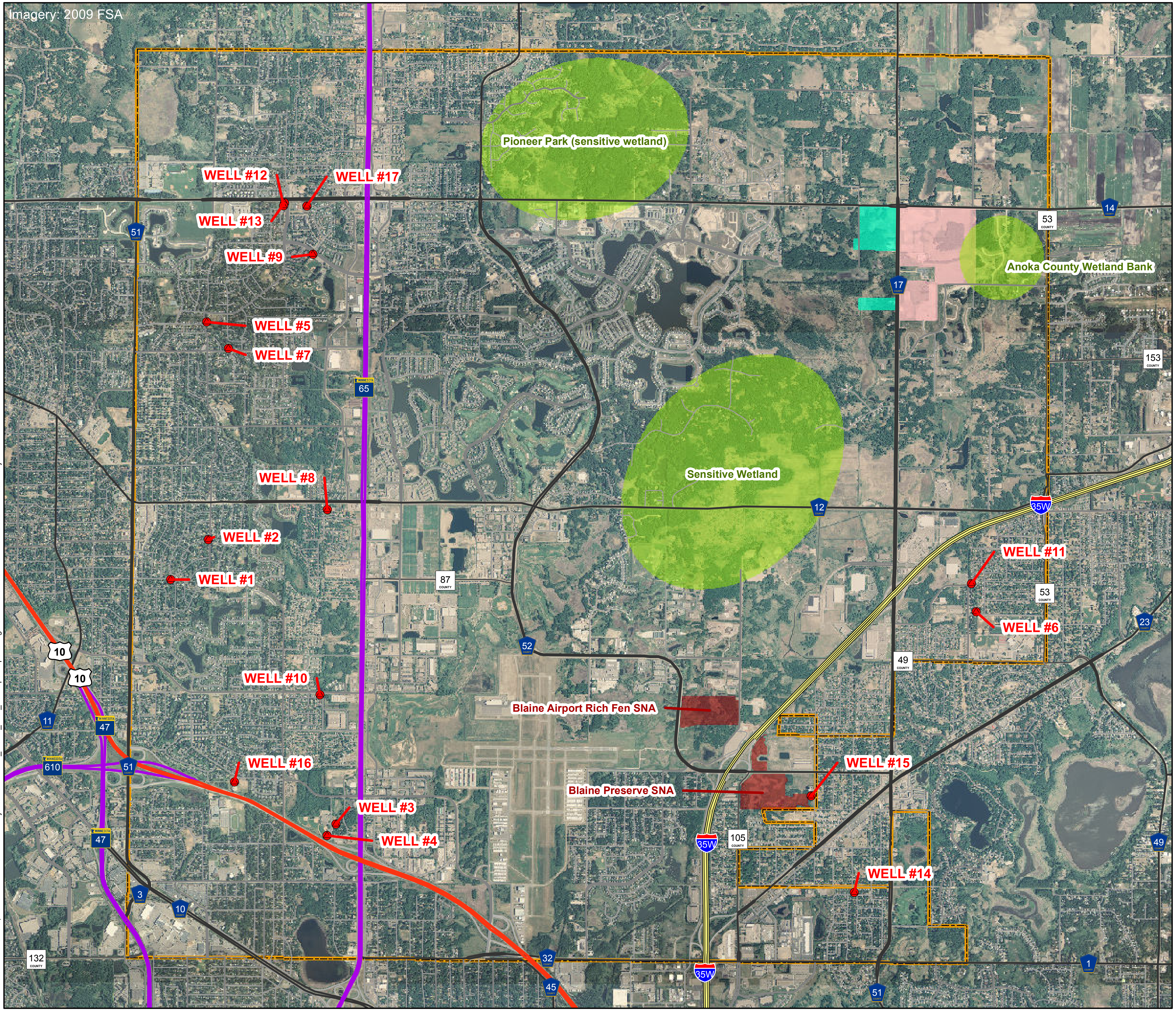
Well	Capacity (gpm)	Capacity (gpd)
1	900	1,296,000
2	1,000	1,440,000
3	1,000	1,440,000
4	1,000	1,440,000
5	700	1,008,000
6	1,000	1,440,000
7	1,000	1,440,000
8	1,200	1,728,000
9	700	1,008,000
10	1,310	1,886,400
11	1,000	1,440,000
12	1,700	2,448,000
13	1,300	1,872,000
14	1,000	1,440,000
16	1,000	1,440,000
17	2,000	2,880,000
Total	17,810	25,646,400

Scenario	Well(s) Off	Water Available From Existing Wells (gpd)	Water Needed to Meet Maximum Demand (gpd)	Water Needed to Meet Maximum Demand (gpm)
Peak1	7	24,206,400	973,600	676
Peak2	12, 17	20,318,400	4,861,600	3,376

Table 4
Definitions of 4-week Maximum Pumping Scenarios
Wells 18 and 19 Siting Evaluation
City of Blaine

		Replacement Wells				
Scenario	**Blaine Well(s) Not Pumping**	**Well ID**	**UTM E**	**UTM N**	**Aquifer**	**Pumping Rate (gpm)**
Peak1_T	7	18	487100	5004364	TCW	676
Peak1_Q	7	18	487100	5004364	Glacial Drift	676
Peak2_T	12,17	18	487100	5004364	TCW	1000
		19	487177	5004770	TCW	1000
		20	486844	5004765	TCW	1000
		21	487152	5003784	TCW	376
Peak2_Q	12,17	18	487100	5004364	Glacial Drift	1000
		19	487177	5004770	Glacial Drift	1000
		20	486844	5004765	Glacial Drift	1000
		21	486766	5004420	Glacial Drift	376
Peak2_TQ	12,17	18	487100	5004364	Glacial Drift	1000
		19	487177	5004770	TCW	1000
		20	486844	5004765	Glacial Drift	1000
		21	487152	5003784	TCW	376

Figures



Blaine Municipal Well

Scientific and Natural Area (SNA)

MnDNR-identified Wetland of Concern

Preferred Well Field Site

Alternate Well Field Site

Blaine City Limits

N

Miles

1 0 1

Kilometers

1 0 1

BARR

Figure 1

NORTHEAST WELL FIELD LOCATIONS
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN

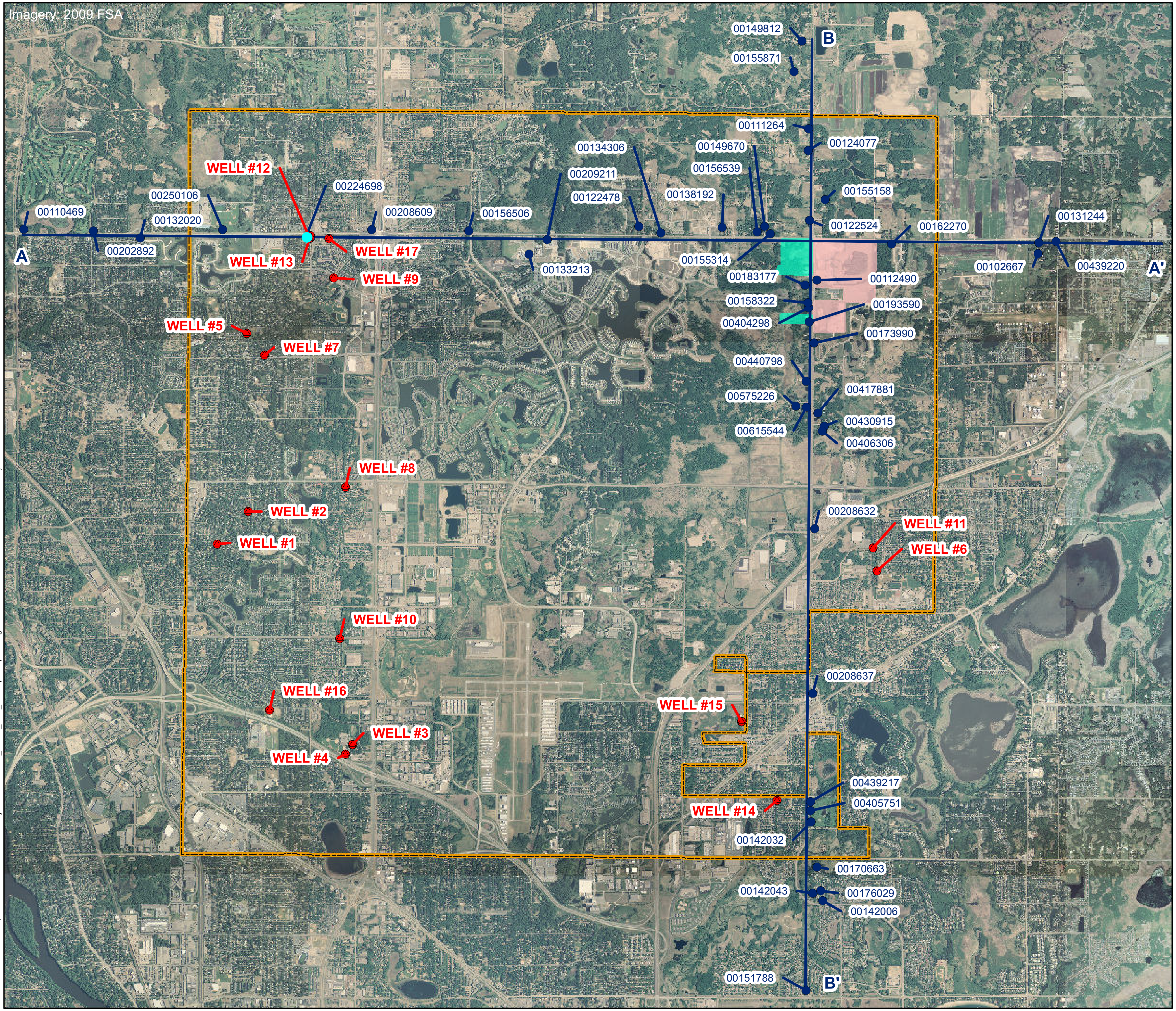
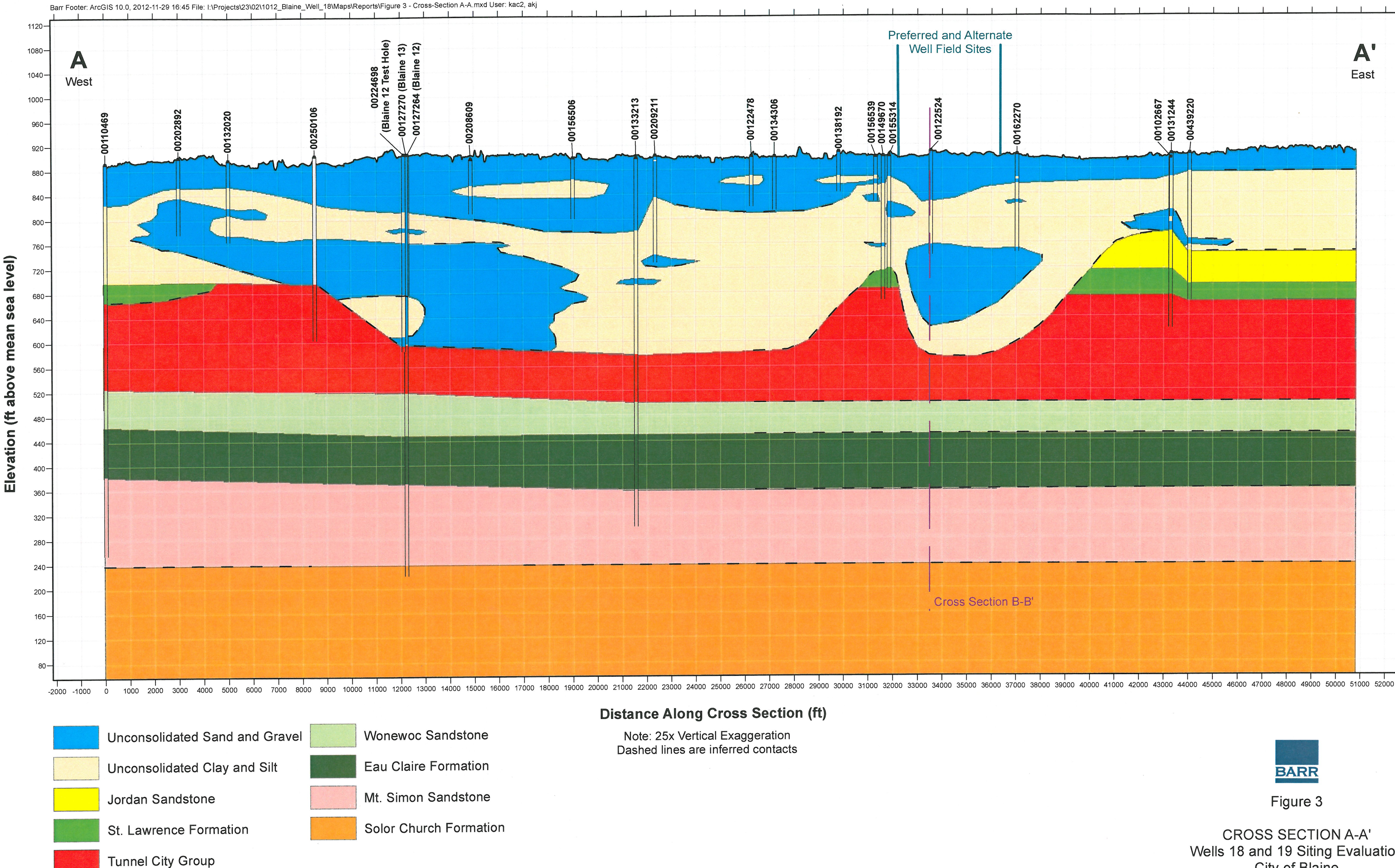


Figure 2

GEOLOGIC CROSS SECTION LOCATIONS
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN

Barr Footer: ArcGIS 10.0, 2012-10-17 10:50 File: I:\Projects\23\02\1012_Blaine_Well_18\Maps\Reports\Figure 2 - Cross Section Locations.mxd User: akj

Barr Footer: ArcGIS 10.0, 2012-11-29 16:45 File: I:\Projects\23\02\1012_Blaine_Well_18\Maps\Reports\Figure 3 - Cross-Section A-A.mxd User: kac2, akj



Note: 25x Vertical Exaggeration
Dashed lines are inferred contacts

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Figure 3

CROSS SECTION A-A'
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN

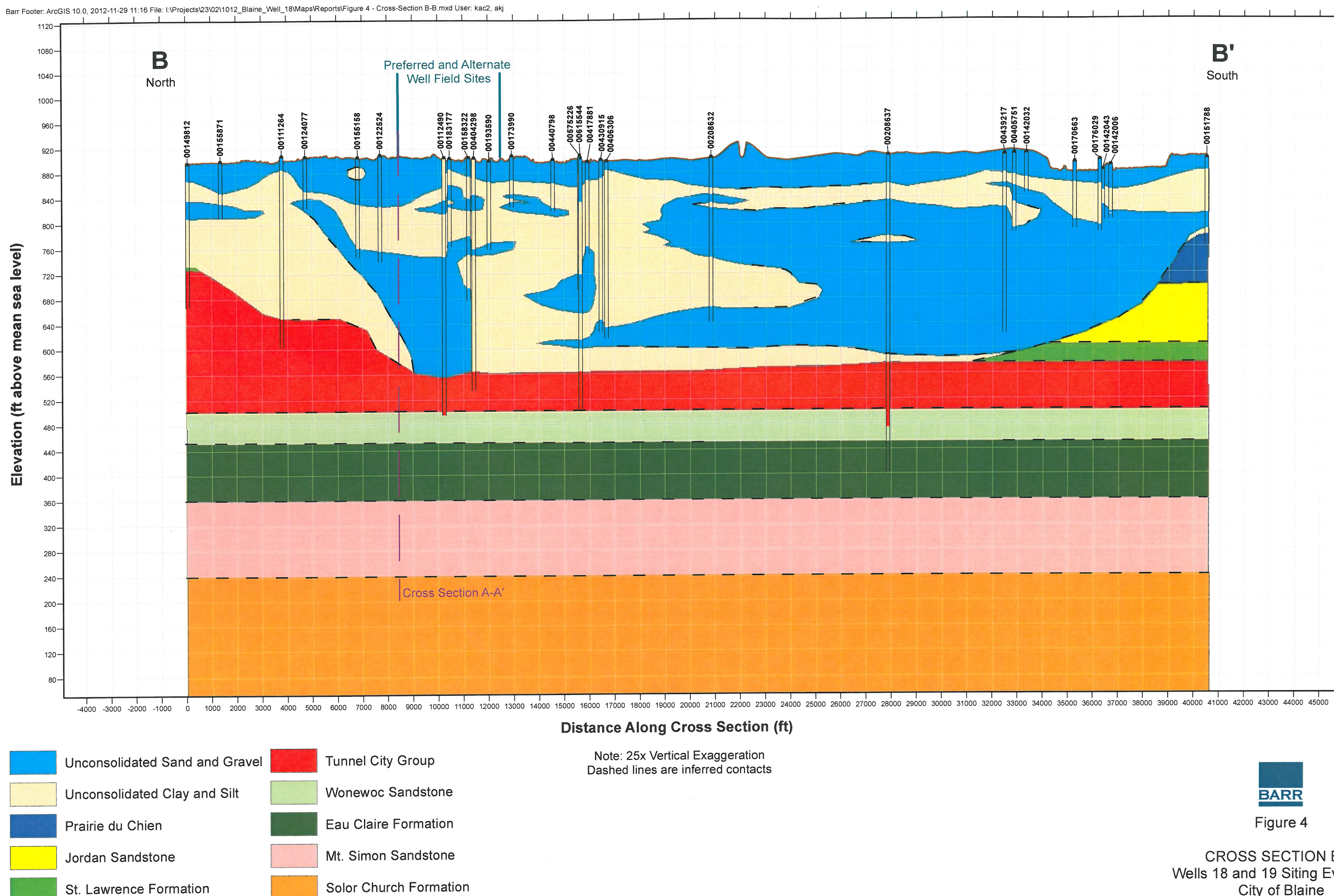

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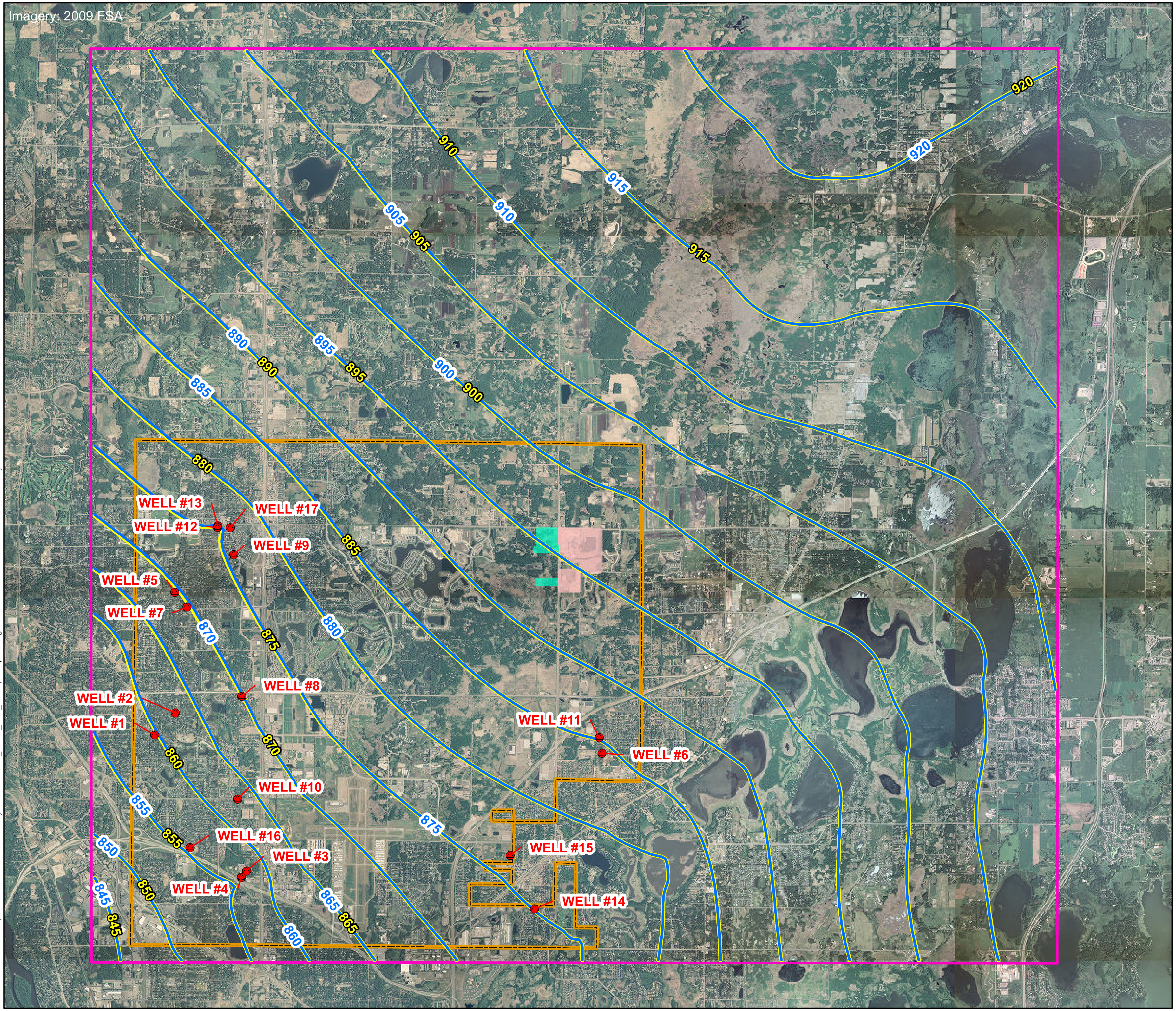
Figure 4

CROSS SECTION B-B'
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN



Blaine Municipal Well

Baseline Head (ft MSL)

Modified Baseline Head (ft MSL)

Model Boundary

Blaine City Limits

Preferred Well Field Site

Alternate Well Field Site

5-foot Contour Interval

N

Miles

1 0 1

Kilometers

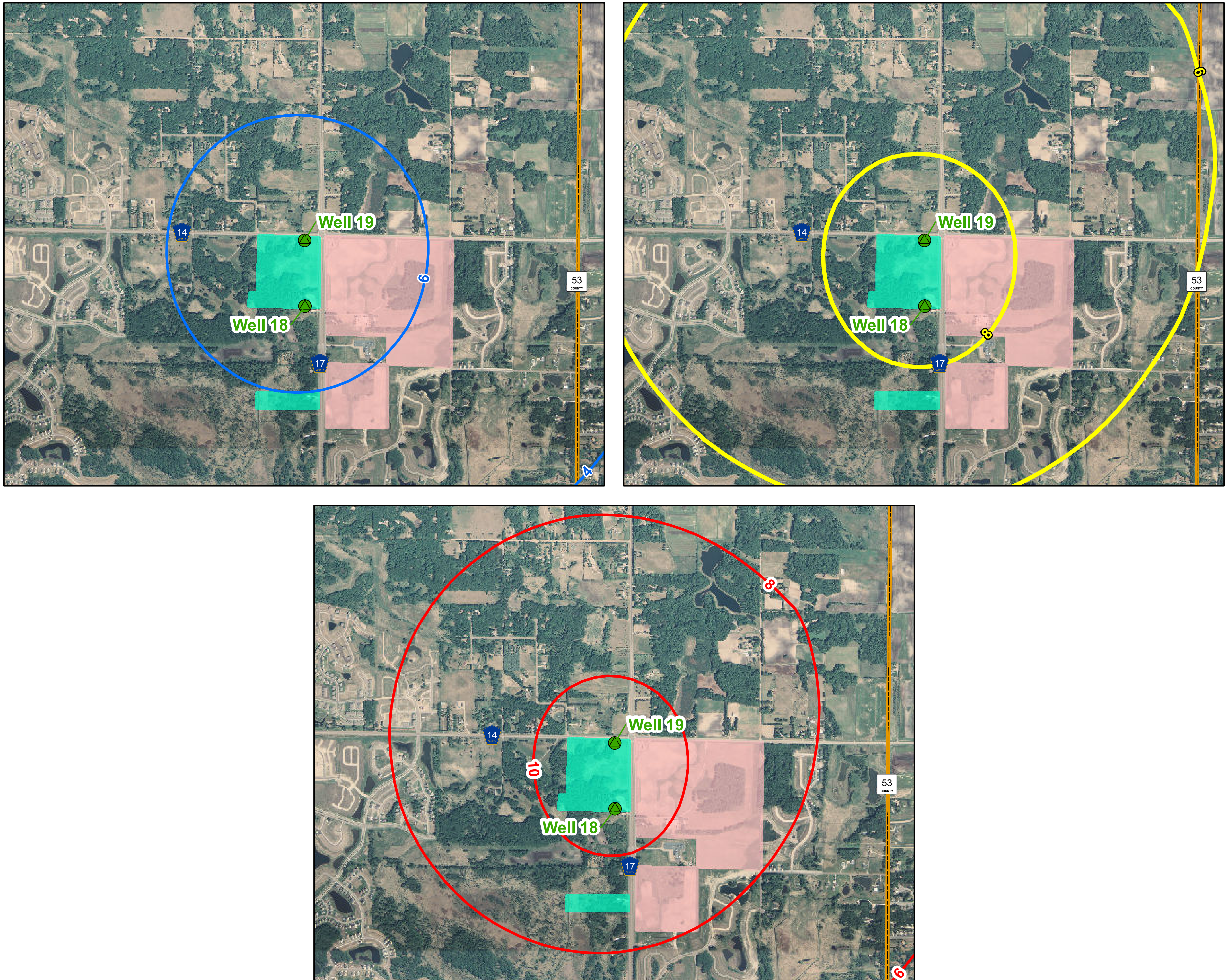
1 0 1

BARR

Figure 5

BASELINE HEAD CONTOURS
MODEL LAYER 1
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN

Barr Footer: ArcGIS 10.0, 2012-11-12 08:56 File: I:\Projects\23\02\1012_Blaine_Well_18\Maps\Reports\Figure 6 - Well 18 & 19 TCW.mxd User: kac2



Proposed Well
800 gpm Drawdown (ft)
1000 gpm Drawdown (ft)
1250 gpm Drawdown (ft)
Blaine City Limits
Preferred Well Field Site
Alternate Well Field Site

2-foot contour interval
Imagery: 2009 FSA

N

Feet
2,000 0 2,000

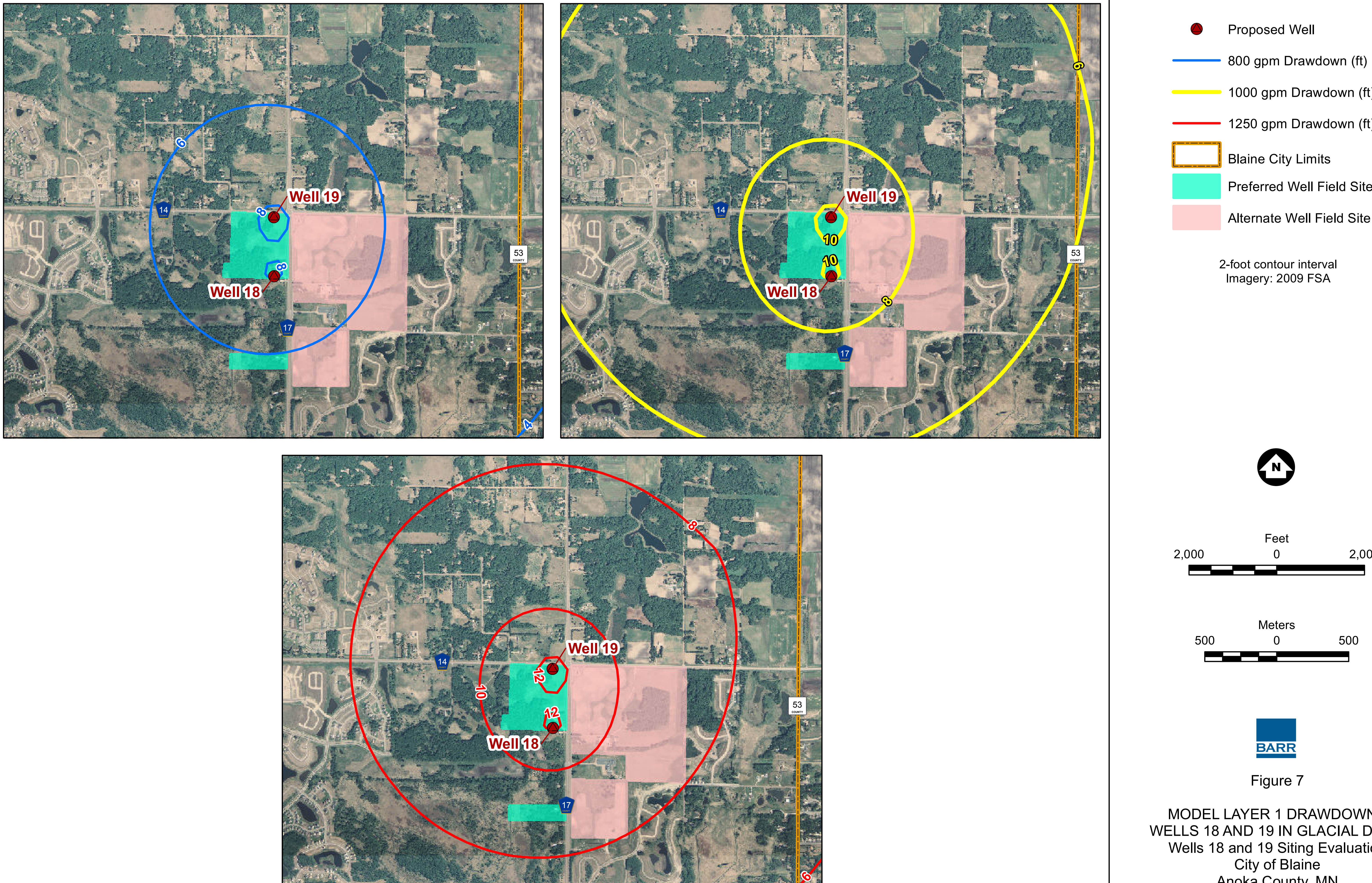
Meters
500 0 500

BARR

Figure 6

MODEL LAYER 1 DRAWDOWNS
WELLS 18 AND 19 IN TUNNEL CITY-WONEWOC
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN

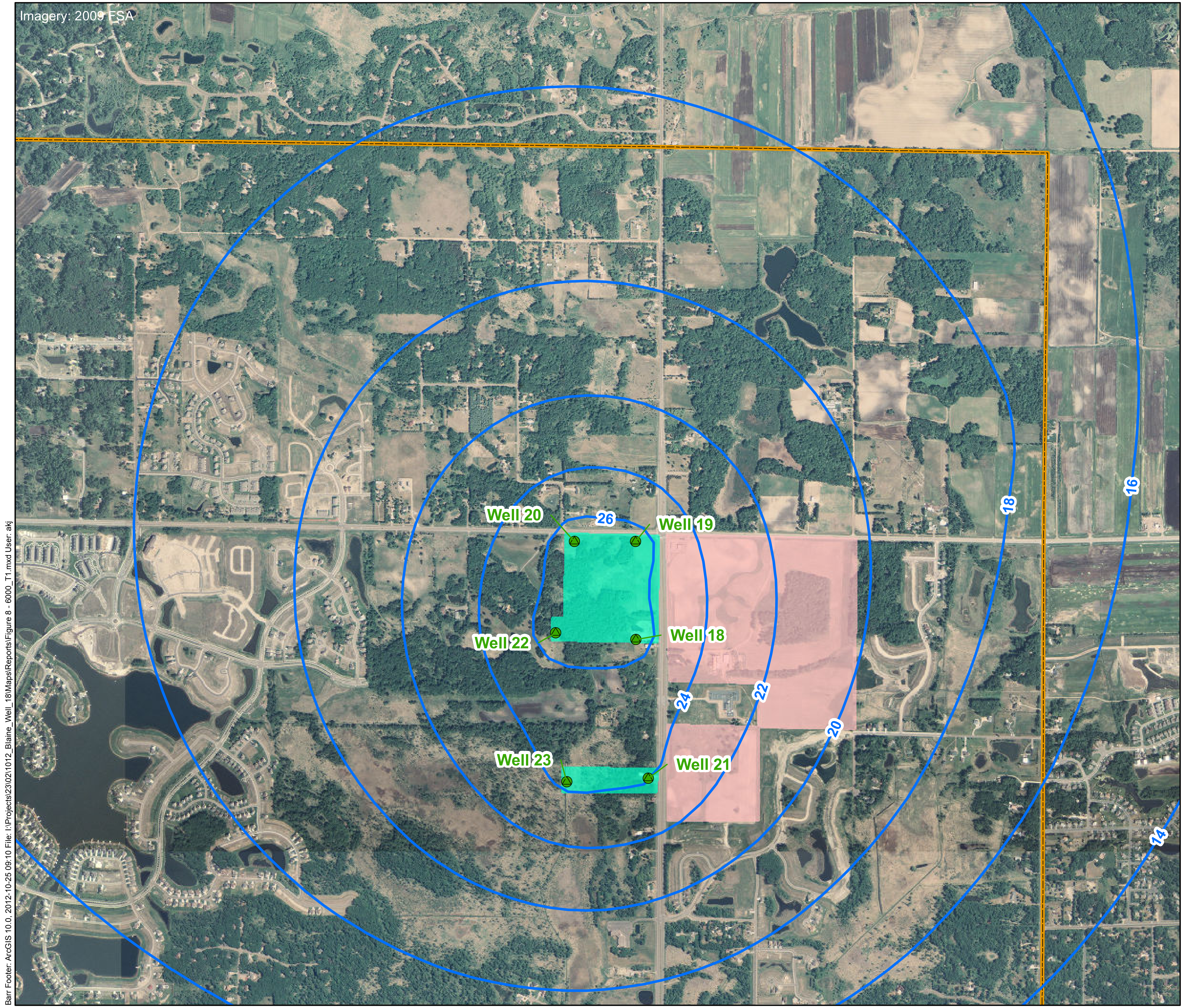
Barr Footer: ArcGIS 10.0, 2012-11-12 09:11 File: I:\Projects\23\02\1012 Blaine Well 18\Maps\Reports\Figure 7 - Well 18 & 19 Quat.mxd User: kac2



BARR

Figure 7

MODEL LAYER 1 DRAWDOWNS
WELLS 18 AND 19 IN GLACIAL DRIFT
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN



Proposed Well

Drawdown (ft)

Blaine City Limits

Preferred Well Field Site

Alternate Well Field Site

2-foot Contour Interval
All wells completed in Tunnel City-Wonewoc
All wells pumping at 1000 gpm

N

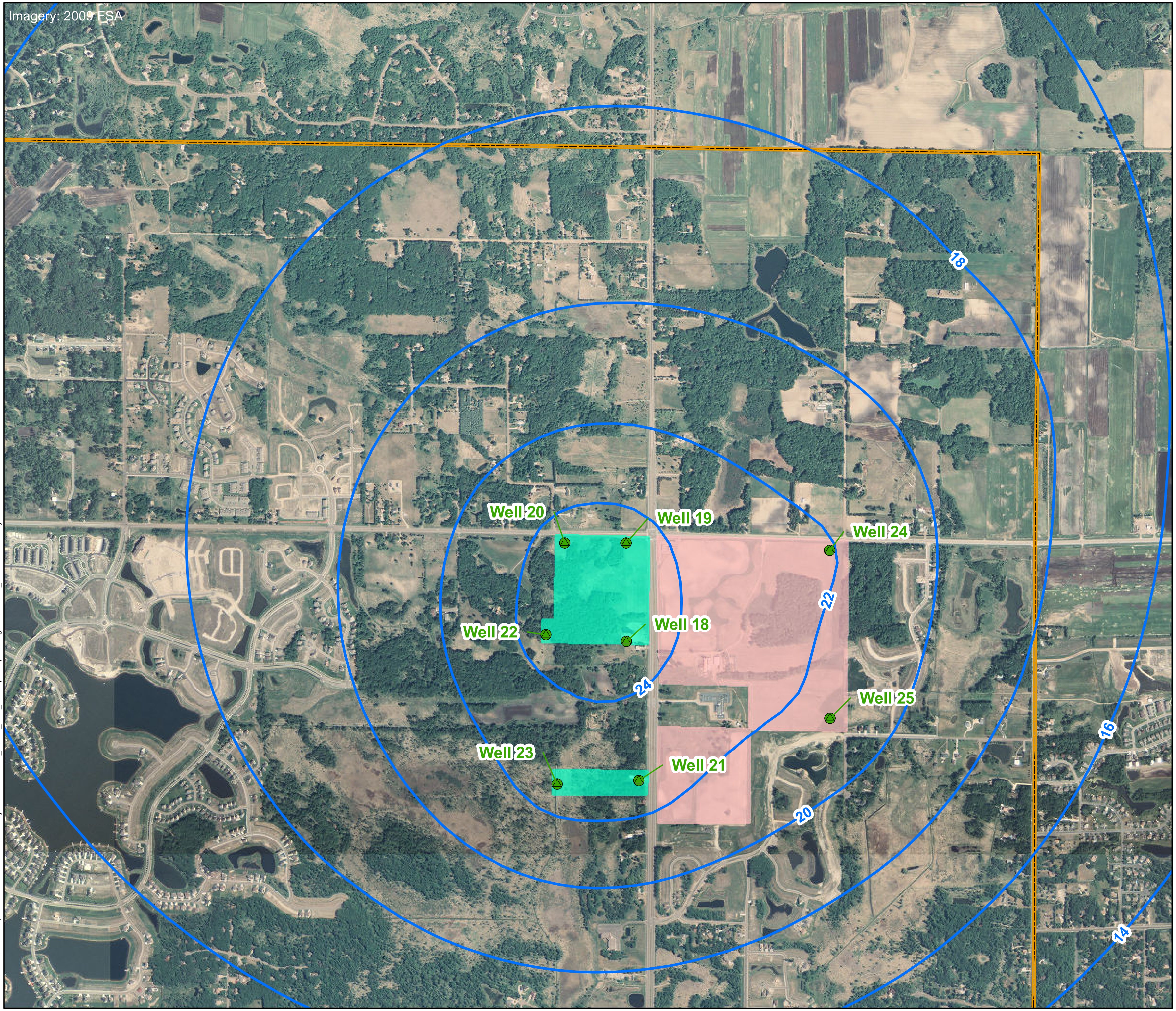
Feet
1,000 0 1,000

Meters
300 0 300

BARR

Figure 8

MODEL LAYER 1 DRAWDOWNS
SCENARIO 6000_T1
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN



Proposed Well

Drawdown (ft)

Blaine City Limits

Preferred Well Field Site

Alternate Well Field Site

2-foot Contour Interval
All wells completed in Tunnel City-Wonewoc
All wells pumping at 750 gpm

N

Feet
1,000 0 1,000

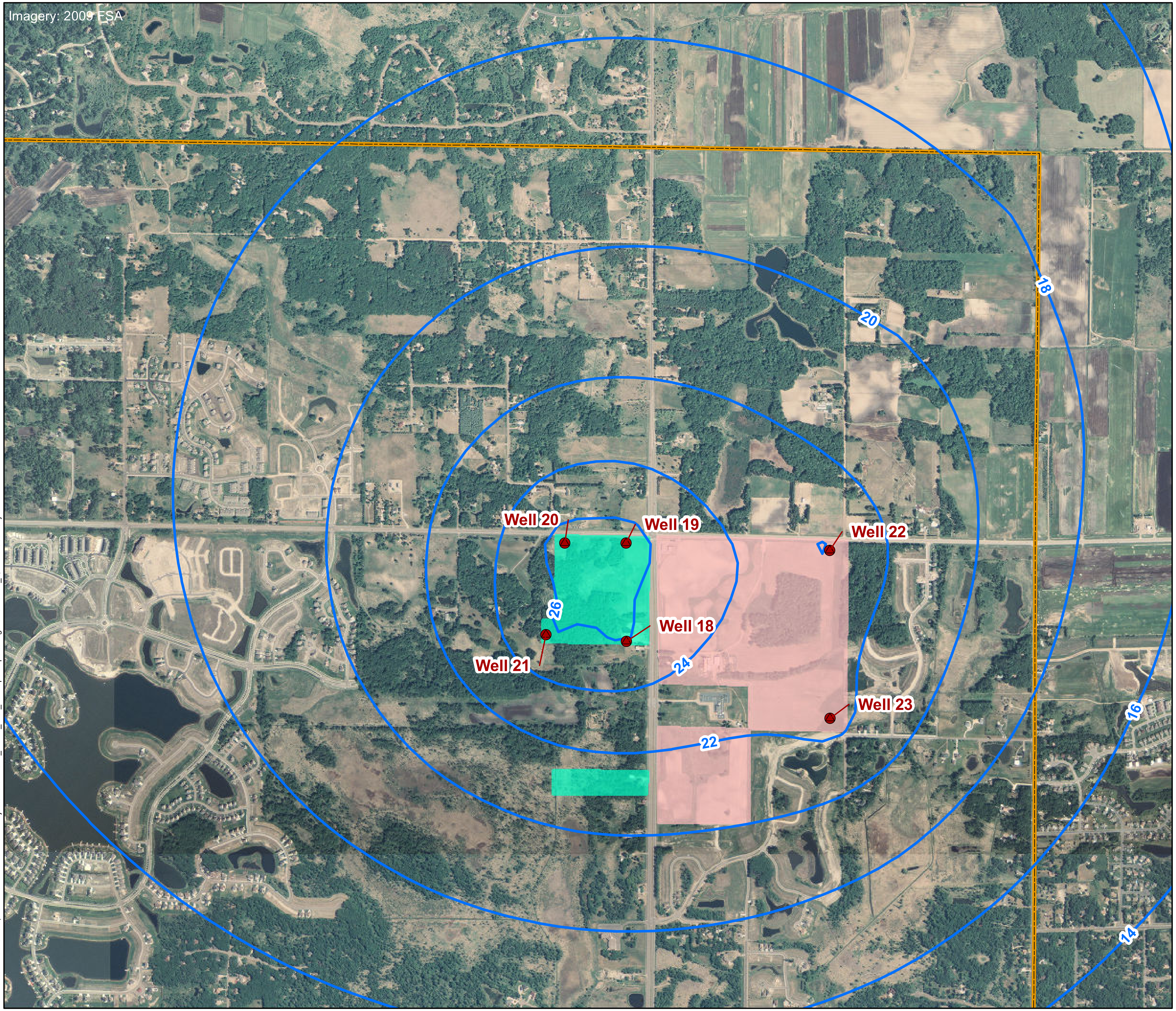
Meters
300 0 300

BARR

Figure 9

MODEL LAYER 1 DRAWDOWNS
SCENARIO 6000_T2
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN

Barr Footer: ArcGIS 10.0, 2012-10-19 08:31 File: I:\Projects\23\02\1012_Blaine_Well_18\Maps\Reports\Figure 9 - 6000_T2.mxd User: akj



Proposed Well

Drawdown (ft)

Blaine City Limits

Preferred Well Field Site

Alternate Well Field Site

2-foot Contour Interval
All wells completed in Glacial Drift
All wells pumping at 1000 gpm

N

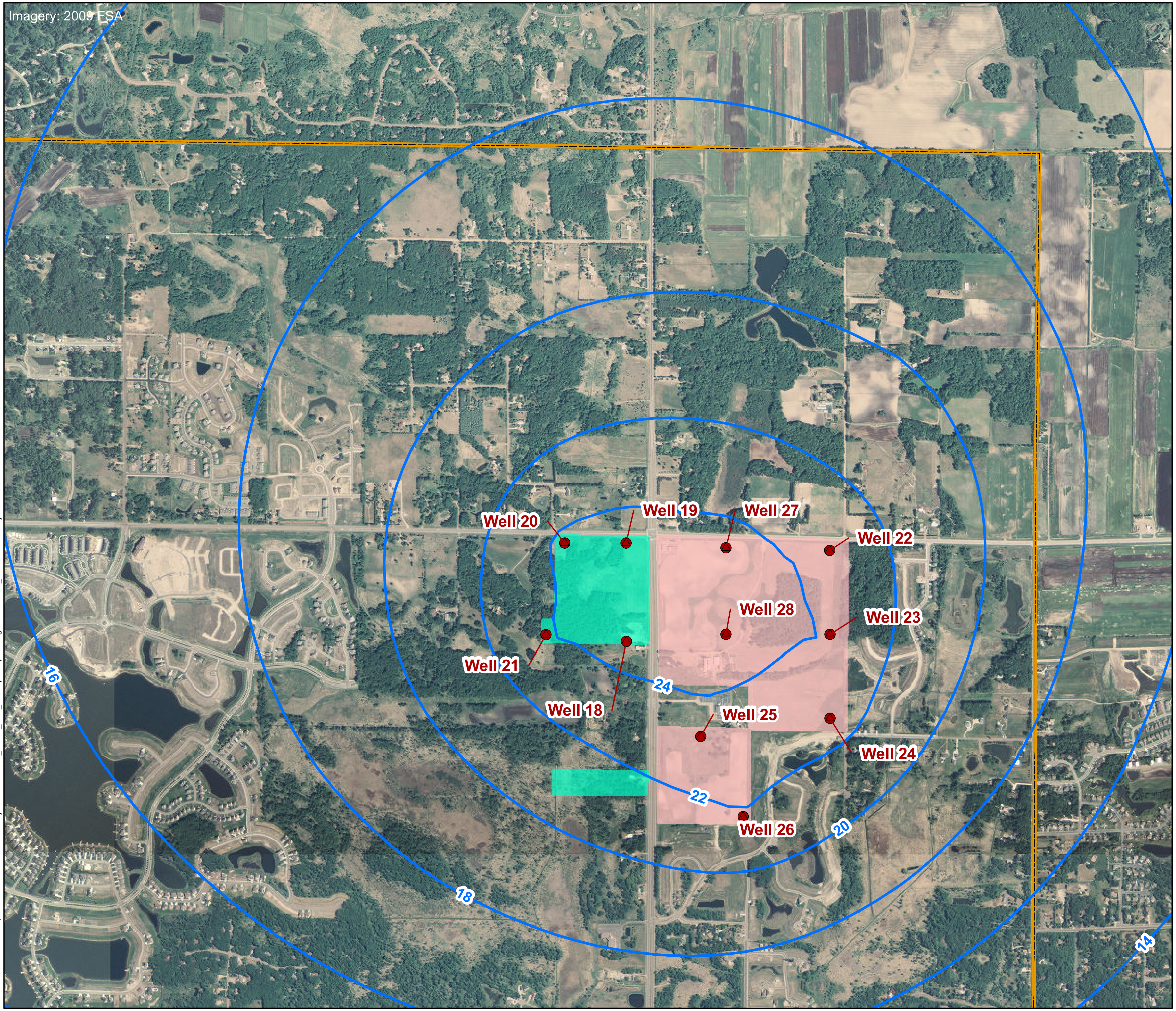
Feet
1,000 0 1,000

Meters
300 0 300

BARR

Figure 10

MODEL LAYER 1 DRAWDOWNS
SCENARIO 6000_Q1
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN



Proposed Well
Drawdown (ft)
Blaine City Limits
Preferred Well Field Site
Alternate Well Field Site

2-foot Contour Interval
All wells completed in Glacial Drift
All wells pumping at 545.45 gpm

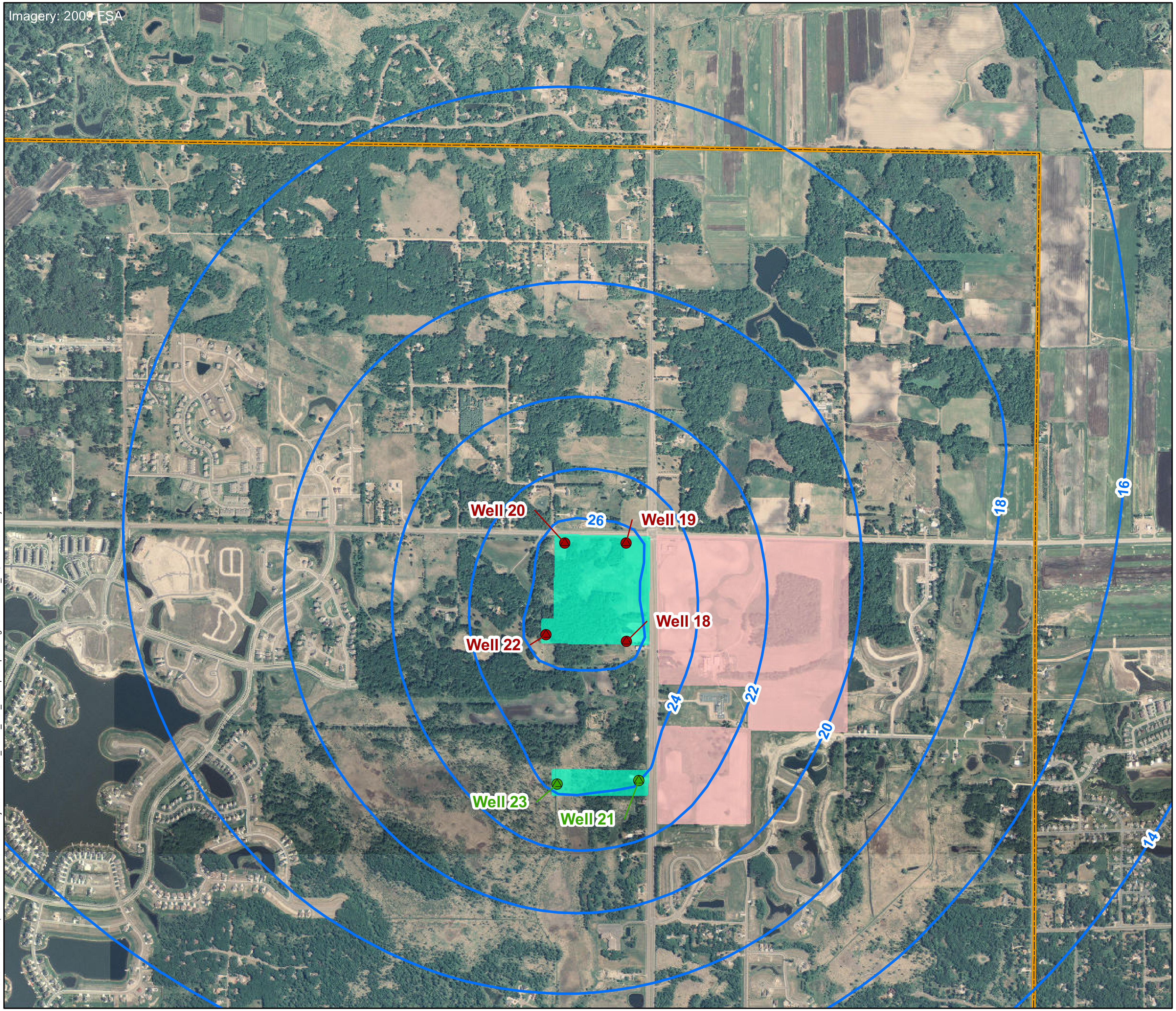
Feet
1,000 0 1,000

Meters
300 0 300

BARR

Figure 11

MODEL LAYER 1 DRAWDOWNS
SCENARIO 6000_Q2
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN



Proposed Well

- Tunnel City-Wonewoc
- Glacial Drift
- Drawdown (ft)
- Blaine City Limits
- Preferred Well Field Site
- Alternate Well Field Site

2-foot Contour Interval
All wells pumping at 1000 gpm

N

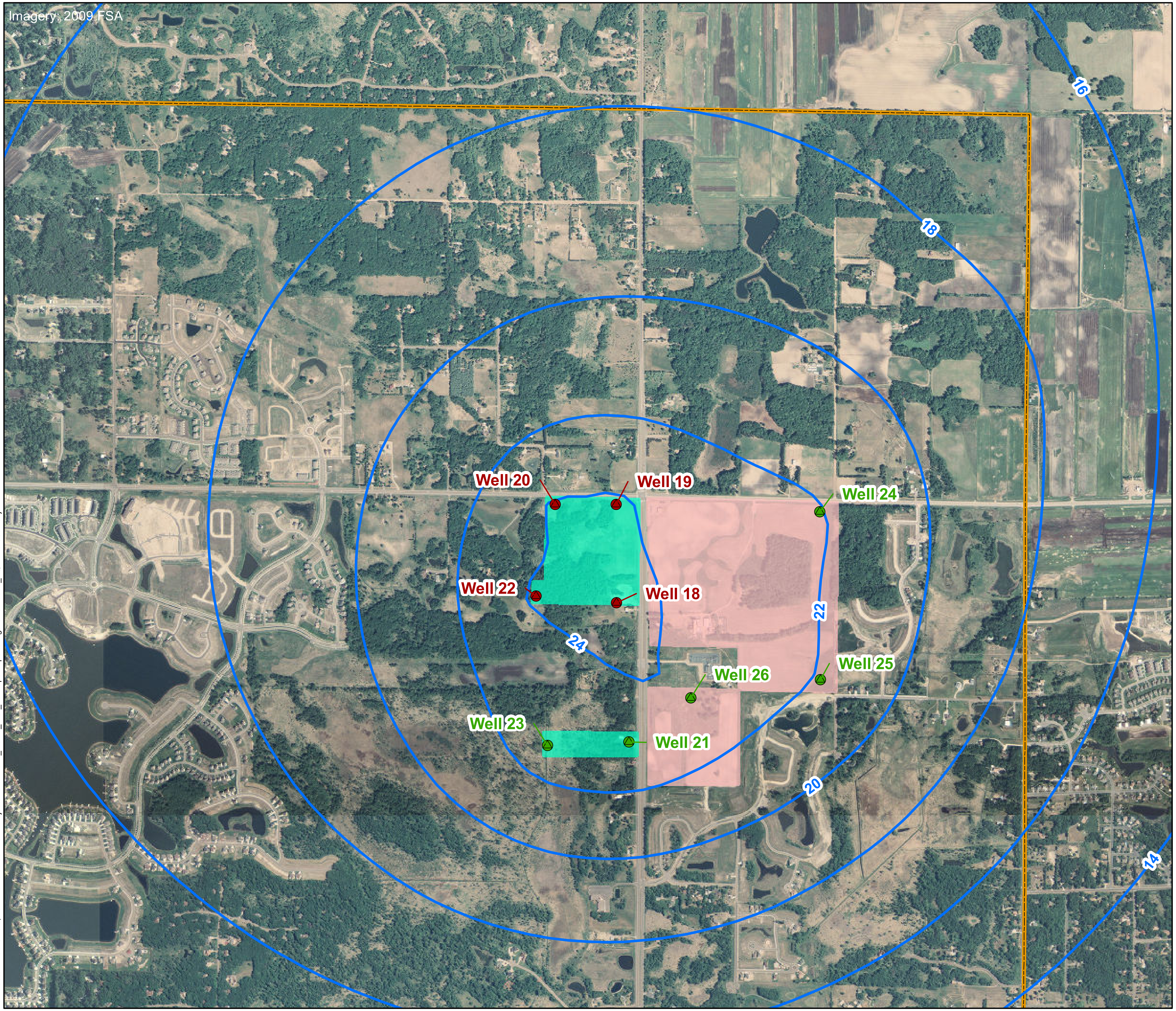
Feet
1,000 0 1,000

Meters
300 0 300

BARR

Figure 12

MODEL LAYER 1 DRAWDOWNS
SCENARIO 6000_TQ1
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN



Proposed Well

- Tunnel City-Wonewoc
- Glacial Drift
- Drawdown (ft)
- Blaine City Limits
- Preferred Well Field Site
- Alternate Well Field Site

2-foot Contour Interval
Pumping rate for TCW Wells = 760 gpm
Pumping rate for Glacial Drift Wells = 550 gpm

N

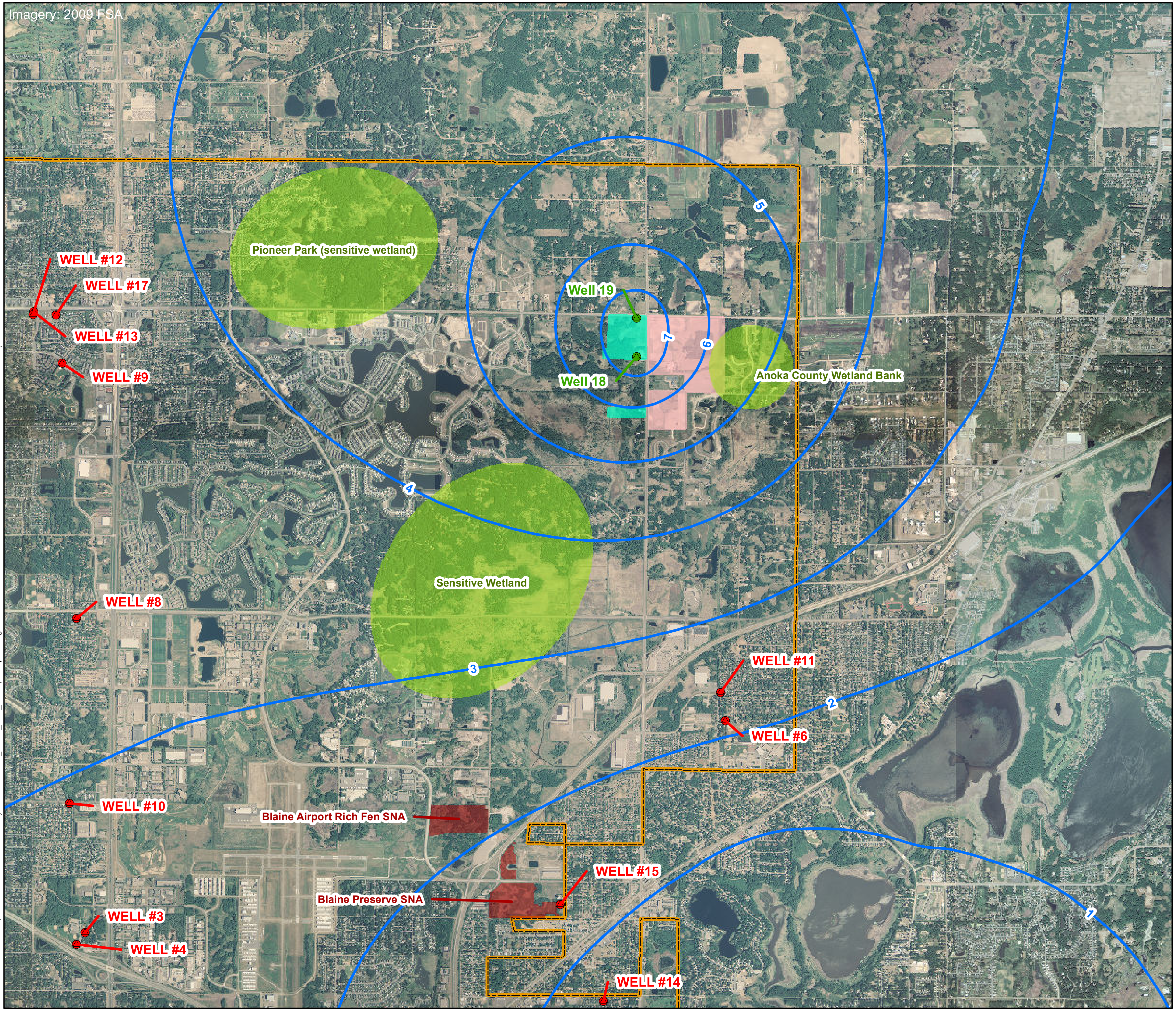
Feet
1,000 0 1,000

Meters
300 0 300

BARR

Figure 13

MODEL LAYER 1 DRAWDOWNS
SCENARIO 6000_TQ2
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN



Proposed Well

Blaine Municipal Well

Modeled Drawdown (ft)

Scientific and Natural Area (SNA)

MnDNR-identified Wetland of Concern

Preferred Well Field Site

Alternate Well Field Site

Blaine City Limits

Wells 18 and 19 both pumping at 800 gpm from TCW
1-foot contour interval

N

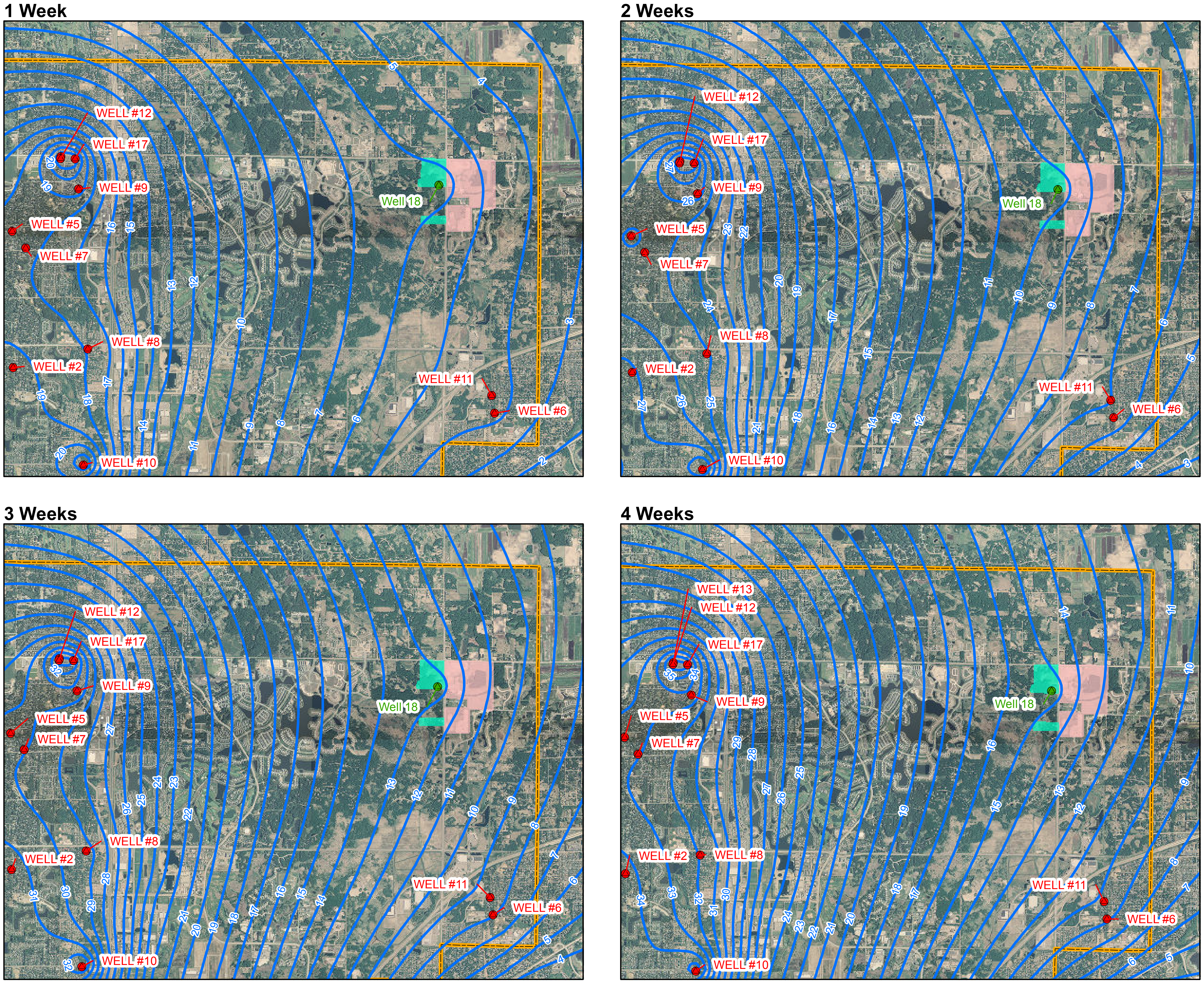
Miles
1 0 1

Kilometers
1 0 1

BARR

Figure 14

MODELED DRAWDOWN NEAR
WETLANDS OF CONCERN AND SNAs
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN



Blaine Municipal Well

Potential Well Location

Drawdown (ft)

Blaine City Limits

Preferred Well Field Site

Alternate Well Field Site

1-foot Contour Interval

Existing Blaine Well Pumping Rates:
1-6, 8-17 at capacity
7 off

New Blaine Well Pumping Rates:

Well	Aquifer	Rate (gpm)
18	TCW	676

N

Miles
1 0 1

Kilometers
1 0 1

BARR

Figure 15

MODEL LAYER 1 DRAWDOWNS
SCENARIO PEAK1_T
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN

Barr Footer: ArcGIS 10.0, 2012-11-27 15:47 File: I:\Projects\23\02\1012_Blaine_Well_18\Maps\Reports\Figure 15 - Peak1T.mxd User: akj

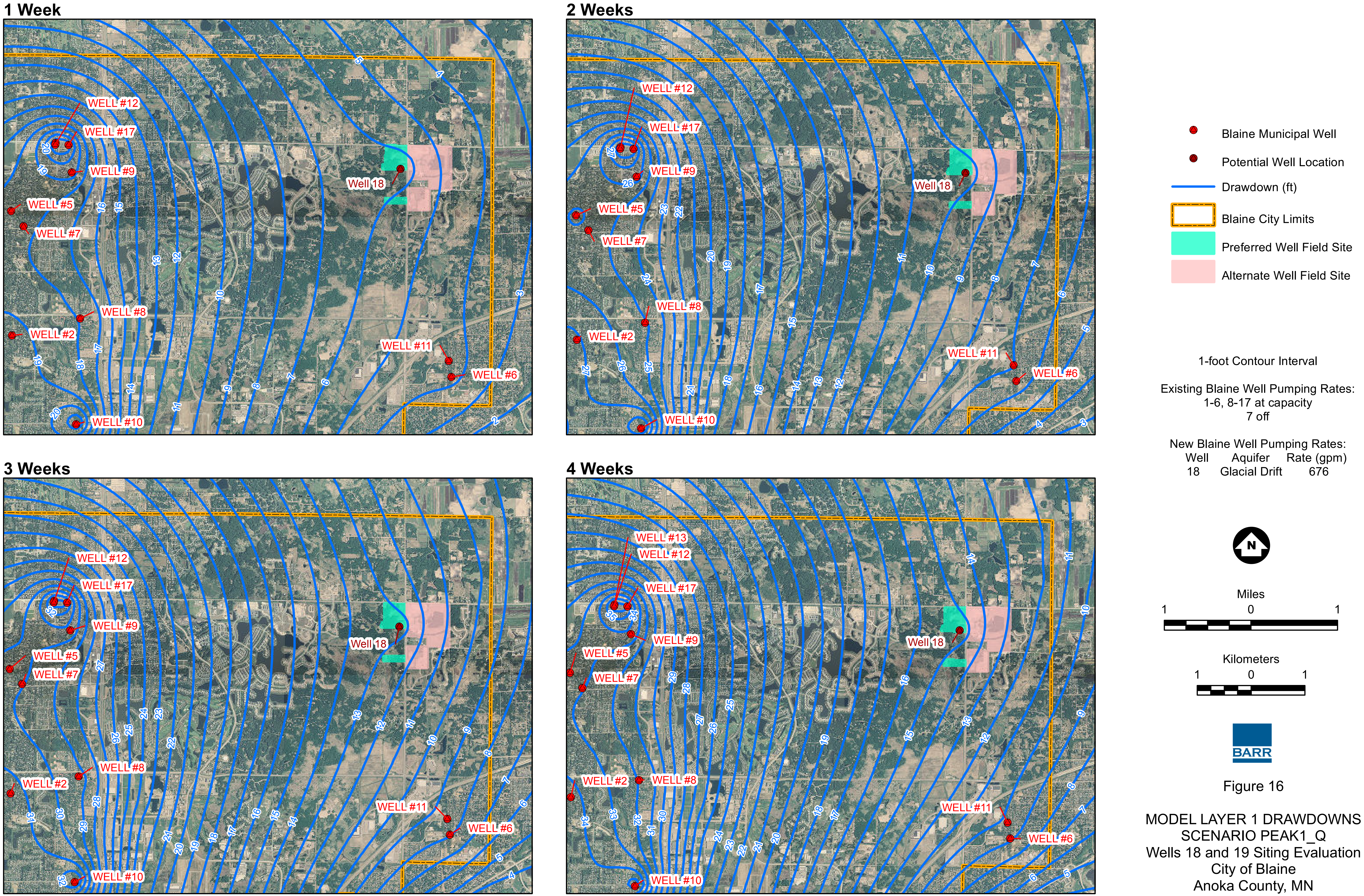
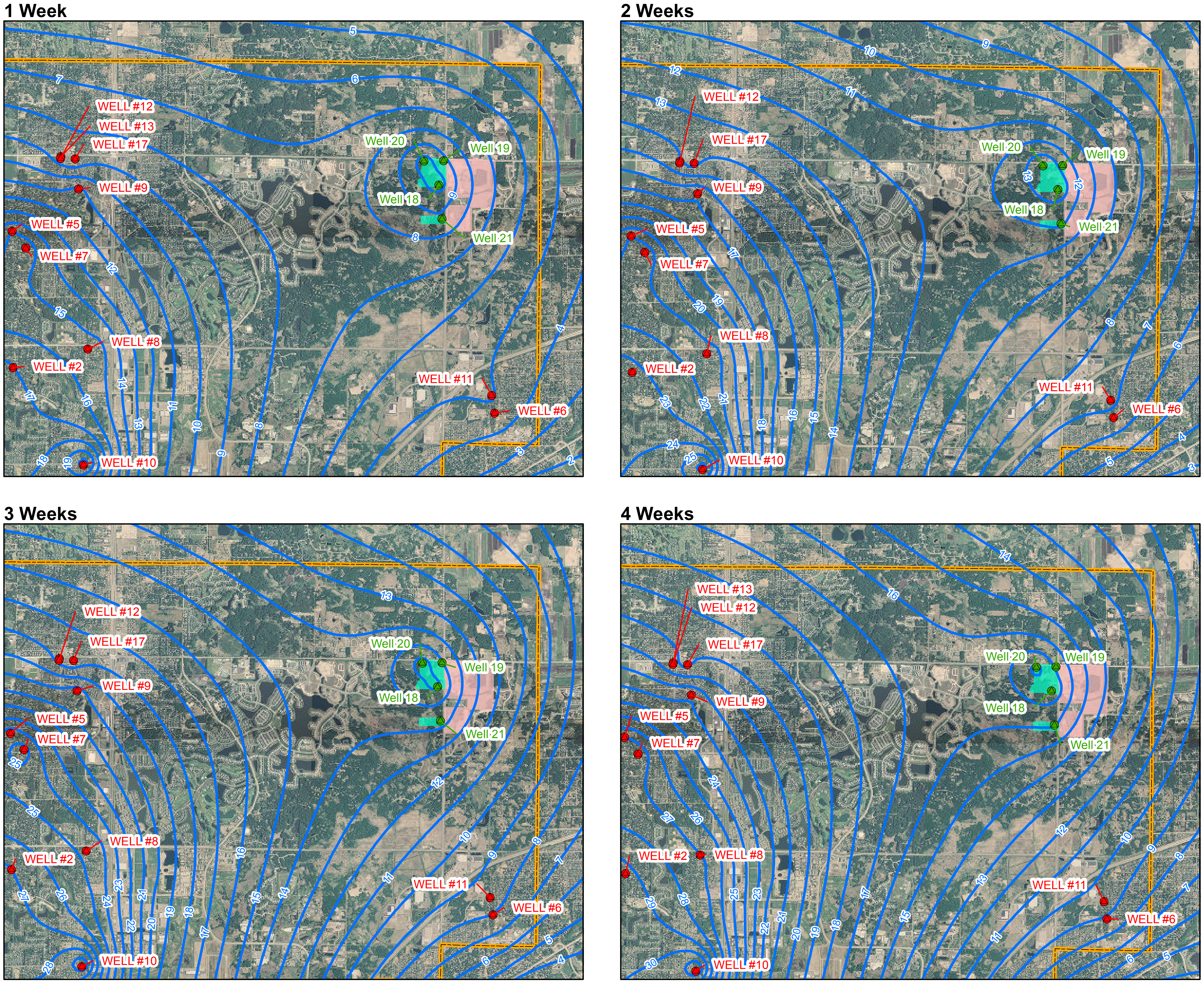


Figure 16

MODEL LAYER 1 DRAWDOWNS
SCENARIO PEAK1_Q
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN

Barr Footer: ArcGIS 10.0, 2012-11-27 15:49 File: I:\Projects\23\02\1012_Blaine_Well_18\Maps\Reports\Figure 16 - Peak1Q.mxd User: akj



Blaine Municipal Well

Potential Well Location

Drawdown (ft)

Blaine City Limits

Preferred Well Field Site

Alternate Well Field Site

1-foot Contour Interval

Existing Blaine Well Pumping Rates:
1-11, 13-16 at capacity
12 and 17 off

New Blaine Well Pumping Rates:

Well	Aquifer	Rate (gpm)
18	TCW	1000
19	TCW	1000
20	TCW	1000
21	TCW	376

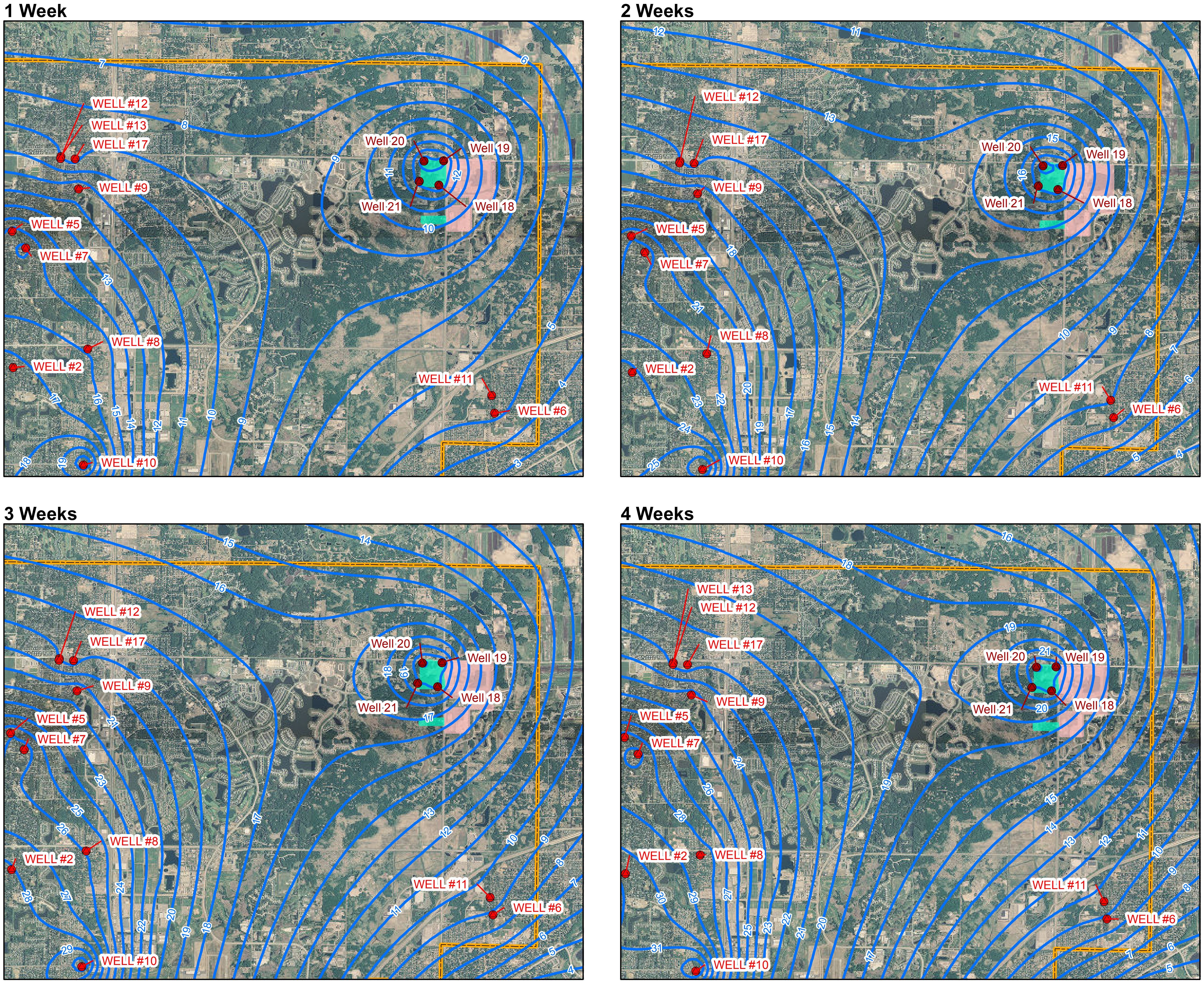
Miles
1 0 1

Kilometers
1 0 1

BARR

Figure 17

MODEL LAYER 1 DRAWDOWNS
SCENARIO PEAK2_T
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN



Blaine Municipal Well
Potential Well Location
Drawdown (ft)
Blaine City Limits
Preferred Well Field Site
Alternate Well Field Site

1-foot Contour Interval

Existing Blaine Well Pumping Rates:
1-11, 13-16 at capacity
12 and 17 off

New Blaine Well Pumping Rates:

Well	Aquifer	Rate (gpm)
18	Glacial Drift	1000
19	Glacial Drift	1000
20	Glacial Drift	1000
21	Glacial Drift	376

N

Miles
1 0 1

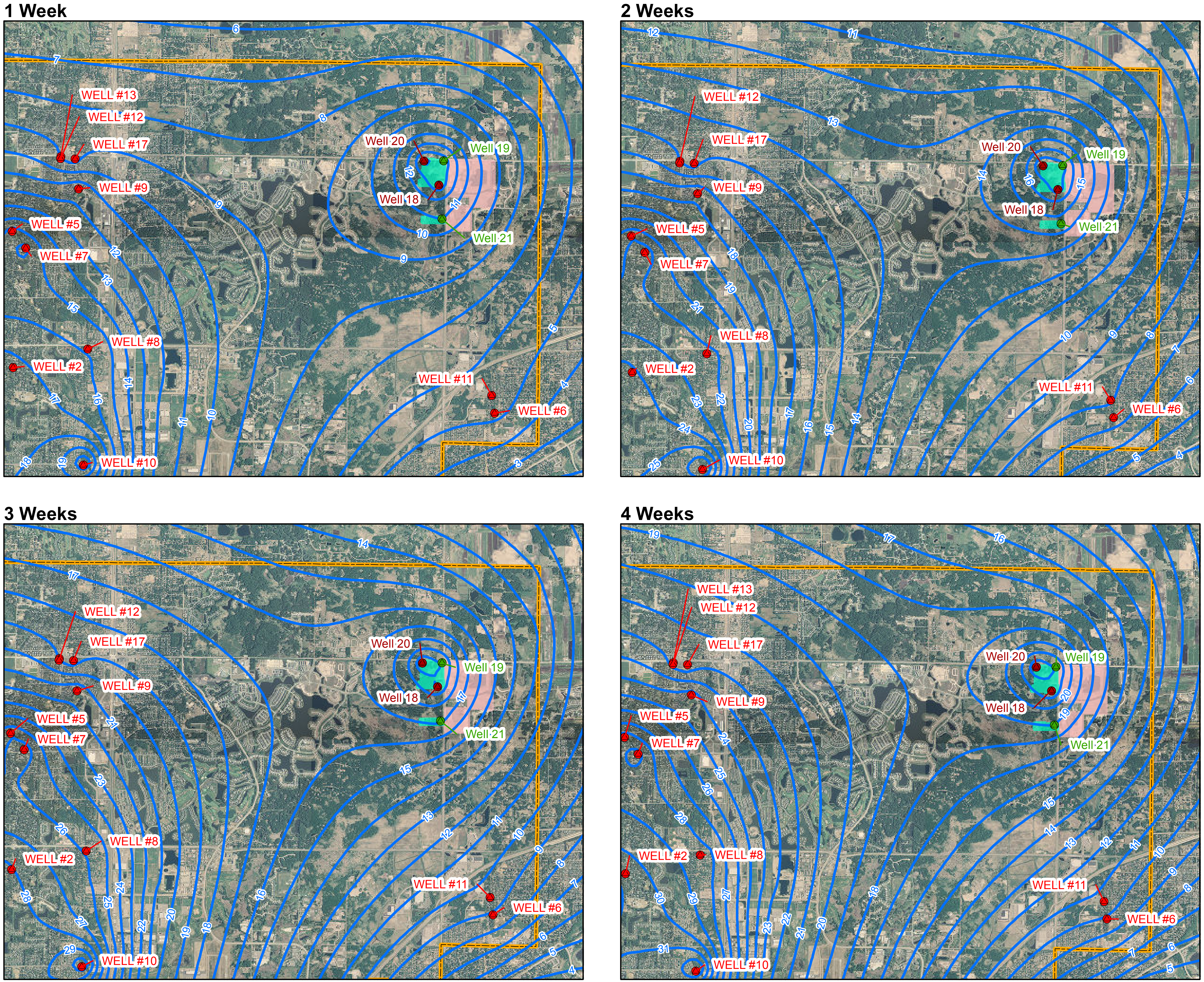
Kilometers
1 0 1

BARR

Figure 18

MODEL LAYER 1 DRAWDOWNS
SCENARIO PEAK2_Q
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN

Barr Footer: ArcGIS 10.0, 2012-11-27 15:52 File: I:\Projects\23\02\1012_Blaine_Well_18\Maps\Reports\Figure 18 - Peak2Q.mxd User: akj



Blaine Municipal Well

Proposed Well Location

Glacial Drift

Tunnel City-Wonewoc

Drawdown (ft)

Blaine City Limits

Preferred Well Field Site

Alternate Well Field Site

1-foot Contour Interval

Existing Blaine Well Pumping Rates:
1-11, 13-16 at capacity
12 and 17 off

New Blaine Well Pumping Rates:

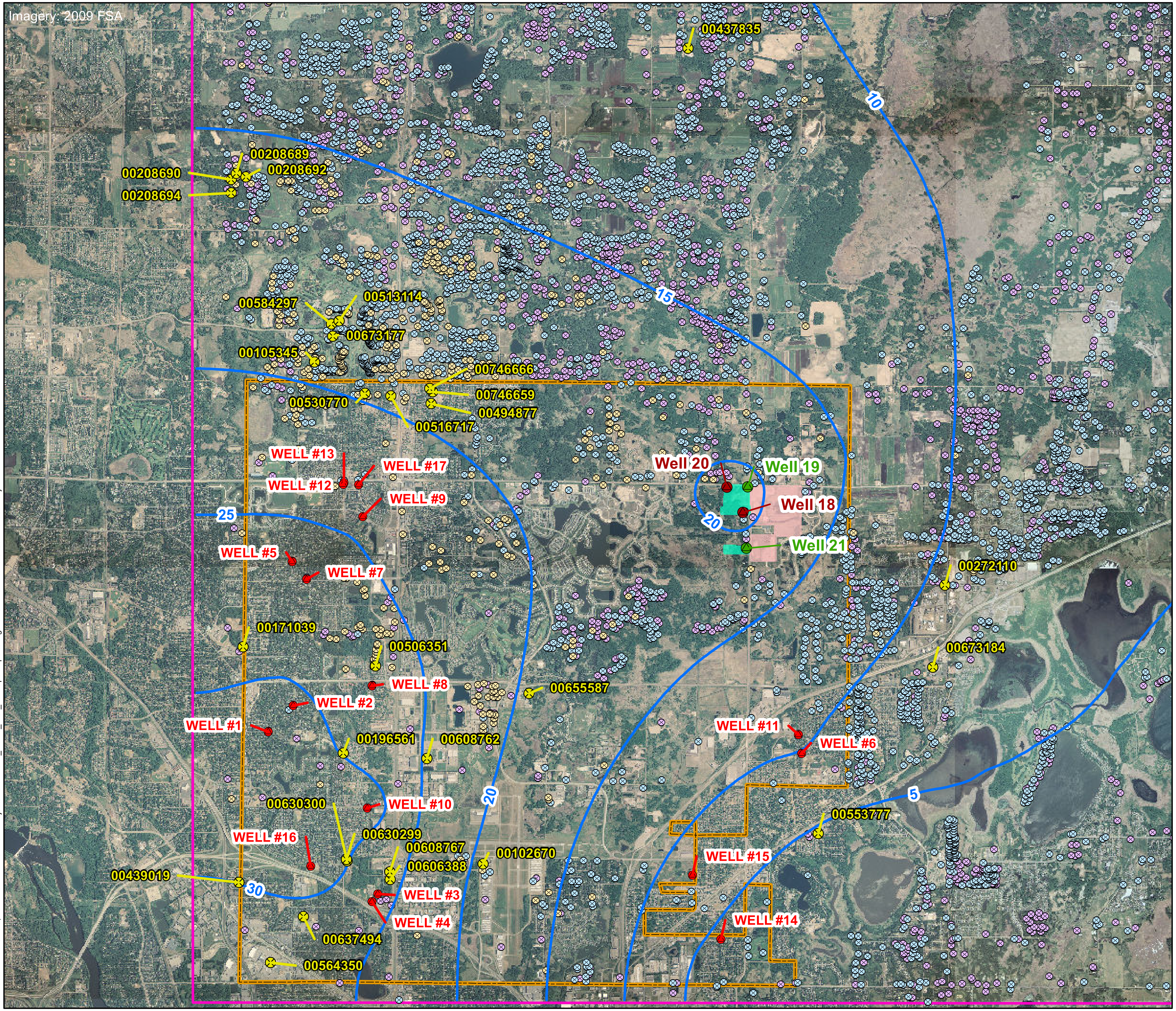
Well	Aquifer	Rate (gpm)
18	Glacial Drift	1000
19	TCW	1000
20	Glacial Drift	1000
21	TCW	376

BARR

Figure 19

MODEL LAYER 1 DRAWDOWNS
SCENARIO PEAK2_TQ
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN

Barr Footer: ArcGIS 10.0, 2012-11-27 15:54 File: I:\Projects\23\02\1012_Blaine_Well_18\Maps\Reports\Figure 19 - Peak2TQ.mxd User: akj



Blaine Municipal Well

Affected Water Well
Drawdown > 50% of available water column

Proposed Well

Glacial Drift

TCW

Glacial Drift Water Well
25% < Drawdown < 50% of available water column

Glacial Drift Water Well
Drawdown < 25% of available water column

Bedrock Water Well
Drawdown < 25% of available water column

Drawdown (ft)

Model Boundary

Blaine City Limits

Preferred Well Field Site

Alternate Well Field Site

5-foot Contour Interval

N

Miles
1 0 1

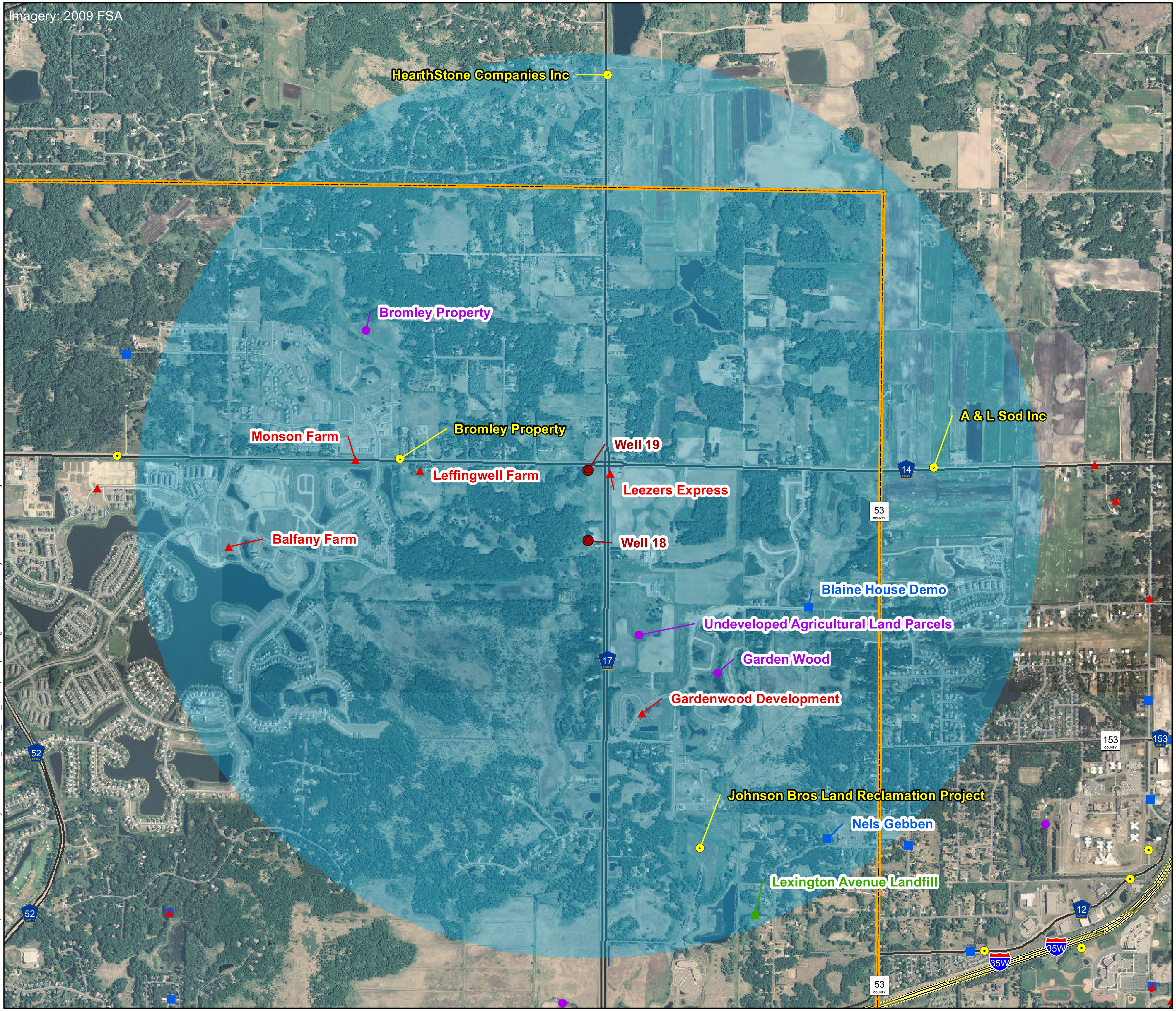
Kilometers
1 0 1

BARR

Figure 20

POTENTIAL WELL INTERFERENCE
SCENARIO PEAK_2TQ, 4 WEEKS
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN

Barr Footer: ArcGIS 10.0, 2012-10-22 14:46 File: I:\Projects\23\02\1012_Blaine_Well_18\Maps\Reports\Figure 20 - Well Interference.mxd User: akj



Proposed Blaine Well

MPCA Site

Hazardous Waste

Investigation and Cleanup

Solid Waste

Tanks and Leaks

Multiple Activities

Blaine City Limits

Preliminary WHPA

Contaminated site data from Minnesota Pollution Control Agency's "What's in My Neighborhood" Database: http://www.pca.state.mn.us/index.php/data/wimn-whats-in-my-neighborhood/whats-in-my-neighborhood.html?menuid=&redirect=1

Feet

2,000 0 2,000

Meters

500 0 500

BARR

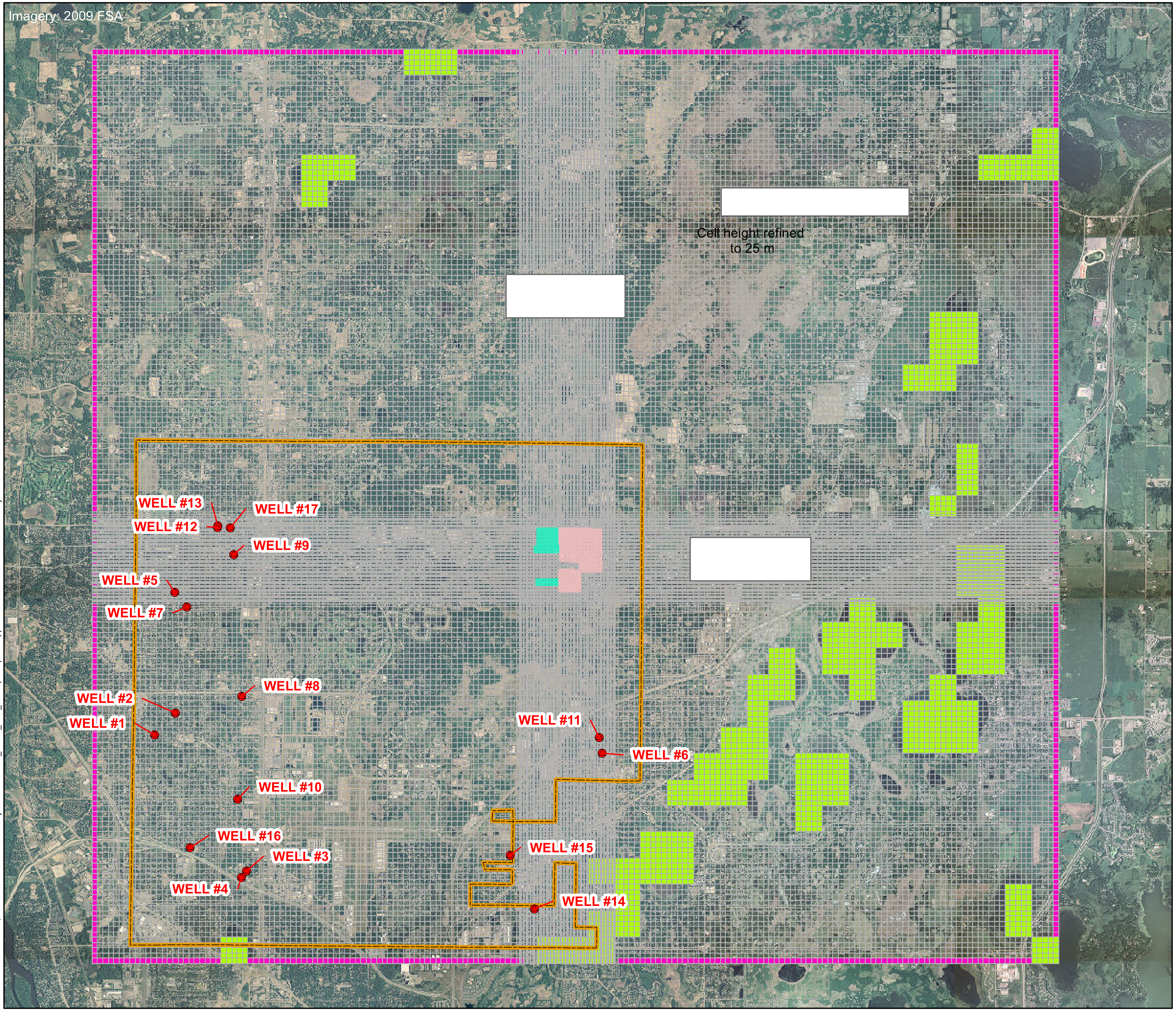
Figure 21

WELLS 18 and 19 PRELIMINARY WHPA
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN

Appendix A

Model Construction Details

to 25 m



Blaine Municipal Well

Blaine City Limits

Preferred Well Field Site

Alternate Well Field Site

Model Grid

Boundary Condition

River Cell

Constant Flux Cell

River cells represent lakes and ponds
River cells in Layer 1 only
Constant flux cells in all layers

N

Miles
1 0 1

Kilometers
1 0 1

BARR

Figure A1

MODEL GRID & BOUNDARIES
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN

Barr Footer: ArcGIS 10.0, 2012-11-28 08:16 File: I:\Projects\23\02\1012_Blaine_Well_18\Maps\Reports\Appendix A1 - Model Grid.mxd User: aki

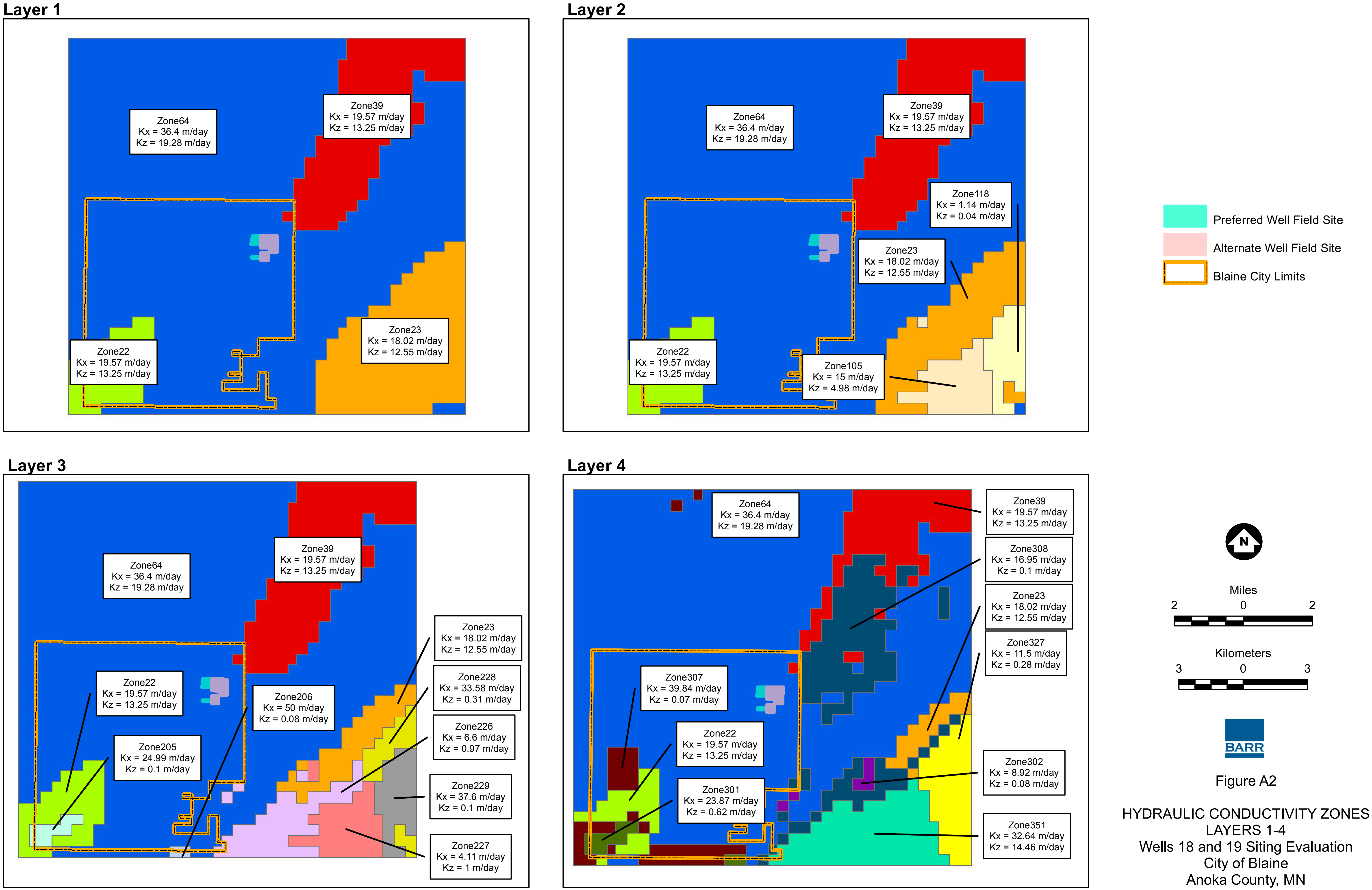
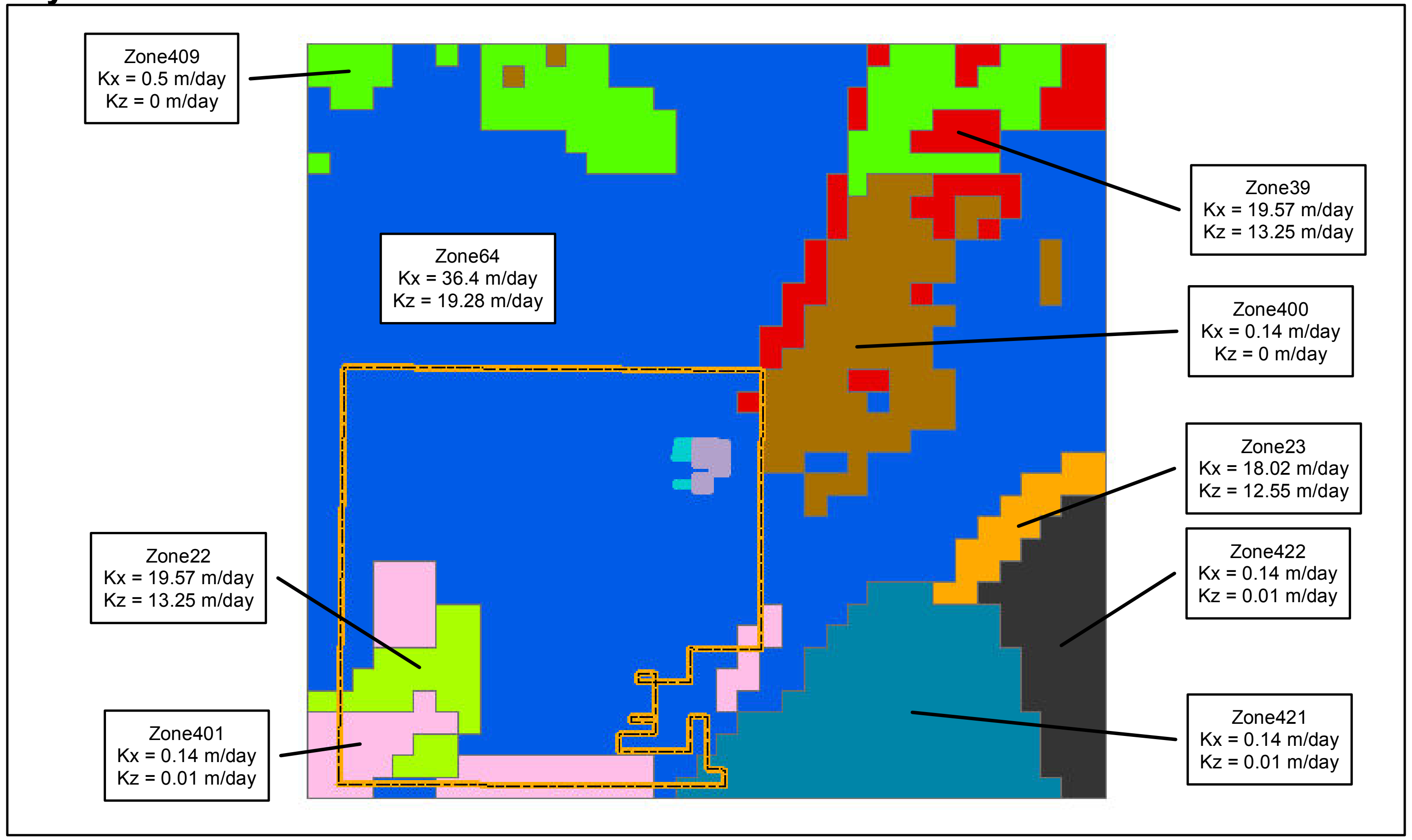


Figure A2

HYDRAULIC CONDUCTIVITY ZONES
LAYERS 1-4
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN

Barr Footer: ArcGIS 10.0, 2012-11-28 15:57 File: I:\Projects\23\02\1012_Blaine_Well_18\Maps\Reports\Appendix A2 - Hydraulic Conductivity Zones 1-4.mxd User: akj

Layer 5



Layer 8 (Eau Claire):
Kx = 7.89e-3 m/day
Kz = 7.95e-7 m/day

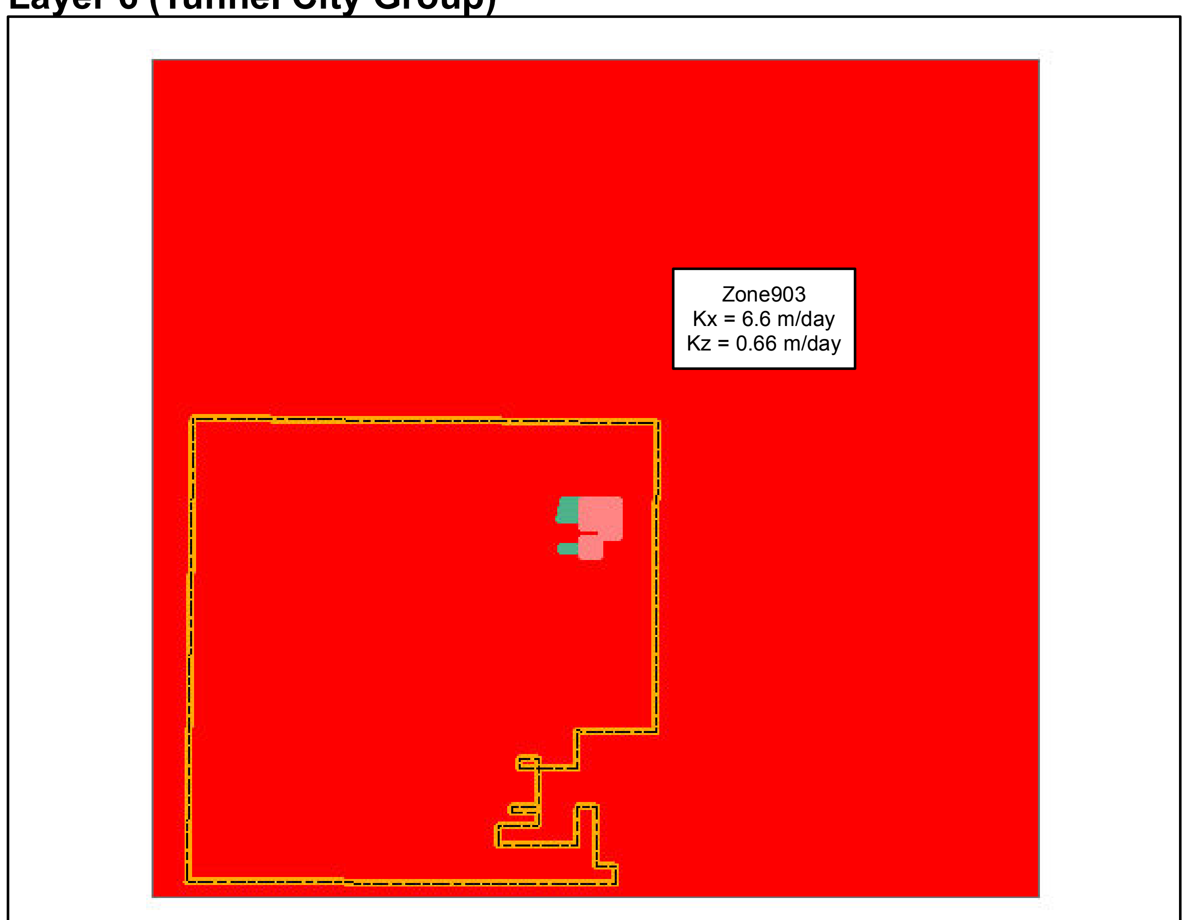
Layer 9 (Mt. Simon):
Kx = 7.41 m/day
Kz = 4.29e-2 m/day

Preferred Well Field Site

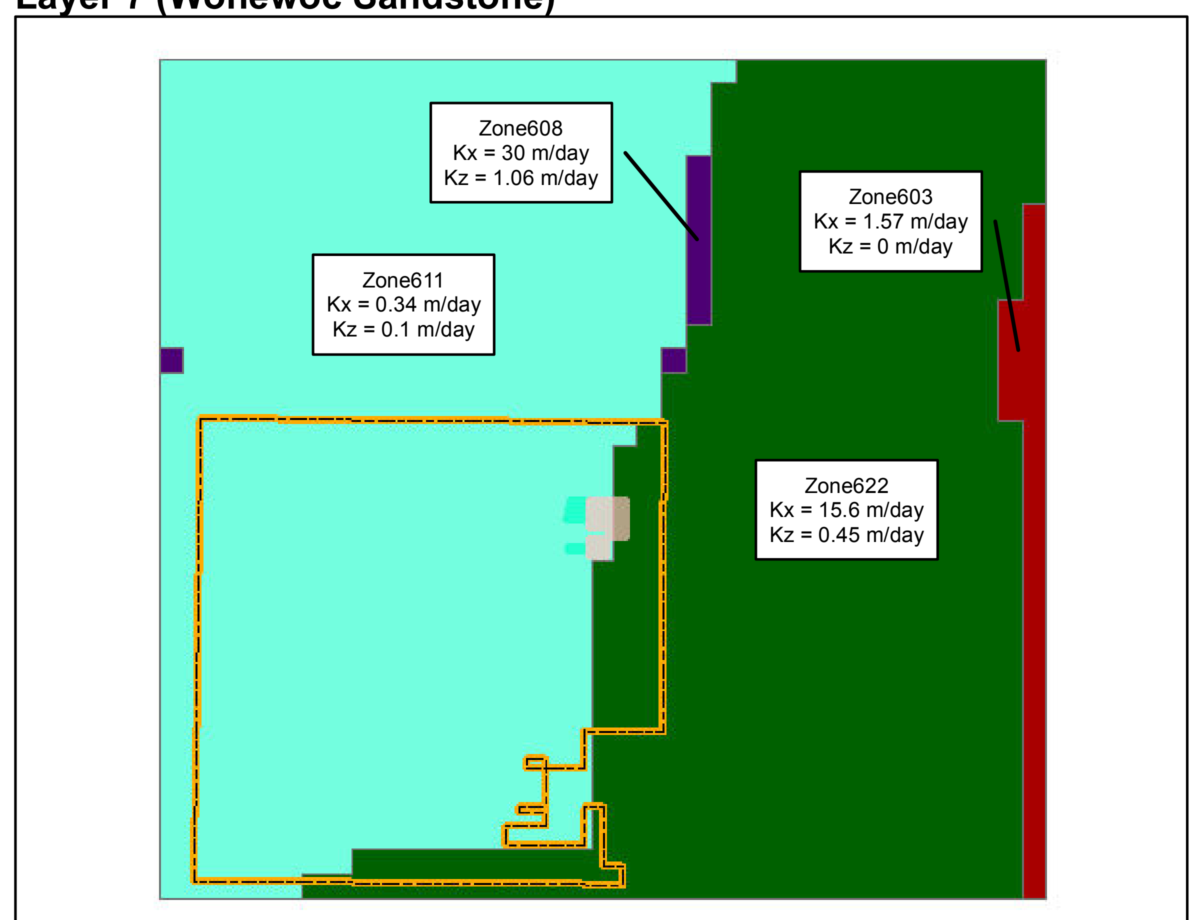
Alternate Well Field Site

Blaine City Limits

Layer 6 (Tunnel City Group)



Layer 7 (Wonewoc Sandstone)



N

Miles
2 0 2

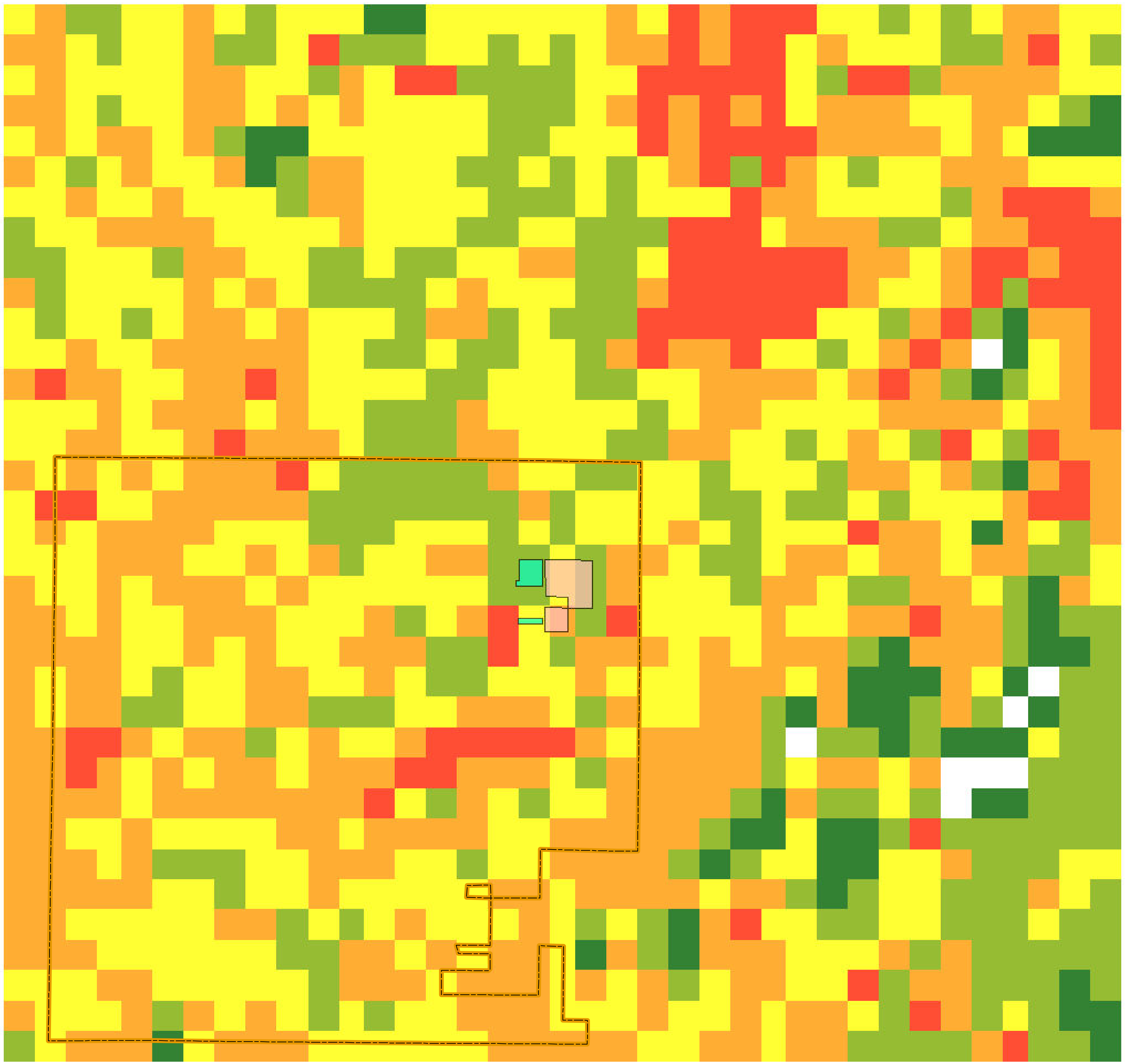
Kilometers
3 0 3

BARR

Figure A3

HYDRAULIC CONDUCTIVITY ZONES
LAYERS 5-7
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN

Barr Footer: ArcGIS 10.0, 2012-11-28 15:59 File: I:\Projects\23\02\1012_Blaine_Well_18\Maps\Reports\Appendix A3 - Hydraulic Conductivity Zones 5-7.mxd User: akj



Blaine City Limits

Preferred Well Field Site

Alternate Well Field Site

Recharge (in/yr)

0.13 - 3.19

3.20 - 5.32

5.33 - 6.06

6.07 - 7.03

7.04 - 8.46

Recharge applied to Layer 1 only

N

Miles

1 0 1

Kilometers

1 0 1

BARR

Figure A4

MODEL RECHARGE
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN

Appendix B

MnDNR Meeting Memo

Memorandum

To: Project File
From: John Greer, PG and Brian LeMon, PE
Subject: Meeting w/ MDNR Staff Regarding Well Siting Study, Blaine Wells 18 and 19
Date: November 5, 2012
Project: 23021012.00
c:

On September 7, 2012, Brian LeMon and John Greer met with Kate Drewry and Paul Putzier of the Minnesota Department of Natural Resources (MDNR) to discuss potential MDNR concerns related to the City of Blaine's plans to develop a new well field in the northeastern portion of the City near Lexington Avenue NE and 125th Avenue (the Northeast Well Field).

During the meeting Brian LeMon and John Greer discussed, in general terms, preliminary findings of a groundwater modeling assessment of pumping in the proposed Northeast Well Field (i.e., modeling suggested that multiple feet of drawdown at the water table may result from pumping of new municipal water supply wells in the proposed Northeast Well Field and that the drawdown may extend a significant distance away from the well field).

During the discussion it was also pointed out that there is a shallow clay till layer within approximately 20 to 30 feet of the ground surface identified in many well logs in the vicinity of the proposed well field. However, data reviewed at this time is insufficient to determine if the shallow clay till in the vicinity of the proposed well field location is continuous in the area. In addition, the clay layer is not represented in the model used for the well field evaluations. Therefore, the groundwater model used for the assessment does not take into account any role the shallow clay till plays in reducing the effect that pumping from new municipal wells from near the Quaternary sediments/bedrock interface or in the bedrock has on the water table in the area of the proposed Northeast Well Field.

Barr asked the MDNR if they would allow the City of Blaine to increase its appropriations and to install new wells to meet growing water demands and if so what the City might be asked to do to obtain the needed permits for the wells. MDNR staff noted that there are sensitive wetland areas, designated Scientific and Natural Areas (SNAs), and an Anoka County wetland bank in the vicinity of the proposed Northeast Well Field location (see Figure 1). MDNR staff stated that these wetlands and SNAs depend on shallow groundwater and that any drawdown of the water table beneath these areas has the potential to adversely affect them.

MNDR staff indicated several steps that the City would be required to take in order to obtain the permits needed to install new wells and increase appropriations. First, as is standard practice for the MDNR in all such requests, they would expect the City to fulfill any earlier commitments related to past water system planning or expansions. In this case they pointed out that when Well 17 was installed the City committed to monitoring water levels in a sensitive wetland in Pioneer Park in order to assess the impacts that pumping in Well 17 might have on that feature. It was believed that a monitoring well was in place but the MDNR did not have record of any follow up data or analysis. Second, they would like to see an aquifer test conducted with water levels recorded in multiple monitoring well nests strategically located to assess the impacts of pumping on the environmental features of concern. The nests should include monitoring wells in the Quaternary aquifer sand units both above and below the clay layer, as well as possibly in the Tunnel City Wonewoc aquifer if deemed appropriate. The test should be conducted from a well constructed in the proposed Northeast Well Field to evaluate the effect of pumping on surrounding wetlands/SNAs. They would like a work plan for the test submitted to the MDNR for review prior to the test. When asked if the City installed a large diameter high capacity well would they be allowed to use it if impacts to the wetlands were observed the MDNR staff stated that they could not guarantee that the well would be permitted to operate at the full rate desired by the City. They said it would likely be permitted at some rate but possibly one much lower than desired in order to protect the wetlands. The determination of allowable pumping rate would be made after reviewing the results of the aquifer test.

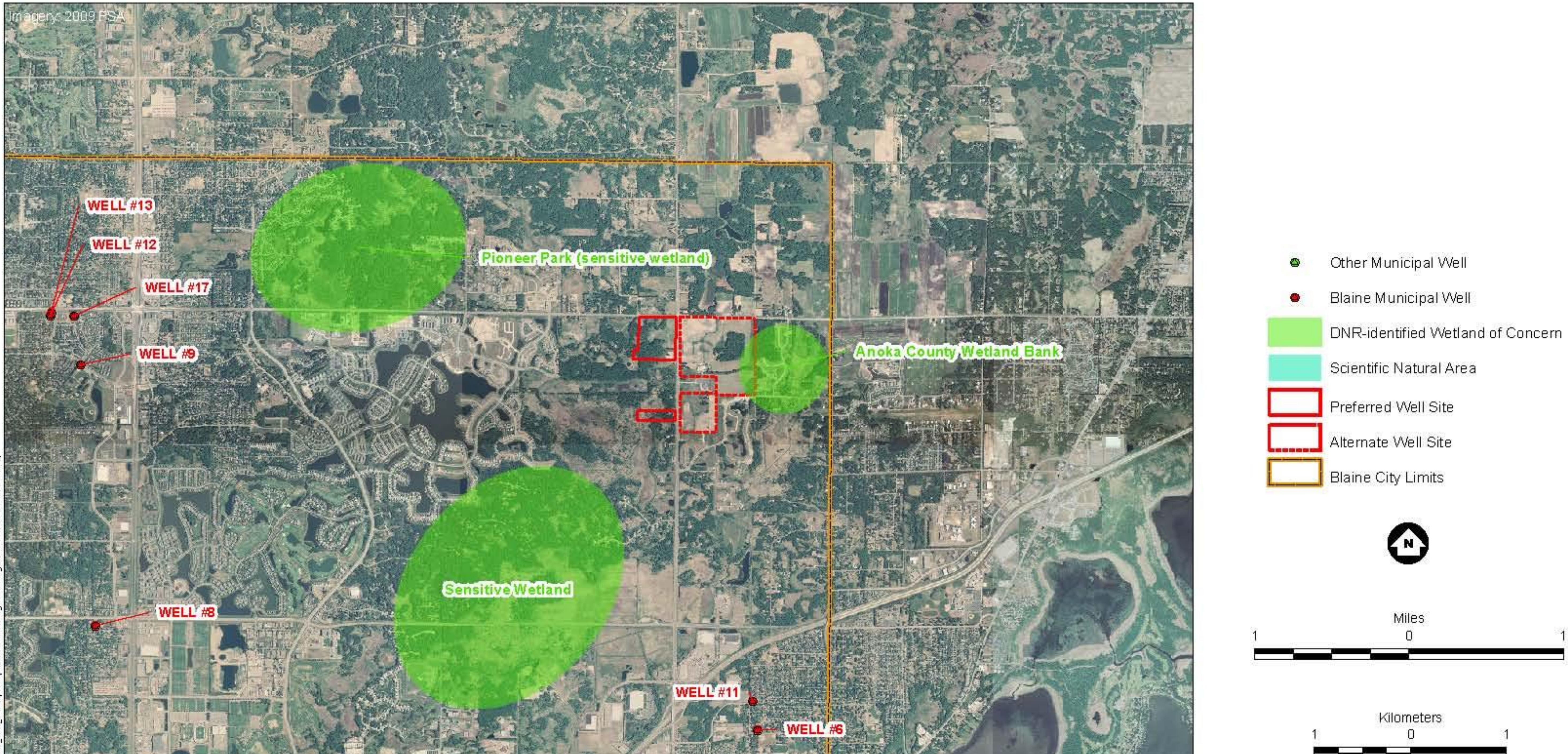


Figure 1

WETLANDS
Wells 18 and 19 Siting Evaluation
City of Blaine
Anoka County, MN

Barr Footer: ArcGIS 10.0, 2012-10-30 16:22 File: I:\Projects\23\02\1012_Blaine_Well_18\Maps\Reports\DNR Meeting memo\Figure 1 - Wetlands.mxd User: akl

Appendix C

Preliminary WHPA Worksheet

MINNESOTA MDH DEPARTMENT OF HEALTH
Environmental Health Division
Drinking Water Protection Section
Source Water Protection Unit
P.O. Box 64975
St. Paul, Minnesota 55164-0975

Preliminary Wellhead Protection Area Guidance

PWS ID:	1020006	PWS Name:	Blaine
Date:	10/24/2012	Completed By:	Adam Janzen and John Greer, PG

As required by the wellhead protection (WHP) rule (part 4720.5310, subpart 1), public water suppliers proposing NEW MUNICIPAL WELLS must complete 1) a preliminary delineation of the WHP area (WHPA) for the proposed well, and 2) an assessment of the impacts that existing land and water uses located within this area may have on the aquifer serving the well. The preliminary WHPA and assessment are to be submitted to the Minnesota Department of Health with the construction plan for the proposed well. The purpose of this guidance is to assist water suppliers in delineating the preliminary WHPA and preparing the assessment.

Part 1
Delineating Preliminary WHPA Boundaries

Getting Started

To calculate the preliminary WHPA, you will need:

1) A map showing the location of the proposed municipal well. This map should be at least 1:24000 scale or greater detail.
2) An estimate of the projected annual demand to be met by the new well.
3) A copy of the well construction diagram showing the proposed well construction and the anticipated geology.

   From this diagram, you will be estimating:

   a) the anticipated length of open interval of the well (or length of well screen) and
   b) whether the aquifer is confined or unconfined.

Note: An aquifer is considered confined or semi-confined when it exhibits artesian conditions. One simple method of determining whether an aquifer is confined is to compare the depth to the aquifer's water level with the depth to the stratigraphic top of the aquifer. If the water level is closer to the land surface than the top of the aquifer, then it is considered confined. Water-level information contained on the records of local wells (having similar construction as the proposed municipal) can be used to evaluate whether the aquifer is confined or unconfined. Confined conditions generally occur where at least several feet of low permeable materials, such as clay or shale, overly the top of the aquifer. Unconfined conditions generally occur in near-surface aquifers or where an aquifer is in direct hydraulic connection with surface-water features such as rivers and lakes.

4) For wells proposed to be completed in unconfined (or water-table) aquifers, you will also need to determine the local direction of groundwater flow.

Step 1

Estimate the expected annual volume of water (Q_{gpy}) to be pumped by the proposed well and multiply by ten. This represents the projected volume of water pumped during the next ten years. If your estimate is in gallons, convert it to cubic feet by dividing by the number of gallons per cubic foot.

2000 gpm = 1.05×10^9 gpy

Projected 10-year Demand $= Q_{10yrs} = \dfrac{Q_{gpy}}{7.48 \text{ gallons/ft}^3} \times 10 \text{ years} = \underline{1.41 \times 10^9}\ \text{ft}^3$

Step 3

From the well construction diagram, estimate the anticipated length of the open interval (or length of well screen) for the proposed well.

Length of Open Interval = **L** = <u>20</u> feet

Step 2

Estimate the effective porosity (n_e) of the aquifer serving the proposed well. If aquifer porosity is not known, select the value from the table corresponding to the material which best represents the aquifer which the well will be completed in.

Aquifer Material	Typical Porosity Value
sand and gravel	.30
sand or sandstone	.25
carbonate bedrock	.10
fractured bedrock	.10

Effective Porosity = n_e = <u>0.30</u>

Step 4

Using the estimate of Q_{10yrs}, n_e, and L determined in Steps 1-3, calculate the radius of the preliminary WHPA using the following equation:

Maximum Radial Distance of the WHPA $= r_{WHPA} = \sqrt{\dfrac{Q_{10\ yrs}}{(n)(L)(\pi)}} = \underline{8635}$ feet

where $\pi = 3.14$

Step 5

On a map showing the location of the proposed well, draw a circle around the well using the radial distance calculated in Step 4. **For confined aquifers or where the radius calculated in Step 4 is greater than ½ mile (greater than or equal to 2,640 feet), this area represents the preliminary WHPA.** *For unconfined aquifers where the calculated radius is less than ½ mile, continue to Step 6.*

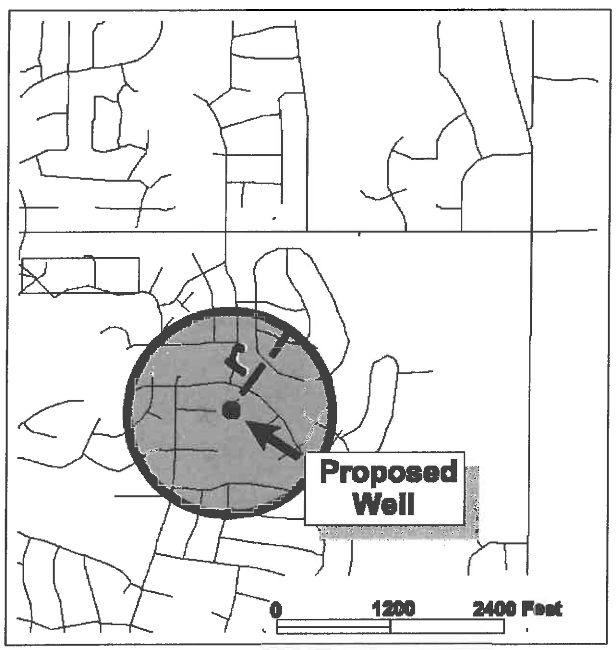
Example

Q_{10yrs} = 250,000,000 gallons = 33,422,460 ft^3

n_e = .25

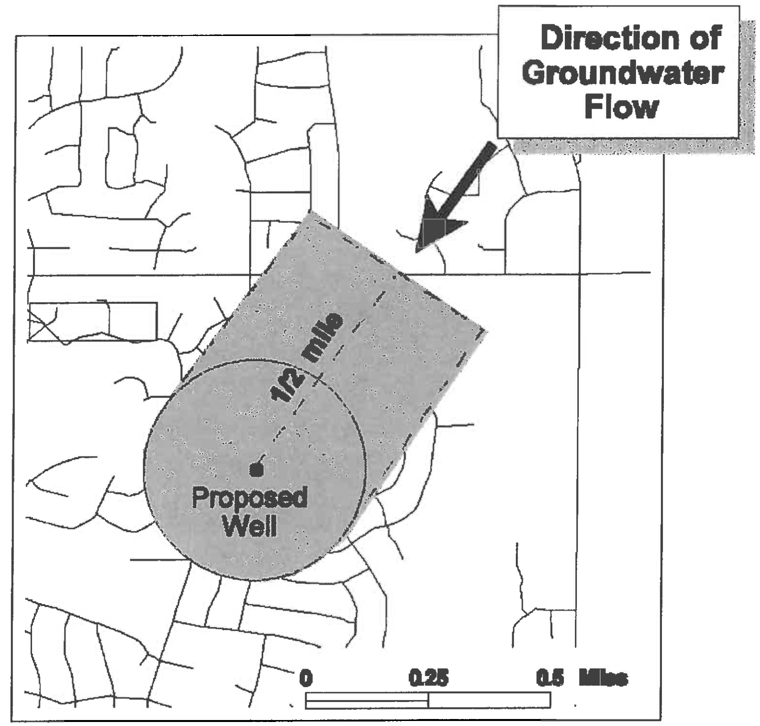
L = 30 feet

$$r_{WHPA} = \sqrt{\frac{33{,}422{,}460\ ft^3}{(.25)\ (30\ ft)\ (\pi)}} = 1190 \text{ feet}$$



Step 6

Unconfined aquifers. Determine the upgradient direction of local groundwater flow relative to the proposed well site. Project the diameter of the circular area calculated in Step 5 for a distance of ½ mile into the upgradient direction.



Note: For information regarding the local direction of groundwater flow in unconfined aquifers, please call (651) 201-4648.

Part 2
Assessing the Impacts of Existing Land Use and Water Use

1) Estimate the percentage of the following land use within the preliminary WHPA determined in Part 1.

Estimated Types of Land Use

Source: Metropolitan Council 2010 Generalized Land Use

Percentage	Land Use
19	Agricultural
<1	Commercial
<1	Industrial
0	Mining
49	Open Space
10	Recreational
18	Residential
2	Open Water/~~Wetlands~~
1	Other: Airport + Highway
33*	Other: Wetlands

* Wetlands data from National Wetlands Inventory. This area overlaps the land uses listed above.

2) Is the preliminary WHPA served by city sewer and water?

☐ All of it
☒ Some of it
☐ None of it

3) Are there high capacity wells using the same aquifer within a mile of the proposed well site?

No

4) Are you aware of any reported groundwater contamination in the preliminary WHPA? If so, explain.

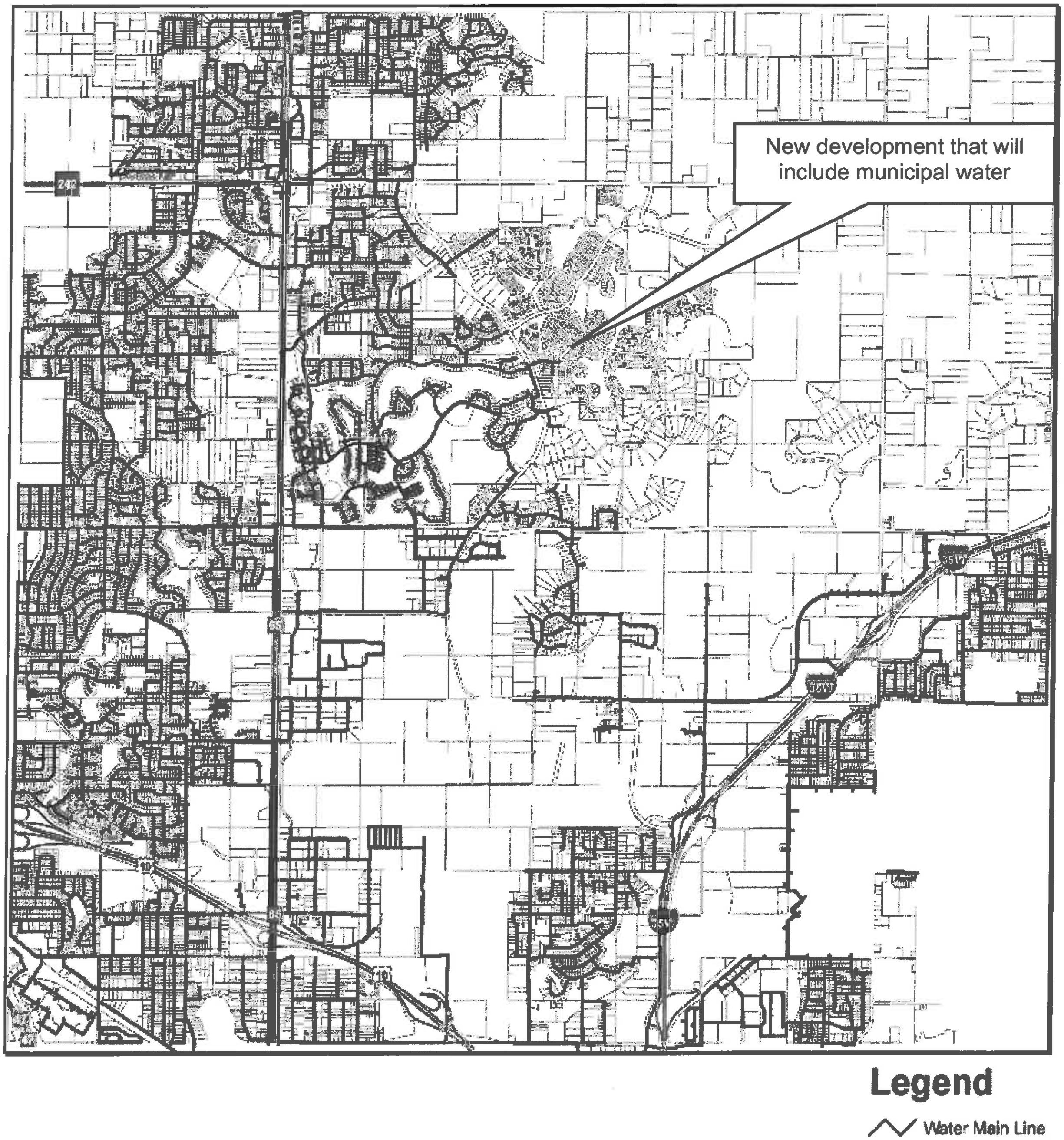
Diesel spills in 2002 at Leffingwell Farm, Balfany Farm
Underground tanks at Leezer's Express, though no leaks reported to date.

5) Do you think existing land or water uses may impact water quality in the proposed municipal well? Explain.

Logs of existing wells in the area indicate a clay layer between the water table and the deeper sand and gravel the proposed wells would be completed in. The continuity of this clay layer will determine the vulnerability of the proposed wells to near-surface contamination.

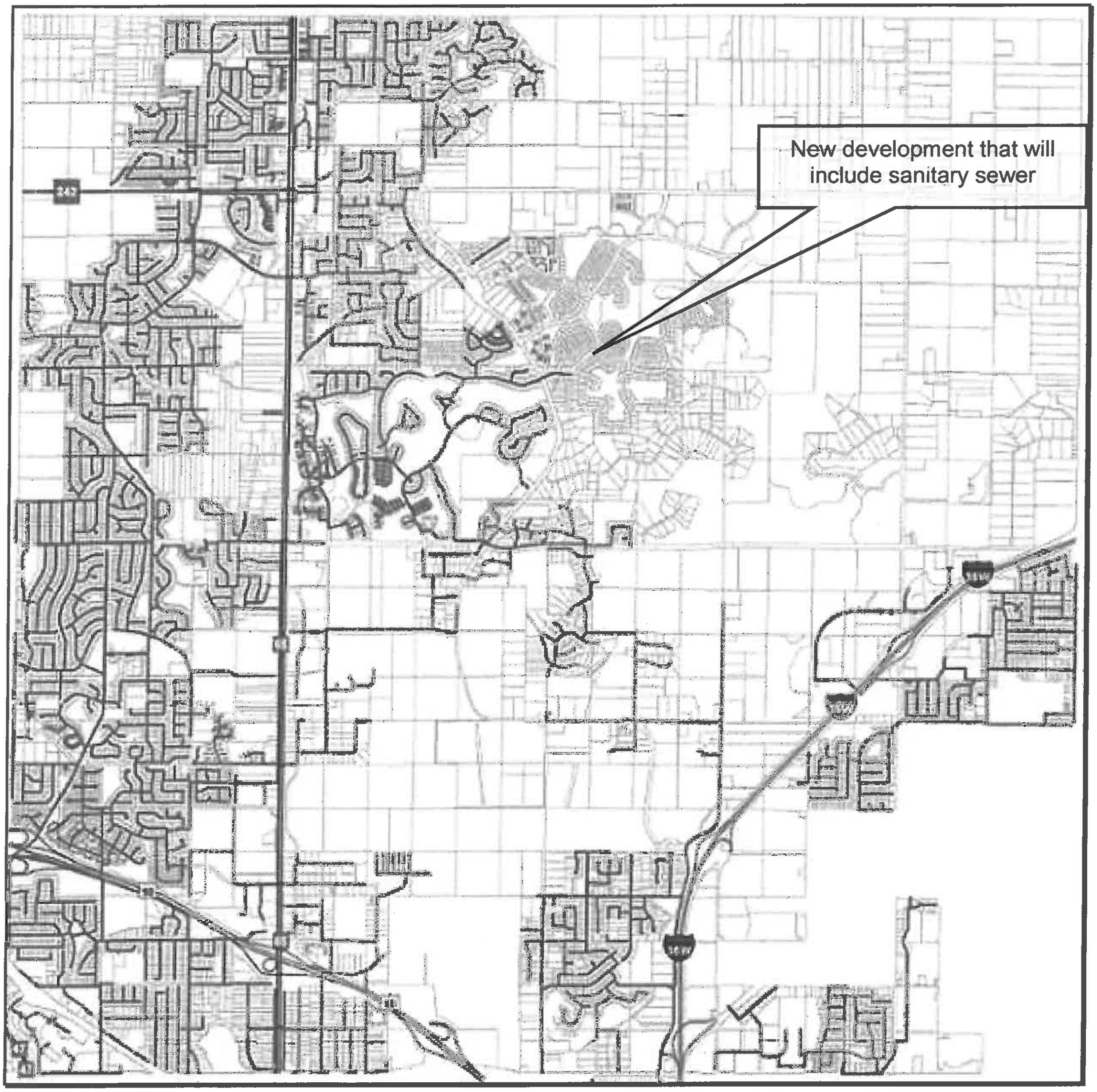
To request this document in another format, please contact our Section Receptionist at (651) 201-4700 or Division TTY at (651) 201-5797.

Figure 11
Municipal Water Supply System



Source:
City of Blaine GIS

Figure 10
Sanitary Sewer System

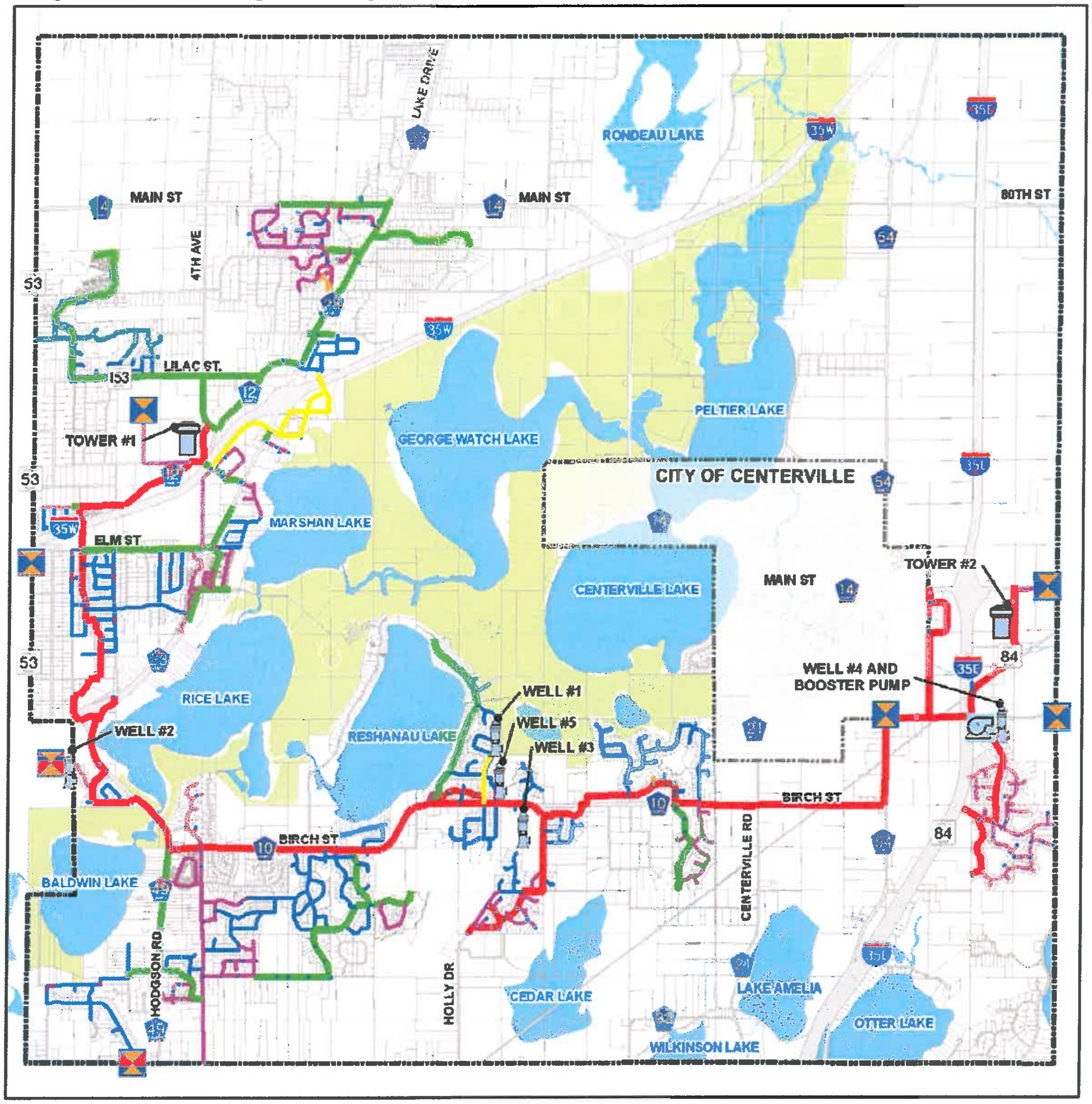


Legend

Sanitary Sewer Line

Source:
City of Blaine GIS

Figure 8-4: Existing Water System



Existing Water System

City of Lino Lakes 2030 Comprehensive Plan Update

Legend

EXISTING WATERMAIN
- 4"
- 6"
- 8"
- 10"
- 12"
- 16"

EXISTING INTERCONNECTIONS

N

4,000 0 4,000 Feet

CITY OF LINO LAKES

JULY 31, 2009

Prepared by TKDA

Figure 8-3: Sanitary Sewer District Map

Sewers currently exist in 2E, 2F, 2B