

**Wellhead Protection Plan**

**Part 1**

**Wellhead Protection Area Delineation  
Drinking Water Supply Management Area Delineation  
Well and Aquifer Vulnerability Assessments**

**For the  
City of Hamburg**

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**Minnesota Department of Health**

**December, 2006**

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## **Glossary of Terms**

**Wellhead Protection Area (WHPA)** – the surface and subsurface area surrounding a well or well field that supplies a public water system, through which contaminants are likely to move toward and reach the well or well field (Minnesota Statutes, Part 103I.005, subdivision 24).

**Drinking Water Supply Management Area (DWSMA)** – the area delineated using identifiable land marks defined that reflects the scientifically calculated wellhead protection area boundaries as closely as possible. (Minnesota Rule 4720.5100, subpart 13).

**Source Water Protection Area (SWPA)** – A source water assessment includes a description of 1) the area to be protected (SWPA), 2) potential contamination sources that may impact the source of drinking water, and 3) the susceptibility of the public water supply to potential contamination sources. For the purposes of this delineation report, the SWPA and the DWSMA are the same.

## **Introduction**

This report documents the technical information necessary to prepare Part 1 of a wellhead protection plan that will help ensure an adequate and safe drinking water supply for the City of Hamburg (public water supply identification number 1100005). It documents the delineation of the wellhead protection area (WHPA), the drinking water supply management area (DWSMA), and the vulnerability assessments for the public water supply wells and DWSMA. An updated source water assessment with a new protection area (SWPA) also is included. Definitions explaining the differences between the terms WHPA, DWSMA, and SWPA are provided in the Glossary of Terms at the beginning of this report.

This delineation was performed in accordance with Minnesota Rules 4720.5100-4720.5590 for preparing and implementing wellhead protection plans for public water supply wells. The Minnesota Department of Health (MDH) prepared this report at the request of the City of Hamburg.

The City of Hamburg operates two primary water supply wells, Well 2A (691883), Well 3 (691884), and one emergency backup well, Well 1 (219000). The wells are located in Sections 28 and 29 of Township 115 North, Range 26 West in Carver County.

The WHPA for the primary water supply wells was determined using the WHPA Code (EPA 1991), the Oneka Model (Barnes and Soule 2002), and the Metro Model (Hansen and Seaberg 2000) to simulate groundwater flow. The DWSMA boundaries were determined using geographic features that the public can visualize, and consist of 1) public land survey lines, and 2) roads. These features are discussed in the section Delineation of the Drinking Water Supply Management Area. Figure 1 shows the boundaries for the WHPA and the DWSMA.

Well 1 (219000) remains connected to the distribution system as an emergency back well. An emergency backup well is not pumped except in emergency situations and the WHPA is defined by a 200-foot radius Inner Wellhead Protection Management Zone (IWMZ). A figure showing the IWMZ for Well 1(219000) is contained in Appendix III.

## **Source Water Assessment**

The MDH is required under Section 1453 of the 1996 Amendments to the federal Safe Drinking Water Act to prepare source water assessments for all public water supply systems. Congress intends that assessments should be used to educate the water supplier and its customers about the source of their drinking water and potential contaminants that may affect people's health. The initial source water assessment was prepared for the City of Hamburg in 2003 and has been updated as part of this report.

## Source Water Assessment City of Hamburg

**Public Water Supply Identification Number:** 1100005

**Water Supplier Contact:** Jeremy Gruenhagen  
(952) 467-3232  
Hamburg City Hall  
181 Broadway Avenue  
Hamburg, MN 55339

**MDH Contact:** Terry Bovee  
(507) 389-6597  
Nichols Office Center  
410 Jackson Street, Suite 500  
Mankato, MN 56001-3752  
terry.bovee@health.state.mn.us

### Status of the Source Water Protection Plan -

The Minnesota Department of Health has approved the 1) delineation of the wellhead protection area, 2) delineation of the drinking water supply management area, and 3) assessments of well and aquifer vulnerability. The City of Hamburg is proceeding with developing the remainder of its wellhead protection plan.

**Source Water Protection Area -** See Figure 1.

**Description of the Source Water -** The water supply for the City of Hamburg comes from the Franconia-Ironton-Galesville Sandstone Aquifer, which exhibits confined hydraulic conditions. The aquifer is about 205 feet thick and is overlain by about 300 feet of clay-rich glacial deposits and bedrock. Generally, groundwater moves in a southeasterly direction within the WHPA.

**Table 1  
Wells Used by the City of Hamburg**

| Well Number | Unique Number | Well Use  | Aquifer Type | Well Depth (feet) | Well Sensitivity | Aquifer Sensitivity |
|-------------|---------------|-----------|--------------|-------------------|------------------|---------------------|
| Well 1      | 219000        | Emergency | Bedrock      | 745               | Very Low         | Very Low            |
| Well 2A     | 691883        | Primary   | Bedrock      | 620               | Very Low         | Very Low            |
| Well 3      | 691884        | Primary   | Bedrock      | 620               | Very Low         | Very Low            |

**Aquifer Sensitivity -** The aquifer used by the water supplier is considered to exhibit a very low sensitivity to potential contamination sources because it is covered by 300 feet of clay-rich glacial deposits and bedrock that will likely prevent the vertical movement of contamination from potential sources to the aquifer.

**Source Water Assessment**  
**City of Hamburg**  
**Page 2**

**Well Construction Assessment** - The wells used by the water supplier meet current State Well Code construction requirements and maintenance requirements for public water supply wells. These factors do not contribute to the susceptibility of the source water to contamination.

**Susceptibility of the Source Water to Contamination** - The source of drinking water used by the city wells is considered not susceptible to potential sources of contamination. Past results indicate that one primary well and the emergency back-up well for this community public water system may exceed the radium Maximum Contaminant Level (MCL) of 5pCi/L. Radium is a naturally occurring contaminant and is found in southern and central Minnesota.

**Contaminants of Concern** - The principal means by which contamination may migrate to the aquifer used by the City of Hamburg is via other wells that reach or penetrate to the same depth as the city's wells. Land uses around these other wells may contribute contaminants that are regulated under the federal Safe Drinking Water Act. A listing of these contaminants is available at <http://www.epa.gov/safewater>.

**Results of Monitoring the Source Water** - Radium, a naturally occurring contaminant regulated under the federal Safe Drinking Water Act, has been detected in the source of drinking water used by the City of Hamburg. A water sample collected from city Well 2A (691883) on June 7, 2005, did not contain detectable tritium when analyzed using an enriched analytical method. This indicates that the well is pumping water that infiltrated from the land surface to the aquifer before the year 1953. No contaminants relating to human activities have been detected in the primary water supply wells. These results indicate that the water in the Franconia-Ironton-Galesville and Mt. Simon Sandstones has been recharged over a long time period.

## **Delineation of the Wellhead Protection Area**

### **Assessment of Data Elements**

This section documents how the data elements specified under Minnesota Rule 4720.5400 were used to describe the physical environment. Figures 2, 3, and 4 show the distribution of the aquifer and its stratigraphic relationships with adjacent geologic materials. They were prepared using well record data that is contained in the County Well Index database. Also, a listing of the geological maps and studies that were used to further define local hydrogeologic conditions are provided in the section of this report entitled Selected References.

The following data elements identified in Minnesota Rule 4720.5400 do not apply because the aquifer exhibits confined hydraulic conditions:

- Information describing soil conditions;
- Information describing surface water resources;
- Information about land use, except parcel, political, or public land survey boundaries used to designate the DWSMA;
- Information about public utility services, except that describing the public water supply wells and other wells within the DWSMA;
- Information about surface water quantity; and
- Information about surface water quality.

### **Local Groundwater Conditions**

In the geographic area that includes the WHPA, the aquifer from which the city wells pump has the following characteristics:

- Is composed of fine to medium-grained quartzose sandstone and is 205 feet thick;
- Exhibits a porosity that is estimated to be 20%;
- Exhibits a base elevation of 390 feet above sea level;
- Exhibits a stratigraphic top elevation of 595 feet above sea level;
- Does not exhibit changes in composition or thickness that constitute a flow boundary (Figures 3 and 4);
- Is covered by approximately 200 to 300 feet of clay-rich geologic materials consisting of glacial deposits and bedrock; and
- Overlying Eau Claire confining bed that retards the vertical movement of aquifer water to stratigraphically lower aquifer materials.

The ambient flow field in the aquifer is oriented from northwest to southeast with an hydraulic gradient of 0.0008 (Figure 5).

The aquifer exhibits confined hydraulic conditions, as determined by the following:

- 1) Aquifer tests conducted on Well 2A (691883) and Well 3 (691884) show confined conditions.
- 2) Comparison of the static water level elevations in the public water supply wells versus surface water elevations indicates an hydraulic separation of 120 feet.
- 3) The aquifer is covered by a sufficient thickness of fine-grained geologic materials to maintain confined hydraulic conditions over the area that contributes water to the wells. The well records in the surrounding area show this condition, which is represented on the geologic cross sections Figures 3 and 4, as a continuous layer of low permeability materials between 200-300 feet thick over the area around the public water supply wells.

The Minnesota Department of Natural Resources (DNR) has developed a procedure for determining geologic sensitivity that is based on an “L” score. The City of Hamburg wells exhibit “L” scores of 17 and 13 using the DNR criteria. An L score of 5 or greater indicates that the aquifer is likely to exhibit a high degree of hydraulic separation from surface water.

### **Criteria Used to Delineate the WHPA**

The criteria for delineating the WHPA, as required in Minnesota Rule 4720.5510, were addressed as follows.

Groundwater Flow Field - The groundwater flow field was determined by compiling static water level elevations from wells that are either completed in the aquifer used by the City of Hamburg or reflect the gradient within it (Figure 5). The angle of ambient groundwater flow toward the wells used by the City of Hamburg is 141 degrees east of north with an hydraulic gradient of 0.0008.

Flow Boundaries - The following conditions define the extent to which flow boundaries must be considered:

The aquifer does not encounter any laterally persistent geologic boundaries that constitute a flow boundary. The overlying and underlying geologic materials serve to retard vertical movement of groundwater into or out of the aquifer used by the City of Hamburg.

The aquifer exhibits confined hydraulic conditions and no surface water features constitute a flow boundary. Static water elevations for wells completed in the aquifer are lower than surrounding surface water elevation.

The State Water Use Data System maintained by the DNR was accessed and identified that no other high-capacity wells, other than those operated by the City of Hamburg, will influence the boundaries of the WHPA.

Daily Volume of Water Pumped – City of Hamburg records were used to identify the maximum volume of water pumped annually by their wells over the previous five-year period, as shown in Table 2 below. These values have been reported to the DNR as required by the city’s water



appropriation permit, No. 756211. The city estimates a five percent increase in pumping for the next five years. The daily volume of discharge used as an input parameter in the model was calculated by dividing the greatest annual pumping volume by 365 days.

**Table 2**  
**Annual Volume of Water Discharged from Water Supply Wells**

| Well Name | PA Number | Unique Number | 2001        | 2002 | 2003 | 2004 | 2005        | Future Pumping |
|-----------|-----------|---------------|-------------|------|------|------|-------------|----------------|
| Well 1    | 756211    | 219000        | <b>17.7</b> | 14.6 | 15.8 | 16.4 | 1.47        | 1.5            |
| Well 2A   | 756211    | 691883        | -           | -    | -    | -    | <b>9.76</b> | 10.3           |
| Well 3    | 756211    | 691884        | -           | -    | -    | -    | <b>3.5</b>  | 3.7            |

(Expressed in millions of gallons) Bolding indicates greatest annual pumping volume.

Aquifer Transmissivity - The aquifer test method used to determine transmissivity meets the requirements of Minnesota Rule 4720.5510, subpart 6, and the aquifer test plan was approved by MDH on May 25, 2006. These were pump tests conducted on the city's two primary wells, Well 2A (691883) and Well 3 (691884). A representative aquifer transmissivity value of 1030 feet<sup>2</sup>/day was obtained. (MDH Aquifer Test Information System, test nos. 2266 and 2267)

Time of Travel - 10 years. Also, a one-year time of travel is used to define the emergency response area, as specified under Minnesota Rule 4720.5250.

### **Description of the Delineation Method**

The WHPA for the City of Hamburg was determined using a combination of three groundwater flow models. The Wellhead Protection Area Code, version 2.0, was used to delineate the capture zone. A second code, using the analytical groundwater flow method named Oneka (Barnes and Soule, 2003), was used to assess the probability of impacts that local variations in hydrogeologic conditions may have on a well capture zone. Thirdly, the Metropolitan Area Groundwater Model (Hansen and Seaberg, 2000), a multi-layer, analytical, steady-state regional groundwater model, was used to assess the impacts that regional flow may have.

The Wellhead Protection Area Code (WHPA Code), version 2.0, is a semi-quantitative method for estimating the capture zones for wells that was developed by the U.S. EPA to provide a basic means for delineating wellhead protection areas (EPA, 1991). It produces a conservative estimate of capture zones because aquifer recharge is not used as an input parameter. However, it has limited capabilities to address aquifer settings that exhibit variable geologic conditions or variations in the direction of the groundwater flow field.

It is appropriate to use the WHPA Code for this delineation because no flow boundaries are known to exist in the up-gradient direction of groundwater flow from the wells; at least in the area defined by a 1-year and 10-year time of travel. A groundwater flow angle using an azimuth of 141 degrees east of north was obtained using the mapping of hydraulic head obtained from water well data (Figure 5). The hydraulic gradient was estimated to be 0.0008 (Figure 5) and the aquifer thickness is 205 feet. A copy of the input files for the WHPA Code solution is available at MDH.

The Oneka code was used to estimate capture zone probability. This model treats the aquifer properties and the available water level measurements as uncertain input parameters. The locations of wells, water levels, and the aquifer geometry are evaluated using information from the County Well Index (CWI). The aquifer transmissivity value was determined using local specific capacity tests for Hamburg Well 2A (691883) and Well 3 (691884). The pumping rates of wells were taken from the DNR State Water Use database. The uncertainty of the water levels is determined based on 1) the uncertainty of the groundwater elevation at the well, and 2) the transient variability of the water levels in the aquifer from local DNR observation well measurements.

For the solution, Oneka finds the flow field that best fits the network of water level elevations using different values of aquifer thickness and transmissivity. Oneka then evaluates the probability of the capture of a given point based on the number of times it is included in the capture areas generated by the total number of solutions. The output from the model is a capture zone probability map for the specified time of travel.

The Metro Model is a regional model, which is comprised of four steady-state, regional groundwater flow models for the seven-county Twin Cities metropolitan area. The lower aquifer model, which represents the Franconia-Ironton-Galesville Aquifer (Layer 4), and the Mt. Simon-Hinckley Aquifer (Layer 5) were used to estimate capture zones for the city primary wells. The model input set was created, calibrated, and tested as part of a project at the Minnesota Pollution Control Agency (MPCA) (Hansen and Seaberg, 2000). The regional transmissivity and aquifer thickness were used, since they were in range of the local values. A porosity of 20% was used for the delineation process in order to be more conservative.

The Metro groundwater flow model, developed using the Multi Layer Analytical Element Model (MLAEM), is regional in nature. Groundwater flow is derived on the basis of a generalized aquifer response to far-field boundary conditions (i.e., recharge from infiltration to the west and discharge to the Mississippi and Minnesota Rivers). While the input set is calibrated to regional head and flow observations, local data do not greatly affect its results. In contrast, the WHPA Code and Oneka models were used to examine local conditions. Simulations generated using the WHPA Code were based on observations in the area locally around Hamburg and southwestern Carver County. Oneka model runs are similarly local, but are based on best-fit solutions to groundwater elevation measurements, with which there is both temporal and measurement uncertainty. Consequently, the use of all three approaches in delineating the WHPA allows models with different strengths to reinforce one another and helps increase the confidence in the final result.

## **Results of Model Calibration and Sensitivity Analysis**

**Model calibration** is a procedure that compares the results of a model based on estimated input values to measured or “known” values. This procedure can be used to define model validity over a range of input values or the confidence with which model results may be used. As a matter of practice, groundwater flow models usually are calibrated using water elevation or flux.

There is nothing to calibrate for the WHPA Code delineation because it is based on calculating flowpath lines using equations that reflect a 1) constant pumping rate, 2) direction of groundwater flow, 3) hydraulic gradient, 4) aquifer thickness, 5) aquifer permeability, and 6) aquifer porosity. As such, it is a simple calculation of the portion of the aquifer that contributes water based on the width of the flow field that is affected by pumping.

Calibration of the Metro Model is described in detail by Hansen and Seaberg (2000). The FIG Aquifer system is simulated by Layer 4 of the Metro Model. Simulation and observed heads were compared at 3450 known data points across the Twin Cities metropolitan area. Detailed calibration statistics are presented in Table 6 of Hansen and Seaberg (2000), but the median error is 2.93 meters. Much of this error results from difficulties matching observed conditions along the St. Croix River. Calibration in the Carver County area is considerably tighter. Figures showing errors between simulated and observed conditions are also presented in Hansen and Seaberg (2000). The modifications adopted here for delineating the Hamburg capture zone delineations were relatively minor and did not affect the overall model calibration.

**Model sensitivity** is the amount of change in the model results caused by the variation of a particular input parameter. Because of the simplicity of the WHPA model, the direction and extent of the modeled capture zone may be very sensitive to any of the parameters mentioned above.

The pumping rate directly affects the volume of the aquifer that contributes water to the wells. An increase in pumping rate leads to an equivalent increase in the volume of aquifer within the capture zone, proportional to the porosity of the aquifer materials. However, the pumping rates are based on the results presented in Table 2 and, therefore, are not a variable factor that will influence the delineation of the WHPA.

The direction of groundwater flow determines the orientation of the capture zone. Variations in the direction of groundwater flow will not affect the size of the capture zones but are important for defining the areas that are the source of water to the wells.

An hydraulic gradient of zero produces a circular capture zone, centered on the well. As the hydraulic gradient increases, the capture zone changes into an elliptical shape, with the wells centered on the down-gradient focal point. The hydraulic gradient was determined by using water level elevations that were taken from wells that have verified locations (Figure 5). Generally, the accuracy of the determination of hydraulic gradient is directly proportional to the amount of available well records.

The aquifer thickness, permeability, and porosity influence the size and shape of the capture zone. A decrease in either thickness or porosity causes a linear, proportional increase in the areal extent of the capture zone; whereas, permeability defines the relative proportions of the capture zone width to length. A decrease in permeability decreases the length of the capture zone and increases the distance to the stagnation point, making the capture zone more circular in shape and centered around the well.

### **Methods Used to Address Model Uncertainty**

Using computer models to simulate groundwater flow necessarily involves representing a complicated natural system in a simplified manner. Local geologic conditions may vary within the capture area of the City of Hamburg wells, but existing information is not sufficiently detailed to define this degree of variability. In addition, the available groundwater flow models may not represent the natural flow system exactly, but the results are valid within a range defined by the reasonable variation of input parameters. The WHPA Code has limited capabilities to address these kinds of uncertainties, other than by varying the six input parameters (i.e., constant pumping rate, hydraulic gradient, direction of flow, aquifer thickness, aquifer permeability, and porosity) in multiple model runs.

- Deficiency in the method used to estimate aquifer transmissivity. Aquifer transmissivity for the Mt. Simon Aquifer was determined from constant-rate, pump test data collected during the construction of Arlington Well 4 (625261). Results from this analysis indicate that the transmissivity values were within the range of regional values, 340 to 1070 ft<sup>2</sup>/day.
- Deficiencies in the coverage of static water level data to define the ambient flow field within the aquifer used by the public water supply wells. Additional well data may increase the coverage of static water level data to better define the ambient flow field within the aquifer used by the public water supply wells.

The uncertainty associated with the WHPA Code results from 1) the deficiencies mentioned above, 2) the sensitivity of the WHPA model, and 3) the fact the model cannot be calibrated. State wellhead rule requirements and procedural steps, which were employed for this delineation to address model uncertainty, are listed below.

The Metro Model is a regionally calibrated groundwater flow model. It was used to predict groundwater flow and the resulting capture zones for Hamburg wells under the conditions most likely to occur in the area, but was not used for the uncertainty analysis. Instead, Oneka and the WHPA Code were used to analyze uncertainty.

#### State Wellhead Rule Requirements:

- 1) Pumping Rate - a maximum historical (5 year) pumping rate or an engineering estimate of future pumping, whichever is greater, be used for each well; and
- 2) Ambient Flow Field - a composite of capture zones be created from angles of flow that are 10 degrees greater and 10 degrees lesser than the representative angle of ambient flow.

#### Other Considerations:

- 3) Aquifer Thickness - the open-hole interval of the wells were used rather than a representative thickness of the aquifer;
- 4) Probability Analysis - use of another analytic groundwater flow model to estimate capture zone probability.

Capture zones were developed for the primary public water supply wells for a range of groundwater flow directions, aquifer permeabilities, and times of travel of one and ten years. As the model code uses constant input values for each run, several runs were required to include all variations in input parameters. Appendix III contains a table that documents the variables used to address model uncertainty.

The Oneka model helps address the uncertainties that are related to aquifer parameters as variations of the flow field. A 10-year capture zone probability map was generated for the city wells. The Oneka results fit well with the capture zones calculated from the WHPA Code model. The probability maps for both of the city wells show that uncertainty of the capture zone increases as the distance from the city wells increase.

To address the uncertainty of the wellhead protection area boundaries, the resulting capture zones from each model were combined to create a composite WHPA. Figure 6 shows the capture zones delineated using the results from modeling with WHPA, Oneka, and the Metro Model for the City of Hamburg.

## **Delineation of the Drinking Water Supply Management Area**

Figure 1 shows the boundaries of the Drinking Water Supply Management Area (DWSMA) that were determined with the assistance of the City of Hamburg, using roads and public land survey coordinates.

### **Assessment of Well Vulnerability**

The wells used by the City of Hamburg exhibit the following conditions:

1. Well construction meets current state Well Code specifications (Minnesota Rule 4725) and a well itself does not provide a pathway for contaminants to enter the aquifer used by the City of Hamburg;
2. The geologic conditions at each well site include a cover of clay-rich geologic materials over the aquifer that is sufficient to retard or prevent the vertical movement of contaminants;
3. None of the human-caused contaminants regulated under the federal Safe Drinking Water Act have been detected at levels indicating that the well itself serves to draw contaminants into the aquifer as a result of pumping.

Therefore, the wells used by the City of Hamburg are not considered to be vulnerable and exhibit a very low well sensitivity, as indicated in the source water assessment.

### **Vulnerability Assessment for the Drinking Water Supply Management Area**

The review of geologic information and groundwater quality data for the aquifer within the DWSMA indicates the following:

1. Isotopic and water chemistry data from wells located within the DWSMA indicate that the aquifer contains water that has no detectable levels of tritium or human-caused contamination.
2. Review of the geologic logs contained in the County Well Index and geological maps and reports indicate that the aquifer exhibits very low geologic sensitivity throughout the DWSMA and is isolated from the direct vertical recharge of surface water.
3. Radium, which is a naturally occurring contaminant, has been detected in the water from city Wells 2A (691883) and 3 (691884). The presence of a naturally occurring contaminant does not indicate that there is a direct pathway between the aquifer and potential contamination sources that occur at the land surface.

Therefore, the vulnerability of the DWSMA has been determined to be very low, as indicated by the source water assessment.

## Selected References

- Barnes, R.J., and Soule, R.G. (2002), *ONEKA: A simple analytical element model for stochastic capture zone delineation*, St. Paul, Minn., draft paper.
- Barnes, R.J., and Soule, R.G. (2003), *A simple analytical element model for probabilistic capture zones*, St. Paul, Minn., draft paper.
- Blandford, T.N., and Huyakorn, P.S. (1991), *WHPA 2.0: A modular semi-analytical model for the delineation of wellhead protection areas*, EPA 68-08-0003, U.S. Environmental Protection Agency, Office of Ground-Water Protection, Washington, D.C., 246 p.
- Delin, G.N., and Woodward, D.G. (1984), *Hydrogeologic setting and potentiometric surfaces of regional aquifers in the Hollandale Embayment, southeastern Minnesota, 1970-1980*, Water-Supply Paper; 2219, U.S. Geological Survey, Mounds View, Minn., 56 p.
- Geologic Sensitivity Project Workgroup (1991), *Criteria and guidelines for assessing geologic sensitivity of ground water resources in Minnesota*, Minnesota Department of Natural Resources, Division of Waters, St. Paul, Minn., 122 p.
- Hansen, D.D., and Seaberg, J.K. (2000), *Metropolitan Area groundwater model project summary: Lower aquifers model layers 4 and 5*, Minnesota Pollution Control Agency, St. Paul, Minn., 76 p.

## Figures

Figure 1: Map of the Wellhead Protection Area and Drinking Water Supply Management Area

Figure 2: Database Map and Trends of Cross Sections

Figure 3: Cross Section A – A'

Figure 4: Cross Section B – B'

Figure 5: Distribution of Hydraulic Head Within the Aquifer Used by the City of Hamburg

Figure 6: Pathlines for WHPA Code Runs, Oneka Probability Analysis and Metro Model Analysis



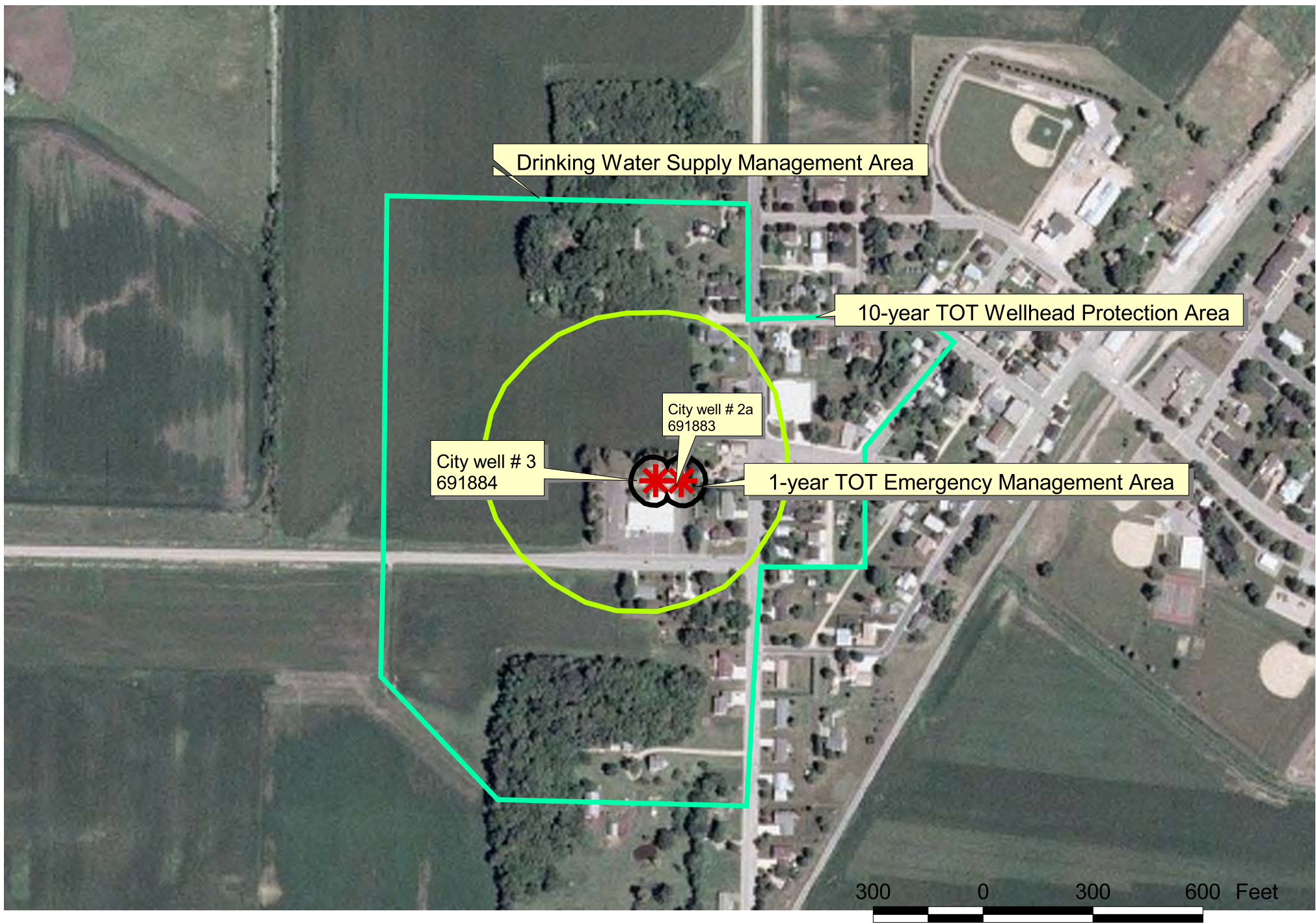


Figure 1. Map of the Wellhead Protection Area and the Drinking Water Supply Management Area



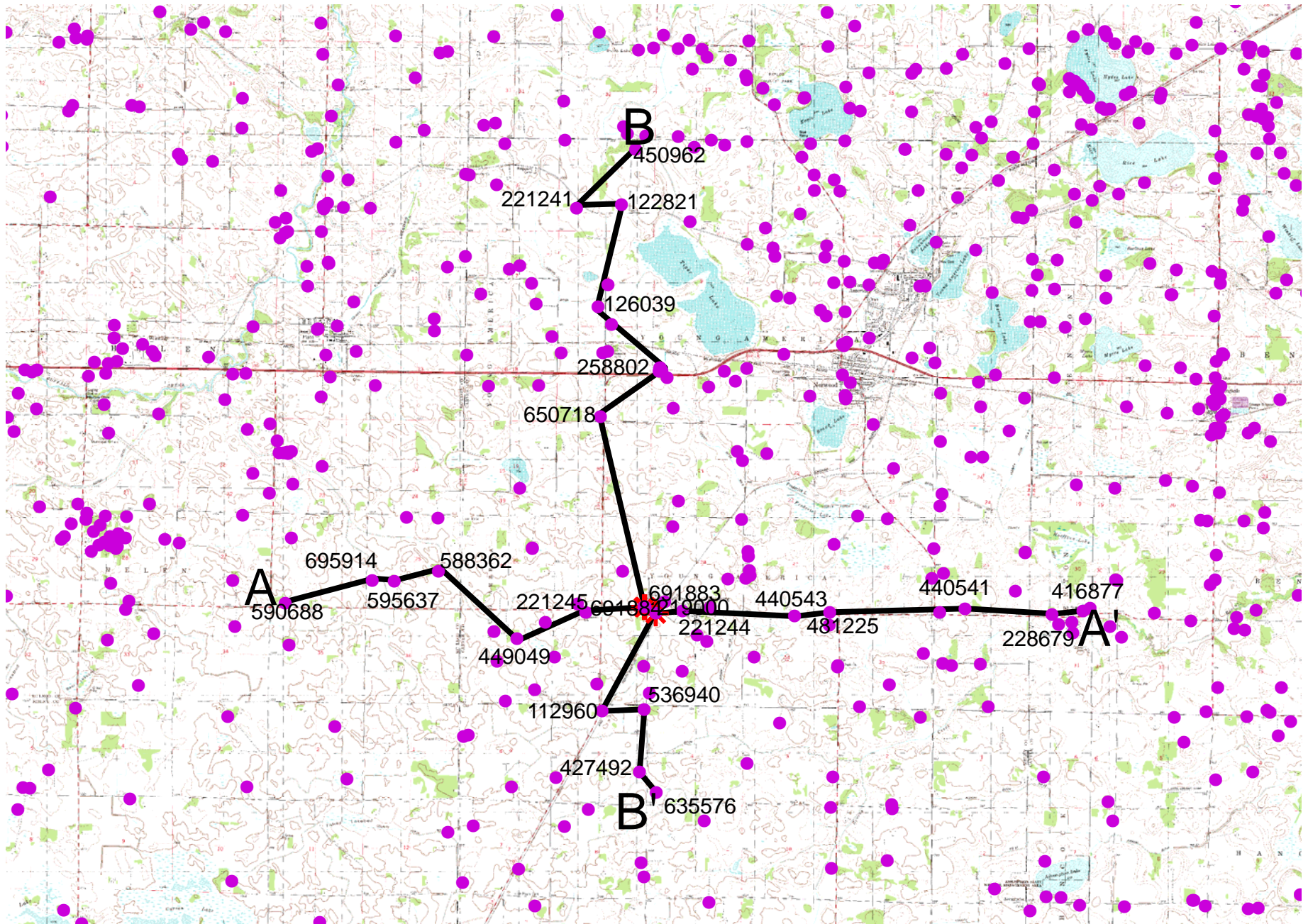
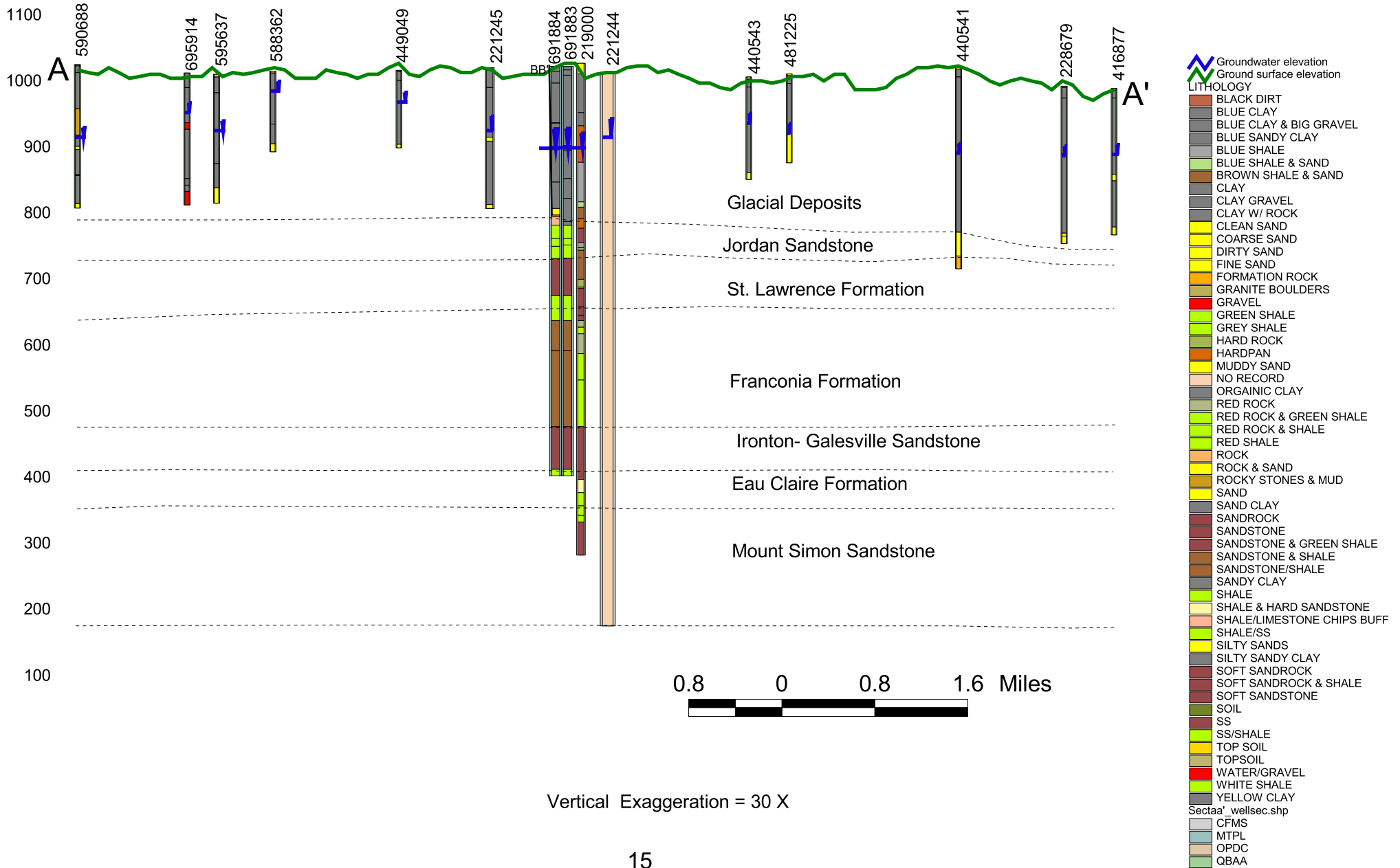


Figure 2. Databse Map and Trends of Cross Sections

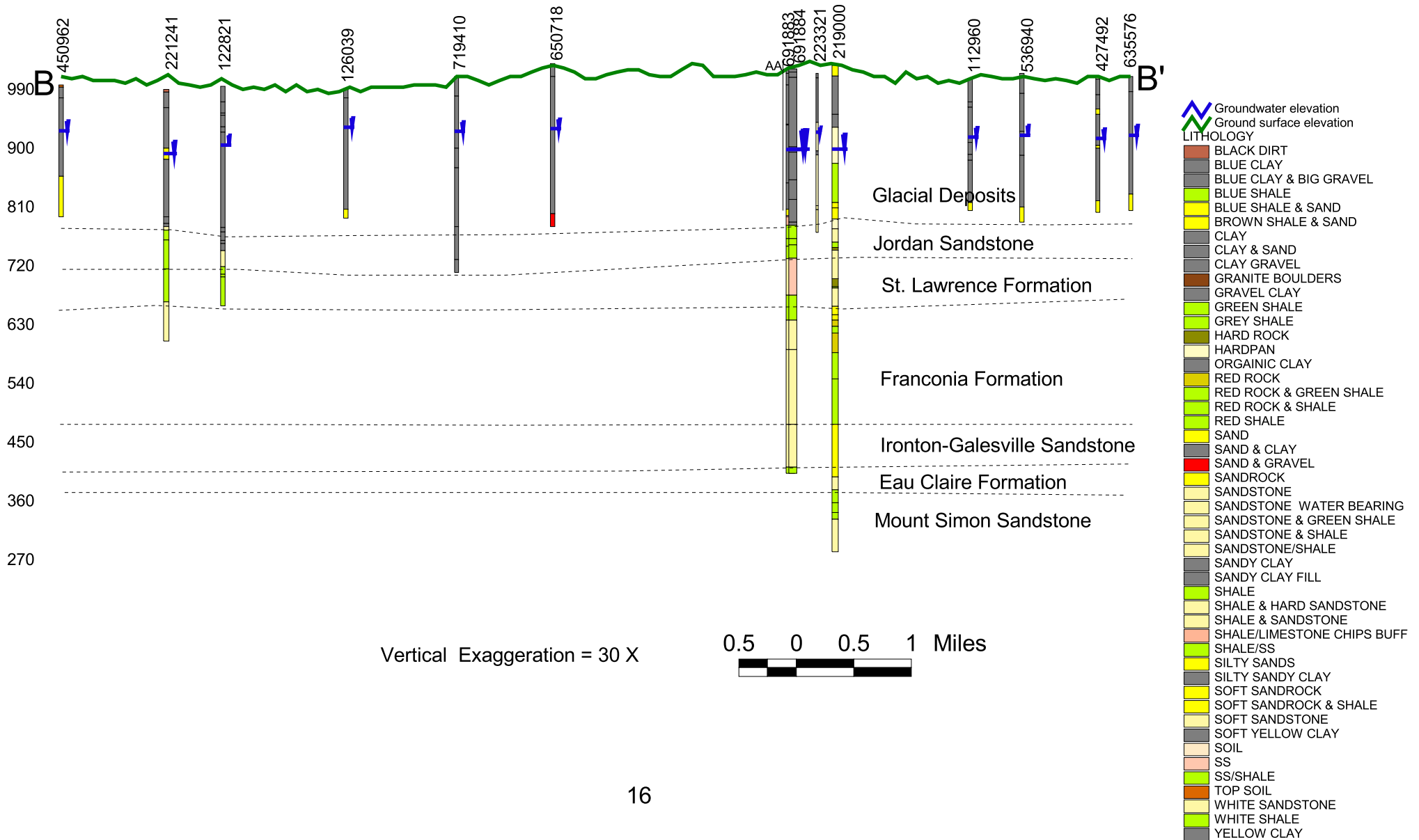


- Wells.shp
- ★ city wells
- cross section lines

# Figure 3. Cross Section A-A'



# Figure 4. Cross Section B-B'





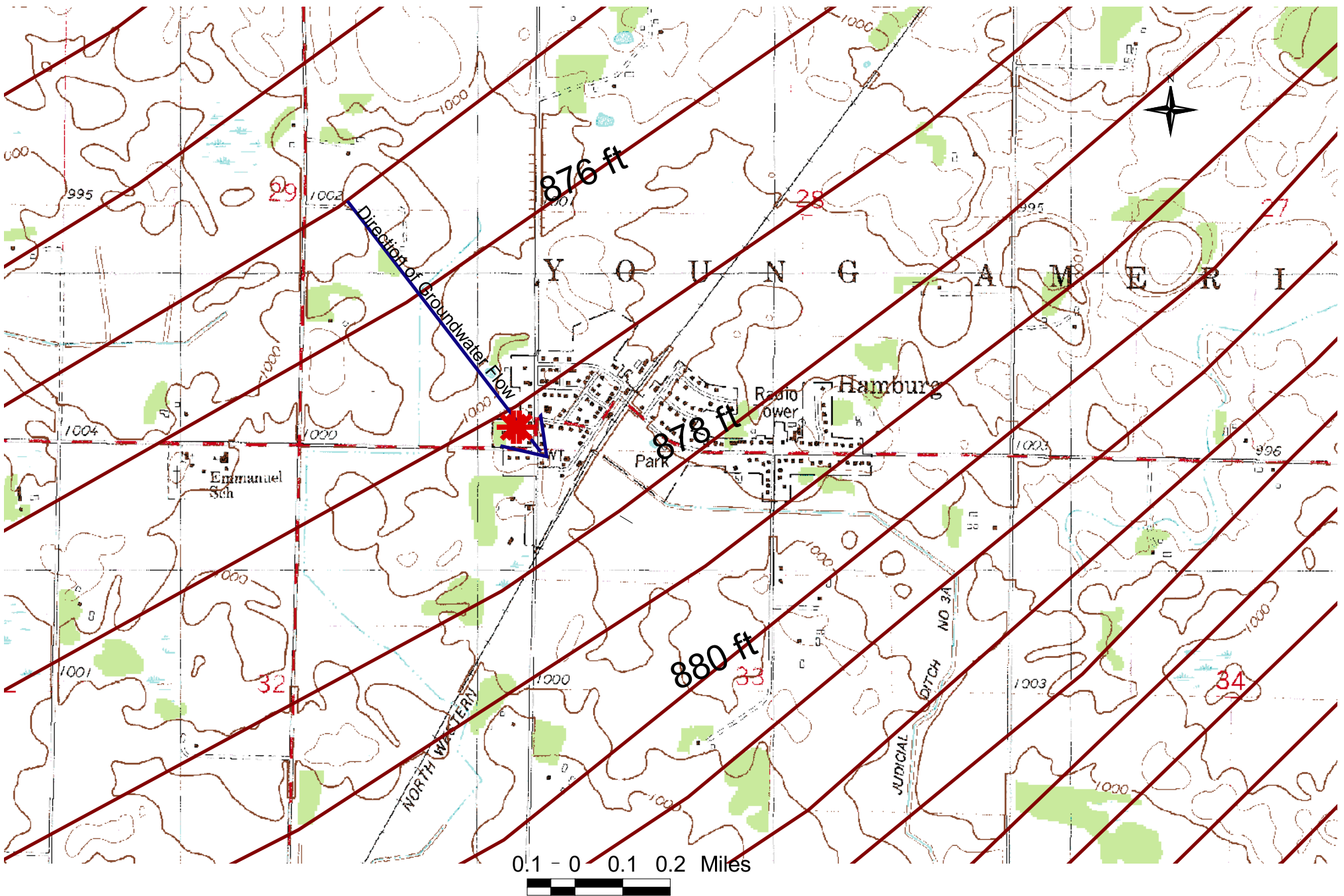



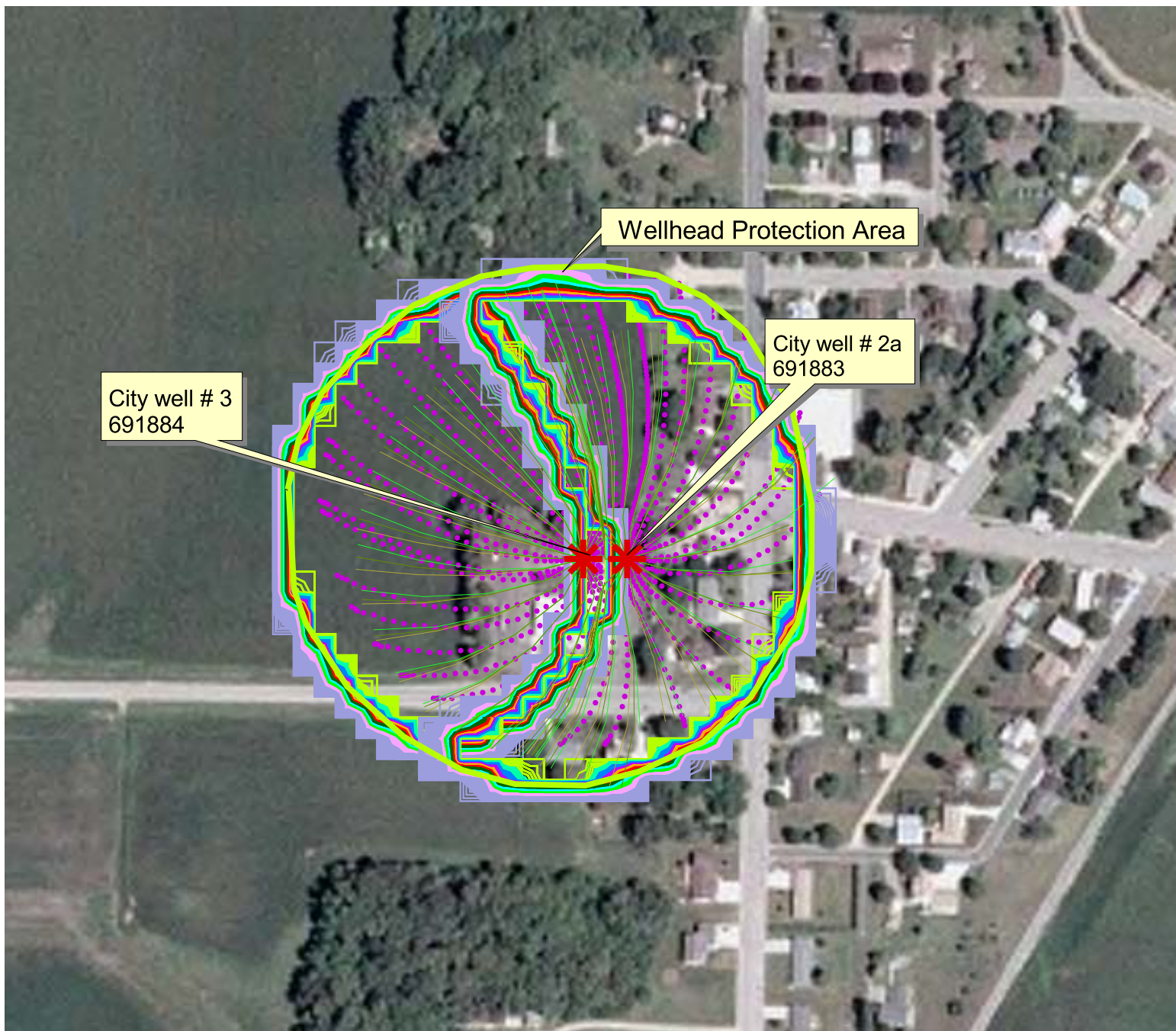


Figure 5. Distribution of Hydraulic Head within the Aquifer used by the City of Hamburg

-  Hamburg city wells
-  Groundwater flow direction
-  Ground water contour lines as feet above sea level



- HamburgWHPA
- ✱ Hamburg city wells
- ∧ WHPA Code capture zone A
- ∧ WHPA Code capture zone C
- ∧ WHPA Code capture zone B
- Probability Contours Hamburg well # 2a
- ∧ 0 - 9%
- ∧ 10%
- ∧ 20%
- ∧ 30%
- ∧ 40%
- ∧ 50%
- ∧ 60%
- ∧ 70%
- ∧ 80%
- ∧ 90%
- ∧ 100%
- Probability Contours Hamburg well # 3
- ∧ 0 - 9%
- ∧ 10%
- ∧ 20%
- ∧ 30%
- ∧ 40%
- ∧ 50%
- ∧ 60%
- ∧ 70%
- ∧ 80%
- ∧ 90%
- ∧ 100%
- Metro Model capture zones

Figure 6. Pathlines for WHPA Code runs, Oneka Probability Analysis and, Metro Model Analysis.

## **APPENDIX I**

### **WELL VULNERABILITY WORKSHEETS**



**MINNESOTA DEPARTMENT OF HEALTH  
SECTION OF DRINKING WATER PROTECTION  
SWP Vulnerability Rating**



625 Robert St. N. St. Paul MN 55155  
P.O. Box 64975 St. Paul MN 55164 - 0975

PWSID: 1100005  
SYSTEM NAME: Hamburg  
WELL NAME: Well #2A

TIER: 6  
WHP RANK:  
UNIQUE WELL #: 00691883

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COUNTY: Carver                      TOWNSHIP NUMBER:                      RANGE:                      SECTION:                      QUARTERS:

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| <u>CRITERIA</u>                            | <u>DESCRIPTION</u>           | <u>POINTS</u>  |
|--|------------------------------|----------------|
| Aquifer Name(s) :                          | Franconia-Ironton-Galesville |                |
| DNR Geologic Sensitivity Rating :          | Very low                     | 0              |
| L Score :                                  | 17                           |                |
| Geologic Data From :                       | Well Record                  |                |
| <br>                                       |                              |                |
| Year Constructed :                         | 2003                         |                |
| Construction Method :                      | Rotary/Drilled               | 0              |
| Casing Depth :                             | 415                          | 0              |
| Well Depth :                               | 620                          |                |
| Casing grouted into borehole?              | Yes                          | 0              |
| Cement grout between casings?              | Yes                          | 0              |
| All casings extend to land surface?        | Yes                          | 0              |
| Gravel - packed casings?                   | No                           | 0              |
| Wood or masonry casing?                    | No                           | 0              |
| Holes or cracks in casing?                 | No                           | 0              |
| Isolation distance violations?             |                              | 0              |
| Pumping Rate :                             |                              | 0              |
| Pathogen Detected?                         |                              | NOT VULNERABLE |
| <br>                                       |                              |                |
| Surface Water Characteristics?             |                              | NOT VULNERABLE |
| Maximum nitrate detected :                 | Unknown                      | 0              |
| Maximum tritium detected :                 | <.8 06/07/2005               | NOT VULNERABLE |
| <br>                                       |                              |                |
| Non-THMS VOCs detected?                    |                              | 0              |
| Pesticides detected?                       |                              | 0              |
| <br>                                       |                              |                |
| Carbon 14 age :                            | Unknown                      | 0              |
| <hr/>                                      |                              |                |
| Wellhead Protection Score :                |                              | 0              |
| Wellhead Protection Vulnerability Rating : |                              | NOT VULNERABLE |
| <hr/>                                      |                              |                |
| Vulnerability Overridden :                 |                              |                |

COMMENTS  
Aquifer appears to span from bottom of St. Lawrence to top of eau Claire.



**MINNESOTA DEPARTMENT OF HEALTH  
SECTION OF DRINKING WATER PROTECTION  
SWP Vulnerability Rating**



625 Robert St. N. St. Paul MN 55155  
P.O. Box 64975 St. Paul MN 55164 - 0975

PWSID: 1100005  
SYSTEM NAME: Hamburg  
WELL NAME: Well #3

TIER: 6  
WHP RANK:  
UNIQUE WELL #: 00691884

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COUNTY: Carver                      TOWNSHIP NUMBER:                      RANGE:                      SECTION:                      QUARTERS:

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| <u>CRITERIA</u>                            | <u>DESCRIPTION</u>           | <u>POINTS</u>  |
|--|------------------------------|----------------|
| Aquifer Name(s) :                          | Franconia-Ironton-Galesville |                |
| DNR Geologic Sensitivity Rating :          | Very low                     | 0              |
| L Score :                                  | 15                           |                |
| Geologic Data From :                       | Well Record                  |                |
| <br>                                       |                              |                |
| Year Constructed :                         | 2003                         |                |
| Construction Method :                      | Rotary/Drilled               | 0              |
| Casing Depth :                             | 415                          | 0              |
| Well Depth :                               | 620                          |                |
| Casing grouted into borehole?              | Yes                          | 0              |
| Cement grout between casings?              | Yes                          | 0              |
| All casings extend to land surface?        | Yes                          | 0              |
| Gravel - packed casings?                   | No                           | 0              |
| Wood or masonry casing?                    | No                           | 0              |
| Holes or cracks in casing?                 | Unknown                      | 0              |
| Isolation distance violations?             |                              | 0              |
| Pumping Rate :                             | 150                          | 5              |
| Pathogen Detected?                         |                              | 0              |
| <br>                                       |                              |                |
| Surface Water Characteristics?             |                              | 0              |
| Maximum nitrate detected :                 | Unknown                      | 0              |
| Maximum tritium detected :                 | Unknown                      | 0              |
| <br>                                       |                              |                |
| Non-THMS VOCs detected?                    |                              | 0              |
| Pesticides detected?                       |                              | 0              |
| <br>                                       |                              |                |
| Carbon 14 age :                            | Unknown                      | 0              |
| <hr/>                                      |                              |                |
| Wellhead Protection Score :                |                              | 5              |
| Wellhead Protection Vulnerability Rating : |                              | NOT VULNERABLE |
| <hr/>                                      |                              |                |
| Vulnerability Overridden :                 |                              |                |

COMMENTS  
Open interval spans from bottom of St. Lawrence to top of Eau Claire.



## **APPENDIX II**

### **TABLE OF MODEL PARAMETERS USED IN WHPA-CODE MODEL RUNS**

**Table of Model Parameters Used in WHPA Code Model Runs**

| <b>File Name</b> | <b>Transmissivity<br/>meter<sup>2</sup>/day</b> | <b>Aquifer Thickness<br/>(meters)</b> | <b>Gradient</b> | <b>Porosity</b> | <b>Flow<br/>Angle</b> | <b>TOT<br/>(Years)</b> | <b>Remarks</b>          |
|------------------|---|---------------------------------------|-----------------|-----------------|-----------------------|------------------------|-------------------------|
| Ahamburg.gen     | 72.03   | 62.5                                  | 0.0008          | 0.20            | 321                   | 10                     | Delineation<br>Settings |
| Bhamburg.gen     | 72.03   | 62.5                                  | 0.0008          | 0.20            | 331                   | 10                     | Delineation<br>Settings |
| Chamburg.gen     | 72.03   | 62.5                                  | 0.0008          | 0.20            | 311                   | 10                     | Delineation<br>Settings |
| Dhamburg.gen     | 72.03   | 62.5                                  | 0.0008          | .020            | 321                   | 1                      | Delineation<br>Settings |
| Ehamburg.gen     | 72.03   | 62.5                                  | 0.0008          | .020            | 331                   | 1                      | Delineation<br>Settings |
| Fhamburg.gen     | 72.03   | 62.5                                  | 0.0008          | .020            | 311                   | 1                      | Delineation<br>Settings |

**Input Values Used for the Sensitivity Analysis**

| <b>File Name</b> | <b>Transmissivity<br/>meter<sup>2</sup>/day</b> | <b>Aquifer Thickness<br/>(meters)</b> | <b>Gradient</b> | <b>Porosity</b> | <b>Flow<br/>Angle</b> | <b>TOT<br/>(Years)</b> | <b>Remarks</b> |
|------------------|---|---------------------------------------|-----------------|-----------------|-----------------------|------------------------|----------------|
| Ghamburg.gen     | 195   | 62.5                                  | 0.0008          | 0.20            | 321                   | 10                     |                |
| Hhamburg.gen     | 48.85   | 62.5                                  | 0.0008          | 0.20            | 321                   | 10                     |                |
| Ihamburg.gen     | 72.03   | 62.5                                  | 0.0008          | 0.25            | 321                   | 10                     |                |
|                  |   |                                       |                 |                 |                       |                        |                |
|                  |   |                                       |                 |                 |                       |                        |                |

## **APPENDIX III**

### **MAP OF INNER WELLHEAD MANAGEMENT ZONES**



Figure 7. Map showing the Inner Wellhead Management Zone for the Emergency Backup well