City of Hastings Wellhead Protection Plan Amendment

Part I:

Delineation of the Wellhead Protection Area (WHPA), Drinking Water Supply Management Area (DWSMA), and Assessments of Well and DWSMA Vulnerability

Prepared for
City of Hastings

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November 2019

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Certifications

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

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General Information

UNIQUE WELL NUMBER(S) 206333, 207993, 207639, 207643, 509053, 686266
SIZE OF POPULATION SERVED 22,713 (2018 estimate)
COUNTY Dakota

Executive Summary

Protection Areas - The recharge area for the wells is known as the wellhead protection area, or WHPA, and represents the area that contributes water to the City's wells within a 10-year time period. For Hastings, the WHPA includes a groundwater contribution area and a surface water contribution area because the Vermillion River is known to contribute water to the aquifer near Hastings. The area that contributes water within a one-year time period is known as the emergency response area, or ERA. Practical reasons require the designation of a management area that fully envelops the WHPA, called the drinking water supply management area, or DWSMA. This report describes how a new WHPA and DWSMA, shown on Figure 8, were delineated for the City of Hastings.

Geology and Groundwater Flow – The city of Hastings has 6 primary water supply wells. Wells 3, 4, 5, 6, 7, and 8 draw water from the Jordan Sandstone aquifer between 188 and 400 feet below ground surface (ft bgs). Regionally, groundwater flow is to the northeast toward the Mississippi River. Well construction information is summarized in Table 2.

Well Vulnerability - The vulnerability of each individual well has been assessed based on 1) well construction details, especially conformance with standards required by the State well code, 2) the geologic sensitivity of the aquifer, and 3) past monitoring results. Wells 3, 4, 5, 6, 7, and 8 are considered vulnerable to contamination based on water quality data (Table 5).

DWSMA vulnerability -The vulnerability of the City's aquifer throughout the DWSMA is based on a published pollution sensitivity map for the Prairie du Chien-Jordan aquifer, the geologic sensitivity ratings of wells in and near Hastings, and tritium data from Wells 4, 6, and 7. Based on this information, high vulnerability has been assigned to the entire DWSMA. High vulnerability suggests that water, and any contaminants, may travel from the land surface to the City's aquifer within a time span of months to a few years.

Water Quality Concerns - At present, none of the contaminants for which the Safe Drinking Water Act has established health-based standards are found above maximum allowable levels in the City's water supply. E. coli bacteria were detected on September 22, 2018 and temporary ongoing disinfection has been implemented, with a permanent gas-chlorine disinfection system scheduled to be fully online by June of 2020. The highest nitrate concentration detected in 2018 was 9.4 ppm, near the MCL of 10 ppm. Nitrate levels are discussed further in Section 6.0 of this report.

Recommendations - Recommendations have been generated to improve future delineations and vulnerability assessments and should be considered for inclusion as management strategies in the City's wellhead protection plan. These recommended activities include water quality monitoring, details of which can be found in Section 7.0 of this report.

1.0 Introduction

In compliance with the Minnesota Wellhead Protection Rules (MN Rules 4720.5100 through 4720.5590), a Wellhead Protection Area (WHPA) and a Drinking Water Supply Management Area (DWSMA) were delineated for the City of Hastings in 2009 (Barr, 2009). Minnesota Rule 4720.5570 states that wellhead protection plans must be reviewed and amended at least every ten years.

As required by Minnesota Rule 4720.5570, a new WHPA and a new DWSMA have been delineated for the City of Hastings. This report summarizes work completed to update the delineation of the Hastings WHPA and DWSMA in compliance with the Minnesota Wellhead Protection Rules and to meet the current MDH requirements. Data elements used in preparation of the report are presented in Table 1.

The City of Hastings currently has 6 primary municipal water supply wells. All 6 wells are completed in the Jordan Sandstone aquifer. Well locations are shown on Figure 1. Table 2 summarizes construction, use, and vulnerability information for the Hastings water supply wells. Appendix A contains well logs for the City's wells.

2.0 Criteria for Wellhead Protection Area Delineation

The following criteria were used to ensure accurate delineation of the WHPA.

2.1 Time of Travel

A minimum 10-year groundwater time of travel criterion must be used to delineate a WHPA (MN Rule 4720.5510) so there is sufficient reaction time to remediate potential health impacts in the event of contamination of the aquifer. A groundwater time of travel of ten years was considered in this study. As required by the Wellhead Protection Rules, the one-year groundwater time of travel zone was also determined for each well addressed in this study.

2.2 Aquifer Transmissivity

For this study, the transmissivity of the Jordan Sandstone aquifer was estimated using a pumping test conducted at Well 5 in 2003. Wells 3 and 4 were used as observation wells. Analysis of the data for this test estimated a representative Jordan transmissivity of 5,444 ft^2/day (505.8 m^2/day). The average aquifer thickness at Wells 3, 4, and 5 of 95.7 feet (29.2 m) was used to compute a representative hydraulic conductivity of 56.9 ft/day (17.3 m/day). A summary of the aquifer test is included in Appendix B. See Section 2.5 below for details regarding how this hydraulic conductivity value was incorporated into the groundwater model.

2.3 Daily Volume of Water Pumped

Pumping data for the City of Hastings for the period 2014 through 2018 are in Table 3. The largest annual withdrawal for 2014-2018 was 899,740,000 gallons in 2014. The City's Local Water Supply Plan projects a 2024 average daily demand of 2.63 million gallons per day. Projected 2024 pumping rates for each well were calculated by multiplying the total 2024 projected demand by the 2014-2018 average percentage of total withdrawal for each well. The pumping rate used in the model for each Hastings well for the WHPA delineation was either this 2024 projection or the historical maximum for the period 2014-2018, whichever was greater. The pumping rates used in the model for delineation of the WHPA are in Table 3. Unaccounted water (the difference between the total volume pumped annually by the City's wells and the total amount billed to users) is approximately 10-15%.

2.4 Conceptual Hydrogeologic Model

The regional hydrogeologic conceptual model is presented in Metropolitan Council (2009). Additional geological information is included below, along with discussion of groundwater flow boundaries and flow directions specific to the Hastings area.

2.4.1 Regional Bedrock Geology

A bedrock map derived from the Twin Cities ten-county metropolitan area geologic map (Mossler, 2013) is shown on Figure 1. Locations of two geologic cross sections through the study area are also shown on

Figure 1. Geologic cross section A-A' (Figure 2) is a north to south cross section that intersects northwest to southeast cross section B-B' (Figure 3) at Well 5.

The hydrostratigraphic units of importance for this study are described in more detail below.

Jordan Sandstone

The Cambrian-aged Jordan Sandstone consists of two interlayered facies: a fine- to coarse-grained, friable, quartz sandstone and a very fine-grained, feldspathic sandstone with lenses of siltstone and shale (Mossler, 2013). Where it is not eroded the Jordan Sandstone is typically 85 to 100 feet thick. As shown on Figure 1, the Jordan Sandstone is the uppermost bedrock along the margins of the bedrock valleys in and near Hastings and has been completely eroded away within the bedrock valleys.

Prairie du Chien Group

The Ordovician-aged Prairie du Chien Group is divided into two formations: the upper Shakopee Formation and the lower Oneota Dolomite. The Shakopee Formation is a heterolithic unit composed of dolostone, sandy dolostone, and sandstone, while the Oneota Dolomite is medium- to thick-bedded dolomite (Mossler, 2013). The Prairie du Chien Group is the uppermost bedrock across much of Hastings. It ranges in thickness from 136 to 268 feet where encountered at Hastings' wells. The Prairie du Chien Group is classified as being highly fractured over much of the Twin Cities metropolitan area, especially under shallow bedrock conditions (overlying bedrock thickness < 200 feet, after Runkel et al. (2003)). Groundwater in the Prairie du Chien Group flows through joints, fractures, and bedding planes (Palen, 1990). No Hastings wells are open to the Prairie du Chien Group, but it is hydraulically connected to the underlying Jordan Sandstone.

2.4.2 Flow Boundaries

The Mississippi River to the north of Hastings is a regional groundwater flow boundary. Figure 1 also shows several faults in the Hastings area. These faults were not explicitly represented in the groundwater flow model (Section 2.5) but were accounted for in the fracture flow delineation (Section 3.2).

2.5 Model Description

To accurately delineate the WHPAs, it is necessary to assess how nearby wells, rivers, lakes, and variations in geologic conditions affect groundwater flow directions and velocities in the aquifer. A groundwater model constructed using the finite difference code MODFLOW-96 (Harbaugh and McDonald, 1996) was used for this study to simulate groundwater flow in the hydrostratigraphic units from the Quaternary aquifer down to the Mt. Simon Sandstone. MODFLOW-96 is public domain software that is available at no cost from the United States Geological Survey. The pre- and post-processor Groundwater Vistas (version 7) (Environmental Simulations, Inc., 2017) was used to create the model data files and evaluate the model results.

2.5.1 Base Model

Consistent with the Scoping Letter (MDH, 2018), the base model used in this study is the same model used for the 2009 Hastings WHPP. The model is based on Metro Model 2 (Metropolitan Council, 2009),

which was developed by Barr Engineering for the Metropolitan Council to assist in evaluating groundwater use and water sustainability issues, regional water planning issues, and groundwater appropriations.

The model is divided into 9 layers to represent the major hydrostatigraphic units in the Twin Cities Metropolitan Area. In Hastings, the model layers represent the following (ordered from youngest to oldest; i.e., shallowest to deepest):

- Layer 1: Quaternary glacial drift
- Layer 2: St. Peter Sandstone or Quaternary glacial drift (where present)
- Layer 3: Prairie du Chien Group or Quaternary glacial drift (where present)
- Layer 4: Jordan Sandstone or Quaternary glacial drift (where present)
- Layer 5: St. Lawrence Formation or Quaternary glacial drift (where present)
- Layer 6: Tunnel City Group
- Layer 7: Wonewoc Sandstone
- Layer 8: Eau Claire Formation
- Layer 9: Mt. Simon Sandstone

Major rivers near Hastings (i.e., the Mississippi, Vermillion, and St. Croix Rivers) are simulated using the River Package within MODFLOW. Baseflow measurements for rivers and streams in the area were used during calibration of Metro Model 2.

Recharge for the groundwater flow model was determined using the SWB recharge model (Westenbroek et. al., 2010) of the Twin Cities Metropolitan Area (Metropolitan Council, 2009). Monthly precipitation data for Hastings from the last 5 years is summarized in Table 4.

Modifications made to the base model for the new Hastings WHPA delineations are discussed in the following section.

2.5.2 Model Modifications and Updates

The following modifications and updates were made to the base model:

- The edges of the Prairie du Chien Group and Jordan Sandstone within the refined grid area were revised to more closely follow the bedrock map (Mossler, 2013).
- The horizontal hydraulic conductivity value (Kx) for the Jordan in zone 346, which includes all of the Hastings wells, was updated to 17.3 m/day to match the aquifer test plan (Appendix B). A vertical anisotropy ratio (Kx/Kz) of 10 was assumed for zone 346. Appendix C includes a map of model hydraulic conductivity field for Layer 4 in the Hastings area (Figure C1).
- The pumping rates for the City's wells were changed to the model input rates shown in Table 3.
- Pumping rates for 23 high-capacity wells within 2 miles of Hastings were updated to use 2013-2017 averages. A list of these wells is included as Table C1 in Appendix C. Nine of these wells (unique numbers listed below) were added to the model because they were not included in the model used for the 2009 WHPP:

    - 170868, permit 1975-6358
    - 250020, permit 1976-6157
    - 250177, permit 1969-1102
    - 257402, permit 1976-6204
    - 749829, permit 1985-6224
    - 768670, permit 2015-1357
    - 771760, permit 1985-6224
    - 806056, permit 2015-1392
    - (no unique number), permit 1993-6152
- After the above modifications were made, modeled heads were compared to observed heads from Minnesota Well Index records located within the model domain. No further calibration was deemed necessary. A plot of modeled versus measured heads is included as Figure C2 in Appendix C. Full discussion of the Metro Model 2 calibration is presented in Metropolitan Council (2009).

MODFLOW files for the updated model are included in Appendix I.

2.6 Groundwater Flow Field

The groundwater flow field used for delineation of the WHPA was determined by the groundwater flow model; modeled contours for the Jordan Sandstone/Quaternary glacial drift (Layer 4) are shown on Figure 4.

In general, Figure 4 shows the Jordan flow direction in Hastings to be northeasterly toward the Mississippi River. The modeled northeasterly flow direction is consistent with a published contour map for the Prairie du Chien – Jordan aquifer from the Dakota County Geologic Atlas (Palen, 1990). Based on this comparison and the acceptable calibration of the groundwater model, the groundwater flow field was determined to be of acceptable accuracy for the WHPA delineation.

3.0 Delineation of the Wellhead Protection Area

Delineation of the WHPA for the Hastings wells involved the evaluation of porous media flow, fracture flow, and surface water contribution (conjunctive delineation) as detailed below.

3.1 Porous Media Flow Evaluation

The groundwater flow model discussed above in Section 2 was used to simulate the groundwater flow field in the vicinity of Hastings. The porous media capture zone for the Hastings well field was delineated using the software program MODPATH (Version 3; Pollock, 1994) with the modeled groundwater flow field. A minimum of 180 particles were tracked from each well. The particles were released from up to 6 vertical points in each layer along the open interval of each well. These particles were tracked backwards in time for both one and ten years. In plan view, the areas encompassed by the particle traces were then outlined as the 1-year and 10-year porous media time of travel zones for the well field.

Porosity values used for the porous media flow evaluation were as follows (Norvitch et al., 1974, Schwartz and Zhang, 2003):

- Quaternary Glacial Drift = 0.25
- St. Peter Sandstone = 0.283
- Prairie du Chien Group = 0.056
- Jordan Sandstone = 0.2

3.1.1 Sensitivity Analysis

A sensitivity analysis was performed to test the sensitivity of the model results to varying hydraulic conductivity in the Jordan Sandstone aquifer. Lower and upper bounds of 20.1 ft/day (6.1 m/day) and 191 ft/day (58.1 m/day), respectively, were tested for horizontal Jordan hydraulic conductivity. These values were derived from the pumping test transmissivity ranges (Appendix B). A vertical anisotropy ratio of 10 was assumed for both sensitivity runs. A plot of the sensitivity analysis results is included in Appendix C (Figure C3).

Multiple particle tracking simulations were conducted to account for uncertainty in the groundwater flow model. In addition to the base model run, particle tracking simulations were also conducted for both of the sensitivity runs. Particle traces from all simulations were used to delineate the 1-year and 10-year porous media capture zones for each well. These capture zones are shown on Figure 5.

3.2 Fracture Flow Evaluation

All of Hastings' wells are open to the Jordan Sandstone, which is likely hydraulically connected to the overlying Prairie du Chien Group. To address fracture flow in the Prairie du Chien Group, MDH (2011a) guidelines for delineating WHPAs in fractured and solution-weathered bedrock were followed using Delineation Technique Number 4 (wells open only to a porous media aquifer that is hydraulically connected to a fractured or solution-weathered aquifer). In addition, the fracture flow capture zones were

also extended along two fault orientations. A summary of the calculations used in the delineation of fracture flow capture zones is presented in Appendix D.

3.2.1 Fixed Radius Capture Zones and Upgradient Extensions

Although the Hastings wells are open to only the Jordan Sandstone, a porous media aquifer, the porous media modeling suggests that the Jordan Sandstone is hydraulically connected to the fractured and solution-weathered Prairie du Chien Group. The water budget software ZONEBUDGET (Harbaugh, 1990) was used to compute the contributions from model layer 3 (Prairie du Chien Group) to the baseline 10-year porous media capture zones in layer 4 (Jordan Sandstone) for each well. Flow from model layer 3 to model layer 4 within the capture zones ranged from 20% at Well 5 to 76% at Well 3 (Table D1 in Appendix D). The MDH guidelines cite a threshold of 10% for determining whether or not recharge from the fractured or solution-weathered aquifer is a significant source of recharge to the porous media aquifer; because the calculated percentages for all Hastings wells were above this threshold, it was necessary to delineate fracture flow capture zones for all wells.

Note that the Prairie du Chien Group is not present at Well 3 (Figure 1). Because the Prairie du Chien is present upgradient of Well 3 and the modeled particle traces from Well 3 travel upgradient into the Prairie du Chien, fracture flow capture zones were delineated for Well 3. The Prairie du Chien thickness at Well 5 was assumed for the purposes of the Well 3 fracture flow calculations.

The ratio of the well discharge to the discharge vector was calculated for each well using the contribution from model layer 3 calculated by ZONEBUDGET as the pumping rate. This ratio was less than 3,000 for all wells, so upgradient extensions were required for the 1-year and 10-year fracture flow capture zones. Hydraulic gradients and upgradient directions (i.e., bearings) were estimated from the baseline model layer 3 flow field.

For the 1-year time of travel, 6-month fixed-radius capture zones and 6-month upgradient extensions were delineated for each individual well using the GIS-based MDH Fracture Flow Tool. For the 10-year time of travel, 5-year fixed-radius capture zones and 5-year upgradient extensions were delineated for each individual well using the MDH Fracture Flow Tool. Table D2 in Appendix D is a summary of the inputs to the Fracture Flow Tool.

To evaluate the potential for overlapping capture zones, 10-year fixed-radius capture zones were calculated for 10 nearby wells as documented in Table D3 in Appendix D. Four of these capture zones (for wells 255924, 251398, 771760, and 207640) overlapped with the preliminary 5-year fixed radius capture zones for three of the Hastings wells (4, 7, and 8). The overlapping areas were calculated using geometric functions within ArcGIS, which allows for a more accurate redistribution of the shared volumes than the method described in the MDH fracture flow guidelines. The areas of the preliminary 5-year fixed radius capture zones for Wells 4, 7, and 8 were adjusted to include the overlapping areas, and the effective pumping rate necessary to generate the enlarged areas was calculated. These effective pumping rates were then used as input to the MDH Fracture Flow Tool to generate the final 10-year capture zones (5-year fixed radius and 5-year upgradient extension). The MDH 2-Well Fracture Flow Tool was used to

account for the slight overlap between the adjusted 5-year fixed radius capture zones for Wells 3 and 7 and for Wells 6 and 8.

The final 5-year fixed-radius fracture flow capture zones and upgradient extensions were truncated at the extents of the Prairie du Chien Group. The truncated capture zones are shown on Figure 6.

3.2.2 Fault Extensions

As discussed at the Predelineation Meeting (MDH, 2019), the 5-year fixed-radius capture zones were extended along two perceived fault orientations (Mossler, 2013): N 52 E (52º / 232 º) and N 33 W (123 º / 303 º). Per the MDH fracture flow guidelines, the capture zones were extended 1 mile from each well along the fault orientations. Because the faults extend through the Jordan Sandstone (Figures 2 and 3), the fault extensions were truncated at the extents of the Jordan Sandstone instead of the extents of the Prairie du Chien Group, as was done for the fixed-radius capture zones and upgradient extensions. The fault extensions were also truncated at the Mississippi River as it constitutes a major hydraulic boundary. The truncated fault extensions are shown on Figure 6.

3.3 Conjunctive Delineation

It is recognized that the Vermillion River is a losing stream west of Hastings. Water samples from the city wells indicate water of relatively young age based on nitrate levels (Dakota County, 2003), and oxygen and hydrogen isotope data indicate a surface water signature in the water from Wells 4 and 6 (Appendix E). Because the Vermillion River is potentially a source of water for the city wells, a surface-water contribution area is required. Because the new groundwater capture area is not significantly different than that from the 2009 delineation, a new surface water contribution area was not delineated and the 2009 surface water contribution area was reused with minor adjustments in Hastings where it coincides with the groundwater capture zone. The surface water contribution area is shown on Figure 7.

3.4 WHPA Delineations

The composite 10-year porous media capture zones, 5-year fixed radius fracture flow capture zones, and 5-year upgradient extensions define Area A of the WHPA. The boundaries of Area A were slightly simplified from the merged capture zones to eliminate “holes” between individual capture zones. The surface water contribution area defines Area B of the WHPA. Much of the groundwater within Area B does not flow to Hastings. However, surface-water runoff within Area B has the potential to reach the Hastings wells via seepage from the Vermillion River. The Emergency Response Area (ERA) is delineated for each well by the composite 1-year porous media capture zones and composite 1-year fracture flow capture zones. The WHPA and ERAs are shown on Figure 8.

4.0 Delineation of the Drinking Water Supply Management Area

The Hastings DWSMA encompasses WHPA Areas A and B with boundaries that correspond to geographically identifiable features (e.g., roads, parcel boundaries, quarter-quarter section lines). Like the WHPA, the DWSMA is broken down into two areas; Area A comprising the groundwater capture zones, and Area B comprising the surface water contribution area. Property parcel boundaries were used to define Area A while quarter-quarter section boundaries were used to define Area B. The Hastings DWSMA is shown on Figure 8. To satisfy Minnesota Rule 4720.5500, Subpart 2, 1:24,000 scale maps of the DWSMAs are included in Appendix F.

5.0 Well Vulnerability Assessment

MDH evaluated the vulnerability of the Hastings municipal wells to contamination from contaminants released at the surface. The evaluation parameters include geology, well construction, pumping rate, and water quality. All Hastings wells are classified as "vulnerable." Copies of the MDH well vulnerability scoring sheets for the Hastings wells are included in Appendix G.

6.0 Drinking Water Supply Management Area Vulnerability Assessment

The vulnerability of the Jordan Sandstone within the DWSMA associated with the Hastings wells was evaluated in a manner consistent with MDH guidance for assessing aquifer vulnerability (MDH, 1997) using a published pollution sensitivity map (Hobbs, 1990), geologic sensitivities based on L scores computed from boring log data, and water quality data from the Hastings wells.

The first step in the assessment is to determine the geologic sensitivity rating of the aquifer. The Minnesota Department of Natural Resources (MnDNR) defines geologic sensitivity based on the travel time of water moving vertically from the surface to the aquifer of interest as follows (see MnDNR, 1991):

- Sensitivity = Very High: vertical travel time is hours to weeks
- Sensitivity = High: vertical travel time is weeks to years
- Sensitivity = Moderate: vertical travel time is years to decades
- Sensitivity = Low: vertical travel time is several decades to a century
- Sensitivity = Very Low: vertical travel time is more than a century.

The pollution sensitivity map for the Prairie du Chien – Jordan aquifer from the Dakota County Geologic Atlas (Hobbs, 1990) was used as a starting point for developing the Jordan Sandstone geologic sensitivity map. This map includes "High-Moderate" and "Low-Moderate" ratings which are not recognized by MDH. Based on the definitions of "High-Moderate" as a travel time of "years to a decade" and "Low-Moderate" as a travel time of "several decades", these areas were remapped to the "Moderate" and "Low" ratings, respectively, on the MnDNR definitions above. The modified geologic sensitivity map is shown on Figure H1 in Appendix H.

"L scores" based on the thickness of low permeability units at Minnesota Well Index well locations in the vicinity of the DWSMA were computed using the MDH L score tool [See MnDNR (1991) for a discussion of how to determine L scores]. The calculated L scores are shown on Figure H1 in Appendix H.

Tritium samples were collected at Well 4 in 2004 and at Wells 6 and 7 in 2016. Tritium (^3H), a radioactive isotope of hydrogen, has been used extensively to date groundwater. Tritium activities peaked during atmospheric hydrogen bomb testing of the 1950s and 1960s, and values of ^3H in precipitation reached a maximum of approximately 10,000 T.U. (tritium units) in 1963 (Mazor, 2004). Natural production of ^3H in the upper atmosphere introduces approximately 5 T.U. to precipitation each year (Mazor, 2004). Because ^3H has a relatively short half-life of 12.43 years, radioactive decay since the bomb peak has reduced tritium activities to near background levels and ^3H is used mostly for relative age dating today. Groundwater that has little or no detectible ^3H is stated to be "vintage" or pre-bomb. Groundwater with detectable concentrations of ^3H is stated to be "young" or post-bomb. The presence of tritium at concentrations above 1 tritium unit indicates the presence of a significant fraction of post-1953 (i.e., recently infiltrated) water in the groundwater sample. As shown on Table 5, tritium was detected in the samples collected from Wells 4, 6, and 7. Table 5 also shows other water quality results from sampling of the City's wells.

The presence of tritium in groundwater samples from a well suggests that the water traveled vertically from the ground surface to the aquifer in less than about 50 years. Based on this information along with the geologic sensitivity ratings and L scores, High vulnerability was assigned to the entire Area A of the DWSMA. Keeping with current MDH policy, high vulnerability was assigned to all of Area B of the DWSMA (the surface water area) as well. The final aquifer vulnerability map is shown on Figure 9.

The City is frequently monitoring nitrate levels in raw water samples at all of its municipal wells but has special focus on Wells 6 and 8. Of the wells that are not currently treated for nitrate, Wells 6 and 8 have historically had the most elevated levels. Before making a significant and permanent investment in a new treatment plant, the City will first work closely with the MDH to attempt all cost-effective solutions for maintaining delivery of water in compliance with the nitrate standard from these two wells. Should a new nitrate reduction/removal treatment plant become necessary, it is presumed that such a facility would be constructed on the site of Well 6. Water system infrastructure has been roughed in to interconnect these two well sites with a transmission main that would allow for water from Well 8 to be transported to a future treatment plant at Well 6.

7.0 Recommendations

As discussed in Section 6.0, it is recommended that the City work with the MDH regarding the nitrate issues at Wells 6 and 8.

It is recommended that the City consider working with the MDH to conduct tritium sampling of wells 3, 4, 5, and 8 in order to have the data available when updating the well and aquifer vulnerability assessments as part of the next wellhead protection plan amendment.

8.0 Supporting Data Files

The groundwater model files and GIS files are included in Appendix I. (Appendix I can be found in the "Part1" folder on the CD.)

The groundwater model can be reviewed using MODFLOW-96 (Harbaugh and McDonald, 1996). MODPATH files can be reviewed using MODPATH Version 3 (Pollock, 1994).

All coordinates in the modeling files are based on UTM NAD 83 Zone 15 N datum. Elevations are in meters above mean sea level (m MSL). Time units are days. Length units are meters.

The GIS files have been named according to the MDH conventions. Shapefiles are in UTM NAD83 Zone 15 N datum.

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Tables

Table 1

Assessment of Data Elements
Hastings WHPP Amendment

Data Element	Present and Future Implications				Data Source
	Use of the Wells	Delineation Criteria	Quality and Quantity of Well Water	Land and Groundwater Use in DWSMA	
Precipitation	M	L	M	M	Minnesota Climatology Working Group
Geology					
Maps and geologic descriptions	M	H	H	H	MGS, MWI
Subsurface data	M	H	H	H	MGS, MDH, MWI
Borehole geophysics	M	M	M	M	MGS
Surface geophysics	L	L	L	L	Not Available
Maps and soil descriptions	L	M	M	M	MGS, NRCS
Eroding lands					
Water Resources					
Watershed units	L	L	L	L	DNR
List of public waters	L	L	L	L	DNR
Shoreland classifications					
Wetlands map					
Floodplain map					
Land Use					
Parcel boundaries map	L	H	L	L	Metropolitan Council, Dakota County
Political boundaries map	L	L	L	L	MNGEO
PLS map	L	L	L	L	DNR
Land use map and inventory					
Comprehensive land use map					
Zoning map					
Public Utility Services					
Transportation routes and corridors	L	M	L	L	MNDOT
Storm/sanitary sewers and PWS system map	L	L	L	L	City of Hastings
Oil and gas pipelines map					

Definitions Used for Assessing Data Elements:

High (H) - the data element has a direct impact
Moderate (M) - the data element has an indirect or marginal impact
Low (L) - the data element has little if any impact
Shaded - the data element was not required by MDH for preparing the WHP plan

MWI – Minnesota Well Index
DNR – Minnesota Department of Natural Resources
MNGEO - Minnesota Geospatial Information Office
MDH – Minnesota Department of Health
MNDOT – Minnesota Department of Transportation
MPCA – Minnesota Pollution Control Agency
NRCS – Natural Resources Conservation Service
SSURGO – Soil Survey Geographic Database
USGS – United States Geological Survey

Table 1

Assessment of Data Elements (Continued)
Hastings WHPP Amendment

Data Element	Present and Future Implications				Data Source
	Use of the Wells	Delineation Criteria	Quality and Quantity of Well Water	Land and Groundwater Use in DWSMA	
Public drainage systems map/ list	L	L	L	L	City of Hastings
Records of well construction, maintenance, and use	H	H	L	L	City of Hastings, MWI, MDH files
Surface Water Quantity					
Stream flow data	L	L	L	L	DNR
Ordinary high water mark data	L	L	L	L	DNR
Permitted withdrawals	L	L	L	L	DNR
Protected levels/flows	L	L	L	L	DNR
Water use conflicts	L	L	L	L	DNR
Groundwater Quantity					
Permitted withdrawals	H	H	H	H	DNR
Groundwater use conflicts	L	L	L	L	DNR
Water levels	H	H	H	H	MWI, MDH
Surface Water Quality					
Stream and lake water quality management classification					
Monitoring data summary	L	L	L	L	MPCA, MDH
Groundwater Quality					
Monitoring data	H	H	H	H	MDH
Isotopic data	H	H	H	H	MDH
Tracer studies	L	L	L	L	Not Available
Contamination site data	L	L	M	M	MPCA, MDH
Property audit data from contamination sites					
MPCA and MDA spills/release reports	L	L	L	L	No relevant data available

Definitions Used for Assessing Data Elements:

High (H) - the data element has a direct impact
Moderate (M) - the data element has an indirect or marginal impact
Low (L) - the data element has little if any impact
Shaded - the data element was not required by MDH for preparing the WHP plan

MWI – Minnesota Well Index
DNR – Minnesota Department of Natural Resources
MNGEO - Minnesota Geospatial Information Office
MDH – Minnesota Department of Health
MNDOT – Minnesota Department of Transportation
MPCA – Minnesota Pollution Control Agency
NRCS – Natural Resources Conservation Service
SSURGO – Soil Survey Geographic Database
USGS – United States Geological Survey

Table 2

Water Supply Well Information
Hastings WHPP Amendment

Local Well ID	Unique Number	Use/ Status[1]	Casing Diameter (in.)	Casing Depth (ft.)	Well Depth (ft.)	Year Constructed	Aquifer	Well Vulnerability
3	206333	P	24 x 16	208	299	1956	Jordan	Vulnerable
4	207993	P	24 x 16	314	400	1961	Jordan	Vulnerable
5	207639	P	30 x 24	277	356	1970	Jordan	Vulnerable
6	207643	P	30 x 24	240	332	1972	Jordan	Vulnerable
7	509053	P	30 x 24	205	285	1989	Jordan	Vulnerable
8	686266	P	30 x 24	188	280	2006	Jordan	Vulnerable

[1] P = Primary

Table 3

Annual and Projected Pumping Rates for Hastings Wells
Hastings WHPP Amendment

		Total Annual Withdrawal (gal/yr)				
Unique Number	Well Name	2014	2015	2016	2017	2018
206333	3	121,075,000	116,785,000	122,351,000	116,770,000	132,275,000
207993	4	153,550,000	175,900,000	156,850,000	173,045,000	165,010,000
207639	5	139,850,000	127,180,000	141,430,000	112,130,000	122,065,000
207643	6	97,880,000	108,330,000	115,525,000	103,950,000	138,920,000
509053	7	239,430,000	207,895,000	202,720,000	225,185,000	160,510,000
686266	8	147,955,000	112,365,000	117,055,000	106,800,000	82,450,000
	Totals	899,740,000	848,455,000	855,931,000	837,880,000	801,230,000

Source: City water use records

		Percentage of Annual Withdrawal					
Unique Number	Well Name	2014	2015	2016	2017	2018	Average Annual % of Withdrawal
206333	3	13.5%	13.8%	14.3%	13.9%	16.5%	14.4%
207993	4	17.1%	20.7%	18.3%	20.7%	20.6%	19.5%
207639	5	15.5%	15.0%	16.5%	13.4%	15.2%	15.1%
207643	6	10.9%	12.8%	13.5%	12.4%	17.3%	13.4%
509053	7	26.6%	24.5%	23.7%	26.9%	20.0%	24.3%
686266	8	16.4%	13.2%	13.7%	12.7%	10.3%	13.3%

		Projected Water Use (2024)			Maximum Total Pumping for Model Input[4]		
Unique Number	Well Name	Total[1] (gal/yr)	% of Total Projected Water Use[2]	Projected Well Pumpage Based on % (gal/yr)[3]	gal/yr	gal/day	m^3/day
206333	3		14.4%	138,611,520	138,611,520	379,758	1,438
207993	4		19.5%	187,703,100	187,703,100	514,255	1,947
207639	5		15.1%	145,349,580	145,349,580	398,218	1,508
207643	6		13.4%	128,985,720	138,920,000	380,603	1,441
509053	7		24.3%	233,906,940	239,430,000	655,973	2,483
686266	8		13.3%	128,023,140	147,955,000	405,356	1,535
	Totals	962,580,000	100.0%	962,580,000	997,969,200	2,734,162	10,351

Appropriation 1,300,000,000

[1] 2024 projected average daily demand of 2.63 million gallons per day from 2016 Hastings Local Water Supply Plan

[2] Percentages for wells based on average 2014-2018 usage per well

[3] Projected per well pumpage based on total 2024 projected withdrawal and projected percent of total pumped by each well

[4] For each well, the greater of the estimated pumpage based on projected 2024 withdrawal and actual annual pumpage for 2014-2018.

P:\Mpls\23 MN\19\23191405 Hastings WHPP Amendment\WorkFiles\Part1\Report\Tables\Table 3 - Well Pumping & Water Use Projection.xlsx

Table 4

Hastings Precipitation Data 2014-2018
Hastings WHPP Amendment

Month	Precipitation (inches)					Average
	2014	2015	2016	2017	2018	
January	0.97	0.53	0.48	1.10	1.28	0.87
February	1.23	0.57	0.89	0.64	0.62	0.79
March	0.76	0.72	2.83	0.77	0.87	1.19
April	5.79	2.24	2.62	4.45	1.66	3.35
May	4.97	3.79	2.59	7.22	3.62	4.44
June	10.69	5.67	4.53	3.65	6.26	6.16
July	2.72	7.49	7.75	4.38	2.94	5.06
August	3.39	3.84	8.47	5.09	4.62	5.08
September	1.66	5.12	4.88	1.79	5.80	3.85
October	1.44	2.60	2.51	4.06	3.66	2.85
November	0.98	4.23	1.60	0.24	1.77	1.76
December	0.63	3.19	3.03	0.63	1.32	1.76
Total	35.23	39.99	42.18	34.02	34.42	37.17

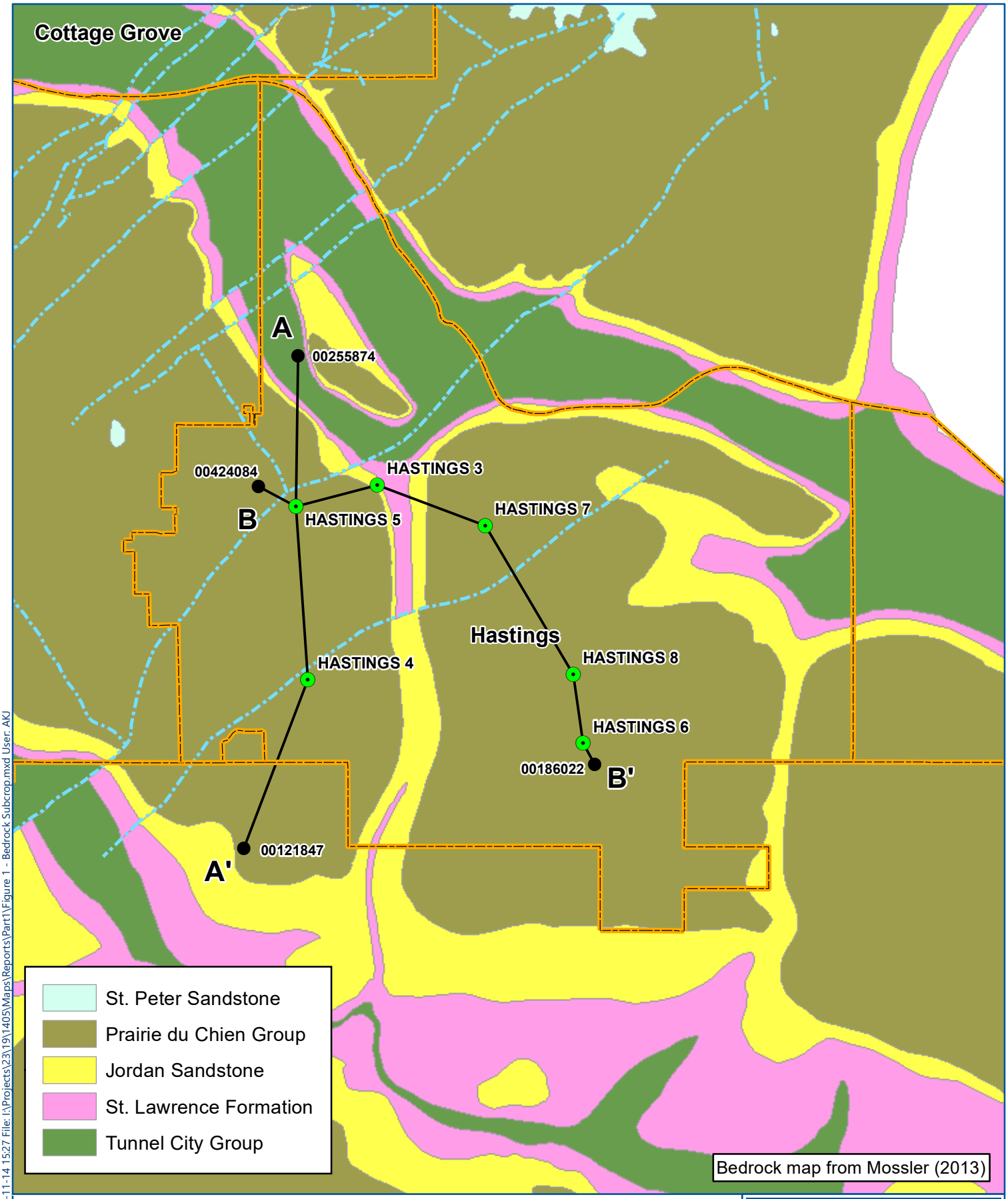
Source: Minnesota Climatology Working Group

Table 5

Hastings Water Quality Data
Hastings WHPP Amendment

Well	Tritium (TU)	Nitrate (mg/L)	Chloride (mg/L)	Bromide (mg/L)	Chloride / Bromide Ratio	Arsenic (µg/L)
3	NA	8.9 (03/12/2019)	3 (09/01/1985)	NA	NA	< 1 (01/14/1999)
4	7.6 (01/13/2004)	3.7 (03/12/2019)	14.8 (03/29/2016)	0.0322 (03/29/2016)	460 (03/29/2016)	< 1 (08/21/2012)
5	NA	8.0 (03/12/2019)	45.2 (08/21/2012)	0.0627 (08/21/2012)	721 (08/21/2012)	< 1 (08/21/2012)
6	3.7 (03/29/2016)	8.2 (01/06/2010)	22.6 (03/17/2015)	0.0346 (03/17/2015)	727 (03/17/2015)	1.47 (09/16/2004)
7	3.8 (03/29/2016) 4.36 (03/29/2016)	6.0 (03/12/2019)	39.3 (03/29/2016)	0.0444 (03/29/2016)	885 (03/29/2016)	< 1 (01/14/1999)
8	NA	7.8 (03/12/2019)	31.3 (08/21/2012)	0.0437 (08/21/2012)	716 (08/21/2012)	< 1 (08/21/2012)

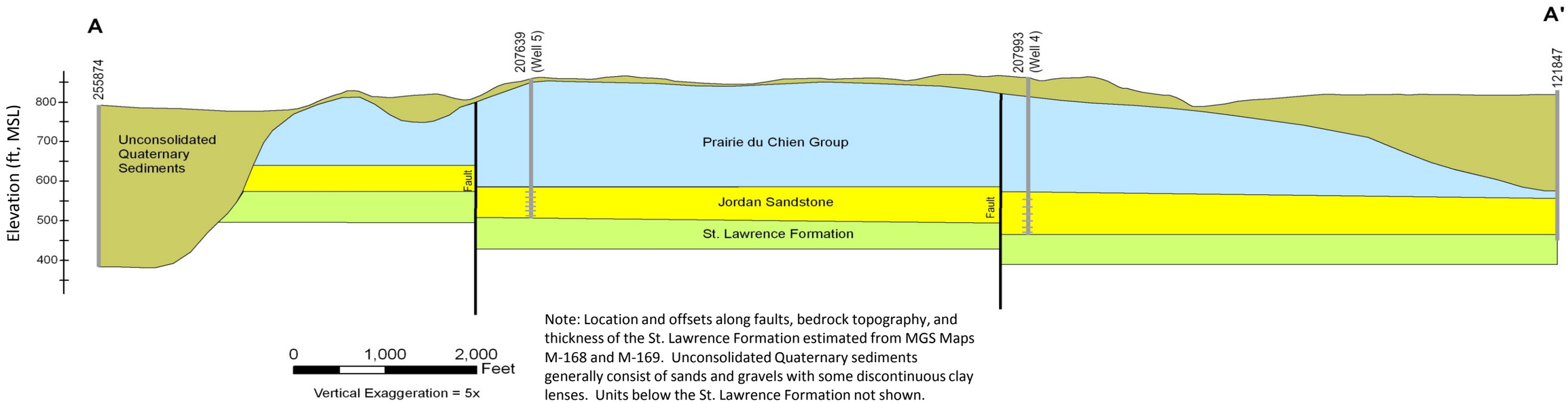
Figures



BARR

BEDROCK SUBCROP
Hastings WHPP Amendment
City of Hastings, MN

FIGURE 1



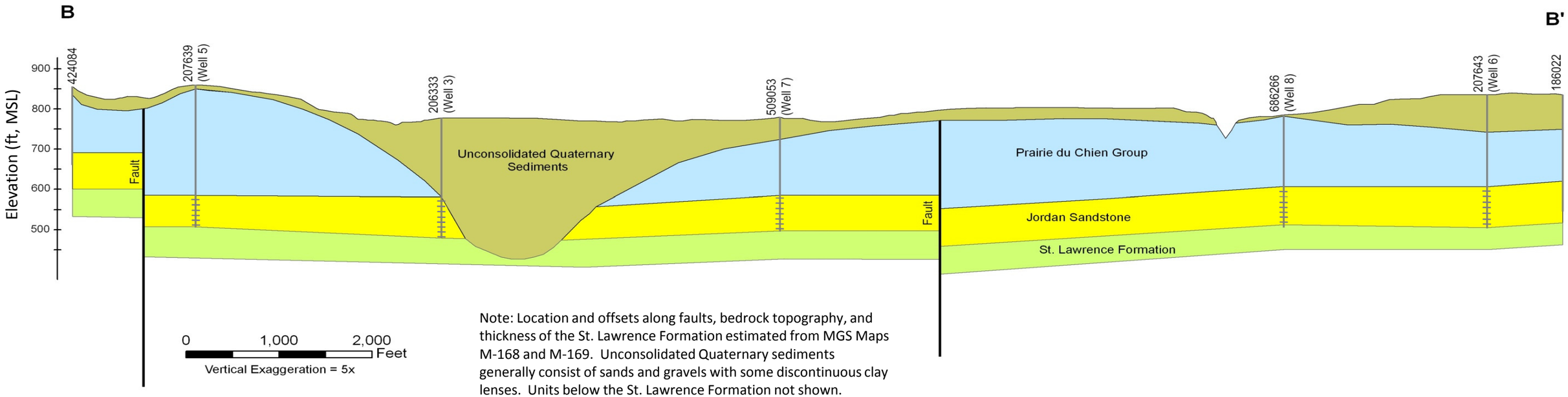
Note: Location and offsets along faults, bedrock topography, and thickness of the St. Lawrence Formation estimated from MGS Maps M-168 and M-169. Unconsolidated Quaternary sediments generally consist of sands and gravels with some discontinuous clay lenses. Units below the St. Lawrence Formation not shown.

BARR

Figure 2

GEOLOGIC CROSS SECTION A TO A'
WHPP Amendment
City of Hastings
Dakota County, MN

P:\Mpls\23 MN\19\2319750\WorkFiles\Part 1 Amendment\X_Sections\X_Sections.pptx



Note: Location and offsets along faults, bedrock topography, and thickness of the St. Lawrence Formation estimated from MGS Maps M-168 and M-169. Unconsolidated Quaternary sediments generally consist of sands and gravels with some discontinuous clay lenses. Units below the St. Lawrence Formation not shown.

BARR

Figure 3

GEOLOGIC CROSS SECTION B TO B'
WHPP Amendment
City of Hastings
Dakota County, MN

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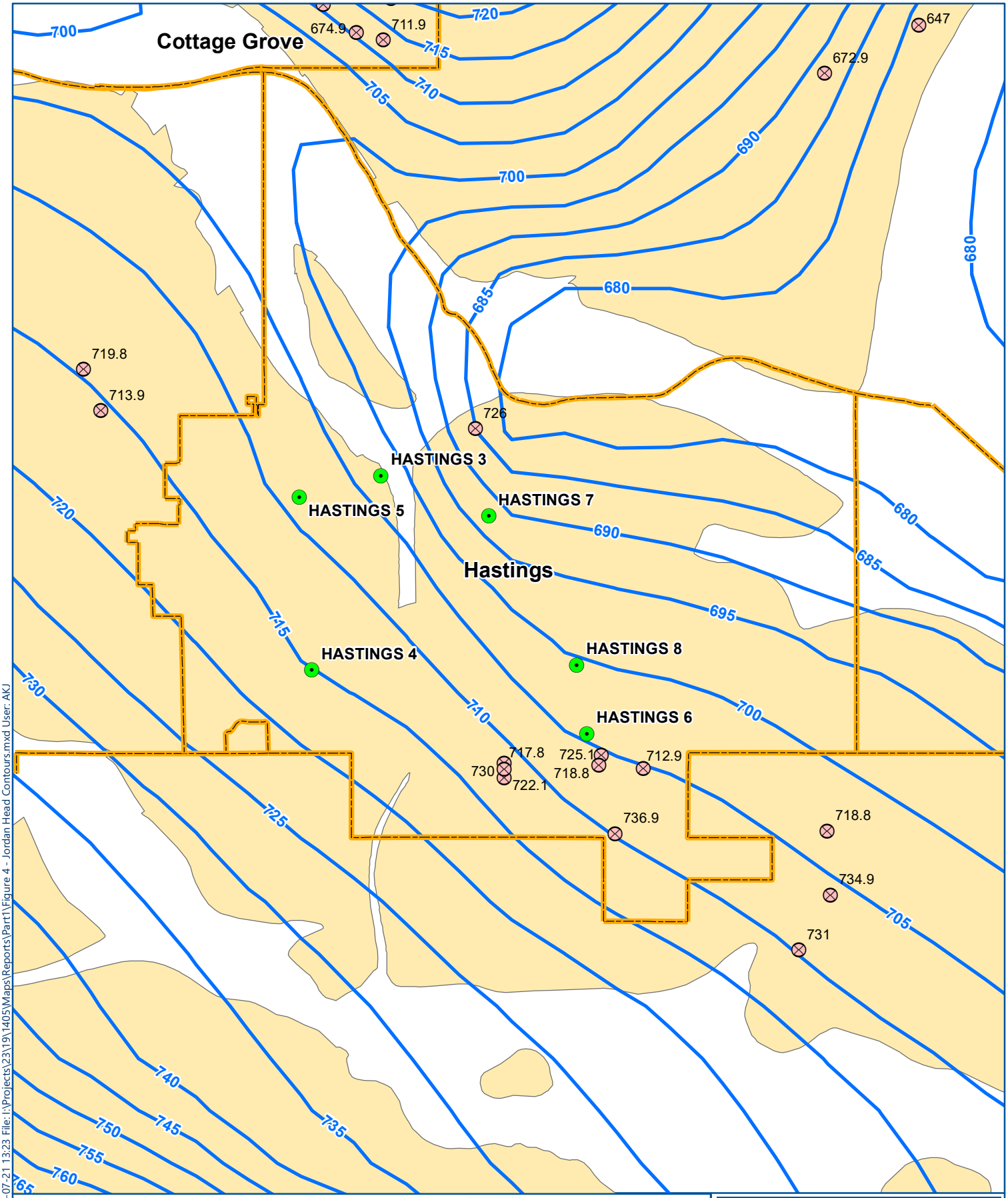
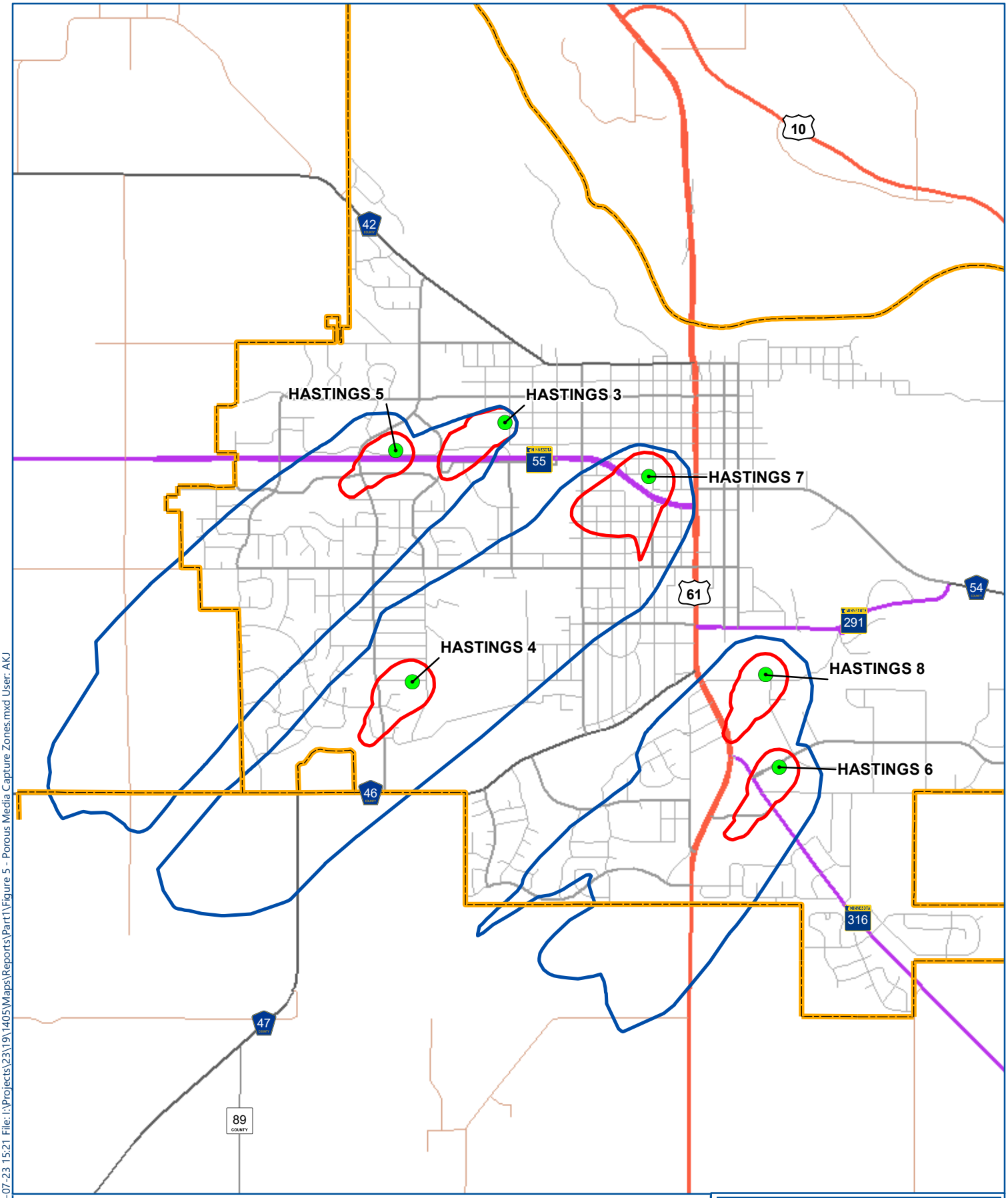

Cottage Grove
Hastings
HASTINGS 3
HASTINGS 4
HASTINGS 5
HASTINGS 6
HASTINGS 7
HASTINGS 8
674.9
711.9
647
672.9
719.8
713.9
726
717.8
725.1
712.9
730
718.8
722.1
736.9
718.8
734.9
731
700
705
710
715
720
690
680
685
695
725
730
740
745
750
755
760
765
735
Hastings Municipal Well
Jordan Head Target (ft MSL)
Modeled Jordan Head Contour (ft MSL)
Jordan Extent
Municipal Boundary
N
0
4,000
Feet
BARR
MODELED HEADS IN
JORDAN SANDSTONE, LAYER 4
Hastings WHPP Amendment
City of Hastings, MN
FIGURE 4
Barr Footer: ArcGIS 10.6.1, 2019-07-21 13:23 File: I:\Projects\23\19\1405\Maps\Reports\Part1\Figure 4 - Jordan Head Contours.mxd User: AKJ



Hastings Municipal Well

Municipal Boundary

Travel Time

1-Year

10-Year

N

0 3,000

Feet

BARR

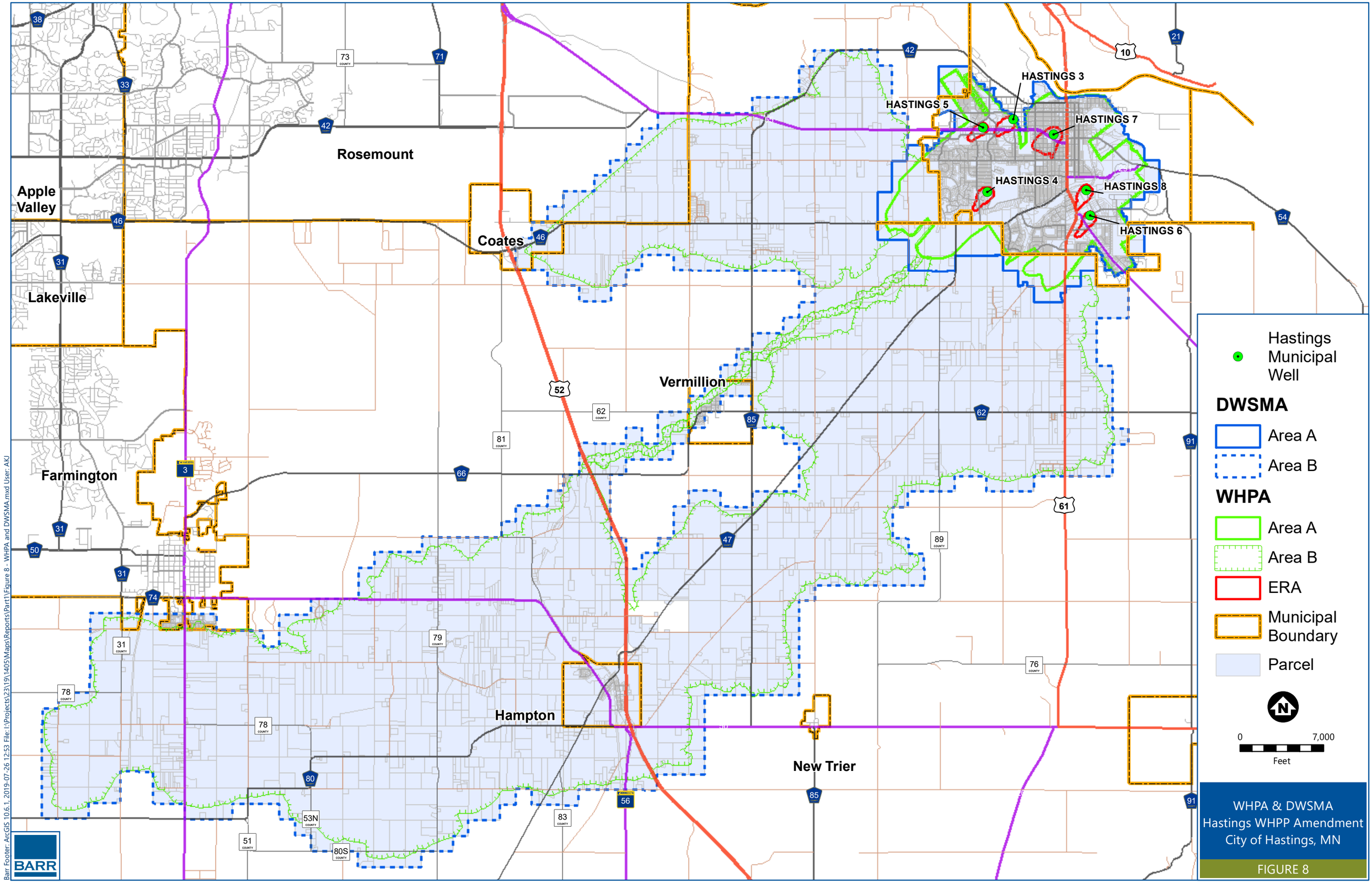
POROUS MEDIA
CAPTURE ZONES
Hastings WHPP Amendment
City of Hastings, MN

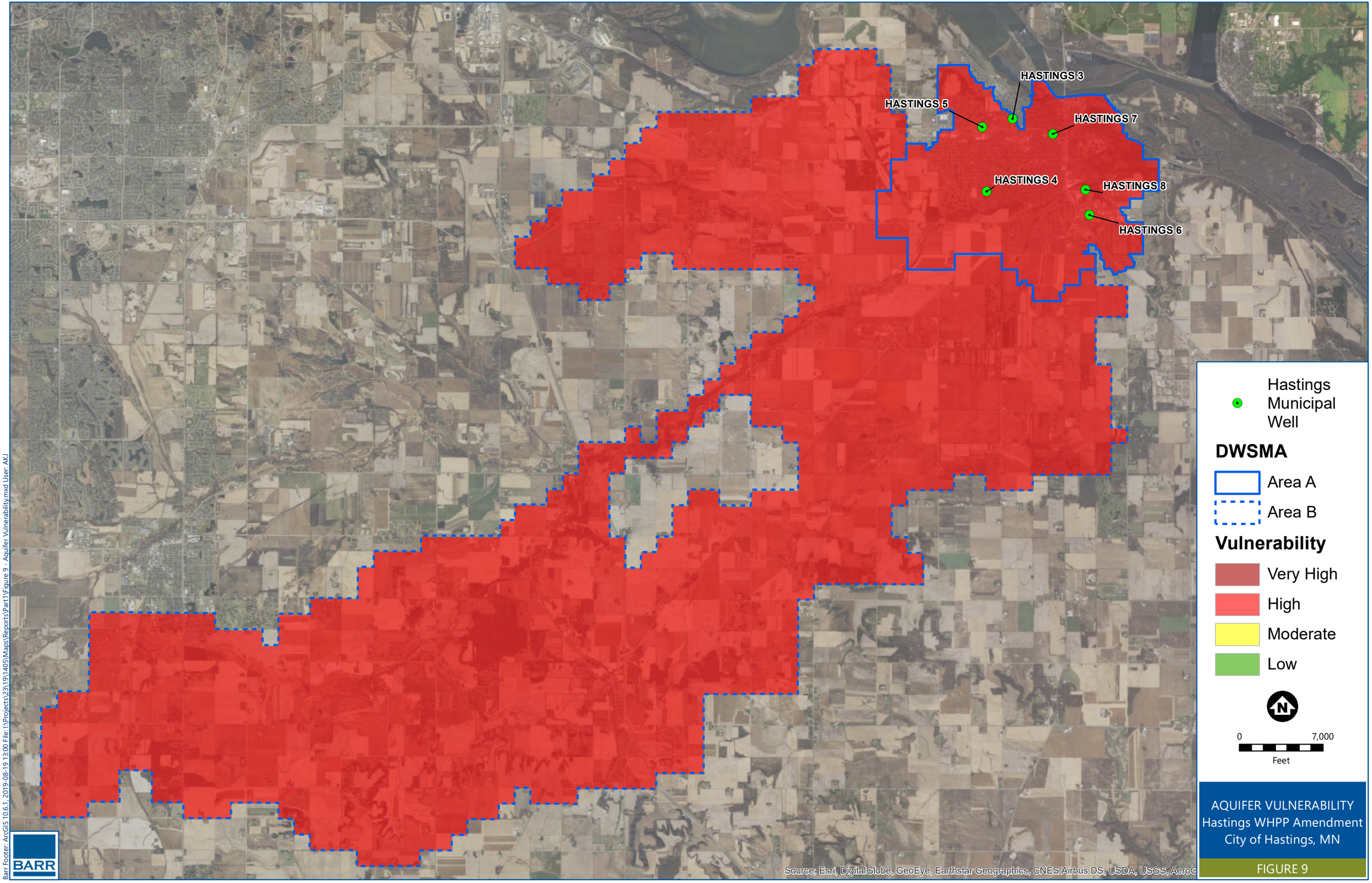
FIGURE 5

Barr Footer: ArcGIS 10.6.1, 2019-07-23 15:21 File: I:\Projects\23\19\1405\Maps\Reports\Part1\Figure 5 - Porous Media Capture Zones.mxd User: AKJ


HASTINGS 5
HASTINGS 3
HASTINGS 7
HASTINGS 4
HASTINGS 8
HASTINGS 6
10
42
55
61
54
291
46
316
Fracture Flow Capture Zone
5-year Fixed Radius
5-year Upgradient Extension
6-month Fixed Radius
6-month Upgradient Extension
Fault Extension
Hastings Municipal Well
Municipal Boundary
Prairie du Chien Extent
Jordan Extent
N
0
2,500
Feet
BARR
FRACTURE FLOW CAPTURE ZONES
Hastings WHPP Amendment
City of Hastings, MN
FIGURE 6
Barr Footer: ArcGIS 10.6.1, 2019-07-25 15:35 File: I:\Projects\23\19\1405\Maps\Reports\Part1\Figure 6 - Fracture Flow Capture Zones.mxd User: AKJ

Rosemount
Apple Valley
Lakeville
Coates
Vermillion
Farmington
Hampton
New Trier
HASTINGS 3
HASTINGS 5
HASTINGS 7
HASTINGS 4
HASTINGS 8
HASTINGS 6
Hastings Municipal Well
Municipal Boundary
SWCA
0
7,000
Feet
SURFACE WATER CONTRIBUTION AREA
Hastings WHPP Amendment
City of Hastings, MN
FIGURE 7
BARR
Barr Footer: ArcGIS 10.6.1, 2019-07-25 15:33 File: I:\Projects\23\19\1405\Maps\Reports\Part1\Figure 7 - Surface Water Contribution Area.mxd User: AKJ


HASTINGS 3
HASTINGS 5
HASTINGS 7
HASTINGS 4
HASTINGS 8
HASTINGS 6
Rosemount
Apple Valley
Lakeville
Coates
Vermillion
Farmington
Hampton
New Trier
Hastings Municipal Well
DWSMA
Area A
Area B
WHPA
Area A
Area B
ERA
Municipal Boundary
Parcel
0
7,000
Feet
WHPA & DWSMA
Hastings WHPP Amendment
City of Hastings, MN
FIGURE 8
BARR
Barr Footer: ArcGIS 10.6.1, 2019-07-26 12:53 File: I:\Projects\23\19\1405\Maps\Reports\Part1\Figure 8 - WHPA and DWSMA.mxd User: AKJ



AQUIFER VULNERABILITY
Hastings WHPP Amendment
City of Hastings, MN

FIGURE 9

BARR

Barr Footer: ArcGIS 10.6.1, 2019-08-19 13:00 File: I:\Projects\23\19\1405\Maps\Reports\Part1\Figure 9 - Aquifer Vulnerability.mxd User: AKJ

Appendix A

Well Construction Records

Minnesota Unique Well Number

206333

County Dakota
Quad Hastings
Quad ID 87A

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING REPORT

Minnesota Statutes Chapter 1031

Entry Date 12/27/1989
Update Date 07/11/2018
Received Date

Well Name	Township	Range	Dir	Section	Subsection
HASTINGS 3	115	17	W	28	BCACDD

Elevation 778 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet)

Address

Contact HASTINGS MN 55033
Well HASTINGS MN 55033

Stratigraphy Information

Geological Material	From	To (ft.)	Color	Hardness
CLAY	0	9		
SAND & GRAVEL	9	79		
SAND & CLAY	79	103		
HARDPAN	103	107		
CLAY	107	137	BLUE	
HARDPAN	137	169		
CLAY	169	176	BLUE	
HARDPAN	176	197		
SANDROCK (JORDAN)	197	267		
SANDSTONE	267	299	GRAY	

Remarks

M.G.S. NO. 146. GWQ NO. 0215.

Well Depth 299 ft. **Depth Completed** 299 ft. **Date Well Completed** 09/20/1956

Drill Method Cable Tool **Drill Fluid**

Use community supply(municipal) **Status** Active

Well Hydrofractured? Yes ☐ No ☐ **From** **To**

Casing Type Step down **Joint**
Drive Shoe? Yes ☐ No ☐ **Above/Below** 2.9 ft.

Casing Diameter	Weight	Hole Diameter
16 in. To 208 ft.	lbs./ft.	24 in. To 299 ft.
24 in. To 197 ft.	lbs./ft.	

Open Hole From 208 ft. To 299 ft.

Screen? ☐ **Type** **Make**

Static Water Level

67 ft. land surface Measure 08/23/1956

Pumping Level (below land surface)

115. ft. 32. hrs. Pumping at 1000 g.p.m.

Wellhead Completion

Pitless adapter manufacturer Model

☐ Casing Protection ☒ 12 in. above grade
☐ At-grade (Environmental Wells and Borings ONLY)

Grouting Information Well Grouted? ☒ Yes ☐ No ☐ Not Specified

Material	Amount	From	To
neat cement	0	0 ft.	208 ft.

Nearest Known Source of Contamination

feet Direction Type

Well disinfected upon completion? ☐ Yes ☐ No

Pump ☐ Not Installed Date Installed

Manufacturer's name

Model Number HP 0 Volt

Length of drop pipe ft Capacity g.p. Typ

Abandoned

Does property have any not in use and not sealed well(s)? ☐ Yes ☐ No

Variance

Was a variance granted from the MDH for this well? ☐ Yes ☐ No

Miscellaneous

First Bedrock Jordan Sandstone Aquifer Jordan
Last Strat Jordan Sandstone Depth to Bedrock 197 ft
Located by Minnesota Department of Health
Locate Method Digitization (Screen) - Map (1:12,000) (>15 meters)
System UTM - NAD83, Zone 15, Meters X 510310 Y 4954139
Unique Number Verification Information from Input Date 01/22/2001

Angled Drill Hole

Well Contractor

Keys Well Co. 62012 KEYS WELL
Licensee Business Lic. or Reg. No. Name of Driller

Minnesota Unique Well No.

206333

County Dakota
Quad Hastings
Quad ID 87A

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Entry Date 12/27/1989
Update
Received Date 07/11/2018

Well Name	Township	Range	Dir	Section	Subsection	Use	Status	Well Depth	Depth Completed	Date Well Completed	Lic/Reg. No.
HASTINGS 3	115	17	W	28	BCACDD	community supply	A	299 ft.	299 ft.	09/20/1956	62012

Elevation 778 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet) **Aquifer** Jordan **Depth to Bedrock** 197 ft **Open Hole** 208 - 299 ft **Static Water Level** 67 ft

Field Located By Minnesota Department of
Unique No. Verified Information from owner-site
Geological Interpretation Bruce Bloomgren
Agency (Interpretation)

Locate Method Digitization (Screen) - Map (1:12,000) (>15
Input Source Minnesota Department of Health
Input Date 01/22/2001

Universal Transverse Mercator (UTM) - NAD83 - Zone 15 -
UTM Easting (X) 510310
UTM Northing (Y) 495413
Interpretaion Method Geologic study 1:24k to 1:100k

			Depth (ft.)			Elevation (ft.)					
Geological Material	**Color**	**Hardness**	**From**	**To**	**Thickness**	**From**	**To**	**Stratigraphy**	**Primary Lithology**	**Secondary**	**Minor Lithology**
CLAY			0	9	9	778	769	clay	clay		
SAND & GRAVEL			9	79	70	769	699	sand +larger	sand	gravel	
SAND & CLAY			79	103	24	699	675	clay+sand	sand	clay	
HARDPAN			103	107	4	675	671	pebbly sand/silt/clay	hardpan		
CLAY	BLUE		107	137	30	671	641	clay-gray	clay		
HARDPAN			137	169	32	641	609	pebbly sand/silt/clay	hardpan		
CLAY	BLUE		169	176	7	609	602	clay-gray	clay		
HARDPAN			176	197	21	602	581	pebbly sand/silt/clay	hardpan		
SANDROCK (JORDAN)			197	267	70	581	511	Jordan Sandstone	sandstone		
SANDSTONE	GRAY		267	299	32	511	479	Jordan Sandstone	sandstone		

Minnesota Unique Well Number

207993

County Dakota
Quad Vermillion
Quad ID 87B

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING REPORT

Minnesota Statutes Chapter 1031

Entry Date 12/27/1989
Update Date 10/04/2018
Received Date

Well Name	Township	Range	Dir	Section	Subsection
HASTINGS 4	115	17	W	32	DABBBA

Elevation 863 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet)

Address

Contact HASTINGS MN 55033
Well HASTINGS MN 55033

Stratigraphy Information

Geological Material	From	To (ft.)	Color	Hardness
SAND & GRAVEL	0	36		
SANDY YELLOW CLAY	36	56		
LIMESTONE & SHALE	56	70		
LIMESTONE & SHALE-	70	124		
LIMESTONE & SOME	124	165		
LIMESTONE, SHALE &	165	180		
LIMESTONE & SHALE	180	235		
LIMESTONE, SHALE-	235	260		
LIMESTONE, SHALE-	260	290		
LIMESTONE &	290	295		
SANDSTONE	295	305		
SANDSTONE	305	341	YELLOW	
SANDSTONE & SHALE	341	360	GRAY	HARD
SANDSTONE	360	385	YELLOW	
SANDSTONE	385	398	GRAY	
SHALE	398	400		

Remarks

COUNTRY ESTATES BLK 5 LOT 1.

16" LINEAR PRESSURE GROUTED FROM BOTTOM TO SURFACE WITH 1:1 SAND-CEMENT READY
MIX. DIAMETER OF OPEN HOLE IN ROCK, 24", EXTENDING FROM BOTTOM OF 16:, TO
BOTTOM OF HOLE AT 400'. SAND CONTENT AT 900GPM AFTER DEVELOPMENT, 2 PPM.

Well Depth 400 ft. **Depth Completed** 400 ft. **Date Well Completed** 08/30/1961

Drill Method Cable Tool **Drill Fluid**

Use community supply(municipal) **Status** Active

Well Hydrofractured? Yes ☐ No ☐ **From** **To**

Casing Type Step down **Joint**
Drive Shoe? Yes ☐ No ☐ **Above/Below**

Casing Diameter	Weight	Hole Diameter
16 in. To 312 ft.	lbs./ft.	24 in. To 400 ft.
24 in. To 58 ft.	lbs./ft.	

Open Hole From 314 ft. To 400 ft.

Screen? ☐ **Type** **Make**

Static Water Level
138 ft. land surface Measure 08/30/1961

Pumping Level (below land surface)
162 ft. hrs. Pumping at 600 g.p.m.

Wellhead Completion
Pitless adapter manufacturer Model
☐ Casing Protection ☐ 12 in. above grade
☐ At-grade (Environmental Wells and Borings ONLY)

Grouting Information Well Grouted? ☒ Yes ☐ No ☐ Not Specified

Material	Amount	From	To
neat cement		0 ft.	314 ft.

Nearest Known Source of Contamination
feet Direction Type
Well disinfected upon completion? ☐ Yes ☐ No

Pump ☐ Not Installed Date Installed
Manufacturer's name
Model Number HP 0 Volt
Length of drop pipe ft Capacity g.p. Typ

Abandoned
Does property have any not in use and not sealed well(s)? ☐ Yes ☐ No

Variance
Was a variance granted from the MDH for this well? ☐ Yes ☐ No

Miscellaneous
First Bedrock Prairie Du Chien Group Aquifer Jordan
Last Strat St.Lawrence Formation Depth to Bedrock 56 ft
Located by Minnesota Department of Health
Locate Method Digitization (Screen) - Map (1:12,000) (>15 meters)
System UTM - NAD83, Zone 15, Meters X 509649 Y 4952284
Unique Number Verification Information from Input Date 01/22/2001

Angled Drill Hole

Well Contractor
Tri-state Well Co. 27118 BENEKE, R.
Licensee Business Lic. or Reg. No. Name of Driller

Minnesota Well Index Report | **207993** | Printed on 03/26/2019 HE-01205-15

Minnesota Unique Well No.

207993

County Dakota
Quad Vermillion
Quad ID 87B

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Entry Date 12/27/1989
Update
Received Date 10/04/2018

Well Name	Township	Range	Dir	Section	Subsection	Use	Status	Well Depth	Depth Completed	Date Well Completed	Lic/Reg. No.
HASTINGS 4	115	17	W	32	DABBBA	community supply	A	400 ft.	400 ft.	08/30/1961	27118

Elevation 863 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet) **Aquifer** Jordan **Depth to Bedrock** 56 ft **Open Hole** 314 - 400 ft **Static Water Level** 138 ft

Field Located By Minnesota Department of
Unique No. Verified Information from owner-site
Geological Interpretation Bruce Bloomgren
Agency (Interpretation)

Locate Method Digitization (Screen) - Map (1:12,000) (>15
Input Source Minnesota Department of Health
Input Date 01/22/2001

Universal Transverse Mercator (UTM) - NAD83 - Zone 15 -
UTM Easting (X) 509649
UTM Northing (Y) 495228
Interpretaion Method Geologic study 1:24k to 1:100k

			Depth (ft.)			Elevation (ft.)					
Geological Material	**Color**	**Hardness**	**From**	**To**	**Thickness**	**From**	**To**	**Stratigraphy**	**Primary Lithology**	**Secondary**	**Minor Lithology**
SAND & GRAVEL			0	36	36	863	827	sand +larger	sand	gravel	
SANDY YELLOW CLAY			36	56	20	827	807	clay+sand-yellow	clay	sand	
LIMESTONE & SHALE			56	70	14	807	793	Prairie Du Chien	dolomite		
LIMESTONE & SHALE-TRACE			70	124	54	793	739	Prairie Du Chien	dolomite		
LIMESTONE & SOME SHALE			124	165	41	739	698	Prairie Du Chien	dolomite		
LIMESTONE, SHALE &			165	180	15	698	683	Prairie Du Chien	dolomite		
LIMESTONE & SHALE			180	235	55	683	628	Prairie Du Chien	dolomite		
LIMESTONE, SHALE-			235	260	25	628	603	Prairie Du Chien	dolomite		
LIMESTONE, SHALE-			260	290	30	603	573	Prairie Du Chien	dolomite		
LIMESTONE & SANDSTONE			290	295	5	573	568	Jordan Sandstone	sandstone	dolomite	
SANDSTONE			295	305	10	568	558	Jordan Sandstone	sandstone		
SANDSTONE	YELLOW		305	341	36	558	522	Jordan Sandstone	sandstone		
SANDSTONE & SHALE	GRAY	HARD	341	360	19	522	503	Jordan Sandstone	sandstone	shale	
SANDSTONE	YELLOW		360	385	25	503	478	Jordan Sandstone	sandstone		
SANDSTONE	GRAY		385	398	13	478	465	Jordan Sandstone	sandstone		
SHALE			398	400	2	465	463	St.Lawrence	shale		

Minnesota Unique Well Number

207639

County Dakota
Quad Vermillion
Quad ID 87B

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING REPORT

Minnesota Statutes Chapter 1031

Entry Date 12/27/1989
Update Date 11/28/2018
Received Date

Well Name	Township	Range	Dir	Section	Subsection
HASTINGS 5	115	17	W	29	ACDDCD

Elevation 860 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet)

Address

Well 55 HY HASTINGS MN 55033
Contact HASTINGS MN 55033

Stratigraphy Information

Geological Material	From	To (ft.)	Color	Hardness
SAND & CLAY	0	8		
SHAKOPEE	8	264		
JORDAN	264	276		
JORDAN	276	353		
SANDROCK AND	353	355		
SHALE	355	356		

Remarks

M.G.S. NO. 583.
GAMMA LOGGED 11-13-2018 BY JIM TRAEN.

Well Depth	Depth Completed	Date Well Completed
356 ft.	355 ft.	09/04/1970

Drill Method Cable Tool **Drill Fluid**

Use community supply(municipal) **Status** Active

Well Hydrofractured? Yes ☐ No ☐ **From** **To**

Casing Type Step down **Joint**
Drive Shoe? Yes ☐ No ☐ **Above/Below** 0 ft.

Casing Diameter		Weight		Hole Diameter	
24 in. To	277 ft.	lbs./ft.		29 in. To	356 ft.
30 in. To	26 ft.	lbs./ft.			

Open Hole From 277 ft. To 356 ft.

Screen? ☐ **Type** **Make**

Static Water Level
147 ft. land surface Measure 09/04/1970

Pumping Level (below land surface)
241 ft. hrs. Pumping at 1800 g.p.m.

Wellhead Completion
Pitless adapter manufacturer Model
☐ Casing Protection ☒ 12 in. above grade
☐ At-grade (Environmental Wells and Borings ONLY)

Grouting Information Well Grouted? ☒ Yes ☐ No ☐ Not Specified

Material	Amount		From	To
neat cement	33	Cubic yards	0 ft.	277 ft.

Nearest Known Source of Contamination
feet Direction Type
Well disinfected upon completion? ☐ Yes ☐ No

Pump ☐ Not Installed Date Installed
Manufacturer's name
Model Number HP 0 Volt
Length of drop pipe ft Capacity g.p. Typ

Abandoned
Does property have any not in use and not sealed well(s)? ☐ Yes ☐ No

Variance
Was a variance granted from the MDH for this well? ☐ Yes ☐ No

Miscellaneous
First Bedrock Prairie Du Chien Group Aquifer Jordan
Last Strat St.Lawrence Formation Depth to Bedrock 8 ft
Located by Minnesota Department of Health
Locate Method Digitization (Screen) - Map (1:12,000) (>15 meters)
System UTM - NAD83, Zone 15, Meters X 509532 Y 4953935
Unique Number Verification Information from Input Date 01/22/2001

Angled Drill Hole

Well Contractor
Keys Well Co. 62012 O'BRIEN, F.
Licensee Business Lic. or Reg. No. Name of Driller

Minnesota Unique Well No.

207639

County Dakota
Quad Vermillion
Quad ID 87B

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Entry Date 12/27/1989
Update
Received Date 11/28/2018

Well Name	Township	Range	Dir	Section	Subsection	Use	Status	Well Depth	Depth Completed	Date Well Completed	Lic/Reg. No.
HASTINGS 5	115	17	W	29	ACDDCD	community supply	A	356 ft.	355 ft.	09/04/1970	62012

Elevation 860 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet) **Aquifer** Jordan **Depth to Bedrock** 8 ft **Open Hole** 277 - 356 ft **Static Water Level** 147 ft

Field Located By Minnesota Department of
Unique No. Verified Information from owner-site
Geological Interpretation Bruce Bloomgren
Agency (Interpretation)

Locate Method Digitization (Screen) - Map (1:12,000) (>15
Input Source Minnesota Department of Health
Input Date 01/22/2001

Universal Transverse Mercator (UTM) - NAD83 - Zone 15 -
UTM Easting (X) 509532
UTM Northing (Y) 495393
Interpretaion Method Cuttings + geophysical log

Geological Material	Color	Hardness	Depth (ft.) From	Depth (ft.) To	Thickness	Elevation (ft.) From	Elevation (ft.) To	Stratigraphy	Primary Lithology	Secondary	Minor Lithology
SAND & CLAY			0	8	8	860	852	clay+sand	sand	clay	
SHAKOPEE			8	264	256	852	596	Prairie Du Chien	dolomite		
JORDAN			264	276	12	596	584	Prairie Du Chien	dolomite		
JORDAN			276	353	77	584	507	Jordan Sandstone	sandstone		
SANDROCK AND SHALE			353	355	2	507	505	St.Lawrence	siltstone	shale	sandstone
SHALE			355	356	1	505	504	St.Lawrence	siltstone	shale	

Minnesota Unique Well Number

207643

County Dakota
Quad Hastings
Quad ID 87A

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING REPORT

Minnesota Statutes Chapter 1031

Entry Date 12/27/1989
Update Date 07/12/2018
Received Date

Well Name	Township	Range	Dir	Section	Subsection
HASTINGS 6	115	17	W	34	CDDBBA

Elevation 835 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet)

Address

Well 316 HY HASTINGS MN 55033
Contact HASTINGS MN 55033

Stratigraphy Information

Geological Material	From	To (ft.)	Color	Hardness
SAND & CLAY	0	8		
SAND	8	33		
GRAVEL	33	40		
SAND	40	64		
GRAVEL AND LIME	64	84		
LIME AND SAND	84	93		
LIME AND SAND	93	102		
SHAKOPEE LIME	102	229		
JORDAN SANDSTONE	229	330		
JORDAN SANDSTONE	330	332		

Remarks

M.G.S. NO. 750.
BAILED 170 YDS. SANDSTONE. DYNAMITE 250 LBS.

Well Depth	Depth Completed	Date Well Completed
332 ft.	332 ft.	02/28/1972

Drill Method Cable Tool **Drill Fluid**

Use community supply(municipal) **Status** Active

Well Hydrofractured? Yes ☐ No ☐ **From** **To**

Casing Type Step down **Joint**
Drive Shoe? Yes ☐ No ☐ **Above/Below** 1 ft.

Casing Diameter	Weight	Hole Diameter
24 in. To 240 ft.	lbs./ft.	23 in. To 332 ft.
30 in. To 98 ft.	lbs./ft.	

Open Hole From 240 ft. To 332 ft.
Screen? ☐ **Type** **Make**

Static Water Level
125 ft. land surface Measure 02/28/1972

Pumping Level (below land surface)
207 ft. hrs. Pumping at 1200 g.p.m.

Wellhead Completion
Pitless adapter manufacturer Model
☐ Casing Protection ☒ 12 in. above grade
☐ At-grade (Environmental Wells and Borings ONLY)

Grouting Information Well Grouted? ☒ Yes ☐ No ☐ Not Specified

Material	Amount	From	To
neat cement	0 Sacks	0 ft.	240 ft.

Nearest Known Source of Contamination
feet Direction Type
Well disinfected upon completion? ☐ Yes ☐ No

Pump ☐ Not Installed Date Installed
Manufacturer's name
Model Number HP 0 Volt
Length of drop pipe ft Capacity g.p. Typ

Abandoned
Does property have any not in use and not sealed well(s)? ☐ Yes ☐ No

Variance
Was a variance granted from the MDH for this well? ☐ Yes ☐ No

Miscellaneous
First Bedrock Prairie Du Chien Group Aquifer Jordan
Last Strat St.Lawrence Formation Depth to Bedrock 93 ft
Located by Minnesota Department of Health
Locate Method Digitization (Screen) - Map (1:12,000) (>15 meters)
System UTM - NAD83, Zone 15, Meters X 512270 Y 4951677
Unique Number Verification Information from Input Date 01/22/2001

Angled Drill Hole

Well Contractor
Keys Well Co. 62012 O'BRIEN, F.
Licensee Business Lic. or Reg. No. Name of Driller

Minnesota Unique Well No.

207643

County Dakota
Quad Hastings
Quad ID 87A

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Entry Date 12/27/1989
Update
Received Date 07/12/2018

Well Name	Township	Range	Dir	Section	Subsection	Use	Status	Well Depth	Depth Completed	Date Well Completed	Lic/Reg. No.
HASTINGS 6	115	17	W	34	CDDBBA	community supply	A	332 ft.	332 ft.	02/28/1972	62012

Elevation 835 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet) **Aquifer** Jordan **Depth to Bedrock** 93 ft **Open Hole** 240 - 332 ft **Static Water Level** 125 ft

Field Located By Minnesota Department of
Unique No. Verified Information from owner-site
Geological Interpretation Bruce Bloomgren
Agency (Interpretation)

Locate Method Digitization (Screen) - Map (1:12,000) (>15
Input Source Minnesota Department of Health
Input Date 01/22/2001

Universal Transverse Mercator (UTM) - NAD83 - Zone 15 -
UTM Easting (X) 512270
UTM Northing (Y) 495167
Interpretaion Method Geologic study 1:24k to 1:100k

Geological Material	Color	Hardness	Depth (ft.) From	Depth (ft.) To	Thickness	Elevation (ft.) From	Elevation (ft.) To	Stratigraphy	Primary Lithology	Secondary	Minor Lithology
SAND & CLAY			0	8	8	835	827	clay+sand	sand	clay	
SAND			8	33	25	827	802	sand	sand		
GRAVEL			33	40	7	802	795	gravel (+larger)	gravel		
SAND			40	64	24	795	771	sand	sand		
GRAVEL AND LIME CHUNKS			64	84	20	771	751	gravel (+larger)	gravel	cobble	
LIME AND SAND			84	93	9	751	742	sand +larger	cobble	sand	
LIME AND SAND			93	102	9	742	733	Prairie Du Chien	dolomite		
SHAKOPEE LIME			102	229	127	733	606	Prairie Du Chien	dolomite		
JORDAN SANDSTONE			229	330	101	606	505	Jordan Sandstone	sandstone		
JORDAN SANDSTONE			330	332	2	505	503	St.Lawrence	siltstone	shale	

Minnesota Unique Well Number

509053

County Dakota
Quad Hastings
Quad ID 87A

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING REPORT

Minnesota Statutes Chapter 1031

Entry Date 03/01/2002
Update Date 07/12/2018
Received Date

Well Name	Township	Range	Dir	Section	Subsection
HASTINGS 7	115	17	W	28	DABDCB

Elevation 784 ft. **Elev. Method** LiDAR 1m DEM (MNDNR)

Address

Well ASHLAND ST HASTINGS MN 55033
Contact 100 SIBLEY ST HASTINGS MN 55033

Stratigraphy Information

Geological Material	From	To (ft.)	Color	Hardness
SAND AND GRAVEL	0	56	BROWN	SOFT
LIMEROCK	56	57	TAN	HARD
SAND	57	59	BROWN	SOFT
LIMEROCK (BROKEN)	59	62	TAN	MEDIUM
LIMEROCK (HARD)	62	65	TAN	HARD
SAND	65	66	BROWN	SOFT
LIMEROCK	66	75	TAN	HARD
SANDSTONE	75	78	TAN	MEDIUM
LIMEROCK	78	195	TAN	HARD
SANDROCK	195	283	TAN	MEDIUM
LIMEROCK	283	285	GRAY	HARD

Remarks

TOTAL PUMP HOURS: 51 HRS. BLATED 150# DYNAMITE AND BAILED OUT.

260 YDS AND LOOSE SANDROCK AND AIR.
DEVELOPMENT 23 HOURS.
1ST TEST - (BEFORE DEVELOPMENT).
935 GPM 78-6FT DD. (3IN/16 SAND).
M.G.S. NO. 2968.
LOGGED GEOSPHERE MIDWEST 11/12/91

Well Depth 285 ft. **Depth Completed** 285 ft. **Date Well Completed** 10/09/1989

Drill Method Cable Tool **Drill Fluid**

Use community supply(municipal) **Status** Active

Well Hydrofractured? Yes ☐ No ☐ **From** **To**

Casing Type Step down **Joint** Welded
Drive Shoe? Yes ☐ No ☐ **Above/Below** 2 ft.

Casing Diameter	Weight	Hole Diameter
24 in. To 205 ft.	94.6 lbs./ft.	29 in. To 205 ft.
30 in. To 63 ft.	118. lbs./ft.	23 in. To 285 ft.

Open Hole From 205 ft. To 285 ft.

Screen? ☐ **Type** **Make**

Static Water Level
84 ft. land surface Measure 10/04/1989

Pumping Level (below land surface)
123 ft. 2 hrs. Pumping at 1000 g.p.m.

Wellhead Completion
Pitless adapter manufacturer Model
☐ Casing Protection ☒ 12 in. above grade
☐ At-grade (Environmental Wells and Borings ONLY)

Grouting Information Well Grouted? ☒ Yes ☐ No ☐ Not Specified

Material	Amount	From	To
neat cement	66 Cubic yards	0 ft.	205 ft.

Nearest Known Source of Contamination
feet Direction Type
Well disinfected upon completion? ☒ Yes ☐ No

Pump ☐ Not Installed Date Installed 04/00/1990
Manufacturer's name PEERLESS
Model Number HP 460 Volt 460
Length of drop pipe 220 ft Capacity 1200 g.p. Typ Turbine

Abandoned
Does property have any not in use and not sealed well(s)? ☐ Yes ☒ No

Variance
Was a variance granted from the MDH for this well? ☐ Yes ☐ No

Miscellaneous
First Bedrock Prairie Du Chien Group Aquifer Jordan
Last Strat St.Lawrence Formation Depth to Bedrock 59 ft
Located by Minnesota Department of Health
Locate Method Digitization (Screen) - Map (1:12,000) (>15 meters)
System UTM - NAD83, Zone 15, Meters X 511337 Y 4953751
Unique Number Verification Info/GPS from data Input Date 01/22/2001

Angled Drill Hole

Well Contractor
Keys Well Co. 62012 RUSSELL, J.
Licensee Business Lic. or Reg. No. Name of Driller

Minnesota Unique Well No.

509053

County Dakota
Quad Hastings
Quad ID 87A

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Entry Date 03/01/2002
Update
Received Date 07/12/2018

Well Name	Township	Range	Dir	Section	Subsection	Use	Status	Well Depth	Depth Completed	Date Well Completed	Lic/Reg. No.
HASTINGS 7	115	17	W	28	DABDCB	community supply	A	285 ft.	285 ft.	10/09/1989	62012

Elevation 784 ft. **Elev. Method** LiDAR 1m DEM (MNDNR) **Aquifer** Jordan **Depth to Bedrock** 59 ft **Open Hole** 205 - 285 ft **Static Water Level** 84 ft

Field Located By Minnesota Department of
Unique No. Verified Info/GPS from data source
Geological Interpretation John Mossler
Agency (Interpretation)

Locate Method Digitization (Screen) - Map (1:12,000) (>15
Input Source Minnesota Department of Health
Input Date 01/22/2001

Universal Transverse Mercator (UTM) - NAD83 - Zone 15 -
UTM Easting (X) 511337
UTM Northing (Y) 495375
Interpretaion Method Geologic study 1:24k to 1:100k

			Depth (ft.)			Elevation (ft.)					
Geological Material	**Color**	**Hardness**	**From**	**To**	**Thickness**	**From**	**To**	**Stratigraphy**	**Primary Lithology**	**Secondary**	**Minor Lithology**
SAND AND GRAVEL	BROWN	SOFT	0	56	56	784	728	sand +larger	sand	gravel	
LIMEROCK	TAN	HARD	56	57	1	728	727	boulder or boulders	boulder		
SAND	BROWN	SOFT	57	59	2	727	725	sand	sand		
LIMEROCK (BROKEN)	TAN	MEDIUM	59	62	3	725	722	Prairie Du Chien	dolomite		
LIMEROCK (HARD)	TAN	HARD	62	65	3	722	719	Prairie Du Chien	dolomite		
SAND	BROWN	SOFT	65	66	1	719	718	Prairie Du Chien	sandstone		
LIMEROCK	TAN	HARD	66	75	9	718	709	Prairie Du Chien	dolomite		
SANDSTONE	TAN	MEDIUM	75	78	3	709	706	Prairie Du Chien	sandstone		
LIMEROCK	TAN	HARD	78	195	117	706	589	Prairie Du Chien	dolomite		
SANDROCK	TAN	MEDIUM	195	283	88	589	501	Jordan Sandstone	sandstone		
LIMEROCK	GRAY	HARD	283	285	2	501	499	St.Lawrence	dolomite	siltstone	

Minnesota Unique Well Number

686266

County Dakota
Quad Hastings
Quad ID 87A

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING REPORT

Minnesota Statutes Chapter 1031

Entry Date 02/15/2006
Update Date 07/12/2018
Received Date 11/06/2006

Well Name	Township	Range	Dir	Section	Subsection
HASTINGS 8	115	17	W	34	BDCDCA

Elevation 785 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet)

Address

Well COMMERCE DR HASTINGS MN 55033
Contact 101 EAST 4TH ST HASTINGS MN 55033

Stratigraphy Information

Geological Material	From	To (ft.)	Color	Hardness
DRIFT	0	3	BLACK	SOFT
LIMESTONE	3	178	YELLOW	HARD
SANDSTONE	178	184	YELLOW	MEDIUM
SANDSTONE	184	273	YELLOW	MEDIUM
SHALE	273	280	GRAY	HARD

Remarks

GAMMA LOGGED 6-28-2006. M.G.S. NO. 4658. LOGGED BY JIM TRAEN.

Well Depth 280 ft. **Depth Completed** 280 ft. **Date Well Completed** 06/00/2006

Drill Method Cable Tool **Drill Fluid** Water

Use community supply(municipal) **Status** Active

Well Hydrofractured? Yes ☐ No ☒ **From** **To**

Casing Type Step down **Joint** Welded
Drive Shoe? Yes ☒ No ☐ **Above/Below** 1 ft.

Casing Diameter	Weight	Hole Diameter
24 in. To 188 ft.	94.7 lbs./ft.	30 in. To 280 ft.
30 in. To 27 ft.	118. lbs./ft.	

Open Hole From 188 ft. To 280 ft.

Screen? ☐ **Type** **Make**

Static Water Level
90 ft. land surface Measure 06/19/2006

Pumping Level (below land surface)
155 ft. 8 hrs. Pumping at 1200 g.p.m.

Wellhead Completion
Pitless adapter manufacturer Model
☐ Casing Protection ☒ 12 in. above grade
☐ At-grade (Environmental Wells and Borings ONLY)

Grouting Information Well Grouted? ☒ Yes ☐ No ☐ Not Specified

Material	Amount	From	To
neat cement	36.5 Cubic yards	ft.	188 ft.

Nearest Known Source of Contamination
150 feet Northeas Direction Body of water Type
Well disinfected upon completion? ☒ Yes ☐ No

Pump ☒ Not Installed Date Installed
Manufacturer's name
Model Number HP Volt
Length of drop pipe ft Capacity g.p. Typ

Abandoned
Does property have any not in use and not sealed well(s)? ☐ Yes ☒ No

Variance
Was a variance granted from the MDH for this well? ☐ Yes ☒ No

Miscellaneous
First Bedrock Prairie Du Chien Group Aquifer Jordan
Last Strat St.Lawrence Formation Depth to Bedrock 3 ft
Located by Minnesota Department of Health
Locate Method GPS SA Off (averaged) (15 meters)
System UTM - NAD83, Zone 15, Meters X 512174 Y 4952335
Unique Number Verification Info/GPS from data Input Date 01/26/2006

Angled Drill Hole

Well Contractor
Keys Well Drilling Co. 1347 ALLAN, J.
Licensee Business Lic. or Reg. No. Name of Driller

Minnesota Unique Well No.

686266

County Dakota
Quad Hastings
Quad ID 87A

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Entry Date 02/15/2006
Update 11/06/2006
Received Date 07/12/2018

Well Name	Township	Range	Dir	Section	Subsection	Use	Status	Well Depth	Depth Completed	Date Well Completed	Lic/Reg. No.
HASTINGS 8	115	17	W	34	BDCDCA	community supply	A	280 ft.	280 ft.	06/00/2006	1347

Elevation 785 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet) **Aquifer** Jordan **Depth to Bedrock** 3 ft **Open Hole** 188 - 280 ft **Static Water Level** 90 ft

Field Located By
Unique No. Verified Info/GPS from data source
Geological Interpretation John Mossler
Agency (Interpretation)

Locate Method GPS SA Off (averaged) (15 meters)
Input Source Minnesota Department of Health
Input Date 01/26/2006

Universal Transverse Mercator (UTM) - NAD83 - Zone 15 -
UTM Easting (X) 512174
UTM Northing (Y) 495233
Interpretaion Method Inferred from geophysical log

Geological Material	Color	Hardness	Depth (ft.) From	Depth (ft.) To	Thickness	Elevation (ft.) From	Elevation (ft.) To	Stratigraphy	Primary Lithology	Secondary	Minor Lithology
DRIFT	BLACK	SOFT	0	3	3	785	782	Recent deposit-black	soil	organic deposits	
LIMESTONE	YELLOW	HARD	3	178	175	782	607	Prairie Du Chien	dolomite		
SANDSTONE	YELLOW	MEDIUM	178	184	6	607	601	Prairie Du Chien	dolomite		
SANDSTONE	YELLOW	MEDIUM	184	273	89	601	512	Jordan Sandstone	sandstone		
SHALE	GRAY	HARD	273	280	7	512	505	St.Lawrence	siltstone	dolomite	

Appendix B

Aquifer Test Data and Analysis

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

Determination of Aquifer Properties and Aquifer Test Plan (DAP-ATP) Form

Public Water Supply ID:	1190012	PWS Name:	City of Hastings

Contact Information for Person Completing this Form

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Aquifer Properties Determination Methods

For Methods 1 - 5, check all that apply - attach Summary of Aquifer Properties Based on Existing Data

- [x] **1.** An existing pumping test that meets the requirements of wellhead protection rule part 4720.5520 and that was previously conducted on a well connected to the public water supply system.
- [ ] **2.** An existing pumping test that meets the requirements of wellhead protection rule part 4720.5520 and that was previously conducted on another well in a hydrogeologic setting determined by the department to be equivalent.
- [ ] **3.** An existing pumping test that does not meet the requirements of wellhead protection rule part 4720.5520 and that was previously conducted on: 1) a public water supply well or 2) another well in a hydrogeologic setting determined by the department to be equivalent.
- [ ] **4.** Existing specific capacity test(s) conducted on the public water supply well(s) or specific capacity tests conducted on other wells in a hydrogeologic setting determined by the department to be equivalent.
- [ ] **5.** An existing published transmissivity value.

For Method 6 or 7 - attach detailed Aquifer Test Plan for Proposed Test

- [ ] **6.** A proposed new test to be conducted on a new or existing well connected to the public water supply system and that meets the requirements for larger-sized water systems (wellhead protection rule part 4720.5520). The test plan must be approved before conducting the test.
- [ ] **7.** A proposed new test to be conducted on a new or existing public well connected to the public water supply system and that meets the requirements for smaller-sized water systems (wellhead protection rule part 4720.5530). The test plan must be approved before conducting the test.

List the unique number of each public water supply well to which this DAP-ATP Form applies

206333 (Well 3)	509053 (Well 7)				
207993 (Well 4)	686266 (Well 8)				
207639 (Well 5)					
207643 (Well 6)					

Submitted by: John Greer	**Prof. License:** PG #30347	**Date:** 4/22/2019
Reviewed by: Amal Djerrari	**Approved:** (•) Yes ( ) No	**Approval Date:** 4/23/2019

Summary of Aquifer Properties Based on Existing Data

Aquifer Name: Jordan Sandstone | **Aquifer Code:** CJDN

Hydraulic Confinement ☑ Confined ☐ Unconfined ☐ Fractured Rock

Aquifer Test Number of test(s) on file used to compile the information tabulated below:

Hastings Well 5 test (October 2001)

Aquifer Properties Summary Table

Representative Values		Unit	Range		+/- %
			Minimum	Maximum	
Top Stratigraphic Elev.	579.3	feet (MSL)	573	584	+0.8/-1
Bottom Stratigraphic Elev.	483.6	feet (MSL)	465	507	+5/-4
Transmissivity (T)	5,444	ft^2/day	1,549	20,580	+278/-72
Aquifer Thickness (b)	95.7	feet	77	108	+13/-20
Saturated Thickness* (b)		feet			
Hydraulic Conductivity (k)	56.9	ft/day	20.1	191	+850/-183
Primary Porosity (e_p)	20	0.00 %			
Secondary Porosity** (e_s)		0.00 %			
Storativity (S)	6.87e-5	dimensionless	3.33e-5	1.21e-4	+76/-52
Characteristic Leakage (L)		feet			
Hydraulic Resistance (c)		days			

Notes: Shaded fields are required - * hydraulically unconfined aquifer - ** dual porosity aquifer because of fractures or solution weathering

Describe rationale for selected method(s). Attach documentation and analysis.

The test was conducted from October 23, 2001 through October 29, 2001. Well 5 (207639) was the pumping well and Wells 3 (20633) and 4 (207993) were used as observation wells. Wells 6 and 7 were periodically pumped during the test.

Test results were used for the previous updates of the Hastings WHPP.

Measured transmissivity ranged from 143.9 m**2/day (1,549 ft**2/day) to 1,912 m**2/day (20,580 ft**2/day). The geometric mean of 505.8 m**2/day (5,444 ft**2/day) was selected as the representative value for the Jordan.

Jordan thickness is 102 feet (31.1 m) at Well 3, 108 ft (32.9 m) at Well 4, and 77 feet (23.5 m) at Well 5. The average thickness is 95.7 feet (29.2 m).

Using the representative T value and average aquifer thickness gives a representative K value of 56.9 ft/day (17.3 m/day). For the model sensitivity analysis, lower and upper bounds of 20.1 ft/day (6.1 m/day) and 191 ft/day (58.1 m/day) were calculated from the upper and lower bounds on transmissivity and aquifer thickness.

The Barr report on analysis of the pumping test data is attached.

Appendix A
City of Hastings Aquifer Test Report

Table of Contents

List of Tables

List of Figures

List of Appendices

1.0 Introduction

An aquifer test was performed in the Jordan Sandstone aquifer from October 23, 2001 through October 29, 2001 using City of Hastings Well 3 (unique number 206333), City of Hastings Well 4 (unique number 207993), and City of Hastings Well 5 (unique number 207639) (Figure A-1). Well construction is summarized on Table A-1 and the well records are presented in Appendix A-1. The aquifer thickness used in analysis of the aquifer test data (94 feet) was based on the formation picks from the well logs (see Table A-1).

The layout of the wells used in the test is shown on Figure A-1. Well 5 was the pumping well for this test and Wells 3 and 4 were used as observation wells.

As planned, a two-day background period preceded the 24-hour pumping period. Per the test plan, a recovery period followed the pumping period. Wells 3 and 4 did not pump at all during the entire test period. A copy of the approved pumping test plan is presented in Appendix A-2.

The test plan called for pressure transducers connected to Hermit data loggers to be installed in Wells 3 and 5. Due to wellhead configuration, it was not possible to place a transducer in Well 5. As attempt was made to record water levels in Well 5 by connecting the City's pressure transducer in that well to a Hermit data logger. Data recorded using the City's transducer could not be correlated with manual water level measurements made in the well. Since the water level data recorded using the City's transducer could not be verified the data were not used. Water levels were measured manually in Wells 4 and 5 periodically during the pumping and recovery periods of the test. Hydrographs for the monitored wells are shown on Figures A-2 through A-4.

Hastings Well 1 (unique number 207821) (Figure A-1) is completed in the Franconia-Ironton-Galesville aquifer. The other Hastings wells are completed in the Jordan Sandstone. No aquifer test was performed in the Franconia-Ironton-Galesville aquifer because the City of Hastings intends to abandon Well 1 before the end of 2002.

2.0 Test Procedures

Pumping rates, volumes, and run times of the Hastings municipal wells during the aquifer test period were measured and recorded by the City's SCADA system (Appendix A-3). Total flow readings for Well 5 were also manually recorded from the totalizing flow meter at the wellhead during the pumping period of the test (Appendix A-4). Pumping of the City's wells during the aquifer test is summarized in Table A-2.

Water levels in Well 3were measured automatically using a Hermit 3000 data logger and a pressure transducer manufactured by In Situ, Inc. As noted above, water levels in Wells 4 and 5 were measured manually periodically during the pumping and recovery periods of the test. Water level data for the aquifer test are included on the compact disk attached to the main report (see Table 2 of the main report). Copies of the field data sheets from the aquifer test are presented in Appendix A-4.

In addition to water levels in Well 3, barometric pressure in Hastings during the aquifer test period was recorded using the Hermit 3000 data logger. The Hermit 3000 has an internal pressure transducer for measuring barometric pressure. Barometric pressure readings were taken throughout the test period at the same frequency as the water level measurements in Well 3.

3.0 Data Analysis

Prior to analyzing the aquifer test data, the water level and barometric pressure data recorded at Well 3 were evaluated to determine if there was any correlation between changes in water levels in the well and changes in barometric pressure. Water level measured in a well open to a confined aquifer will fluctuate with changes in barometric pressure. These fluctuations in water level may be large enough to measure. The change in water level relative to the change in barometric pressure is called the barometric efficiency (e.g., Walton, 1987; Kruseman and de Ridder, 1991) and is expressed as a percentage of the change in barometric pressure when the barometric pressure is expressed in the same units as the water levels (e.g., feet or meters of water). If present, such a correlation must be filtered out of the water level data prior to data analysis.

Data from the background (i.e., prior to initiation of pumping in Well 5) and recovery periods of the test were used to try and determine a correlation between water level changes in Well 3 and changes in barometric pressure. Barometric pressures and water levels recorded at Well 3 are shown on Figure A-2. It appears that there were measurable water level fluctuations in Well 3 due to pumping in other City of Hastings wells during the background and recovery periods. These fluctuations were larger than the magnitude of potential water level changes due to barometric pressure changes. Thus, no correlation between changes in water level in Well 3 and changes in barometric pressure could be determined.

The pumping test data were analyzed with the software AQTESOLV for Windows (Duffield, 2000) using the Neuman-Witherspoon method (1969) for layered aquifers. This analysis assumes the aquifer is a layered, leaky system and that pumping is from one of the layers. Effects of leakage from the unpumped layer and release of water from the unpumped layer are included in the analysis. In the vicinity of the City of Hastings wells used for this test, the pumped layer is the Jordan Sandstone, the confining layer is the Oneota Dolomite (where present) and the unpumped layer is the upper part of the Prairie du Chien Group (where present) and overlying unconsolidated units. Well 3 appears to be located on the western side of a buried tributary bedrock valley. According to the Dakota County Geologic Atlas (Balaban and Hobbs, 1990), this tributary valley trends approximately north-south and the Jordan Sandstone subcrops in the center of this valley.

As described above, Hastings Well 5 was the pumping well for this aquifer test. In order to meet water demand during the test period, Hastings Wells 6 and 7 were pumped periodically during the aquifer test period. AQTESOLV is able to account for multiple pumping wells in the data analysis.

Data for the pumping and recovery periods for each well were combined in the analysis using the Neuman-Witherspoon (see Figures A-5 through A-7). As indicated in Table A-3, the transmissivities determined using the Neuman-Witherspoon method varied by less than a factor of 3. This suggests that the aquifer properties are approximately uniform over the area affected by the aquifer test.

Recovery period data from each well were also analyzed separately using the Theis (1935) recovery method in AQTESOLV (see Figures A-8 through A-10). It should be noted that in order to use AQTESOLV for the Theis recover method analysis, pumping of Wells 6 and 7 that occurred after the cessation of pumping in Well 5 could not be included in the analysis. Transmissivity determined from the recovery data for each well is somewhat higher than that determined using the Neuman-Witherspoon method. As indicated in Table A-3, the transmissivities determined using the Theis recovery method vary by a factor of approximately 2 to 13.

References

Balaban, N.H. and H.C. Hobbs, 1990. Geologic Atlas – Dakota County, Minnesota. Minnesota Geologic Survey, County Atlas Series, Atlas C-6.

Duffield, G.M., 2000. AQTESOLV for Windows Ver.3.0. HydroSOLVE, Inc., Reston, Virginia.

Kruseman, G.P. and N.A. de Ridder, 1991. Analysis and Evaluation of Pumping Test Data, 2nd edition, International Institute for Land Reclamation and Improvement, Wageningen, the Netherlands.

Neuman, S.P. and P.A. Witherspoon, 1969. Applicability of Current Theories in Leaky Aquifers. Water Resources Research, Vol. 5, No. 4, p. 817-829.

Theis, C.V., 1935. The Relation Between Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Groundwater Storage, Trans. Amer. Geophys. Union, Vol. 16, p. 519-524.

Walton, W.C., 1987. Groundwater Pumping Tests – Design & Analysis, Fifth Printing, Lewis Publishers, Inc., Chelsea, Michigan.

Table A-1

Well Construction Summary

Well Identification	Depth to Top of Jordan SS Aquifer (ft below ground surface)	Depth to Base of Jordan SS Aquifer (ft below ground surface)	Open Hole Interval (ft below ground surface)
Well 1(207821)	195	280	250-575
Well 3(206333)	197	>299	208-299
Well 4 (207993)	290	385	314-400
Well 5 (207639)	264	353	277-356
Well 6 (207643)	229	>332	240-332
Well 7(509053)	195	283	205-285

Well Identification	Unique Number	Easting (UTM NAD83)	Northing (UTM NAD83)	X Distance from Well 5 (m)	Y Distance from Well 5 (m)
Well 1*	207821	511658	4953826	2126	-109
Well 3	206333	510310	4954140	778	205
Well 4	207993	509649	4952285	117	-1650
Well 5	207639	509532	4953935	0	0
Well 6*	207643	512270	4951677	2738	-2258
Well 7*	509053	511352	4953764	1820	-171

*Well not involved in the WHPA aquifer test.

Table A-2

Summary of Pumping Events During the Aquifer Testing Period

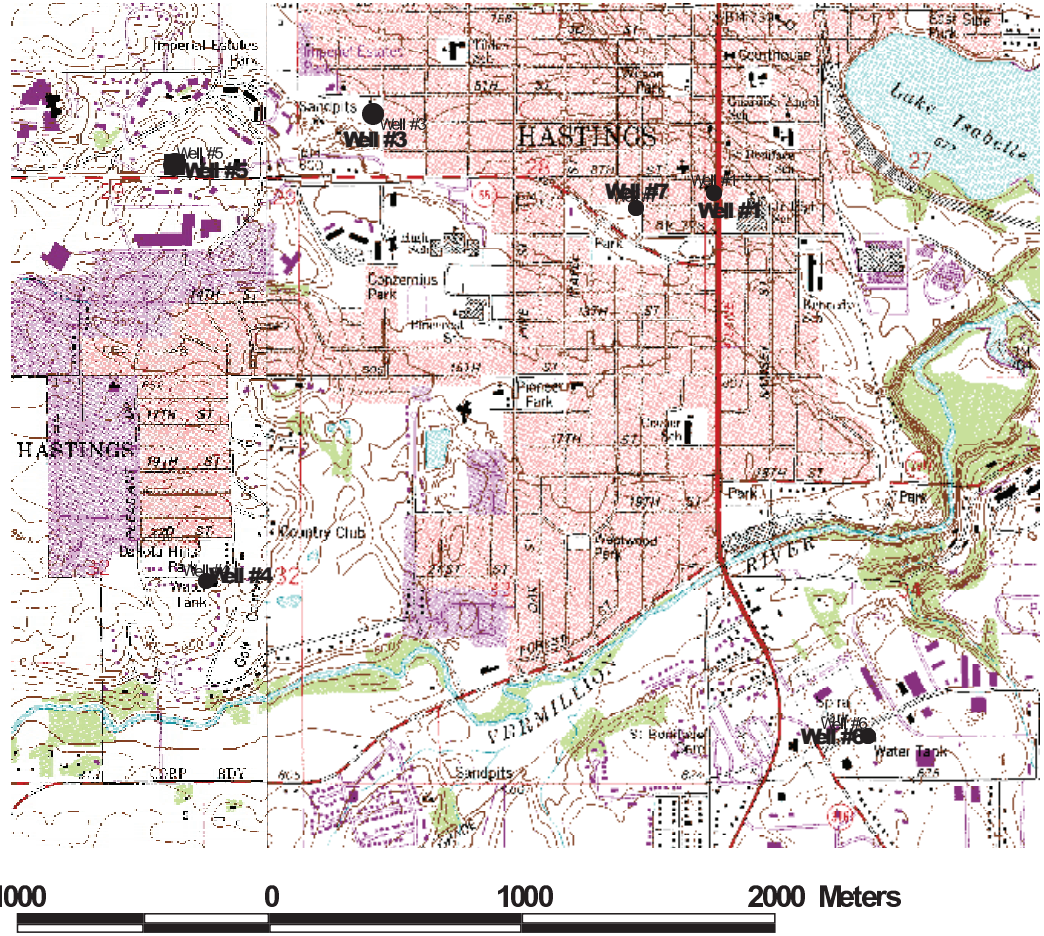
Time Since Pumping Began in Well 5 (min.)	Pumping Rates (gpm)		
	Well 5	Well 6	Well 7
0	1089	0	554.7
315	805	0	544.7
500	818	0	554.7
1170	818	0	0
1290	813	0	0
1365	813	1003.8	0
1440	0	1003.8	1209.7
1533	0	0	1209.7
1598	0	0	0
1695	0	1003.8	0
1768	0	1003.8	1209.7
1826	0	1003.8	0
1893	0	0	0
1946	0	0	1209.7
2021	0	0	0
2055	0	1003.8	0
2141	0	0	1209.7
2216	0	0	0
2253	0	0	0
2351	0	0	1209.7
2415	0	1003.8	1209.7
2426	0	1003.8	0
2651	0	0	1209.7
2741	0	0	0

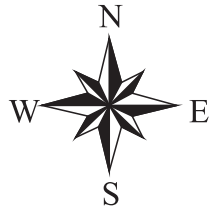
Table A-3
Aquifer Test Results Summary

Well #	Test Phase	Neuman-Witherspoon		Theis-Recovery	
		Transmissivity (m^2/day)	Storage Coefficient	Transmissivity (m^2/day)	Storage Coefficient
Well 3	Pumping & Recovery	324.0	8.05^{-5}	na	na
	Recovery only	na	na	651.4	S'=2.296
Well 4	Pumping & Recovery	143.9	$3.33x10^{-5}$	na	na
	Recovery only	na	na	1912.4	S'=2.5
Well 5	Pumping & Recovery	355.0	$1.21x10^{-4}$	na	
	Recovery only	na	na	812.2	S'=3.162

Geometric Mean	
Transmissivity (m^2/day)	Storage Coefficient
505.8	$6.87x10^{-5}$

Note: Geometric mean of the transmissivity calculated using results from both the Neuman-Witherspoon and Theis-recovery analyses. Geometric mean of the storage coefficient calculated using results of only the Neuman-Witherspoon analyses.





● Hastings Municipal Well

Figure A-1
Hastings Municipal Well Locations

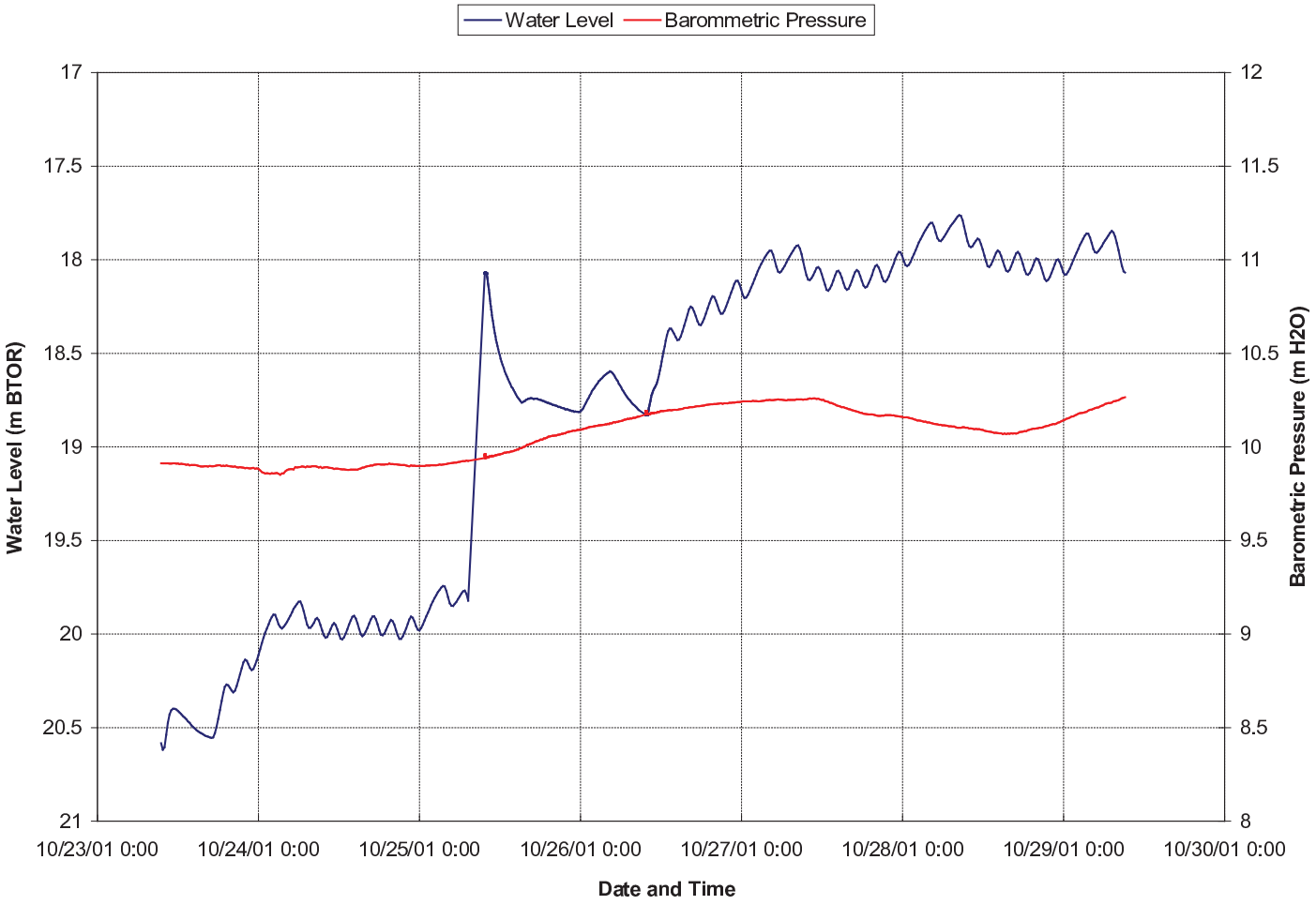


Figure A-2

Hydrograph for Hastings Well 3

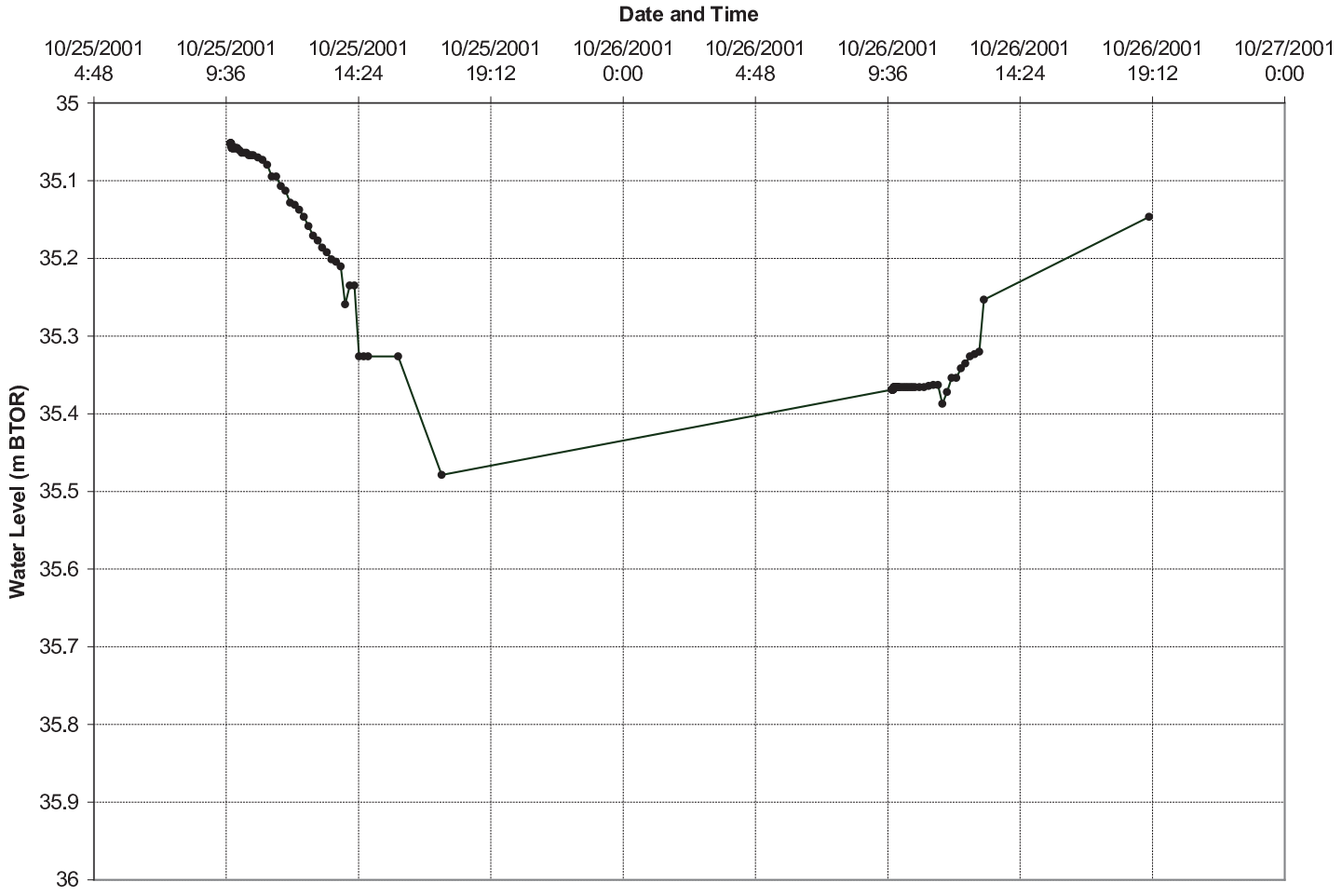


Figure A-3

Hydrograph for Hastings Well 4

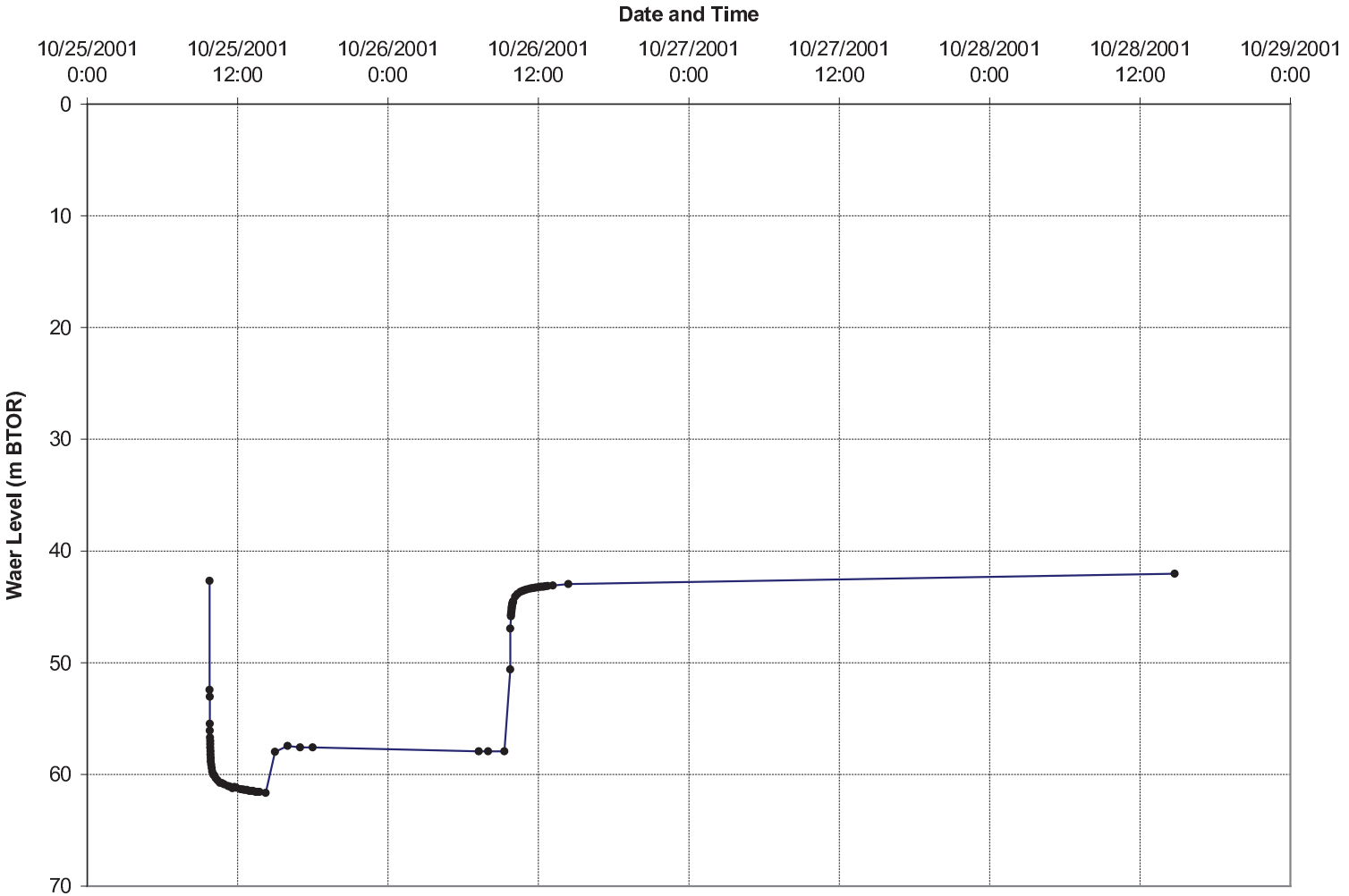


Figure A-4

Hydrograph for Hastings Well 5

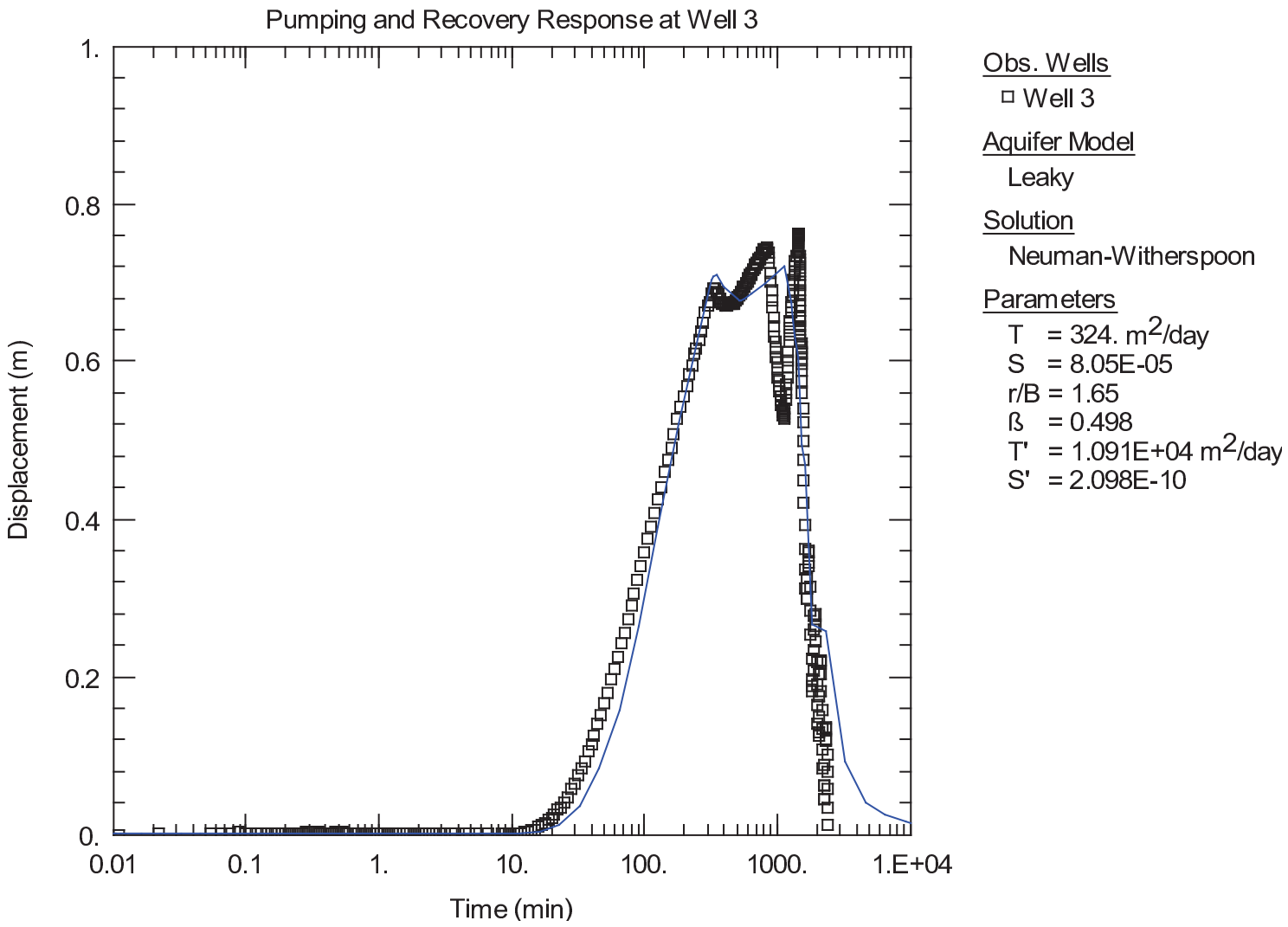


Figure A-5

Analysis of Well 3 Drawdown and Recovery Data

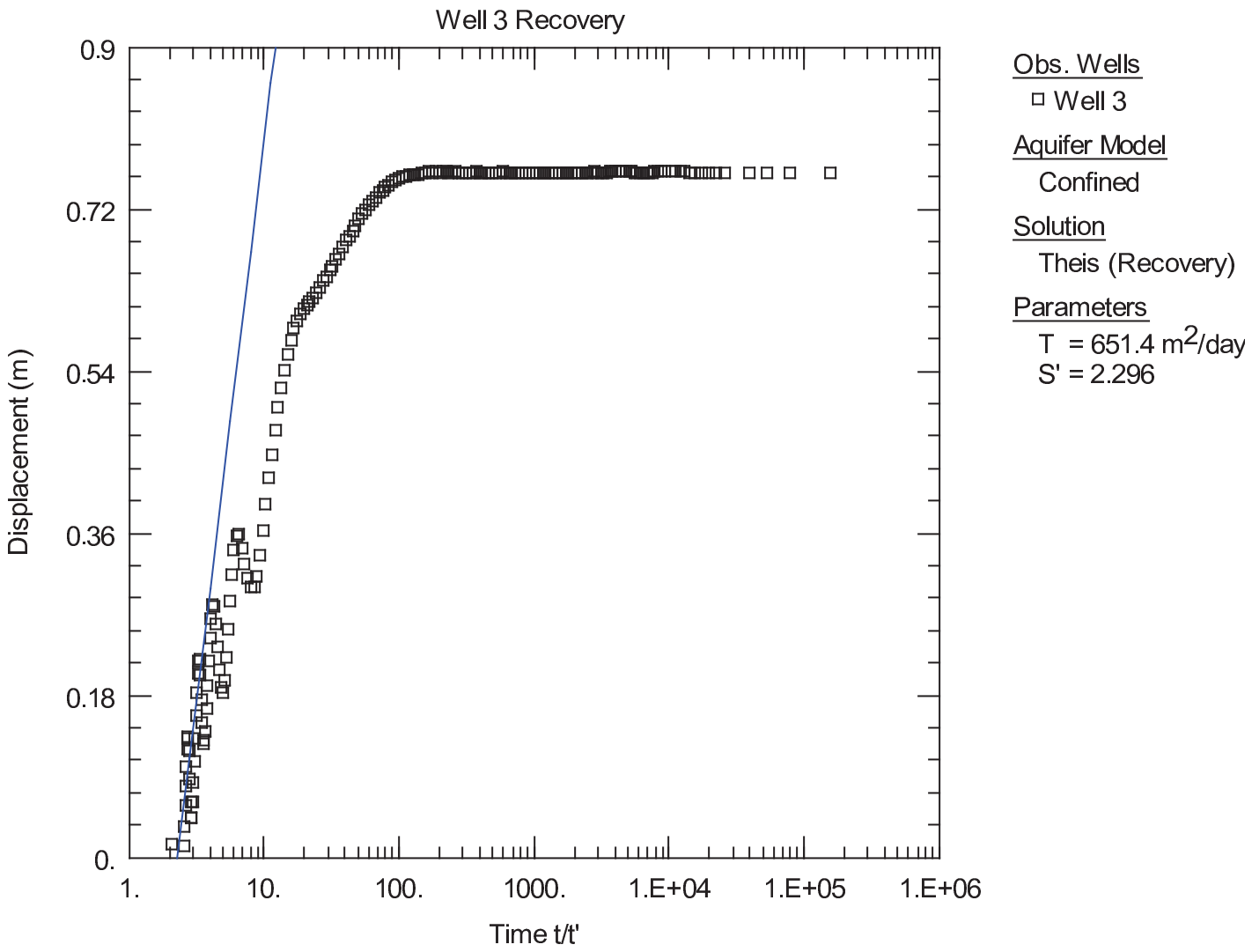


Figure A-8

Analysis of Well 3 Recovery Data

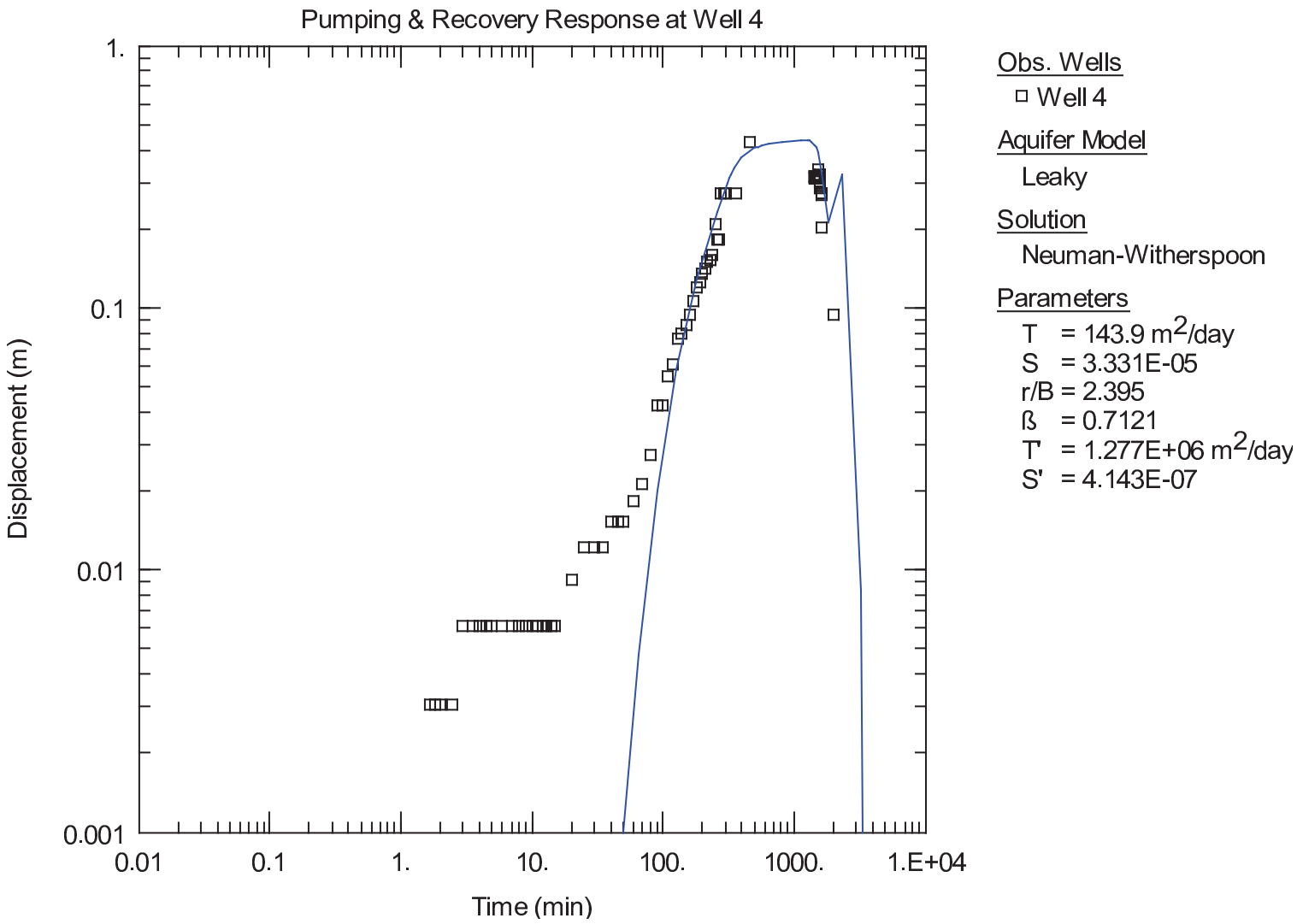


Figure A-6

Analysis of Well 4 Drawdown and Recovery Data

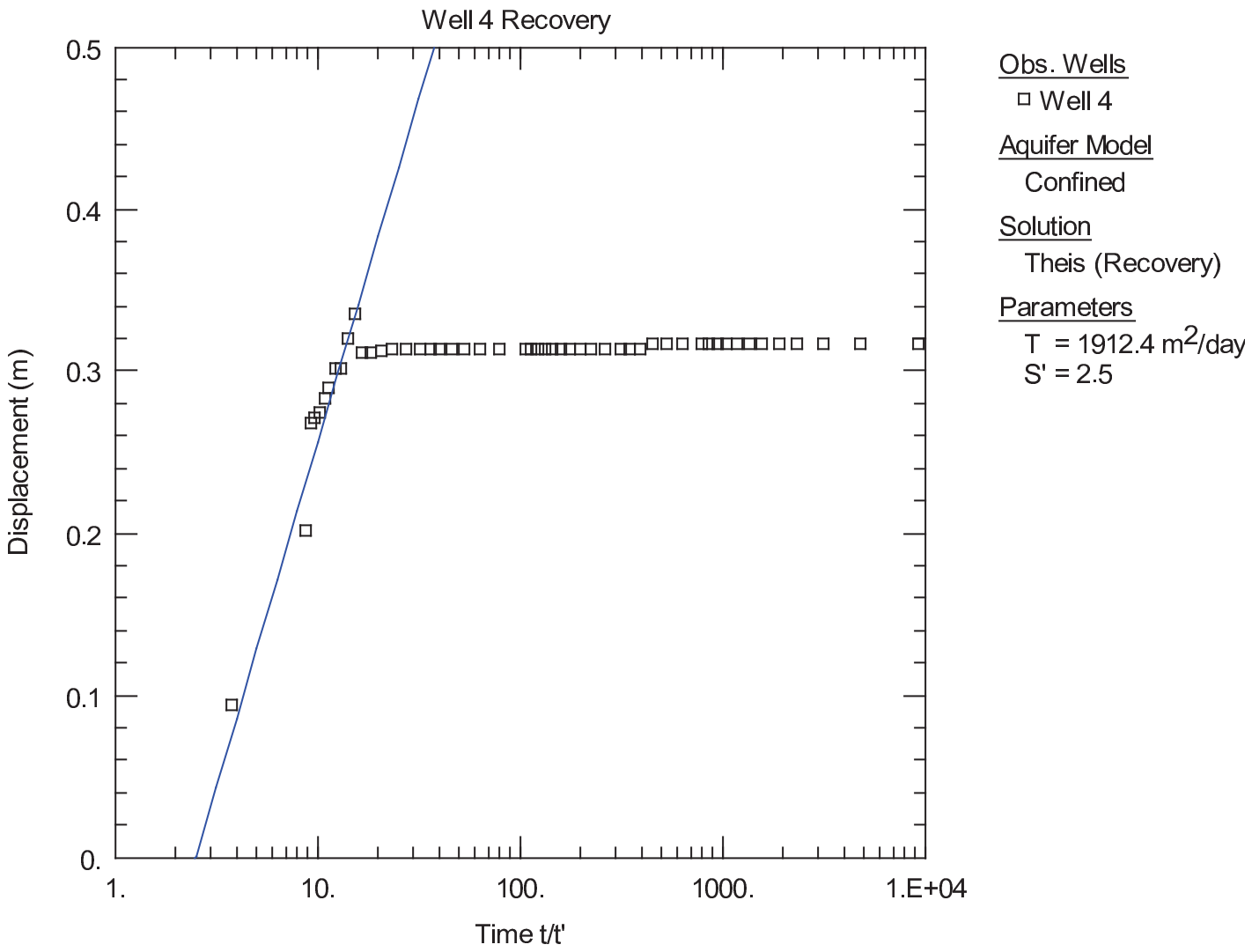


Figure A-9

Analysis of Well 4 Recovery Data

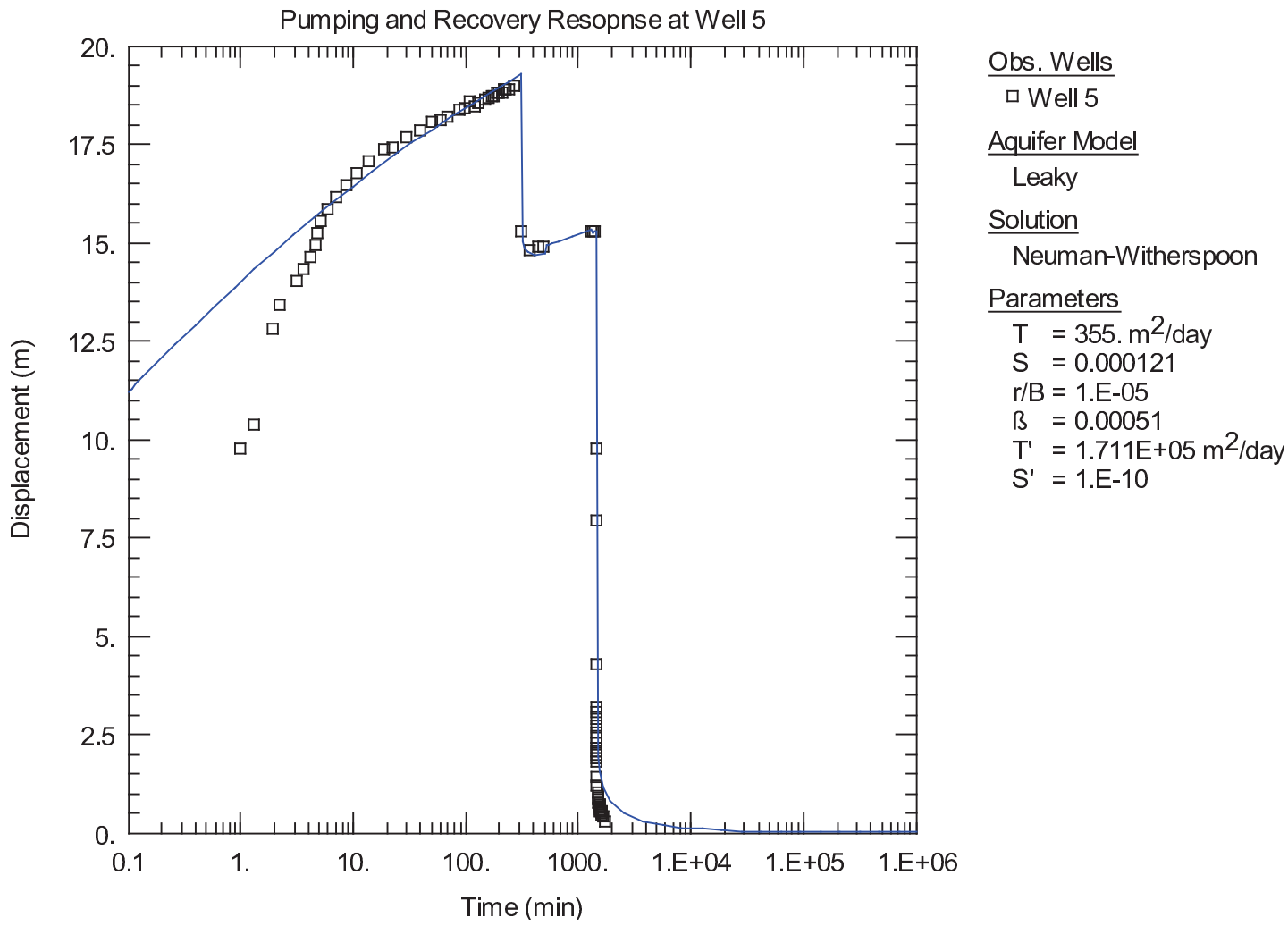


Figure A-7

Analysis of Well 5 Drawdown and Recovery Data

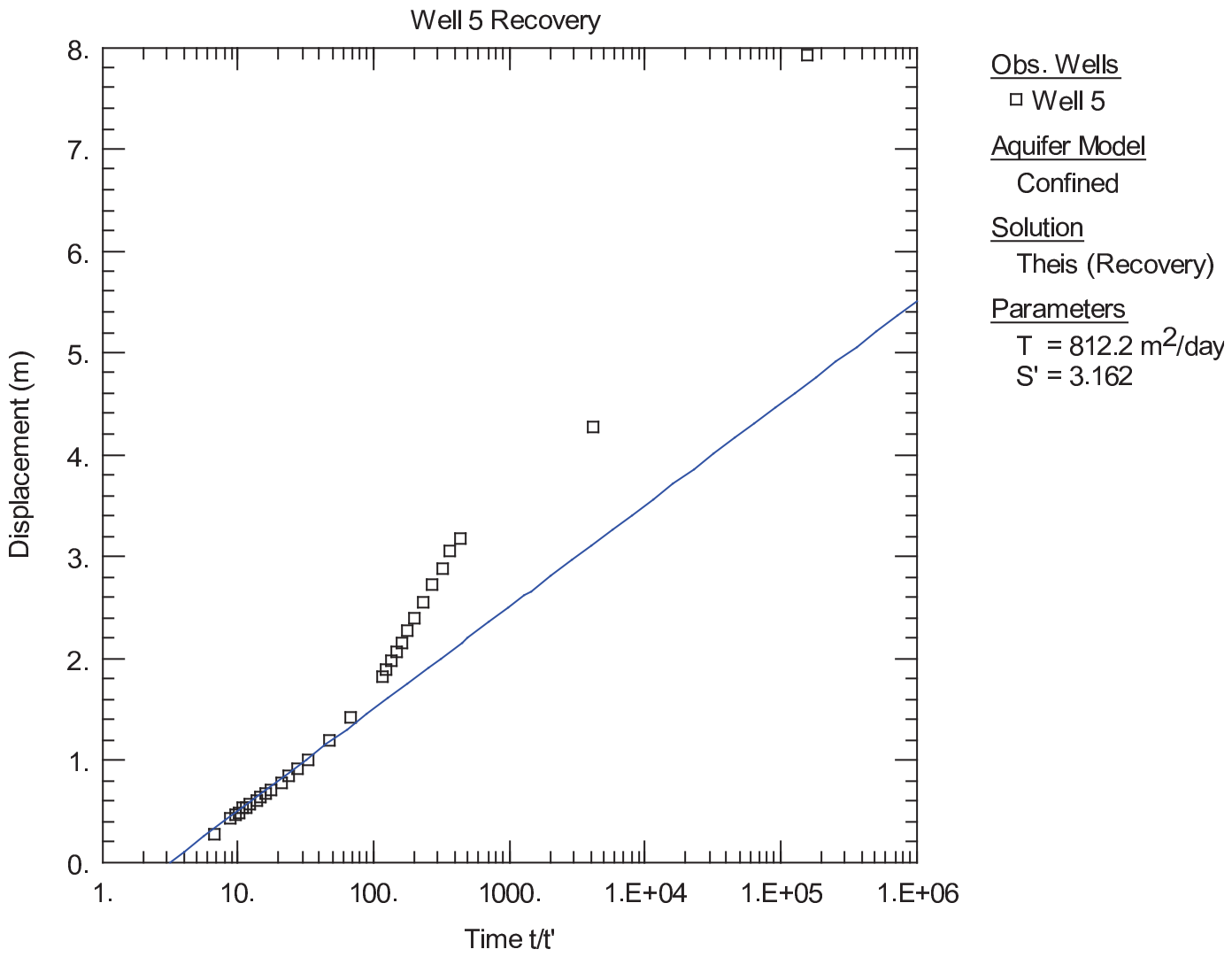


Figure A-10

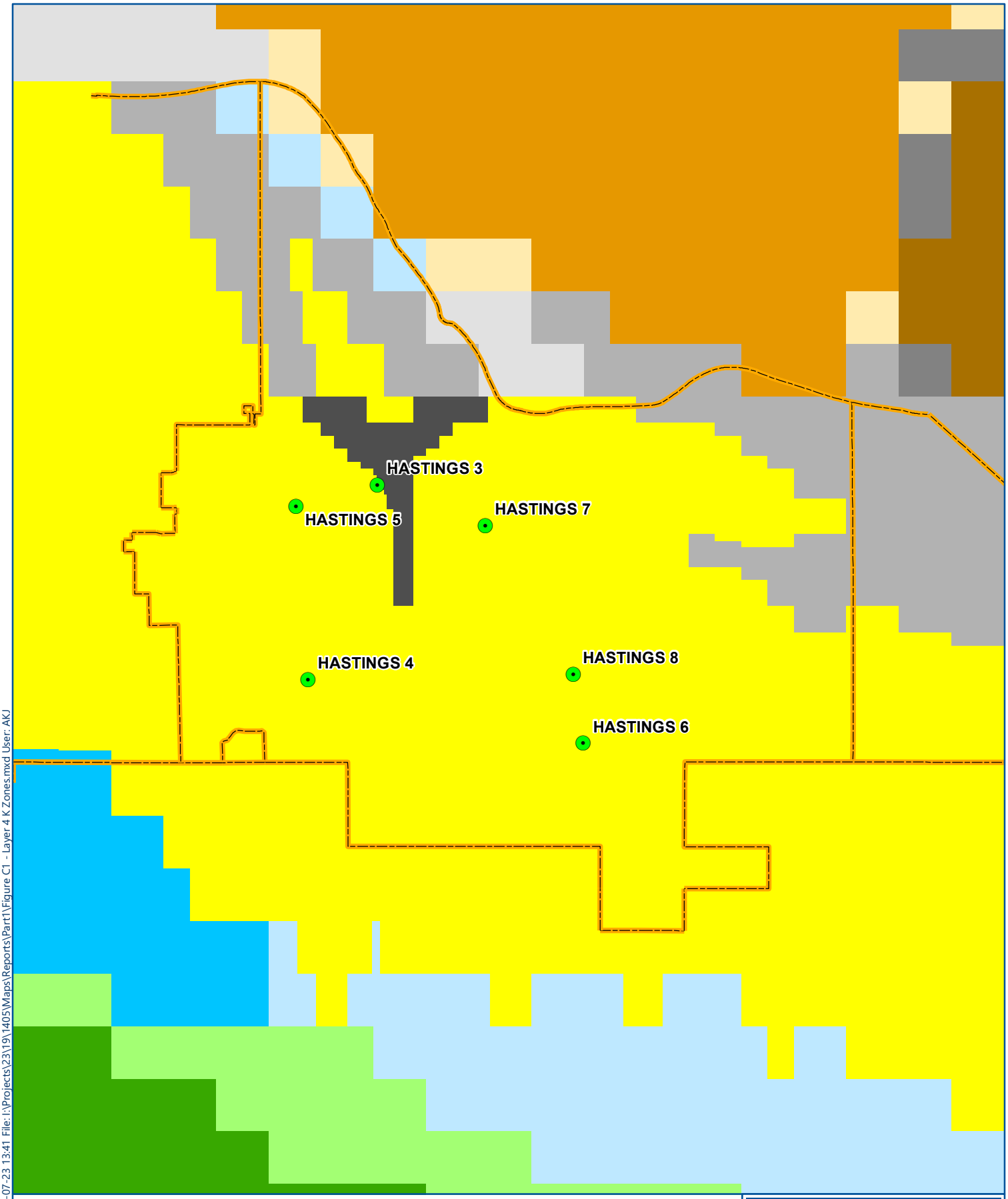
Analysis of Well 5 Recovery Data

Appendix C

Groundwater Model Details

Table C1
Updated High-Capacity Pumping
Hastings WHPP Amendment

Unique Number	Name	Permit	Annual Pumped Volume (million gallons)					2013-2017 Average	
			2017	2016	2015	2014	2013	gpm	m^3/d
250177	Bauer, Loren; Bauer, Willard	1969-1102	17.8000	8.2250	30.8360	33.7730	46.9840	52.34	285.31
121821	Bauer, Robert	1975-6126	18.3600	17.2800	18.9600	45.4400	61.9000	61.59	335.74
251398	Ardent Mills	1975-6278	6.8335	8.8863	11.4520	7.7116	6.6392	15.79	86.08
170868	Finnegan, David	1975-6358	22.4000	23.1500	23.2000	23.6248	23.6250	44.12	240.49
236554	Bauer, Jerry	1975-6374	18.4440	15.3180	24.7470	27.6960	41.5170	48.57	264.79
(blank)	Bauer, Loren	1976-6084	15.2800	11.3000	26.1500	34.6500	46.3600	50.86	277.27
250020	Becker, Edward	1976-6157	21.6672	14.8464	16.0515	24.8355	34.9440	42.73	232.91
121847	Bauer, Brian	1976-6184	11.9586	11.5347	15.4500	19.6052	29.2862	33.40	182.10
257402	Ries, Marcelline; Ries, Nick	1976-6204	49.0650	36.0000	17.6723	20.8517	41.1832	62.66	341.61
216367	Bauer, Loren	1977-6441	16.9500	11.7500	23.5300	39.5600	39.7220	50.02	272.65
255924	Ind School District 200	1978-6167	0.3360	0.0721	0.7550	0.5107	0.8807	0.97	5.30
242343	Bauer, Loren	1978-6190	14.4920	12.5000	28.2960	32.8520	37.6200	47.83	260.73
207642	Mn Dept Of Veterans Affairs	1985-6224	0.0250	0.0000	0.3350	0.4050	0.5590	0.50	2.74
749829	Mn Dept Of Veterans Affairs	1985-6224	0.0000	0.0000	0.0000	0.0960	0.0960	0.07	0.40
771760	Mn Dept Of Veterans Affairs	1985-6224	7.8400	7.1600	6.4370	8.0060	7.6000	14.09	76.80
207640	All Pro Holdings, LLC d.b.a. Dakota Pines Golf Club	1986-6243	18.1799	15.2725	15.6998	13.4913	30.8863	35.57	193.91
672739	All Pro Holdings, LLC d.b.a. Dakota Pines Golf Club	1986-6243	12.4003	10.1817	10.4532	8.9942	0.0000	15.98	87.14
(blank)	Barton Sand and Gravel Co.	1993-6152	0.0600	0.0552	0.0650	0.0650	0.0000	0.09	0.51
603062	Ind School District 200	2005-3014	0.5450	0.2381	0.7366	1.7752	2.2725	2.12	11.54
672578	Ind School District 200	2005-3014	0.1432	0.0684	0.3920	0.5838	0.7687	0.74	4.06
121088	Pettit, Marlene	2006-0420	3.1620	2.8050	3.0600	6.5790	5.8140	8.15	44.41
768670	Wagner, Ralph	2015-1357	6.3580	4.9800	12.0037	12.0037	--	16.80	91.59
806056	Mulvihill, Glenn M	2015-1392	11.9102	8.9401	7.4996	--	--	17.96	97.92



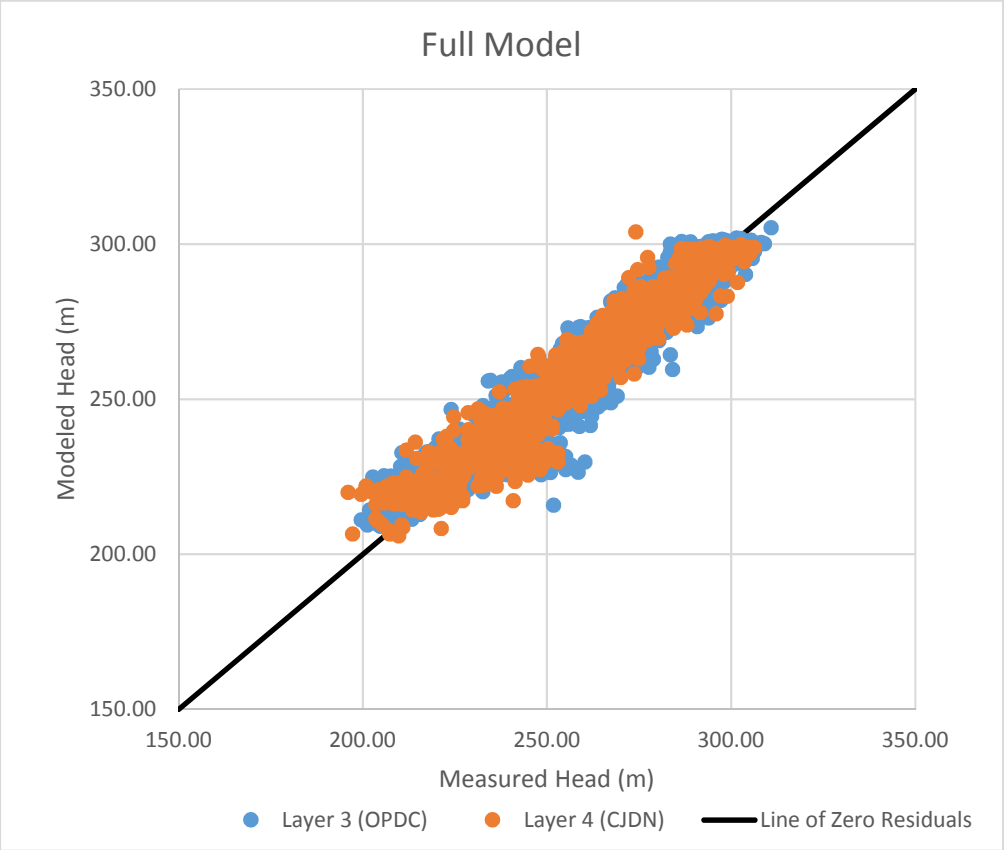
HYDRAULIC CONDUCTIVITY ZONES: LAYER 4

Hastings WHPP Amendment
City of Hastings, MN

FIGURE C1

BARR

Figure C2
Model Calibration
Hastings WHPP Amendment



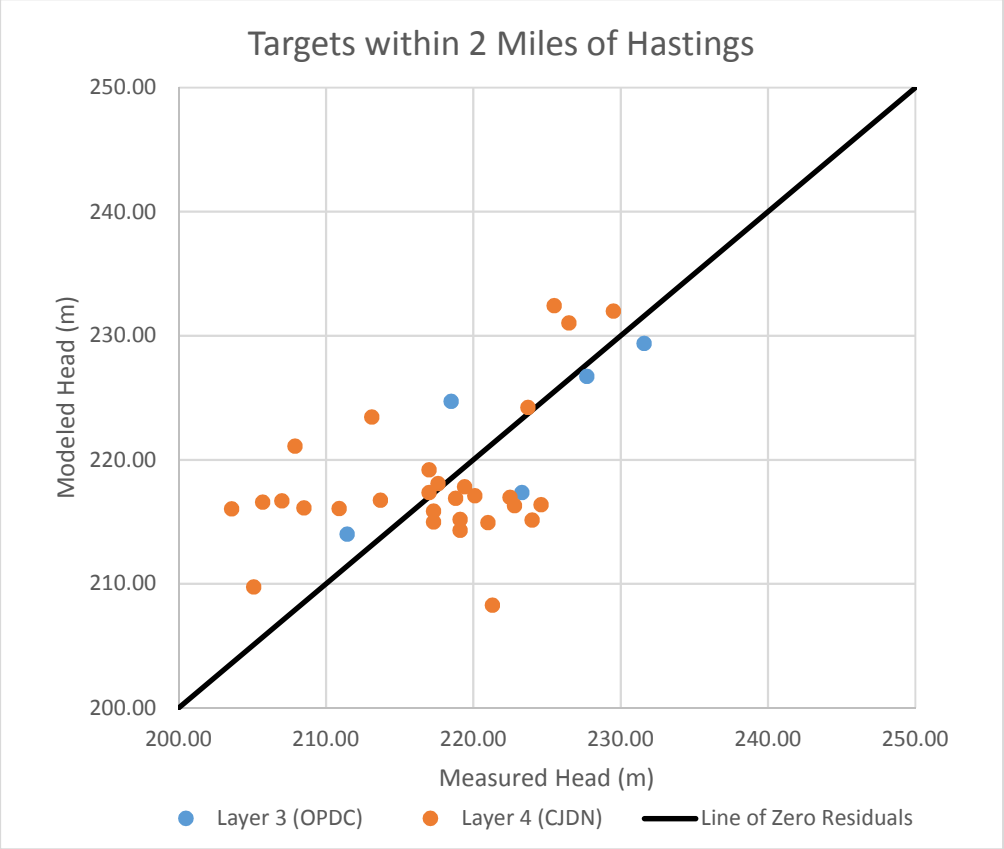


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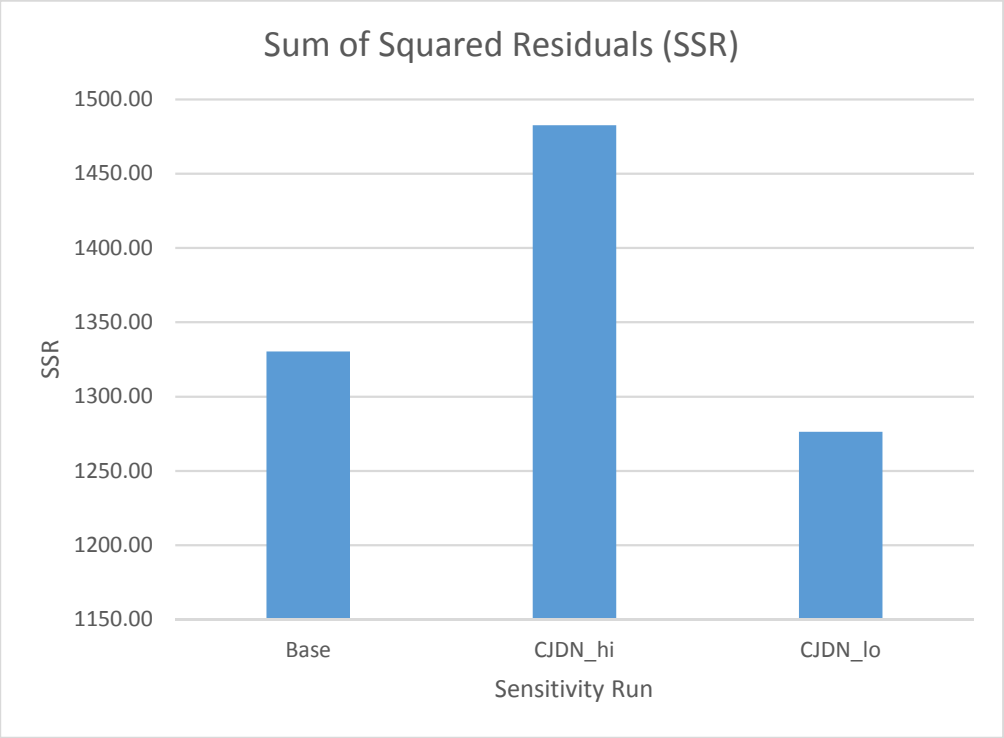
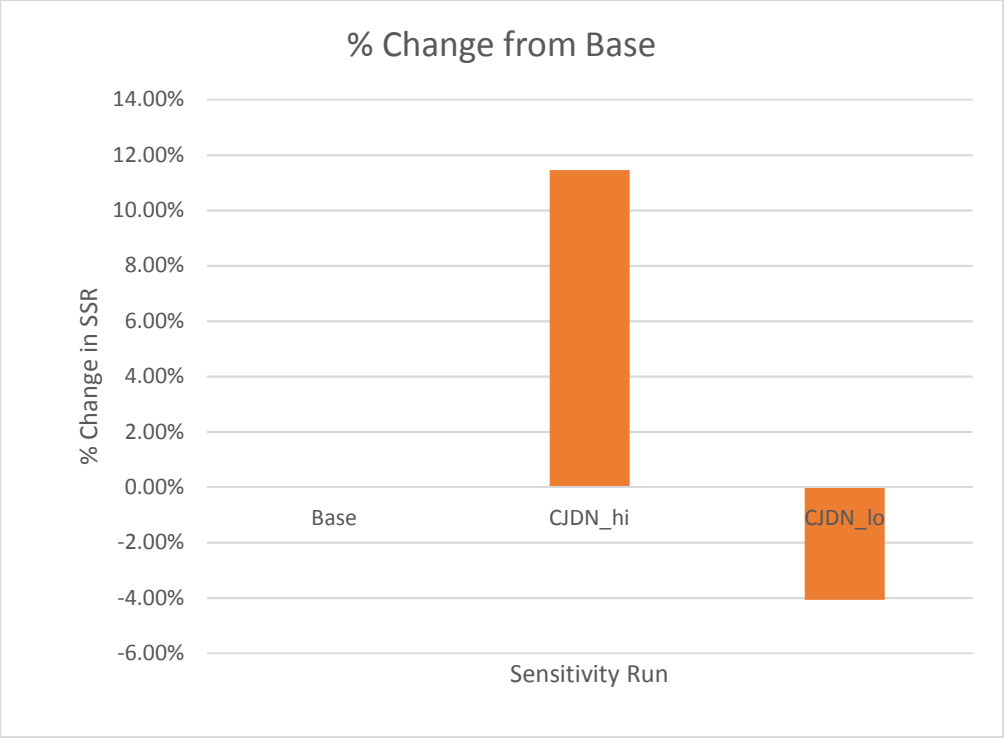
Figure C3
Sensitivity Analysis Summary
Hastings WHPP Amendment





Note: Results shown for Layer 4 targets within 2 miles of Hastings only

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Appendix D

Fracture Flow Delineation

Table D1
Estimated Contributions from Prairie du Chien Group
Hastings WHPP Amendment

Unique	Well	Well Pumping Rate (m^3/day)	Base Model Net Layer 3 Contribution to Layer 4 Capture Zone (m^3/day)	
			(m^3/day)	% of pumping rate
206333	3	1,438	1,098	76%
207993	4	1,947	829	43%
207639	5	1,508	296	20%
207643	6	1,441	311	22%
509053	7	2,483	1,788	72%
686266	8	1,535	720	47%

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Table D2
Fracture Flow Tool Input
Hastings WHPP Amendment

Unique	Well	Model Pumping Rate (m^3/day)	Fraction from OPDC	Fracture Flow Pumping Rate (m^3/day)	OPDC Thickness from Log[1] (ft)	OPDC Thickness to Use (ft)	K (m/day)	Gradient	Q/Qs (m)	Upgradient Extension Required?	Bearing (degrees east of north)
206333	3	1,438	0.76	1098	268	200	33.45	0.0022	249	YES	234
207993	4	1,947	0.43	829	234	200	33.45	0.0022	188	YES	221
207639	5	1,508	0.20	296	268	200	33.45	0.0022	67	YES	235
207643	6	1,441	0.22	311	136	136	33.45	0.0022	104	YES	220
509053	7	2,483	0.72	1788	136	136	33.45	0.0022	597	YES	225
686266	8	1,535	0.47	720	181	181	33.45	0.0022	181	YES	217

[1] Actual OPDC thickness at Well 3 is zero, assumed thickness from nearby Well 5 for fracture flow calcs

$$Q/Qs = \frac{Q\left(\frac{1\,ft^3}{7.48\,gal}\right)\left(\frac{1440\,\text{min}}{1day}\right)\left(\frac{0.0283m^3}{1\,ft^3}\right)}{(H)\left(\frac{0.3048m}{1\,ft}\right)(K)(i)}$$

P:\Mpls\23 MN\19\23191405 Hastings WHPP Amendment\WorkFiles\Part1\Report\Appendices\Appendix D - Fracture Flow\support\Hastings Fracture Flow Capture Zones.xlsx

Table D3
Overlapping High Capacity Wells
Hastings WHPP Amendment

Unique	OPDC Thickness from Log[1,2,3] (ft)	OPDC Thickness to Use (ft)	OPDC Thickness to Use (m)	Model Pumping Rate (m^3/day)	10-year Fixed Radius (m)	Overlaps with Hastings well...	Overlapping Area (m^2)
121847	19	19	5.79	182.10	807.70	none	0
207640	235	200	60.96	193.91	256.89	4	97625.18
207642	137	137	41.76	2.74	36.90	none	0
250177	234	200	60.96	285.31	311.61	none	0
251398	187	187	57.00	86.08	177.01	8	62380.58
255924	136	136	41.45	5.30	51.50	7	8311.23
408251	191	191	58.22	176.54	250.83	none	0
672739	185	185	56.39	87.14	179.06	none	0
771760	149	149	45.42	76.80	187.31	8	2791.52
806056	19	19	5.79	97.92	592.28	none	0

[1] No OPDC thickness on log for well 250177. Used thickness from Hastings 4.

[2] No OPDC thickness on log for well 255924. Used thickness from Hastings 7.

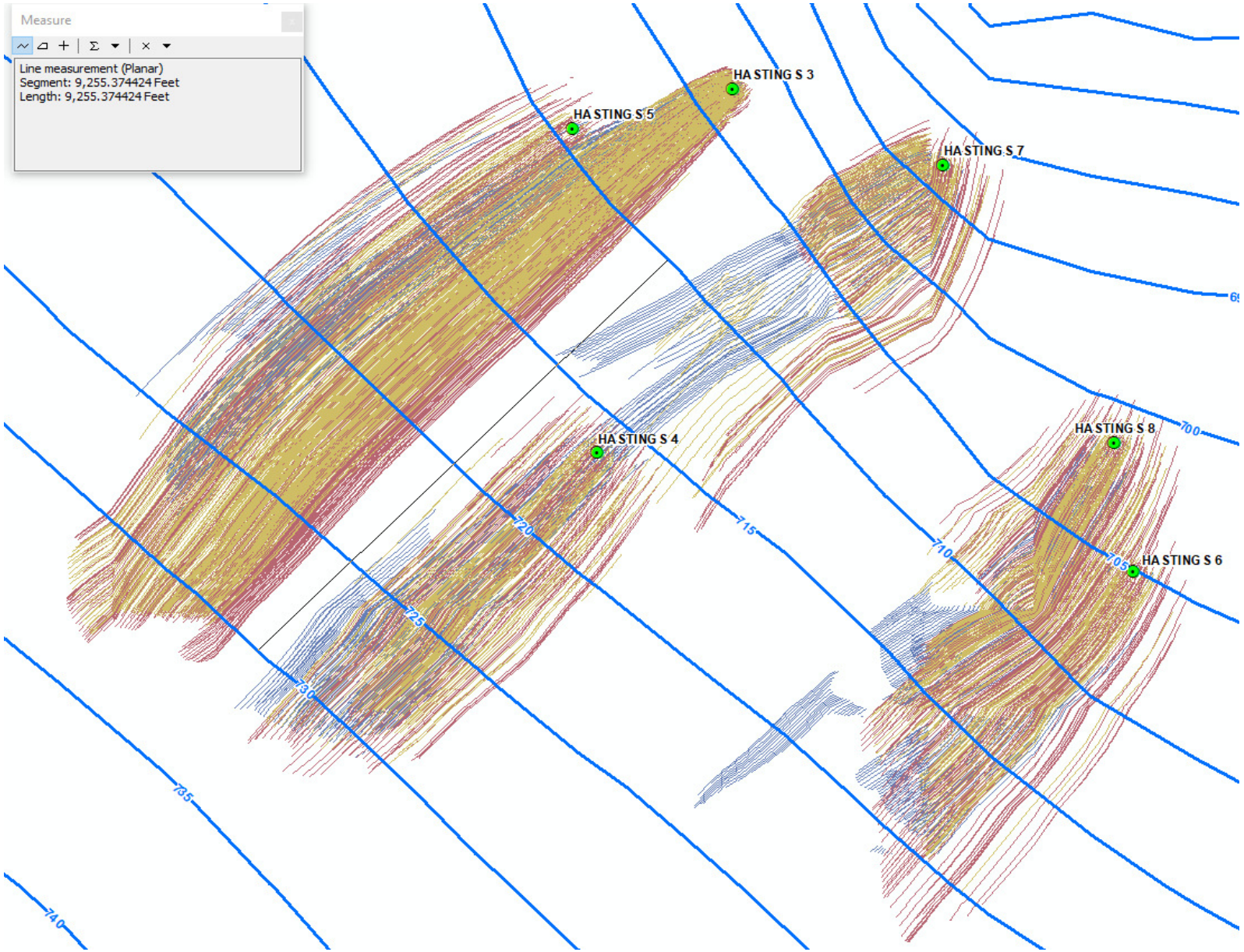
[3] No log for well 806056. Used thickness from well 121847.

Porosity 0.056

Unique	Well	Preliminary 5-year Fixed Radius Capture Zone Area (m^2)	Total Overlapping Area (m^2)	Adjusted Area (m^2)	Adjusted 5-year Fixed Radius (m)	Effective Pumping Rate for Fracture Flow Tool (m^3/day)
206333	3	586813.36	0	586813.3573	432.19	1098
207993	4	443029.01	97625.18	540654.1972	414.84	1011
207639	5	158149.29	0	158149.2943	224.37	296
207643	6	244385.89	0	244385.8913	278.91	311
509053	7	1405407.37	8311.23	1413718.6	670.82	1798
686266	8	425164.52	65172.10	490336.6127	395.07	830

Contours and particle traces shown for Layer 3 only

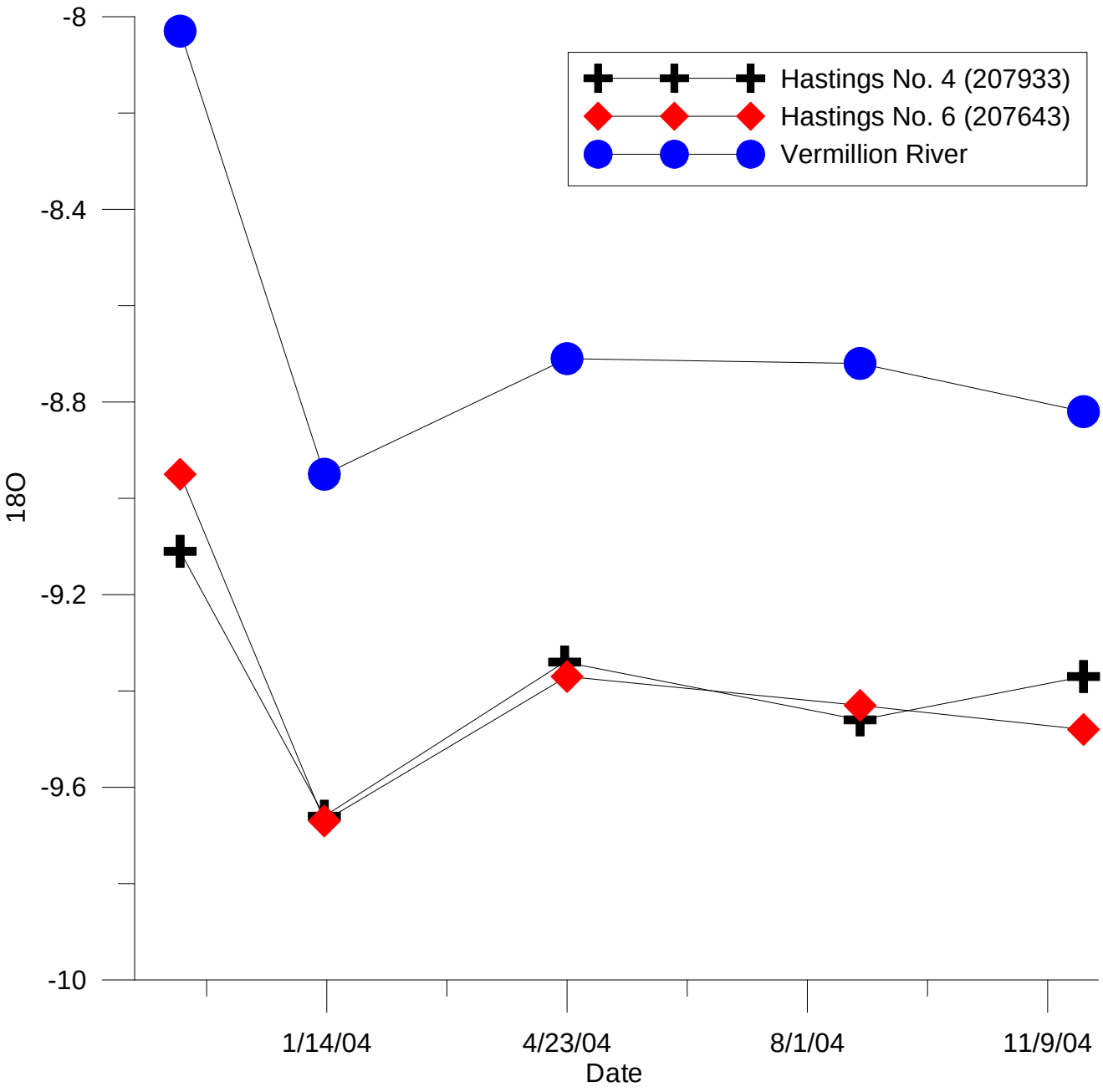
Gradient = 0.0022



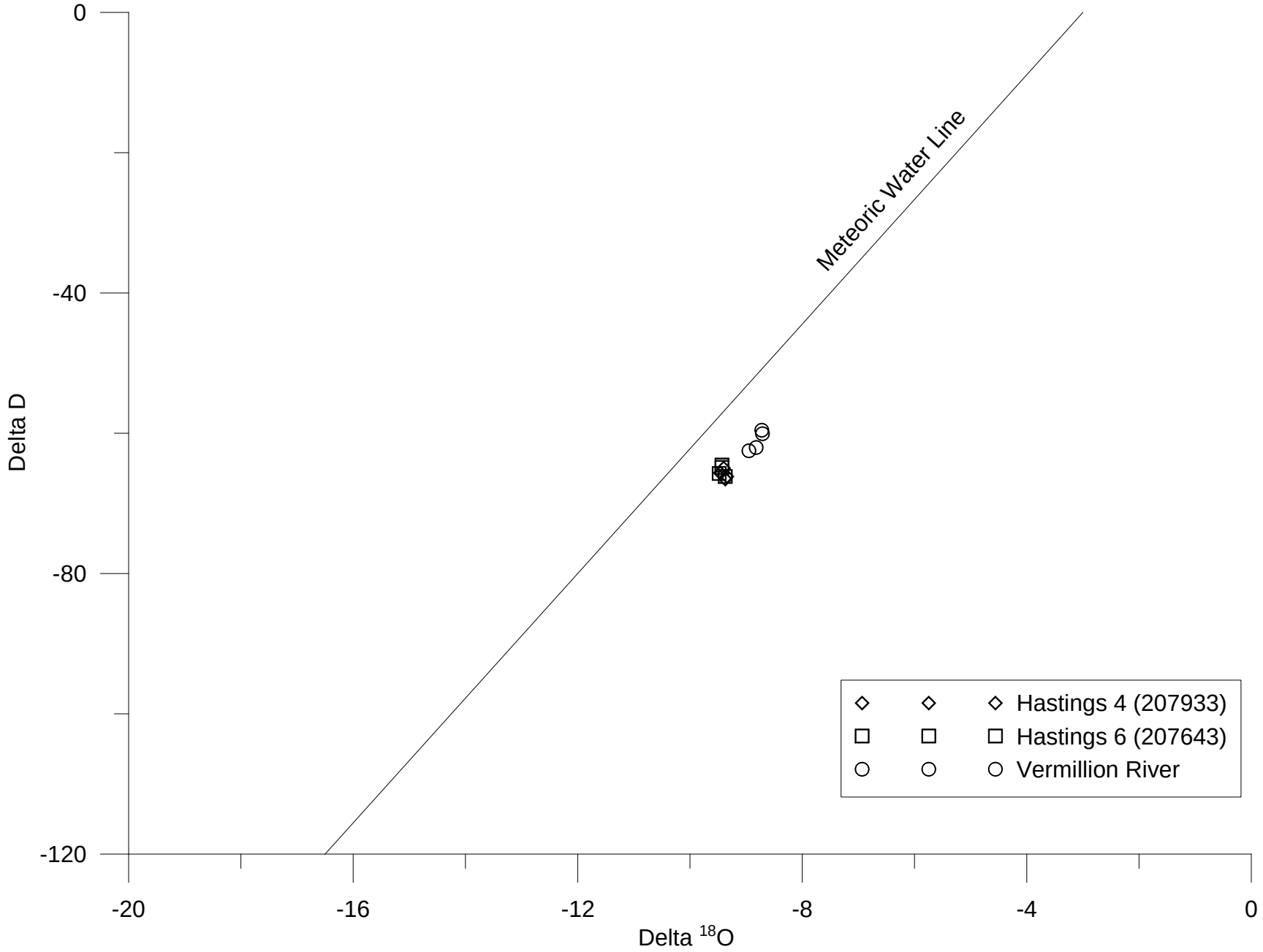
Appendix E

Isotope Data

Figure 1. Oxygen Isotope Results Show Close Correlation Between Vermillion River and Hastings Wells

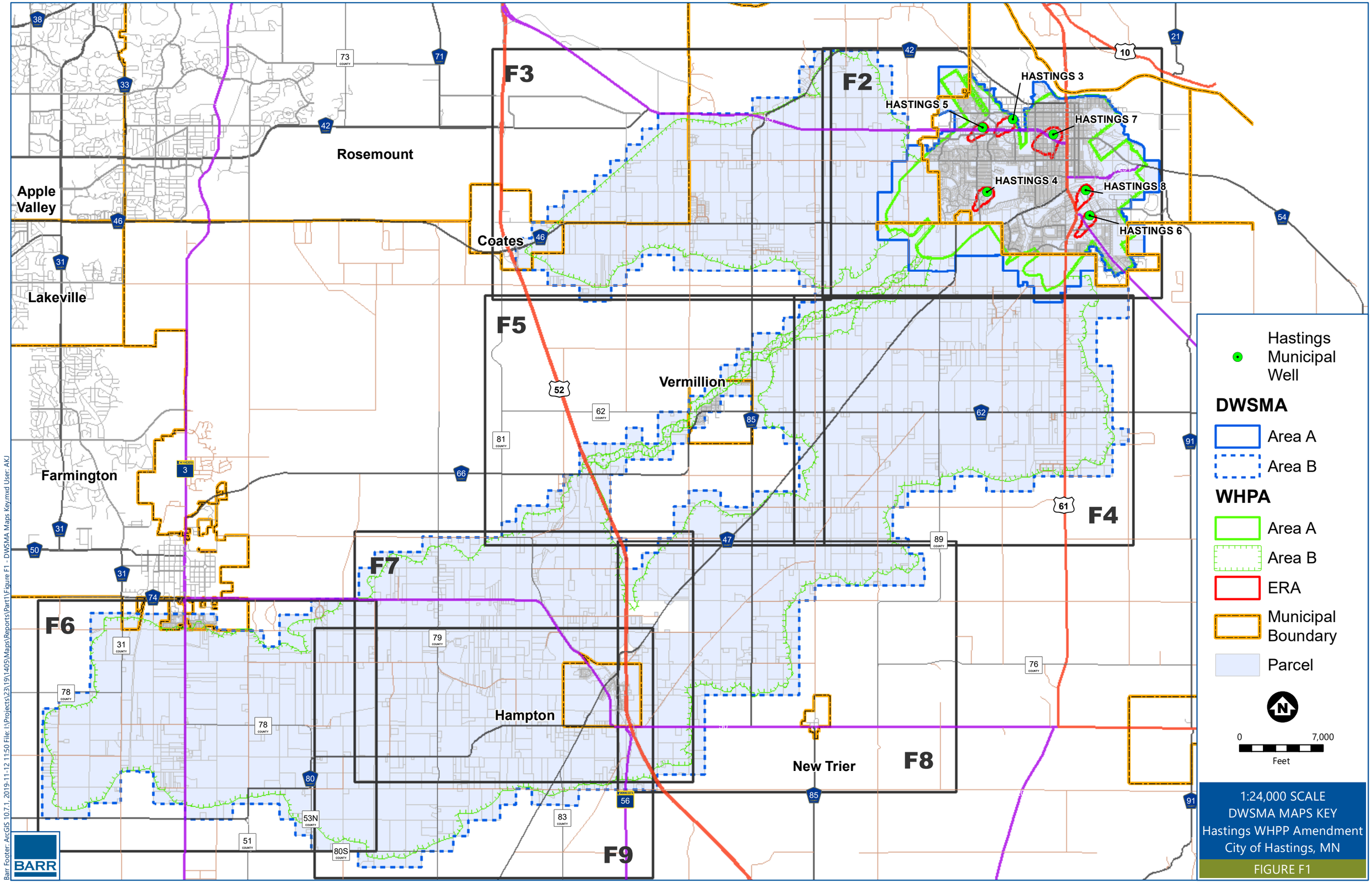


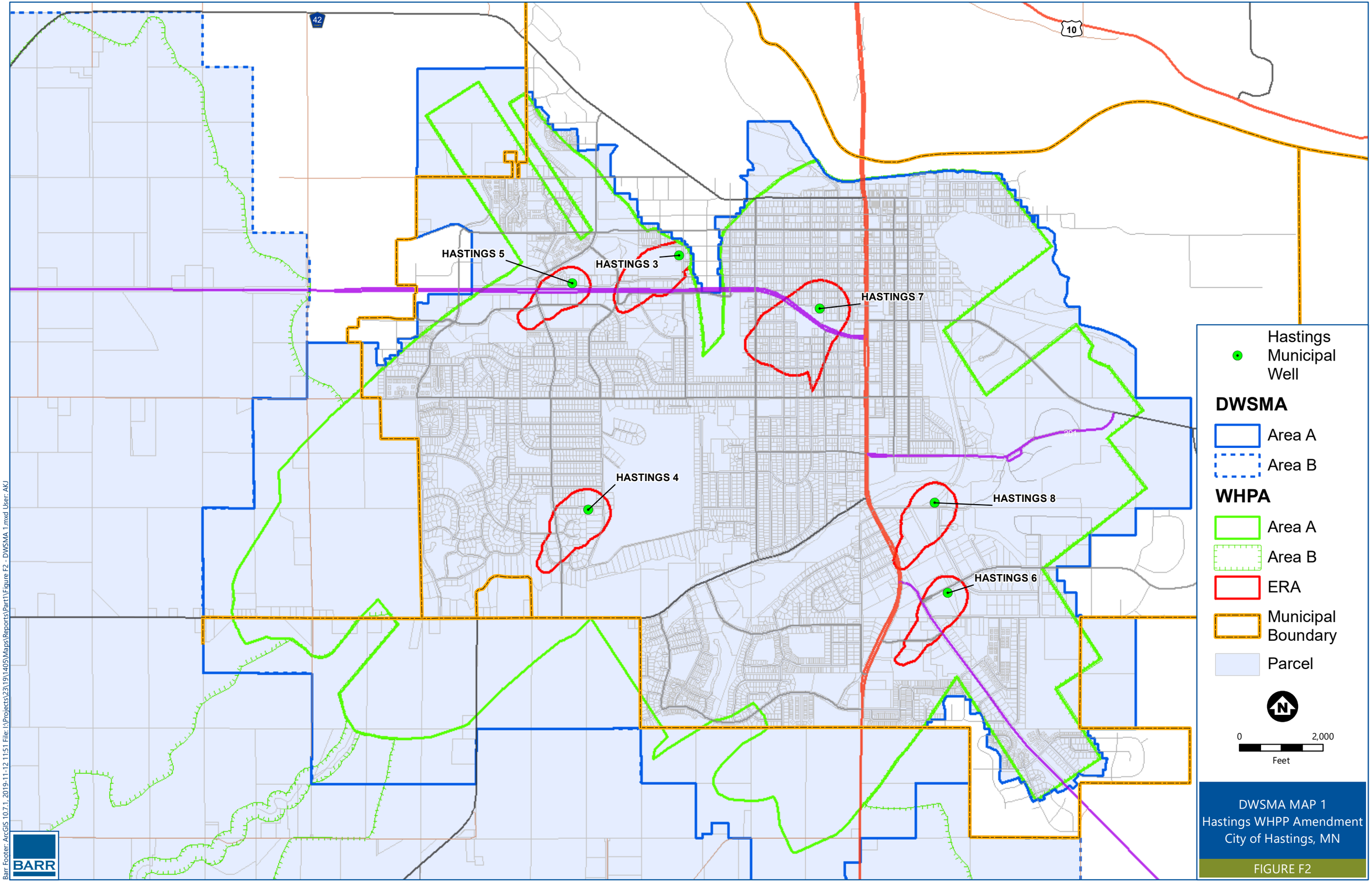
Oxygen and Hydrogen Isotope Analysis
Hastings Wells 4, 6, and Vermillion River



Appendix F

1:24,000 Scale DWSMA Maps


F3
F2
F5
F7
F6
F4
F8
F9
HASTINGS 3
HASTINGS 5
HASTINGS 7
HASTINGS 4
HASTINGS 8
HASTINGS 6
Rosemount
Apple Valley
Lakeville
Coates
Vermillion
Farmington
Hampton
New Trier
Hastings Municipal Well
DWSMA
Area A
Area B
WHPA
Area A
Area B
ERA
Municipal Boundary
Parcel
0
7,000
Feet
1:24,000 SCALE
DWSMA MAPS KEY
Hastings WHPP Amendment
City of Hastings, MN
FIGURE F1
BARR
Barr Footer: ArcGIS 10.7.1, 2019-11-12 11:50 File: I:\Projects\23\19\1405\Maps\Reports\Part1\Figure F1 - DWSMA Maps Key.mxd User: AKJ


42
10
HASTINGS 5
HASTINGS 3
HASTINGS 7
HASTINGS 4
HASTINGS 8
HASTINGS 6
Hastings Municipal Well
DWSMA
Area A
Area B
WHPA
Area A
Area B
ERA
Municipal Boundary
Parcel
N
0
2,000
Feet
DWSMA MAP 1
Hastings WHPP Amendment
City of Hastings, MN
FIGURE F2
BARR
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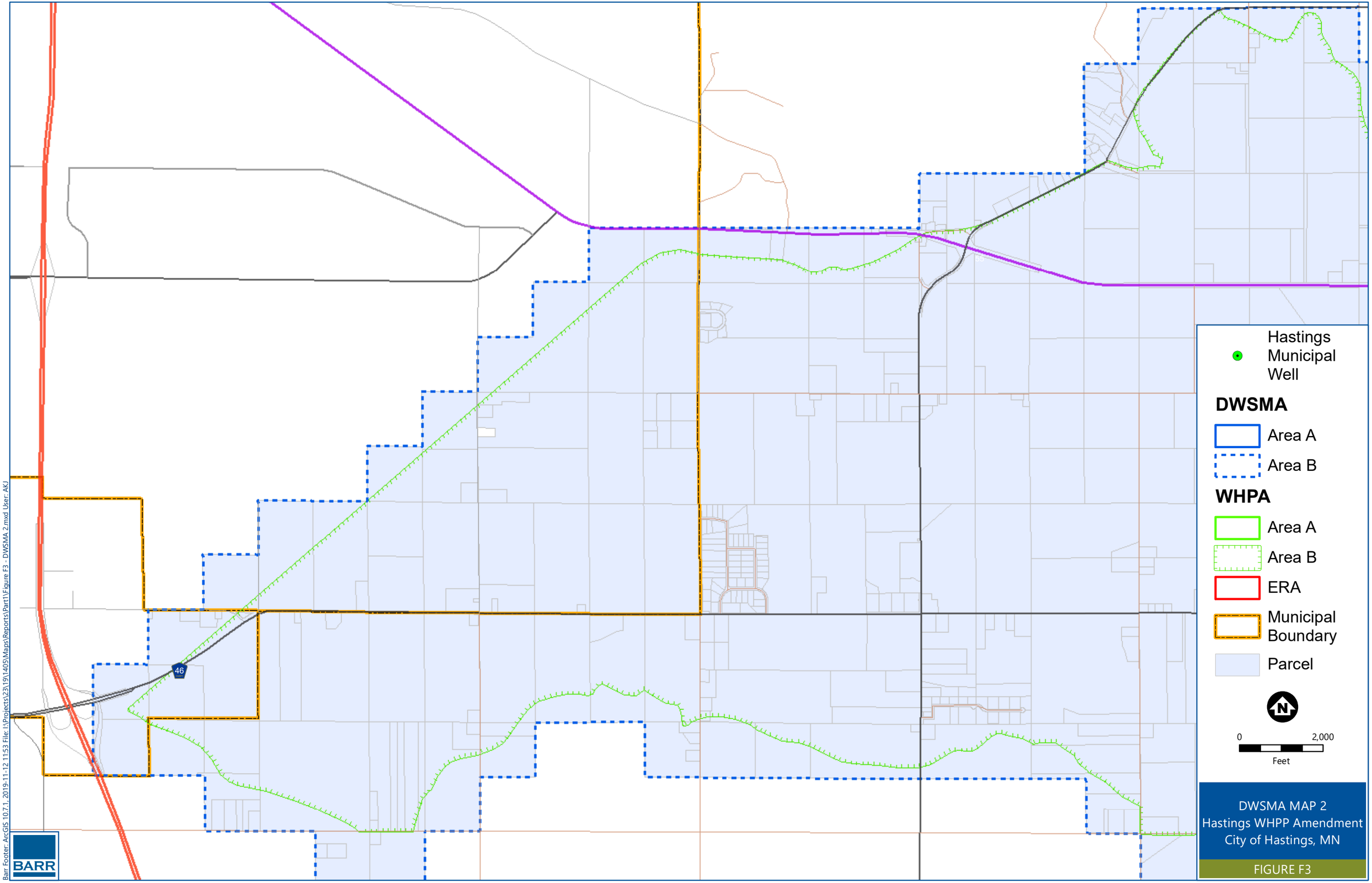
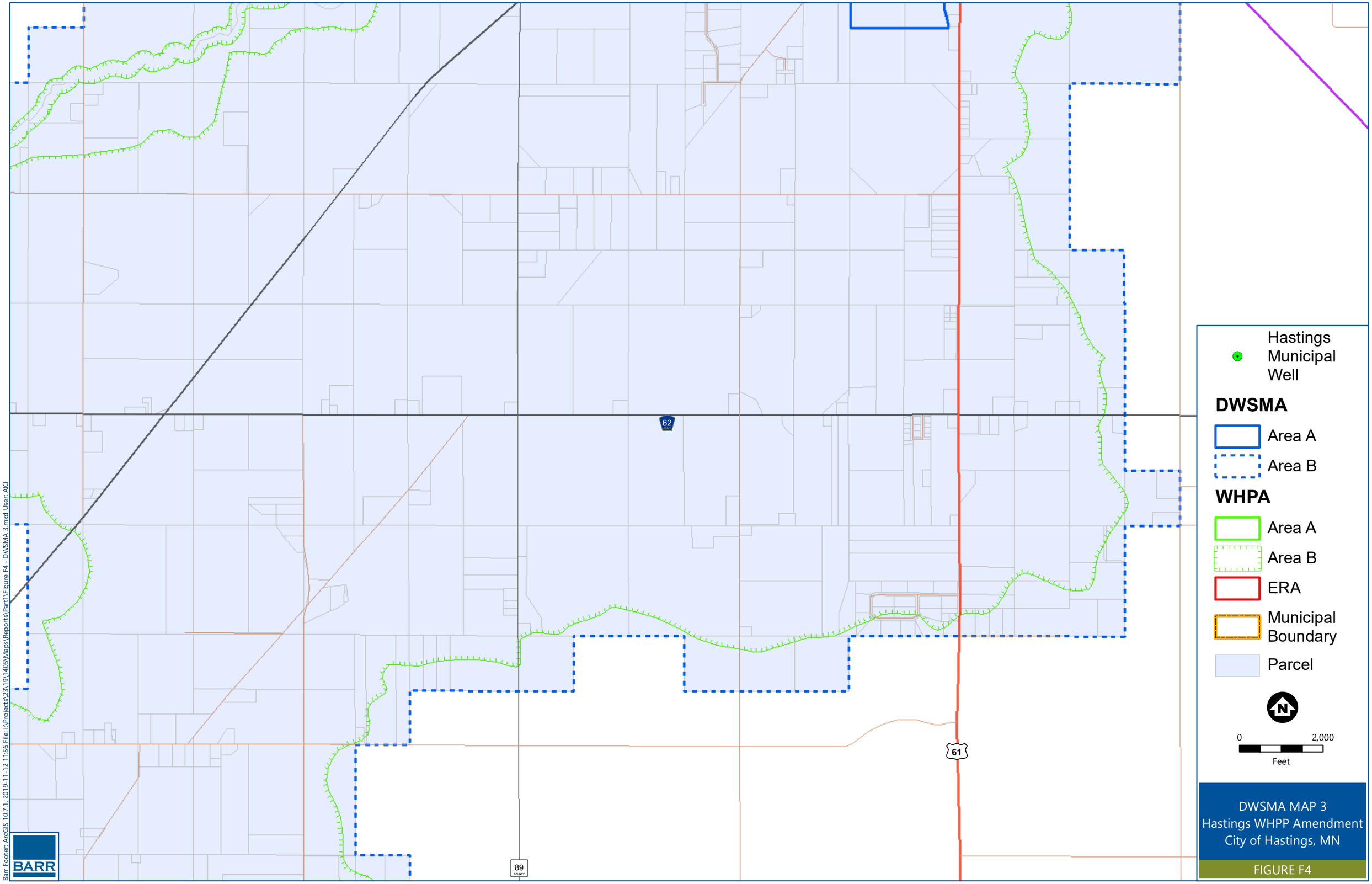


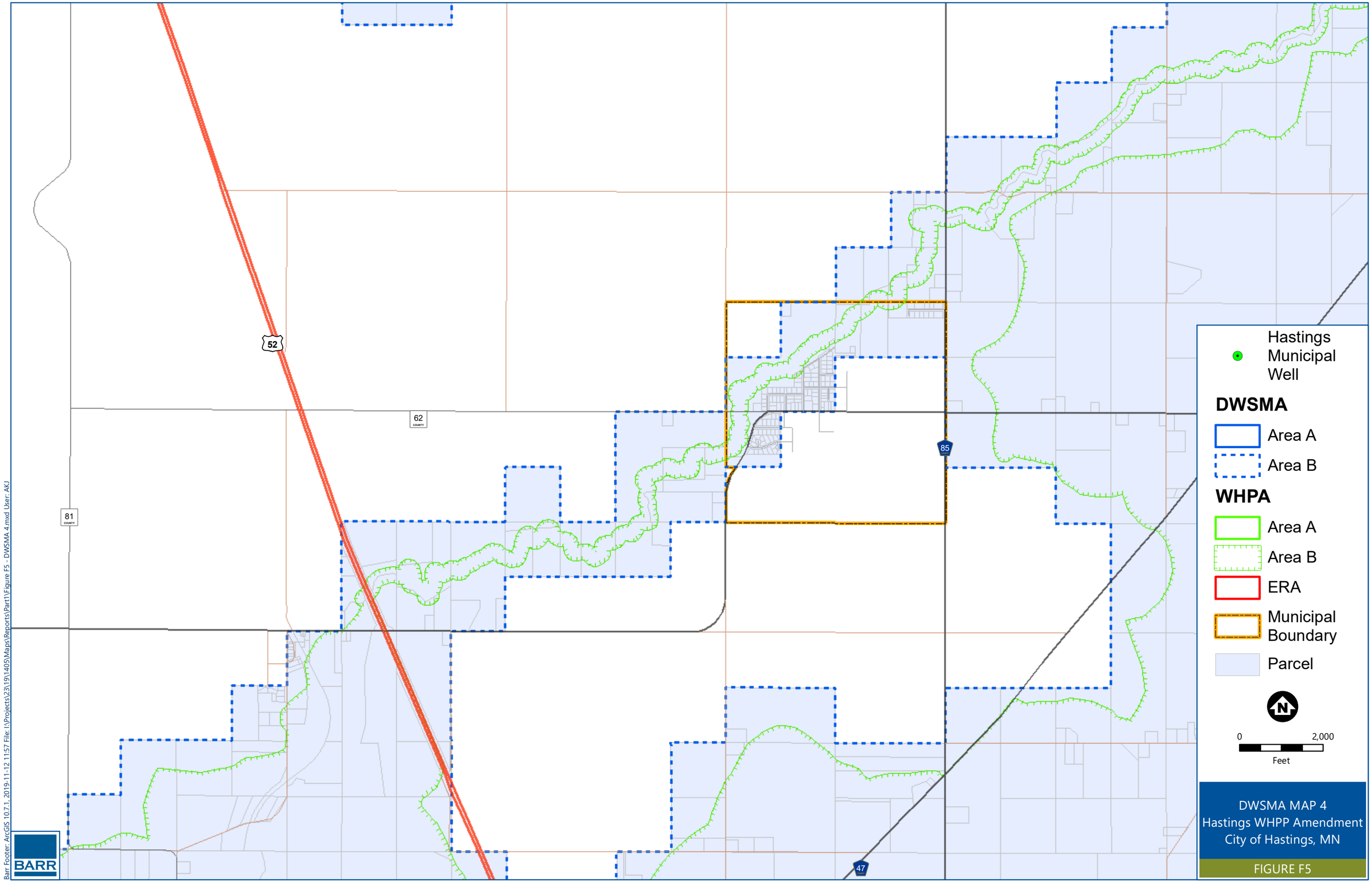
DWSMA MAP 2
Hastings WHPP Amendment
City of Hastings, MN

FIGURE F3

BARR

Barr Footer: ArcGIS 10.7.1, 2019-11-12 11:53 File: I:\Projects\23\19\1405\Maps\Reports\Part1\Figure F3 - DWSMA 2.mxd User: AKJ


62
61
89
COUNTY
Hastings Municipal Well
DWSMA
Area A
Area B
WHPA
Area A
Area B
ERA
Municipal Boundary
Parcel
N
0
2,000
Feet
DWSMA MAP 3
Hastings WHPP Amendment
City of Hastings, MN
FIGURE F4
BARR
Barr Footer: ArcGIS 10.7.1, 2019-11-12 11:56 File: I:\Projects\23\19\1405\Maps\Reports\Part1\Figure F4 - DWSMA 3.mxd User: AKJ



DWSMA MAP 4
Hastings WHPP Amendment
City of Hastings, MN

FIGURE F5

BARR

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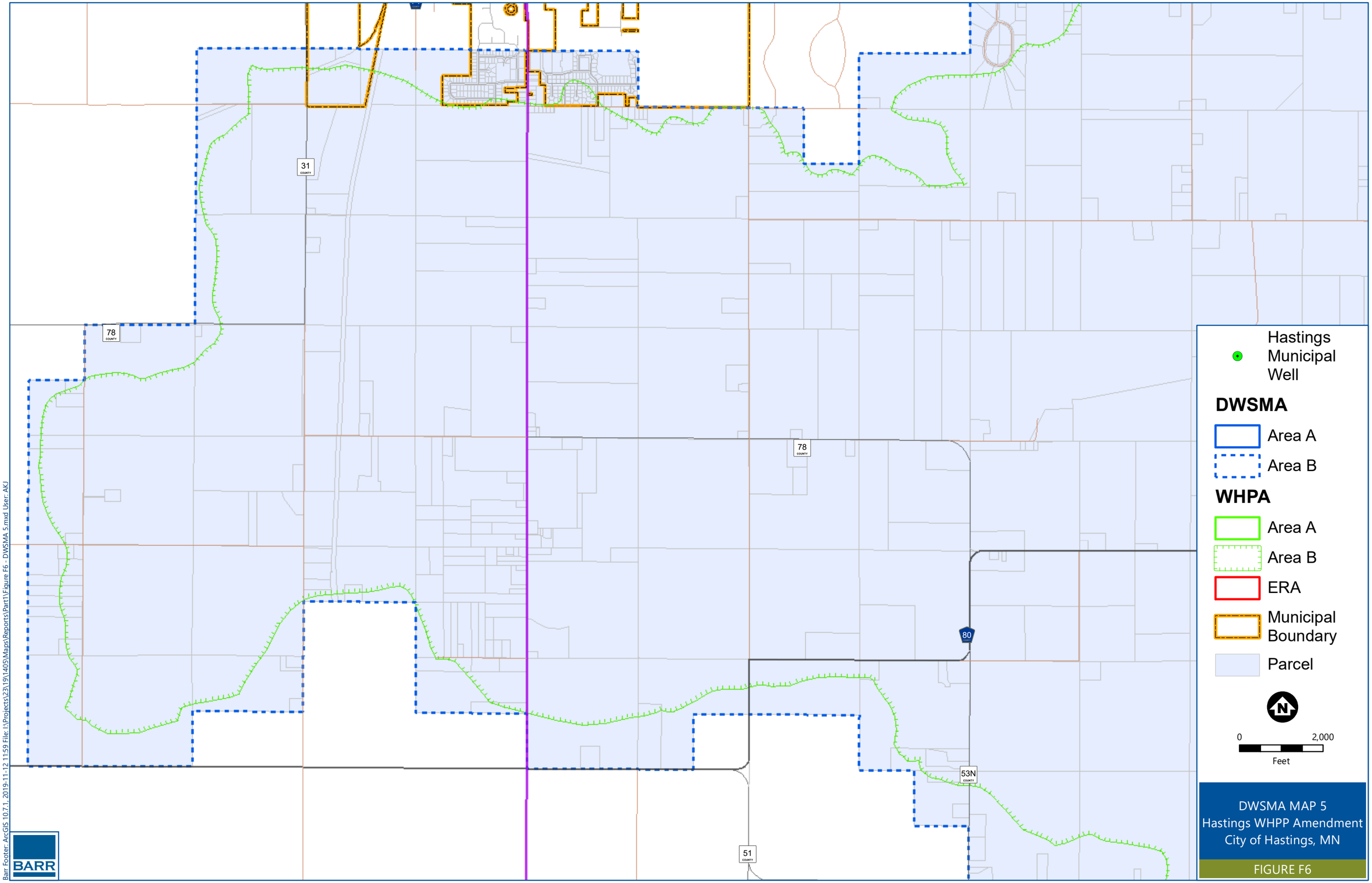
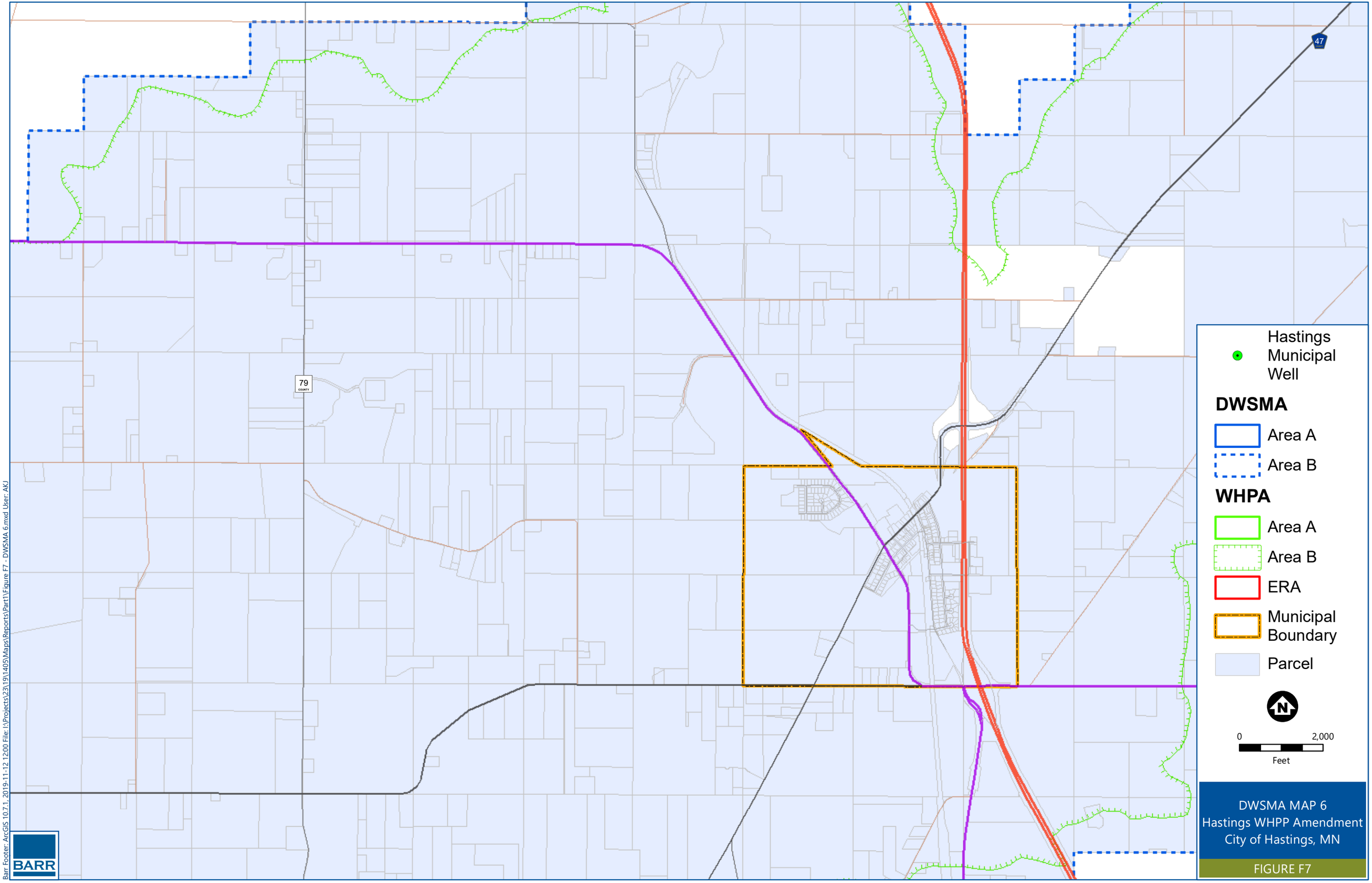

31
COUNTY
78
COUNTY
78
COUNTY
80
53N
COUNTY
51
COUNTY
Hastings Municipal Well
DWSMA
Area A
Area B
WHPA
Area A
Area B
ERA
Municipal Boundary
Parcel
N
0
2,000
Feet
DWSMA MAP 5
Hastings WHPP Amendment
City of Hastings, MN
FIGURE F6
BARR
Barr Footer: ArcGIS 10.7.1, 2019-11-12 11:59 File: I:\Projects\23\19\1405\Maps\Reports\Part1\Figure F6 - DWSMA 5.mxd User: AKJ



DWSMA MAP 6
Hastings WHPP Amendment
City of Hastings, MN

FIGURE F7

BARR

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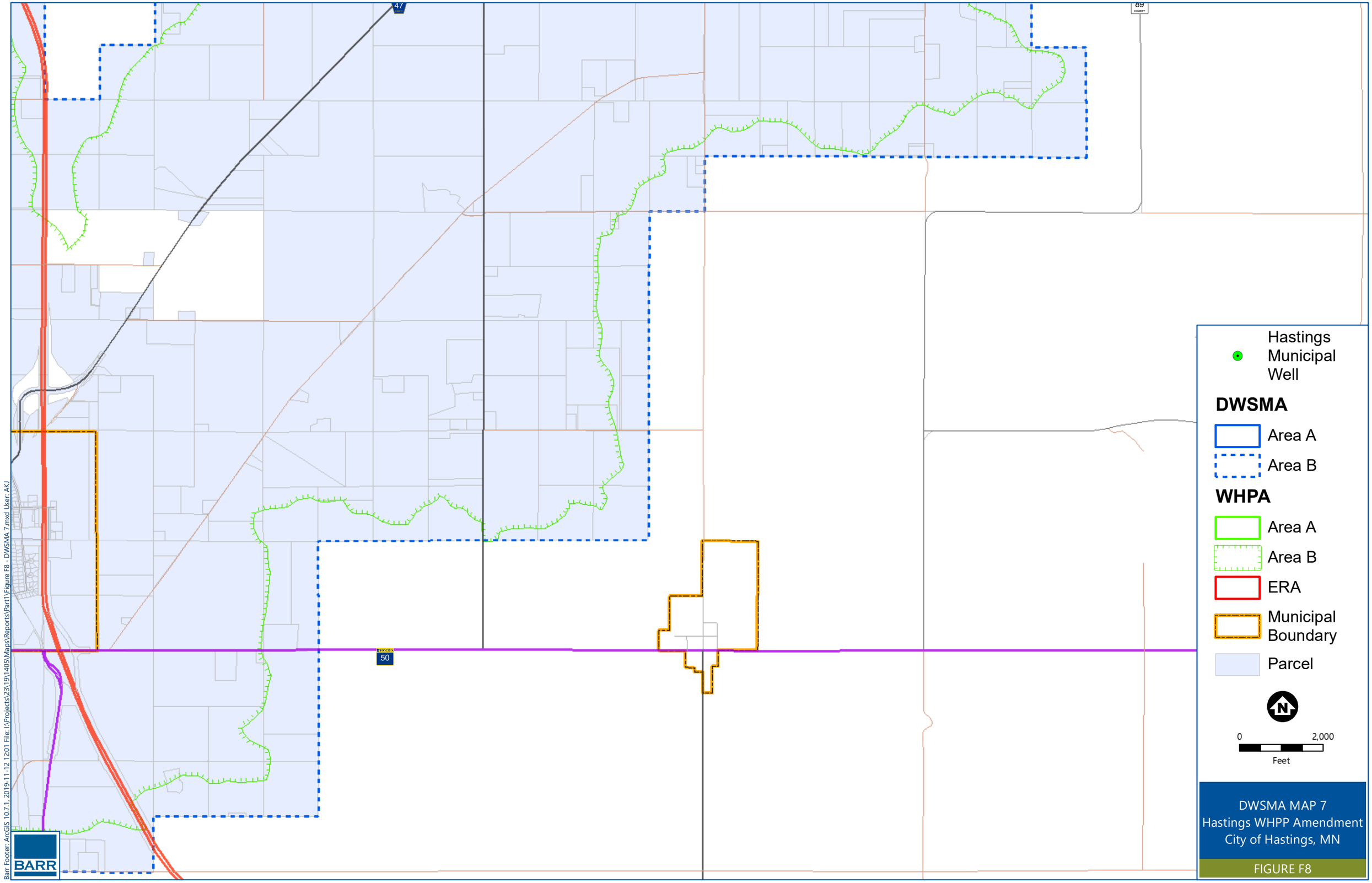
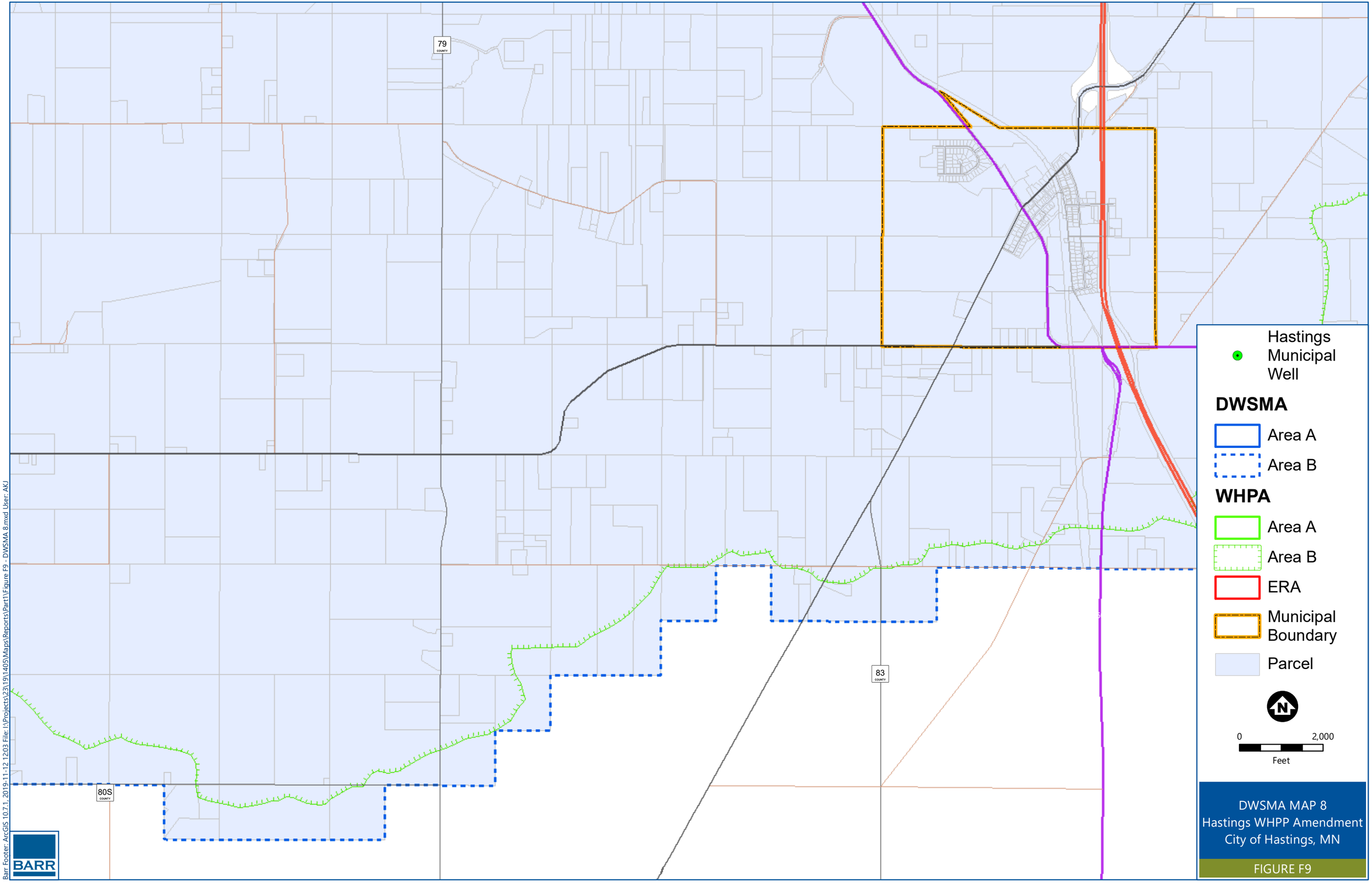

47
89
COUNTY
50
Hastings Municipal Well
DWSMA
Area A
Area B
WHPA
Area A
Area B
ERA
Municipal Boundary
Parcel
N
0
2,000
Feet
DWSMA MAP 7
Hastings WHPP Amendment
City of Hastings, MN
FIGURE F8
BARR
Barr Footer: ArcGIS 10.7.1, 2019-11-12 12:01 File: I:\Projects\23\19\1405\Maps\Reports\Part1\Figure F8 - DWSMA 7.mxd User: AKJ


79
COUNTY
83
COUNTY
80S
COUNTY
Hastings Municipal Well
DWSMA
Area A
Area B
WHPA
Area A
Area B
ERA
Municipal Boundary
Parcel
N
0
2,000
Feet
DWSMA MAP 8
Hastings WHPP Amendment
City of Hastings, MN
FIGURE F9
BARR
Barr Footer: ArcGIS 10.7.1, 2019-11-12 12:03 File: I:\Projects\23\19\1405\Maps\Reports\Part1\Figure F9 - DWSMA 8.mxd User: AKJ

Appendix G

MDH Well Vulnerability Assessments

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

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

PWSID: 1190012 TIER: 1
SYSTEM NAME: Hastings WHP RANK:
WELL NAME: Well #3 UNIQUE WELL #: 00206333

COUNTY: Dakota TOWNSHIP NUMBER: 115 RANGE: 17 W SECTION: 28 QUARTERS: BCAC

CRITERIA		DESCRIPTION		POINTS
Aquifer Name(s)	:	Jordan		
DNR Geologic Sensitivity Rating	:	Very low		10
L Score	:	9		
Geologic Data From	:	Well Record		
Year Constructed	:	1956		
Construction Method	:	Cable Tool/Bored		0
Casing Depth	:	208		5
Well Depth	:	299		
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	:	1000		10
Pathogen Detected?				0
Surface Water Characteristics?				0
Maximum nitrate detected	:	9 04/29/2004		30
Maximum tritium detected	:	Unknown		0
Non-THMS VOCs detected?		Trichloroethene (TCE)	09/14/1990	VULNERABLE
Pesticides detected?		Atrazine	08/15/1989	VULNERABLE
Carbon 14 age	:	Unknown		0
Wellhead Protection Score	:			55
Wellhead Protection Vulnerability Rating	:			VULNERABLE
Vulnerability Overridden	:			

COMMENTS

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

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

PWSID: 1190012 TIER: 1
SYSTEM NAME: Hastings WHP RANK:
WELL NAME: Well #4 UNIQUE WELL #: 00207993

COUNTY: Dakota TOWNSHIP NUMBER: 115 RANGE: 17 W SECTION: 32 QUARTERS: DABB

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	Low	20
L Score	:	2	
Geologic Data From	:	Well Record	
Year Constructed	:	1961	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	314	5
Well Depth	:	400	
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	:	1000	10
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	4.1 09/12/2016	30
Maximum tritium detected	:	3.7 03/29/2016	VULNERABLE
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		65
Wellhead Protection Vulnerability Rating	:		VULNERABLE
Vulnerability Overridden	:		

COMMENTS

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

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

PWSID: 1190012 TIER: 1
SYSTEM NAME: Hastings WHP RANK:
WELL NAME: Well #5 UNIQUE WELL #: 00207639

COUNTY: Dakota TOWNSHIP NUMBER: 115 RANGE: 17 W SECTION: 29 QUARTERS: ACDD

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	High	VULNERABLE
L Score	:	0	
Geologic Data From	:	Well Record	
Year Constructed	:	1970	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	277	5
Well Depth	:	355	
Casing grouted into borehole?		Unknown	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	:	1225	20
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	8.7 06/03/2008	30
Maximum tritium detected	:	Unknown	0
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		55
Wellhead Protection Vulnerability Rating	:		VULNERABLE
Vulnerability Overridden	:		

COMMENTS

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

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

PWSID: 1190012 TIER: 1
SYSTEM NAME: Hastings WHP RANK:
WELL NAME: Well #6 UNIQUE WELL #: 00207643

COUNTY: Dakota TOWNSHIP NUMBER: 115 RANGE: 17 W SECTION: 34 QUARTERS: CDDB

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	High	0
L Score	:	0	
Geologic Data From	:	Well Record	
Year Constructed	:	1972	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	240	5
Well Depth	:	332	
Casing grouted into borehole?		Unknown	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	:	1010	20
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	11 05/06/1999	VULNERABLE
Maximum tritium detected	:	7.6 01/13/2004	VULNERABLE
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		25
Wellhead Protection Vulnerability Rating	:		VULNERABLE

Vulnerability Overridden :

COMMENTS

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

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

PWSID: 1190012 TIER: 1
SYSTEM NAME: Hastings WHP RANK:
WELL NAME: Well #7 UNIQUE WELL #: 00509053

COUNTY: Dakota TOWNSHIP NUMBER: RANGE: SECTION: QUARTERS:

CRITERIA		DESCRIPTION		POINTS
Aquifer Name(s)	:	Jordan		
DNR Geologic Sensitivity Rating	:	High		0
L Score	:	0		
Geologic Data From	:	Data Inferred From Nearby Wells		
Year Constructed	:	1989		
Construction Method	:	Cable Tool/Bored		0
Casing Depth	:	205		5
Well Depth	:	285		
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	:	1200		20
Pathogen Detected?				0
Surface Water Characteristics?				0
Maximum nitrate detected	:	6.3 02/08/2016		30
Maximum tritium detected	:	4.36 03/29/2016		VULNERABLE
Non-THMS VOCs detected?		Trichloroethene (TCE)	03/03/1992	VULNERABLE
Pesticides detected?				0
Carbon 14 age	:	Unknown		0
Wellhead Protection Score	:			55
Wellhead Protection Vulnerability Rating	:			VULNERABLE
Vulnerability Overridden	:			Jim Walsh

COMMENTS

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

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

PWSID: 1190012 TIER: 1
SYSTEM NAME: Hastings WHP RANK:
WELL NAME: Well #8 UNIQUE WELL #: 00686266

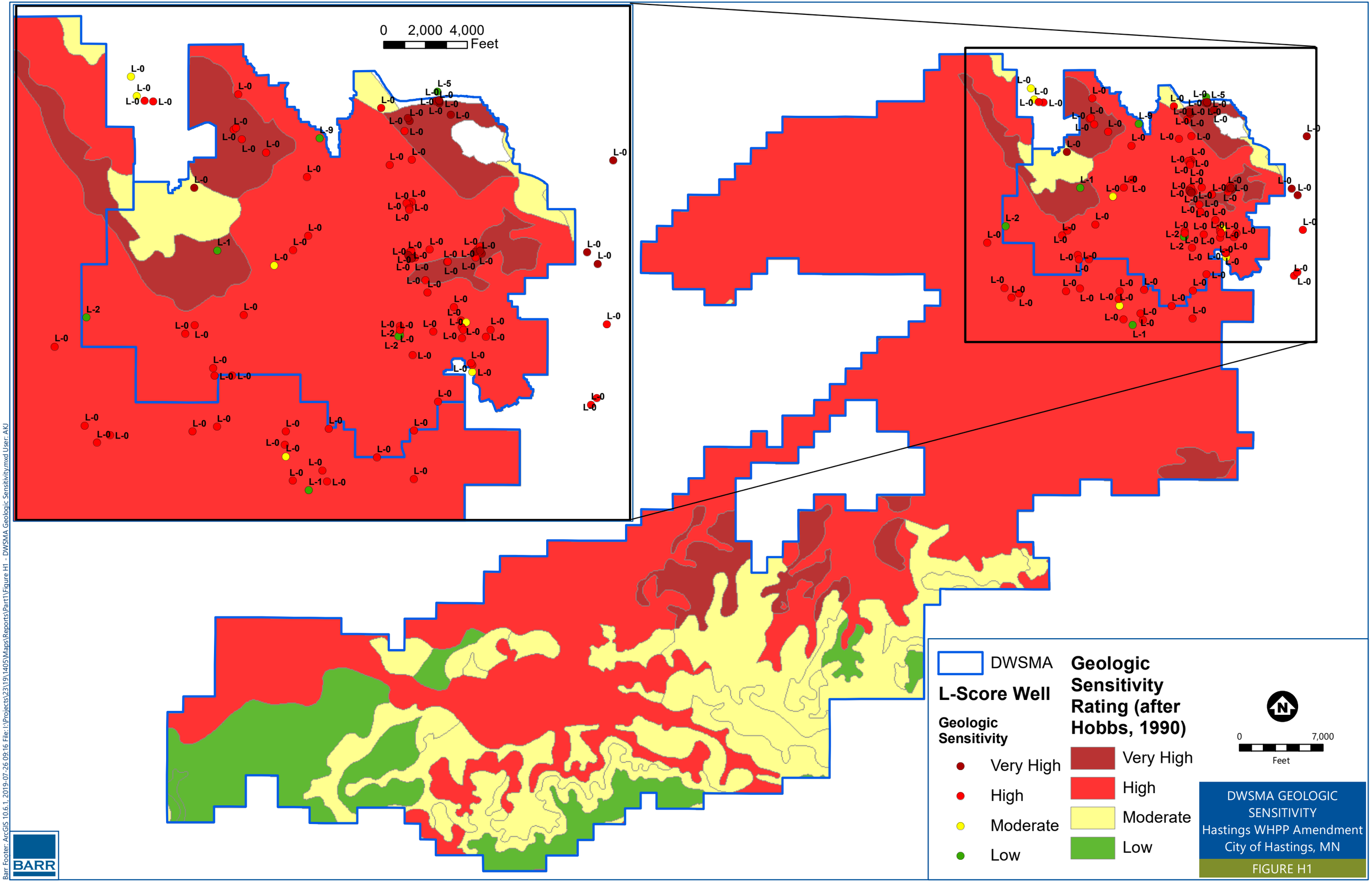
COUNTY: Dakota TOWNSHIP NUMBER: RANGE: SECTION: QUARTERS:

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	High	VULNERABLE
L Score	:	0	
Geologic Data From	:	Well Record	
Year Constructed	:	2006	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	188	10
Well Depth	:	280	
Casing grouted into borehole?		No	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	:	1200	20
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	9 10/02/2013	30
Maximum tritium detected	:	Unknown	0
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		60
Wellhead Protection Vulnerability Rating	:		VULNERABLE
Vulnerability Overridden	:		

COMMENTS

Appendix H

Aquifer Vulnerability Supporting Information


0 2,000 4,000
Feet
DWSMA
L-Score Well
Geologic Sensitivity
Very High
High
Moderate
Low
Geologic Sensitivity Rating (after Hobbs, 1990)
Very High
High
Moderate
Low
0 7,000
Feet
DWSMA GEOLOGIC SENSITIVITY
Hastings WHPP Amendment
City of Hastings, MN
FIGURE H1
BARR
Barr Footer: ArcGIS 10.6.1, 2019-07-26 09:16 File: I:\Projects\23\19\1405\Maps\Reports\Part1\Figure H1 - DWSMA Geologic Sensitivity.mxd User: AKJ

Appendix I

Groundwater Model Files and GIS Shapefiles