City of Fridley 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 Fridley

July 2018

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4300 MarketPointe Drive, Suite 200
Minneapolis, MN 55435
Phone: 952.832.2600
Fax: 952.832.2601

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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.

Digitally signed by John C. Greer
DN: cn=John C. Greer, o=Barr Engineering Co., ou, email=jgreer@barr.com, c=US
Date: 2018.07.05 12:18:39 -05'00'
Adobe Acrobat version: 11.0.23

July 5, 2018

John C. Greer — Date

PG #: 30347

Public Water Supply Profile

The following persons are the contacts for the Fridley Wellhead Protection Plan:

Public Water Supply Contact

Jason Wiehle
Lead Water Operator
Fridley Municipal Center
6431 University Avenue NE
Fridley, Minnesota 55432
Telephone: 763-238-8074
Email: jason.wiehle@fridleymn.gov

Wellhead Protection Manager

Jim Kosluchar
Public Works Director/City Engineer
Fridley Municipal Center
6431 University Avenue NE
Fridley, Minnesota 55432
Telephone: 763-572-3550
Email: jim.kosluchar@fridleymn.gov

Wellhead Protection Consultant

John Greer, PG
Barr Engineering Company
4300 MarketPointe Drive, Suite 200
Minneapolis, Minnesota 55435
Telephone: 952-832-2600
Fax: 952-832-2601
E-mail: jgreer@barr.com

General Information

UNIQUE WELL NUMBER(S) 206674, 206670, 201158, 206675, 206673, 206678, 206669, 206672, 206658, 206657, 209207

SIZE OF POPULATION SERVED 27,208 (2010 Census)

COUNTY Anoka

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. 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 9, were delineated for the City of Fridley.

Geology and Groundwater Flow – The city of Fridley has eleven primary water supply wells:

- Wells 2, 3, 4, and 5 draw water from the Mt. Simon Sandstone aquifer between 656 and 845 feet below ground surface (ft bgs)
- Wells 6, 7, 8, and 9 draw water from the Prairie du Chien Group aquifer between 138 and 265 ft bgs (Wells 6 and 9 are also open to small [22 and 5 feet, respectively] thickness of the Jordan Sandstone.)
- Well 10 draws water from a buried sand and gravel aquifer between 128 and 199 ft bgs
- Well 11 is open to the St. Lawrence Formation aquitard and the Tunnel City Group, Wonewoc Sandstone, and Mt. Simon Sandstone aquifers between 325 and 669 ft bgs (note: the contribution to the total volume pumped by Well 11 from the St. Lawrence is considered negligible relative to the Tunnel City Group, Wonewoc, and Mt. Simon)
- Well 12 draws water from the Jordan Sandstone aquifer between 234 and 276 ft bgs

Regionally, groundwater flow is to the southwest in the shallower aquifers and to the south in the Mt. Simon aquifer.

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 6, 7, 8, 9, 10, 11, and 12 are considered vulnerable to contamination, while Wells 2, 3, 4, and 5 are considered not vulnerable.

DWSMA vulnerability -The vulnerability of the City's aquifer throughout the DWSMA is based on the geologic sensitivity ratings of wells and their monitoring data. Based on this information, regions of high, moderate, and low vulnerability have been assigned to the DWSMA. The majority of the DWSMA has moderate vulnerability, which suggests that water, and any contaminants, may travel from the land surface to the City's aquifers within a time span of a few years to a few decades. High vulnerability, meaning that water may travel from the land surface to the City's aquifers within a time span of months to a few years, and low vulnerability, meaning that water may travel from the land surface to the City's aquifers within a time span of decades to centuries, were assigned to small portions of the DWSMA. Due to the presence of high vulnerability in the DWSMA, additional water quality monitoring has been recommended.

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 (Fridley, 2017). Low levels of trichloroethene (TCE) were detected in Well 9 in 2017 and traces of 1,4-dioxane were detected in multiple wells. Well 10 was shut down in late 2016 due to detections of per- and poly-fluoroalkyl substances (PFAS).

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), wellhead protection areas (WHPAs) and a Drinking Water Supply Management Area (DWSMA) were delineated for the City of Fridley in 2002. Minnesota Rule 4720.5570 states that wellhead protection plans must be reviewed and amended at least every ten years. In addition, the Minnesota Department of Health (MDH) has instituted requirements for inclusion of fracture-flow analysis in the delineation of WHPAs since the last delineation of the City's WHPAs and DWSMA.

As required by Minnesota Rule 4720.5570, a new WHPA and a new DWSMA have been delineated for the City of Fridley. This report summarizes work completed to update the delineation of the Fridley 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 Fridley currently has 11 primary municipal water supply wells. In order of shallowest to deepest aquifer the wells:

- Well 10 (unique number 206658) is completed in the buried Quaternary glacial drift aquifer;
- Wells 7 (unique number 206678) and 8 (unique number 206669) are completed in the Prairie du Chien Group aquifer;
- Wells 6 (unique number 206673) and 9 (unique number 206672) are completed in both the Prairie du Chien Group and Jordan Sandstone aquifers;
- Well 12 (unique number 209207) is completed in the Jordan Sandstone aquifer;
- Well 11 is completed in both the Tunnel City Group-Wonewoc Sandstone and Mt. Simon Sandstone aquifers;
- Wells 2 (unique number 206674), 3 (unique number 206670), 4 (unique number 201158), and 5 (unique number 206675) are completed in the Mt. Simon Sandstone aquifer.

Well locations are shown on Figure 1. Table 2 summarizes construction, use, and vulnerability information for the Fridley water supply wells. Well logs for the City's wells are presented in Appendix A.

2.0 Criteria for Wellhead Protection Area Delineation

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

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, transmissivities of the buried Quaternary glacial drift aquifer, the Prairie du Chien Group aquifer, the Jordan Sandstone aquifer, the Tunnel City Group-Wonewoc Sandstone aquifer, and the Mt. Simon Sandstone aquifer were estimated using pumping tests conducted at Well 10 (Quaternary), Wells 6 and 8 (Prairie du Chien), Brooklyn Center Well 9 (Jordan), Blaine Well 7 (Tunnel City-Wonewoc), and Wells 2 and 3 (Mt. Simon). Summaries of the aquifer tests are included in Appendix B. See Section 2.5 below for details regarding how these transmissivity values were incorporated into the groundwater model.

Analysis of specific capacity data from Well 10 using the TGuess Method (Bradbury and Rothschild, 1985) estimated a transmissivity of 64,000 ft^2/day (5,950 m^2/day) for the buried Quaternary aquifer.

Analysis of data from pumping tests conducted at Wells 6 and 8 estimated a representative transmissivity of 149,000 ft^2/day (13,800 m^2/day) for the Prairie du Chien Group aquifer.

Analysis of data from a pumping test conducted at Brooklyn Center Well 9 (unique number 110493) estimated a representative transmissivity of 2,773 ft^2/day (258 m^2/day) for the Jordan Sandstone aquifer. This transmissivity was scaled by the ratio of the average Jordan thickness at Fridley Wells 2, 3, and 5 (87.3 feet) to the Jordan thickness at Brooklyn Center Well 9 (90 feet) to obtain a representative Jordan transmissivity in Fridley of 2,689 ft^2/day (250 m^2/day).

Analysis of data from a pumping test conducted at Blaine Well 7 (unique number 208616) estimated a representative transmissivity of 1,300 ft^2/day (121 m^2/day) for the combined Tunnel City Group-Wonewoc Sandstone aquifer. This transmissivity was scaled by the ratio of the combined Tunnel City-Wonewoc thickness at Fridley Well 11 (198 feet) to Tunnel City-Wonewoc thickness at Blaine Well 7 (191 feet) to obtain a representative Tunnel City-Wonewoc transmissivity in Fridley of 1,348 ft^2/day (125 m^2/day). In the absence of sufficient data to determine individual transmissivities of the Tunnel City Group and Wonewoc Sandstone, it was assumed that both units have the same hydraulic conductivity and so the transmissivity was simply apportioned between units by the ratio of their individual thicknesses at Well 11 to the combined total. Therefore a transmissivity of 953 ft^2/day (89 m^2/day) was assigned to the Tunnel City

Group (140 feet thick at Well 11) and a transmissivity of 345 ft^2/day (37 m^2/day) was assigned to the Wonewoc Sandstone (58 feet thick at Well 11).

Analysis of two production tests at Well 2 and three production tests at Well 3 estimated a geometric mean transmissivity of 5,048 ft^2/day (469 m^2/day) for the Mt. Simon Sandstone.

2.3 Daily Volume of Water Pumped

Pumping data for the City of Fridley for the period 2013 through 2017 are summarized in Table 3. The largest annual withdrawal for 2013-2017 was 1,299,357,000 gallons in 2016. It should be noted that on average during the period 1995-2014 the City imported approximately 27% of its total distributed water from New Brighton. During the period 2015-2017 the City had to pump its wells more because the New Brighton source was unavailable. The City's Water Supply Plan (Fridley, 2016) projects a 2023 average daily demand of 3.66 million gallons per day. For this plan, it was assumed that the City's wells would supply the full 2023 projected demand (i.e., potential water imports from New Brighton were ignored). Projected 2023 pumping rates for each well were calculated by multiplying the total 2023 projected demand by the 2013-2017 average percentage of total withdrawal for each well. The pumping rate used in the model for each Fridley well for the WHPA delineation was either this 2023 projection or the historical maximum for the period 2013-2017, whichever was greater. The maximum 2013-2017 rates were greater than the projected 2023 rates for all wells. Table 3 summarizes the pumping rates used in the model for delineation of the WHPAs. Unaccounted water (the difference between the total volume pumped annually by the City's wells and the total amount billed to users) averaged approximately 9% from 2010-2015 (Fridley, 2016).

2.4 Conceptual Hydrogeologic Model

The regional hydrogeologic conceptual model is presented in Metropolitan Council (2014). Additional geological information is included below, along with discussion of groundwater flow boundaries and flow directions specific to the Fridley 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 west to east cross section that intersects north to south cross section B-B' (Figure 3) at Fridley Well 4.

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

Mt. Simon Sandstone

The Cambrian-aged Mt. Simon Sandstone consists of multiple beds of medium- to coarse-grained quartz sandstone intermixed with beds of siltstone and feldspathic sandstone (Mossler, 2012). The formation is 125-200 feet thick in Anoka County. The Mt. Simon Sandstone is overlain by the Eau Claire Formation (a confining unit) throughout Fridley.

Eau Claire Formation

The Cambrian-aged Eau Claire Formation is comprised of very fine feldspathic sandstone, siltstone, and shale, and is 75-80 feet thick in Anoka County (Mossler, 2012). The Eau Claire Formation functions as a regional confining unit throughout Fridley.

Wonewoc Sandstone (formerly Ironton and Galesville Sandstones)

The Cambrian-aged Wonewoc Sandstone is fine- to coarse-grained, quartzose sandstone, with its upper part coarser-grained than its lower part (Mossler, 2012). It is 50-60 feet thick in Anoka County.

Tunnel City Group (formerly Franconia Formation)

The Cambrian-aged Tunnel City Group is divided into two formations: the Mazomanie Formation and the Lone Rock Formation. The Mazomanie Formation is mostly a fine- to medium-grained friable, quartz sandstone. The Lone Rock Formation underlies the Mazomanie Formation and consists of fine grained glauconitic, feldspathic sandstone and shale with dolostone interclasts (Mossler, 2012). The Tunnel City Group is the uppermost bedrock in northwestern Fridley. It is 135 to 180 feet thick where not eroded. The Mazomanie Formation is present in the uppermost 60-80 feet of the unit.

St. Lawrence Formation

The Cambrian-aged St. Lawrence Formation is composed of dolomitic, feldspathic siltstone with interbedded very fine-grained sandstone and shale (Mossler, 2012). The St. Lawrence Formation is 38 to 50 feet thick in Anoka County and typically functions as a confining unit between the overlying Jordan Sandstone and the underlying Tunnel City Group.

Jordan Sandstone

The Cambrian-aged Jordan Sandstone consists of two interlayered facies: a medium- to coarse-grained, friable, quartz sandstone and a very fine-grained, feldspathic sandstone with lenses of siltstone and shale (Mossler, 2012). 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 in the bedrock valley within which Wells 10 and 11 are located.

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, 2012). The Prairie du Chien Group is the uppermost bedrock across much of Fridley. It is 125 to 140 feet thick where not eroded. 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 fractures and macropores (Berg, 2016).

Quaternary Glacial Drift

The Quaternary-aged sediments that overlie the bedrock in Fridley were deposited by multiple glacial advances during the Pleistocene Epoch (Meyer et al., 2013) and vary in thickness from approximately 50 feet thick where the St. Peter Sandstone is the uppermost bedrock at the western end of cross-section A-A′ to nearly 300 feet thick where the Tunnel City Group is the uppermost bedrock in northwestern Fridley. The west-east cross section (Figure 2) shows the Quaternary sediments thickening from west to east in Fridley, with these deposits primarily composed of sand and gravel. A confining unit of clay and silt is first encountered at Well 7 and continues to the east, separating the Quaternary sand and gravel into shallow and deep units. Well 10 is completed in the deep unit in a buried valley to the north of the cross section.

2.4.2 Flow Boundaries

The Mississippi River to the west of Fridley is a regional groundwater flow boundary. Local flow directions, especially in the Mt. Simon aquifer, are influenced by multiple high-capacity pumping wells in the area; see Section 2.6 below for more discussion.

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-NWT (Niswonger, et al., 2011) was used for this study to simulate groundwater flow in the hydrostratigraphic units from the Quaternary aquifer down to the Mt. Simon Sandstone. MODFLOW-NWT 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

Since the previous Fridley Wellhead Protection Plan was prepared, the Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3.0 (Metropolitan Council, 2014) was developed by Barr Engineering for the Metropolitan Council. A new model based on Metro Model 3 was developed by Barr for the Coon Rapids Wellhead Protection Plan Amendment (Barr, 2016). This model includes local edits to the Metro Model 3 hydraulic conductivity field and projected 2020 pumping rates for the Coon Rapids municipal wells. Because Coon Rapids is adjacent to Fridley, the Coon Rapids model was used as the base model for the new Fridley WHPA delineations.

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

- Layer 1: Quaternary glacial drift or Platteville and Glenwood Formations (where present)
- 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 Fridley (i.e., the Mississippi River) as well as lakes in the area are simulated using the River Package within MODFLOW-NWT. Baseflow measurements for rivers and streams in the area were used during calibration of Metro Model 3.

Recharge for the groundwater flow model was determined using the SWB recharge model (Westenbroek et al., 2010) for the Twin Cities metropolitan area as described in Metropolitan Council (2012). Monthly precipitation data for Fridley from the last 5 years is summarized in Table 4.

Modifications made to the base model for the Fridley 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 model grid was refined from the 500-m square cells in the far field of the base model down to 125-m square cells throughout the Fridley city limits and down to 7.81-m square cells in the immediate vicinity of the Fridley wells.
- The Layer 2 bottom surface was adjusted in the vicinity of Well 10 so that the open interval of this well would be entirely contained within Layer 3 instead of straddling the contact between Layers 2 and 3.
- 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.
- Horizontal hydraulic conductivity values (Kx) were updated so that model layer transmissivities in the vicinity of the Fridley wells match aquifer test transmissivities (Section 2.2; Appendix B) as described below. Table C1 in Appendix C summarizes the effective hydraulic conductivity values used in the model in order to match the aquifer test transmissivities. Appendix C also includes maps of model hydraulic conductivity fields for the modified model layers (Figures C1-C7).
    - Quaternary. The estimated transmissivity of 64,000 ft^2/day (5,946 m^2/day) was divided by the saturated aquifer thickness of 161 ft (49 m) to obtain an effective Kx value of 398 ft/day (121 m/day). This Kx value was applied within the buried valley containing Well 10 in Layer 3. The detailed Quaternary mapping from the Anoka County Geologic Atlas (Meyer et al., 2013) was used to infer appropriate regions within which to apply the pumping test Kx value in Layers 1 and 2. A Kx/Kz ratio of 10 was assumed for all modified Quaternary cells.
    - St. Peter Sandstone. The Metro Model 3 Kx value of 206 ft/day (62.7 m/day) and Kz value of 67.3 ft/day (20.5 m/day) seemed too high for this unit. A St. Peter Kx value of 38.7 ft/day (11.8 m/day) from Runkel et al. (2003) was applied to model cells

representing the St. Peter Sandstone within the refined area in Layer 2. A Kx/Kz ratio of 10 was assumed for these cells.
    - Prairie du Chien. The representative pumping test transmissivity of 149,000 ft^2/day (135 m^2/day) was divided by the formation thickness of 135 ft (41 m) to obtain an effective Kx value of 1,104 ft/day (336 m/day). This Kx value was applied to model cells representing the Prairie du Chien Group within the refined grid area in Layer 3. A Kx/Kz ratio of 66, derived from the calibrated Metro Model 3 Kx and Kz for the Prairie du Chien Group in this area, was assumed for these cells.
    - Jordan. The scaled pumping test transmissivity of 2,689 ft^2/day (250 m^2/day) was divided by the average Jordan thickness in Fridley of 87.3 ft (27 m) to obtain an effective Kx value of 30.8 ft/day (9.39 m/day). This Kx value was applied to model cells representing the Jordan Sandstone within the refined grid area in Layer 4. A Kx/Kz ratio of 10 was assumed for these cells.
    - Tunnel City Group and Wonewoc Sandstone. As described above in Section 2.2, the combined transmissivity was apportioned between the two units by assuming that the hydraulic conductivity of both units was the same. Therefore, the scaled pumping test transmissivity of 1,348 ft^2/day (125 m^2/day) for the combined Tunnel City Group-Wonewoc Sandstone aquifer was divided by the combined thickness of 198 feet (60.3 m) to obtain an effective hydraulic conductivity of 6.81 ft/day (2.08 m/day). This Kx value was applied to model cells within the refined zone in Layers 6 and 7. A Kx/Kz ratio of 100 was assumed for the Layer 6 (Tunnel City) cells based on the significant fraction of shale in the Tunnel City Group indicated on the logs for the Fridley wells that penetrate this unit. A Kx/Kz ratio of 10 was assumed for the Layer 7 (Wonewoc) cells.
    - Mt. Simon Sandstone. The pumping test transmissivity of 5,048 ft^2/day (469 m^2/day) was divided by the formation thickness of 206.5 ft (62.9 m) to obtain an effective Kx value of 24.4 ft/day (7.45 m/day). This Kx value was applied to model cells within the refined grid area in Layer 9. A Kx/Kz ratio of 10 was assumed for these cells.
- 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. Plots of modeled versus measured heads are included as Figures C8 and C9 in Appendix C. Full discussion of the Metro Model 3 calibration is presented in Metropolitan Council (2014).
- The pumping rates for the City's wells were changed to the model input rates shown in Table 3.
- Pumping rates for 95 high-capacity wells within 3 kilometers of Fridley were updated to use 2012-2016 averages. A list of these wells is included as Table C2 in Appendix C.

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

2.6 Groundwater Flow Field

The groundwater flow field used for delineation of the WHPAs was determined by the groundwater flow model; modeled contours for the Prairie du Chien Group/Quaternary glacial drift (Layer 3), Jordan

Sandstone/Quaternary glacial drift (Layer 4), Tunnel City Group and Wonewoc Sandstone (Layers 6 and 7), and Mt. Simon Sandstone (Layer 9) are shown on Figures 4, 5, 6, and 7, respectively.

In general, Figures 4, 5, and 6 show westerly to southwesterly flow directions in the Quaternary, Prairie du Chien, Jordan, and Tunnel City-Wonewoc aquifers. The modeled Quaternary, Prairie du Chien, and Jordan flow directions are consistent with published contour maps for these aquifers in Anoka County (Berg, 2016); the Tunnel City and Wonewoc contour maps from the same publication do not show contours in Fridley. Figure 7 shows generally southerly flow directions in the Mt. Simon aquifer, with a notable cone of depression around Fridley Wells 2-5. Berg (2016) shows southerly- to southeasterly flow in the Mt. Simon in this area. Based on these comparisons and the acceptable calibration of the groundwater model, the groundwater flow field was determined to be of acceptable accuracy.

3.0 Delineation of the Wellhead Protection Area

Delineation of the WHPA for the Fridley wells involved the evaluation of both porous media flow and fracture flow 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 Fridley. The porous media capture zone for the Fridley well field was delineated using the software program MODPATH (Version 6; Pollock, 2012) 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 = 0.2
- Prairie du Chien Group = 0.056
- Jordan Sandstone = 0.2
- St. Lawrence Formation = 0.2
- Tunnel City Group = 0.2
- Wonewoc Sandstone = 0.2
- Eau Claire Formation = 0.01
- Mt. Simon 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 Quaternary glacial drift, Prairie du Chien Group, Jordan Sandstone, Tunnel City Group-Wonewoc Sandstone, and Mt. Simon Sandstone aquifers. Table C1 in Appendix C summarizes the upper and lower hydraulic conductivity bounds used in the sensitivity analysis. These values were calculated from (1) pumping test transmissivity ranges for the Tunnel City-Wonewoc and Mt. Simon aquifers (Appendix B), (2) plus and minus 50 percent of the base hydraulic conductivity for the Quaternary glacial drift and Jordan Sandstone aquifers, and (3) the upper pumping test transmissivity and original Metro Model 3 hydraulic conductivity for the Prairie du Chien Group aquifer. The ratio of horizontal to vertical hydraulic conductivity used in the base model run was preserved for each sensitivity run. The model was most sensitive to raising the hydraulic conductivity of the Tunnel City Group and Wonewoc Sandstone and lowering the hydraulic conductivity of the Mt. Simon Sandstone. A plot of the sensitivity analysis results is included in Appendix C (Figure C10).

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 conducted for the upper and lower conductivity bounds of each sensitivity run. Particle traces from all simulations were used to delineate the 1-year and 10-year porous media capture zones for each well.

3.2 Fracture Flow Evaluation

As noted in Section 1.0, Wells 6, 7, 8, and 9 are open to the Prairie du Chien Group. Well 12 is open to the Jordan Sandstone, which is likely hydraulically connected to the 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 2 for Wells 6-9 and Delineation Technique Number 4 (wells open only to a porous media aquifer that is hydraulically connected to a fractured or solution-weathered aquifer) for Well 12. A summary of the calculations used in the delineation of fracture flow capture zones is presented in Appendix D. The fracture flow capture zones are shown on Figure 8.

3.2.1 Fixed Radius Capture Zones and Upgradient Extensions

Due to the close proximity of Wells 6, 7, 8, and 9, these wells were treated as a single well for the fracture flow delineation. Coordinates for this effective single well were determined using a pumping-rate weighted average of the coordinates of each individual well. The pumping rate applied to the effective single well was the sum of the individual model pumping rates for Wells 6, 7, 8, and 9 (Table 3). Delineation Technique Number 1 was used to delineate a 1-year fixed radius capture zone for the combined Wells 6-9. Next, following the MDH guidelines (MDH, 2011a), the ratio of the well discharge to the discharge vector was calculated. This ratio was less than 3,000, so Delineation Technique Number 2 was used to delineate a 5-year fixed radius capture zone with a 5-year upgradient extension. Both the 5-year fixed radius capture zone and the 5-year upgradient extension were truncated along the edge of the Prairie du Chien Group to the north and east of the wells.

Although Well 12 is 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 contribution from model layer 3 (Prairie du Chien Group) to the baseline 10-year porous media capture zone for Well 12. Flow from model layer 3 to model layer 4 within the Well 12 capture zone was approximately 50% of the Well 12 pumping rate. 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; since the calculated percentage for Well 12 was above this threshold, it was necessary to delineate a fracture flow capture zone for this well.

The ratio of the well discharge to the discharge vector was calculated for Well 12 using the contribution from model layer 3 calculated by ZONEBUDGET as the pumping rate. This ratio was less than 3,000, so an upgradient extension was required for the 10-year fracture flow capture zone. Delineation Technique Number 1 was used to delineate a 1-year fixed radius capture zone and Delineation Technique Number 2 was used to delineate a 5-year fixed radius capture zone with a 5-year upgradient extension. The 5-year fixed radius capture zone and the 5-year upgradient extension were truncated along the edge of the Prairie du Chien Group to the south and northeast, respectively, of Well 12.

3.3 WHPA Delineations

The composite 10-year porous media capture zones, 5-year fixed radius fracture flow capture zones, and 5-year upgradient extensions define the WHPA. The Emergency Response Area (ERA) is delineated for each well by the composite 1-year porous media capture zones and 1-year fixed radius fracture flow capture zones. The WHPA and ERAs are shown on Figure 9.

3.4 Conjunctive Delineation

While there is an area of high aquifer vulnerability within the DWSMA, as discussed below in section 6.0, current MDH policy is to recommend stable isotope sampling to assess groundwater/surface water interaction. Stable isotope samples have not yet been collected from the City's wells but are recommended (see Section 7.0). In the absence of isotope data, a conjunctive delineation (i.e., inclusion of a surface water catchment area) was not completed at this time.

4.0 Delineation of the Drinking Water Supply Management Area

The Fridley DWSMA encompasses the WHPA with boundaries that correspond to geographically identifiable features (e.g., roads, parcel boundaries, quarter-quarter section lines). 2017 parcel data from Anoka and Ramsey Counties and quarter-quarter section lines were used to delineate the DWSMA, which extends east of the Fridley city limits into New Brighton and Mounds View and north into Spring Lake Park. The Fridley DWSMA is shown on Figure 9.

5.0 Well Vulnerability Assessment

MDH evaluated the vulnerability of the Fridley municipal wells to contamination from contaminants released at the surface. The evaluation parameters include geology, well construction, pumping rate, and water quality. Fridley Wells 2, 3, 4, and 5 are classified as “not vulnerable.” Fridley Wells 6, 7, 8, 9, 10, 11, and 12 are classified as “vulnerable.” Copies of the MDH well vulnerability scoring sheets for the Fridley wells are included in Appendix E.

6.0 Drinking Water Supply Management Area Vulnerability Assessment

The vulnerabilities of the Quaternary glacial drift, Prairie du Chien Group, and Jordan Sandstone within the DWSMA associated with the Fridley wells were evaluated in a manner consistent with MDH guidance for assessing aquifer vulnerability (MDH, 1997) using geologic sensitivities based on L scores computed from boring log data and water quality data for the Fridley 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 months
- 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 majority of the Fridley WHPA, and therefore also the DWSMA, is defined by the fracture flow capture zones for the Prairie du Chien Group. Therefore, the geologic sensitivity of the Prairie du Chien group was assumed to represent the geologic sensitivity of the DWSMA. The geologic sensitivity of the Prairie du Chien Group within the Fridley DWSMA was evaluated using 2 methods:

- Within Anoka County - Pollution sensitivity map for the top of bedrock surface from Part B of the Anoka County Geologic Atlas (Berg, 2016). While the Prairie du Chien Group is not the uppermost bedrock throughout the DWSMA, the overlying St. Peter Sandstone is thin (< 20 feet thick) at the Fridley wells where it is encountered. In the buried valley where the Prairie du Chien Group is not present, the pollution sensitivity maps for the deep Quaternary (Sx aquifer) and the top of bedrock were identical.
- Within Ramsey County - “L scores” based on the thickness of low permeability units at CWI well locations in the vicinity of the DWSMA, computed using the MDH L score tool [See MnDNR (1991) for a discussion of how to determine L scores]. L scores were calculated for 10 wells completed in the Prairie du Chien Group and/or Jordan Sandstone in the vicinity of the Fridley DWSMA in Ramsey County.

Figure F1 in Appendix F shows a composite geologic sensitivity map for the Fridley DWSMA. Geologic sensitivity is low over a majority of the DWSMA, though regions of high and very high geologic sensitivity exist both east and west of Fridley’s primary well field.

The second step in the assessment is to refine the geologic sensitivity using water quality data from the water supply wells. In their source water assessment program, MDH uses a classification scheme that rates the vulnerability of groundwater to surface contamination based on sampling data for a list of parameters that indicate man-made impacts or similarity to rainwater (MDH, 2011) and gives some indication of relative groundwater residence time in the subsurface. There are five main categories lettered A to E in descending order of vulnerability, ranging from Category A which indicates that groundwater has been recharged rapidly from precipitation to Category E which indicates old, saline groundwater with a very long residence time in the subsurface. Table 5 summarizes the available water quality data from the Fridley wells. Water from Wells 2, 3, and 4 was classified as Category D1 ("Pre-1953 Impacted Non-Pathogen"), water from Well 5 was classified as Category D2 ("Pre-1953 Vintage"), water from Wells 6, 8, and 12 was classified as Category B4 ("Post-1953 Impacted Non-Pathogen"), and water from Well 10 was classified as Category B3 ("Road Salt/Water Softener Impacted").

Tritium samples were collected at Wells 10 and 11 in 1999 and 1997, respectively. 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 10 and 11 at concentrations of 6.5 and 1.1 T.U., respectively.

When water quality data does not indicate the presence of tritium or other constituents that are consistent with contamination from the surface the aquifer vulnerability classification and the geologic sensitivity rating can be the same. 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. When tritium has been detected in a well, geologic sensitivity ratings of low or very low would not be consistent with water quality data, unless groundwater flow information would indicate a nearby connection to an area of rapid vertical movement of water (e.g., a buried bedrock valley filled with sand and gravel) where water could travel from the surface to the aquifer quickly enough that tritium could be detected in a well with a geologic sensitivity rating of low or very low. If there is no hydraulic connection to an area of rapid vertical movement of water, the aquifer vulnerability would need to be classified as no lower than moderate to explain the presence of tritium in the well.

Similarly, when other contaminants (such as volatile organic compounds [VOCs] and per- and polyfluoroalkyl substances [PFAS]) have been detected in a well, geologic sensitivity ratings of low or very low would not be consistent with these detections. If there is no hydraulic connection to an area of rapid vertical movement of water, the aquifer vulnerability would need to be classified as no lower than moderate to explain the presence of these contaminants in the well.

As noted earlier, the majority of the Fridley DWSMA is defined by the fracture flow capture zones for the Prairie du Chien Group; the remainder is defined by the porous media capture zones for the Quaternary (Well 10), Jordan (Well 12), and Tunnel City-Wonewoc (Well 11) aquifers. Tritium has been detected at both Wells 10 and 11, so moderate vulnerability was assigned to these areas of the DWSMA because the geologic sensitivity was low. No tritium data are available for the Prairie du Chien and Jordan aquifers; however, low levels of VOCs have been detected over the years at Wells 6, 7, 8, 9, and 12 (see Appendix E) and PFAS have been detected at Well 10. The low-level detections are consistent with a travel time of decades to the wells, so moderate vulnerability was assigned to the areas of the DWSMA with low geologic sensitivity defined by the fracture flow and Jordan porous media capture zones. Moderate geologic sensitivity was mapped directly to moderate vulnerability. Areas of high and very high geologic sensitivity larger than 40 acres were mapped to high vulnerability. Small areas of low vulnerability were assigned in the far eastern extents of the Fridley DWSMA for consistency with the overlapping Mounds View DWSMA. The final aquifer vulnerability map is shown on Figure 10.

7.0 Recommendations

It is recommended that the City work with the MDH to conduct tritium sampling of the municipal wells in order to have current data available when updating the aquifer vulnerability assessment as part of the next wellhead protection plan amendment. A minimum list of suggested wells for tritium sampling includes Well 3 (Mt. Simon), Well 6 (Prairie du Chien-Jordan), and Well 12 (Jordan).

As discussed in Sections 3.4 and 6.0, there are areas of high aquifer vulnerability within the Fridley DWSMA but a conjunctive delineation (i.e., inclusion of a surface water catchment area) was not completed at this time due to the absence of water quality data (i.e., stable isotopes) that would indicate rapid recharge of water from the ground surface (including surface water bodies) to the aquifer. The wells most likely to be influenced by potential rapid recharge of surface water are Wells 6, 7, 8, and 9. Stable isotope sampling of these wells is recommended prior to the next wellhead protection plan amendment to assess groundwater/surface water interaction and determine the need for a conjunctive delineation.

8.0 Supporting Data Files

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

The groundwater model can be reviewed using MODFLOW-NWT (Niswonger et al., 2011). MODPATH files can be reviewed using MODPATH Version 6 (Pollock, 2012).

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
Fridley 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, CWI
Subsurface data	M	H	H	H	MGS, MDH, CWI
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, Anoka 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 Fridley
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

CWI – Minnesota County 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)
Fridley WHPP Amendment

Data Element	Present and Future Implications: Use of the Wells	Delineation Criteria	Quality and Quantity of Well Water	Land and Groundwater Use in DWSMA	Data Source
Public drainage systems map/ list	L	L	L	L	City of Fridley
Records of well construction, maintenance, and use	H	H	L	L	City of Fridley, CWI, 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	CWI, 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	MDH, MPCA

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

CWI – Minnesota County 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
Fridley WHPP Amendment

Local Well ID	Unique Number	Use/ Status[1]	Casing Diameter (in.)	Casing Depth (ft.)	Well Depth (ft.)	Year Constructed	Aquifer	Well Vulnerability
2	206674	P	24 x 16	675	842	1960	Mt. Simon	Not Vulnerable
3	206670	P	24 x 16 x 10	784	836	1961	Mt. Simon	Not Vulnerable
4	201158	P	24 x 16	663	831	1961	Mt. Simon	Not Vulnerable
5	206675	P	16	656	845	1961	Mt. Simon	Not Vulnerable
6	206673	P	24	153	255	1972	Prairie du Chien - Jordan	Vulnerable
7	206678	P	24 x 16 x 12	138	262	1970	Prairie du Chien	Vulnerable
8	206669	P	16 x 12	138	265	1969	Prairie du Chien	Vulnerable
9	206672	P	30 x 24	153	255	1972	Prairie du Chien - Jordan	Vulnerable
10	206658	P	24 x 16	128	199	1969	Confined Quaternary	Vulnerable
11	206657	P	30 x 24	325	669	1970	St. Lawrence – Mt. Simon	Vulnerable
12	209207	P	30 x 24	234	276	1970	Jordan	Vulnerable

[1] P = Primary

Table 3

Annual and Projected Pumping Rates for Fridley Wells
Fridley WHPP Amendment

		Total Annual Withdrawal (gal/yr)				
Unique Number	Well Name	2013	2014	2015	2016	2017
206674	2	74,051,000	79,307,000	97,780,000	36,620,000	54,288,000
206670	3	80,778,000	7,492,000	6,361,000	180,586,000	188,104,000
201158	4	44,591,000	77,042,000	96,109,000	105,095,000	123,090,000
206675	5	26,970,000	28,949,000	86,516,000	84,889,000	52,376,000
206673	6	38,244,000	41,605,000	70,681,000	144,788,000	155,268,000
206678	7	141,000	6,201,000	193,000	34,329,000	13,958,000
206669	8	152,578,933	119,448,000	135,190,000	261,475,000	286,642,000
206672	9	62,768,000	140,100,000	150,352,000	56,294,000	49,938,000
206658	10	114,662,000	104,938,000	105,434,000	10,079,000	48,000
206657	11	163,316,000	124,015,000	116,542,000	90,609,000	38,966,000
209207	12	217,233,000	178,272,000	214,798,000	294,593,000	271,900,000
	Totals	975,332,933	907,369,000	1,079,956,000	1,299,357,000	1,234,578,000

Source: MPARS, City water use records

		Percentage of Annual Withdrawal					
Unique Number	Well Name	2013	2014	2015	2016	2017	Average Annual % of Withdrawal
206674	2	7.6%	8.7%	9.1%	2.8%	4.4%	6.5%
206670	3	8.3%	0.8%	0.6%	13.9%	15.2%	7.8%
201158	4	4.6%	8.5%	8.9%	8.1%	10.0%	8.0%
206675	5	2.8%	3.2%	8.0%	6.5%	4.2%	4.9%
206673	6	3.9%	4.6%	6.5%	11.1%	12.6%	7.8%
206678	7	0.0%	0.7%	0.0%	2.6%	1.1%	0.9%
206669	8	15.6%	13.2%	12.5%	20.1%	23.2%	16.9%
206672	9	6.4%	15.4%	13.9%	4.3%	4.0%	8.8%
206658	10	11.8%	11.6%	9.8%	0.8%	0.0%	6.8%
206657	11	16.7%	13.7%	10.8%	7.0%	3.2%	10.3%
209207	12	22.3%	19.6%	19.9%	22.7%	22.0%	21.3%

Table 3

Annual and Projected Pumping Rates for Fridley Wells
Fridley WHPP Amendment

		Projected Water Use (2023)			Maximum Total Pumping for Model Input[3]		
Unique Number	Well Name	Total[1] (gal/yr)	% of Total Projected Water Use Well[2]	Projected Well Pumpage Based on % (gal/yr)	gal/yr	gal/day	m^3/day
206674	2		6.5%	86,833,500	97,780,000	267,890	1,014
206670	3		7.8%	104,200,200	188,104,000	515,353	1,951
201158	4		8.0%	106,872,000	123,090,000	337,233	1,277
206675	5		4.9%	65,459,100	86,516,000	237,030	897
206673	6		7.8%	104,200,200	155,268,000	425,392	1,610
206678	7		0.9%	12,023,100	34,329,000	94,052	356
206669	8		16.9%	225,767,100	286,642,000	785,321	2,973
206672	9		8.8%	117,559,200	150,352,000	411,923	1,559
206658	10		6.8%	90,841,200	114,662,000	314,142	1,189
206657	11		10.3%	137,597,700	163,316,000	447,441	1,694
209207	12		21.3%	284,546,700	294,593,000	807,104	3,055
	Totals	1,335,900,000		1,335,900,000	1,694,652,000	4,642,882	17,576

Appropriation 2,400,000,000

[1] 2023 projected average daily demand of 3.66 million gallons per day from Fridley Water Supply Plan (City of Fridley, 2016)

[2] Percentages for all wells are based the average % of annual withdrawal for the period 2013 through 2017

[3] For each well, the greater of the estimated pumpage based on projected 2023 withdrawal and actual annual pumpage for 2013 - 2017.

Table 4

Fridley Precipitation Data 2013-2017
Fridley WHPP Amendment

Month	2013	2014	2015	2016	2017	Average
January	0.69	1.37	0.23	0.28	0.75	0.66
February	1.12	1.51	0.36	0.50	0.68	0.83
March	2.03	0.79	0.72	1.54	0.62	1.14
April	3.78	7.43	1.88	4.28	2.52	3.98
May	5.00	5.02	5.49	2.69	7.11	5.06
June	7.43	8.02	3.82	3.29	3.51	5.21
July	3.61	2.76	7.14	4.88	2.45	4.17
August	1.05	4.39	4.20	9.66	6.01	5.06
September	1.33	1.60	4.56	8.45	1.43	3.47
October	4.06	1.16	2.32	3.28	6.07	3.38
November	0.44	1.15	3.95	3.39	0.51	1.89
December	1.60	0.95	1.55	1.88	0.70	1.34
Total	32.14	36.15	36.22	44.12	32.36	36.20

Source: Minnesota Climatology Working Group

Table 5

Fridley Water Quality Data
Fridley WHPP Amendment

Well	Sample Date	Aquifer	Br (mg/L)	Cl (mg/L)	Cl/Br	NO_3 (mg/L)	SO_4 (mg/L)	NH_3 (mg/L)	^3H (TU)	MDH Classification
2	7/23/2013	Mt. Simon	0.18	38.2	212	< 0.05	2.93	0.32	-	D1(1)
3	7/23/2013	Mt. Simon	0.1	19.5	195	< 0.05	2.54	0.29	-	D1(1)
4	6/4/2007	Mt. Simon	0.1	22.6	226	-	3.58	-	-	D1(1)
5	7/23/2013	Mt. Simon	0.04	7.27	182	< 0.05	1.77	0.27	-	D2
6	7/23/2013	Prairie du Chien - Jordan	0.04	24.4	610	< 0.05	27.6	0.18	-	B4(2)
8	7/23/2013	Prairie du Chien	0.04	19.6	490	< 0.05	25	0.16	-	B4(2)
10	7/23/2013	Quaternary	0.03	55.1	1837	< 0.05	38.4	0.34	6.5(3)	B3
11	4/23/1997	St. Lawrence-Mt. Simon	-	-	-	-	-	-	1.1	-(4)
12	7/23/2013	Jordan	0.03	8.75	292	0.38(5)	8.02	0.34	-	B4(6)

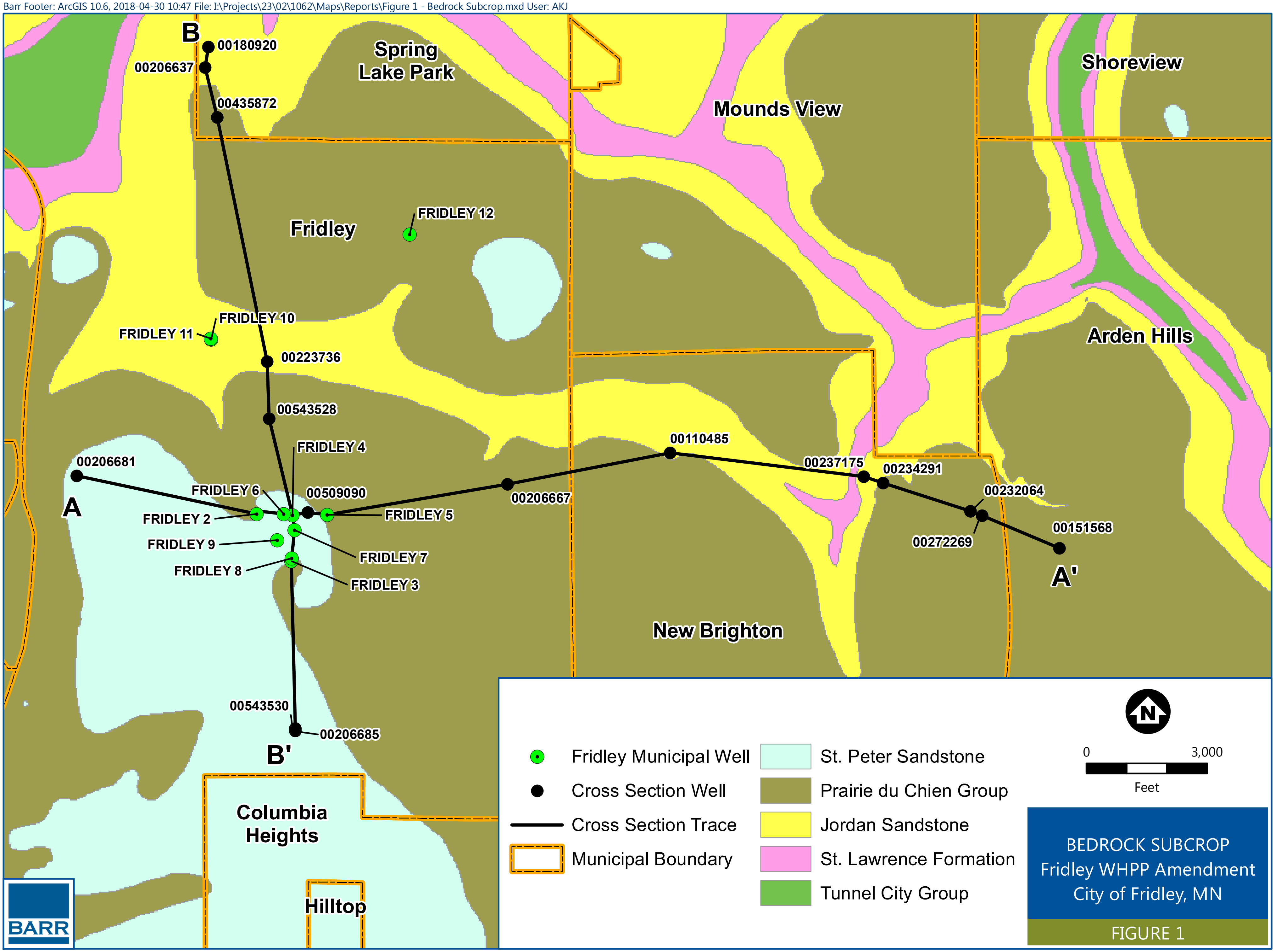
Notes:

(1) Cl/Br ratio is not greater than 250 but Cl is too high for D2 classification.
(2) B4 designation chosen despite lack of ^3H data due to detections of 1,1,2-Trichloroethane
(3) Tritium sample collected on 11/4/1999
(4) Insufficient data to classify the water from this well
(5) NO_3 sample collected on 5/20/2014
(6) B4 designation chosen despite lack of ^3H data due to detections of xylenes

MDH Classification	Description
B3	Road Salt/Water Softener Impacted
B4	Post-1953 Impacted Non-Pathogen
C	Post-1953 Unimpacted
D1	Pre-1953 Impacted Non-Pathogen
D2	Pre-1953 Vintage

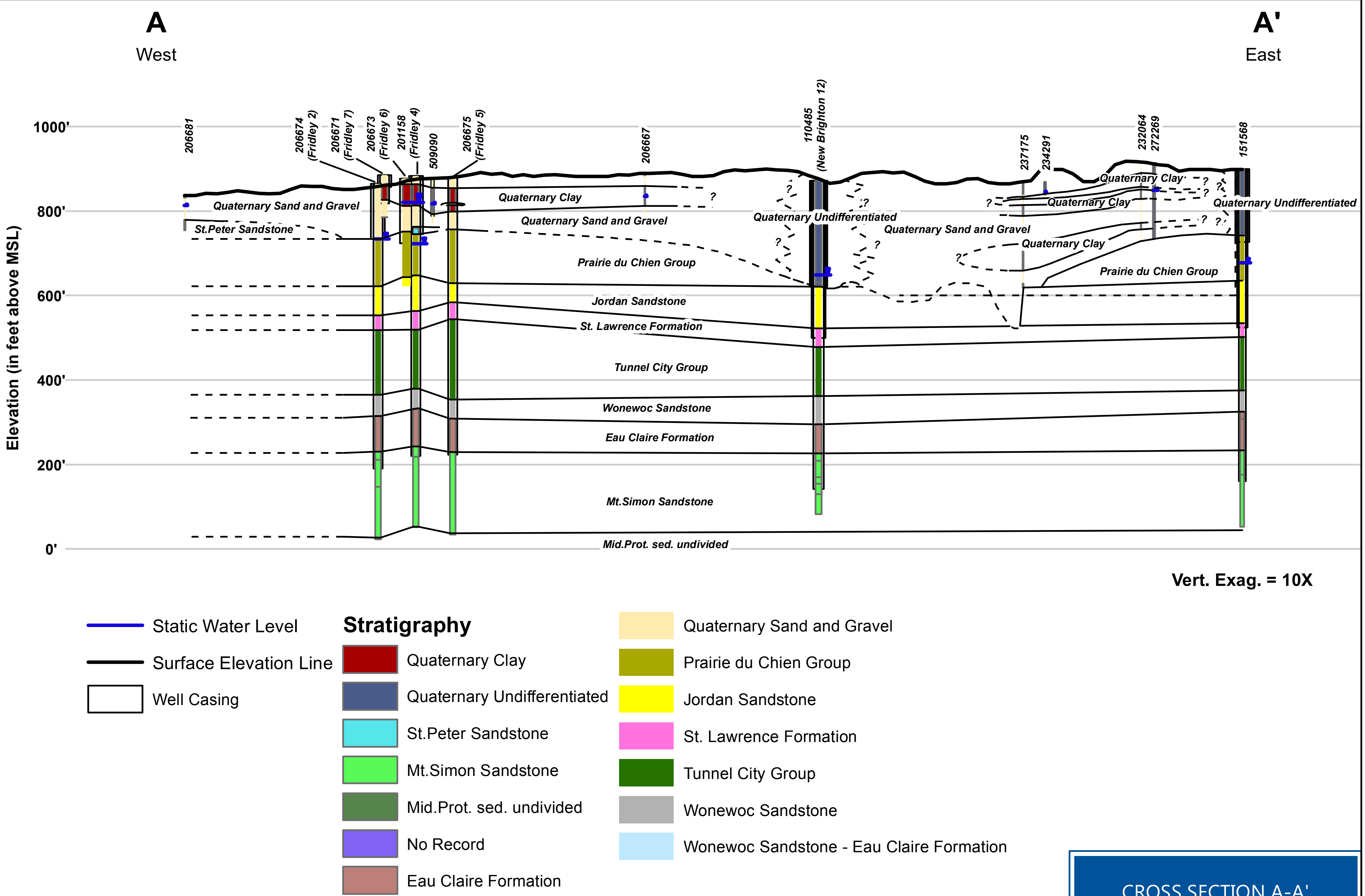
Figures

Barr Footer: ArcGIS 10.6, 2018-04-30 10:47 File: I:\Projects\23\02\1062\Maps\Reports\Figure 1 - Bedrock Subcrop.mxd User: AKJ



BEDROCK SUBCROP
Fridley WHPP Amendment
City of Fridley, MN

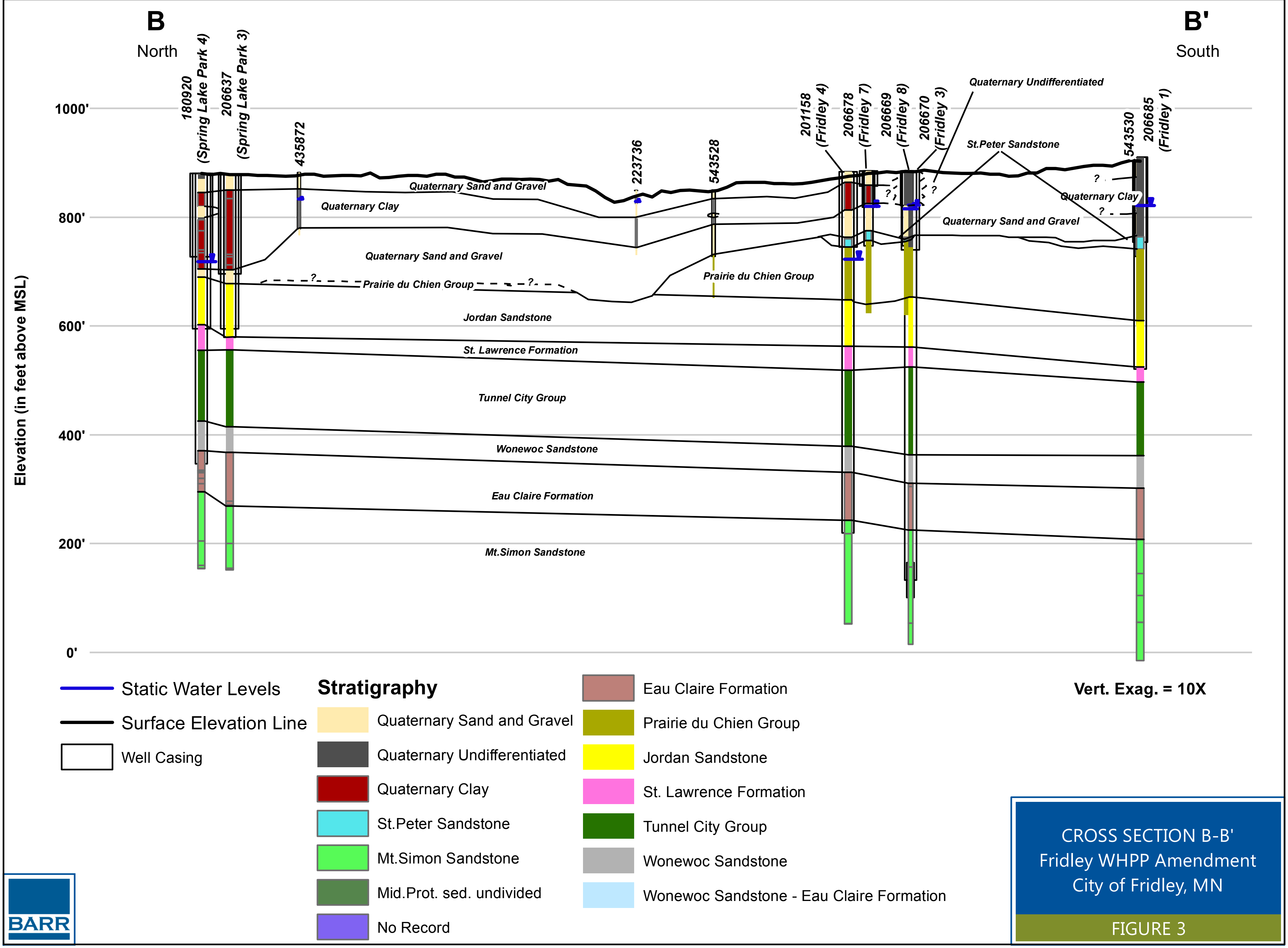
FIGURE 1



CROSS SECTION A-A'
Fridley WHPP Amendment
City of Fridley, MN

FIGURE 2

BARR

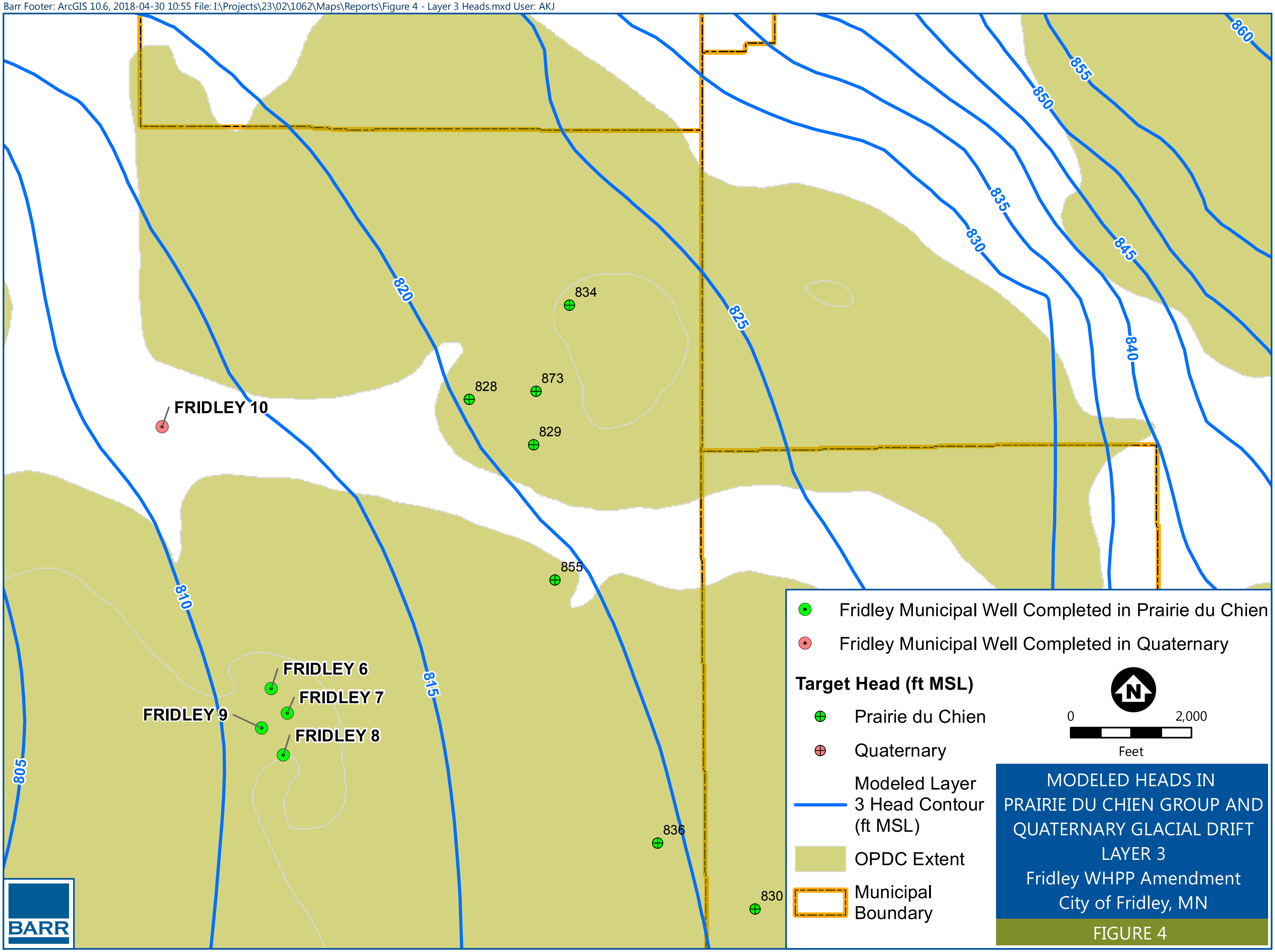


CROSS SECTION B-B'
Fridley WHPP Amendment
City of Fridley, MN

FIGURE 3

BARR

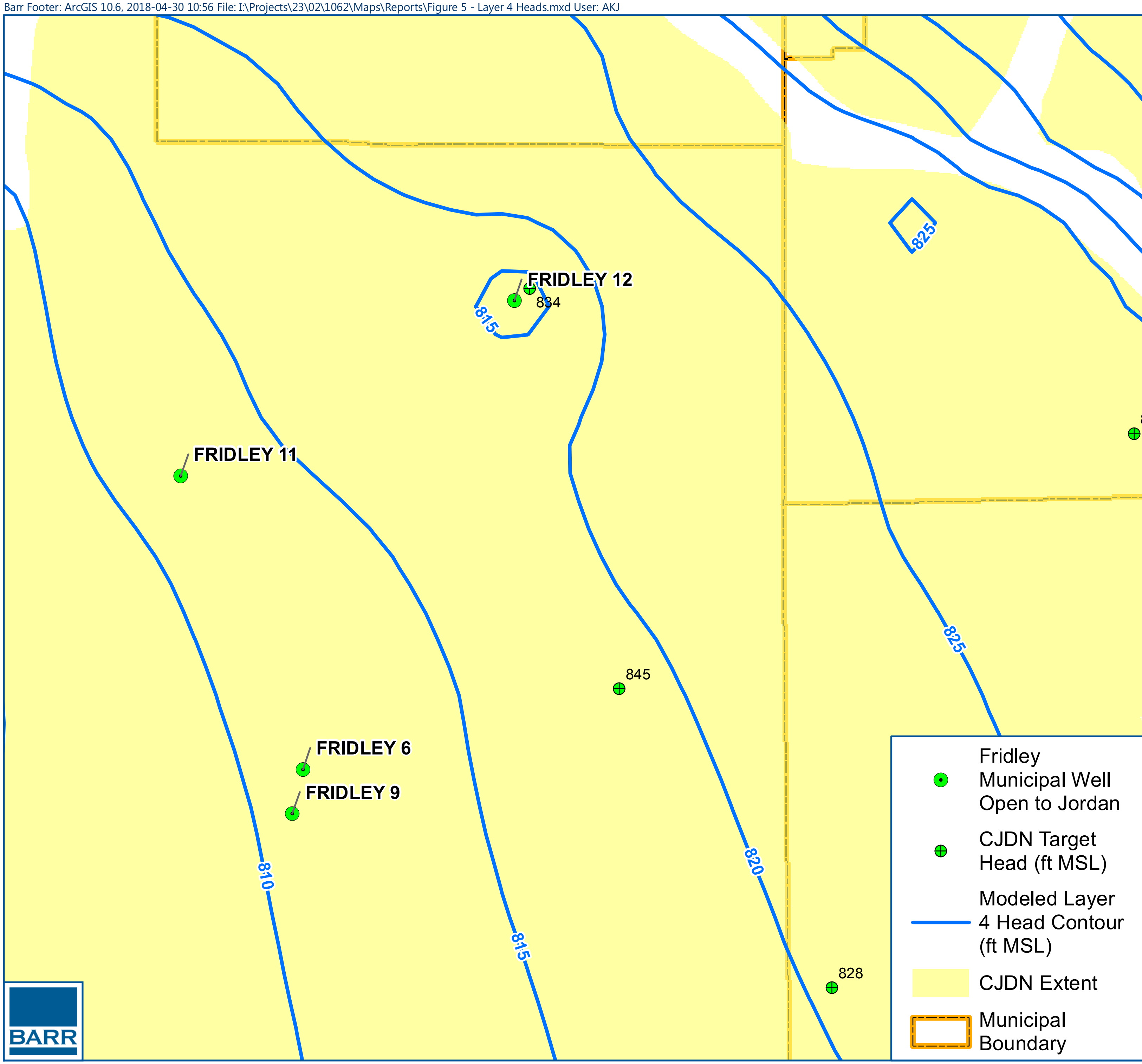
Barr Footer: ArcGIS 10.6, 2018-04-30 10:55 File: I:\Projects\23\02\1062\Maps\Reports\Figure 4 - Layer 3 Heads.mxd User: AKJ



MODELED HEADS IN PRAIRIE DU CHIEN GROUP AND QUATERNARY GLACIAL DRIFT LAYER 3
Fridley WHPP Amendment
City of Fridley, MN

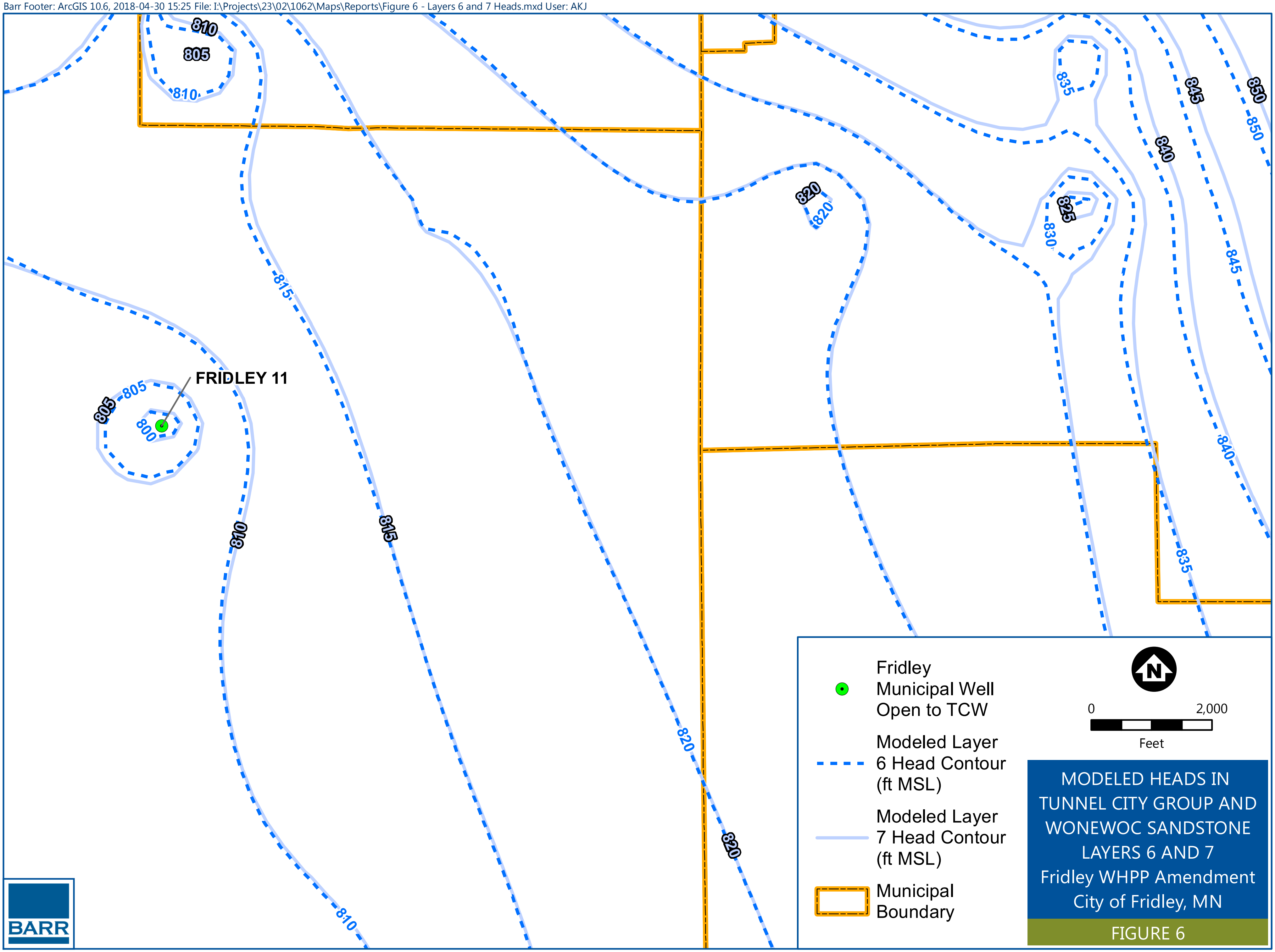
FIGURE 4

Barr Footer: ArcGIS 10.6, 2018-04-30 10:56 File: I:\Projects\23\02\1062\Maps\Reports\Figure 5 - Layer 4 Heads.mxd User: AKJ

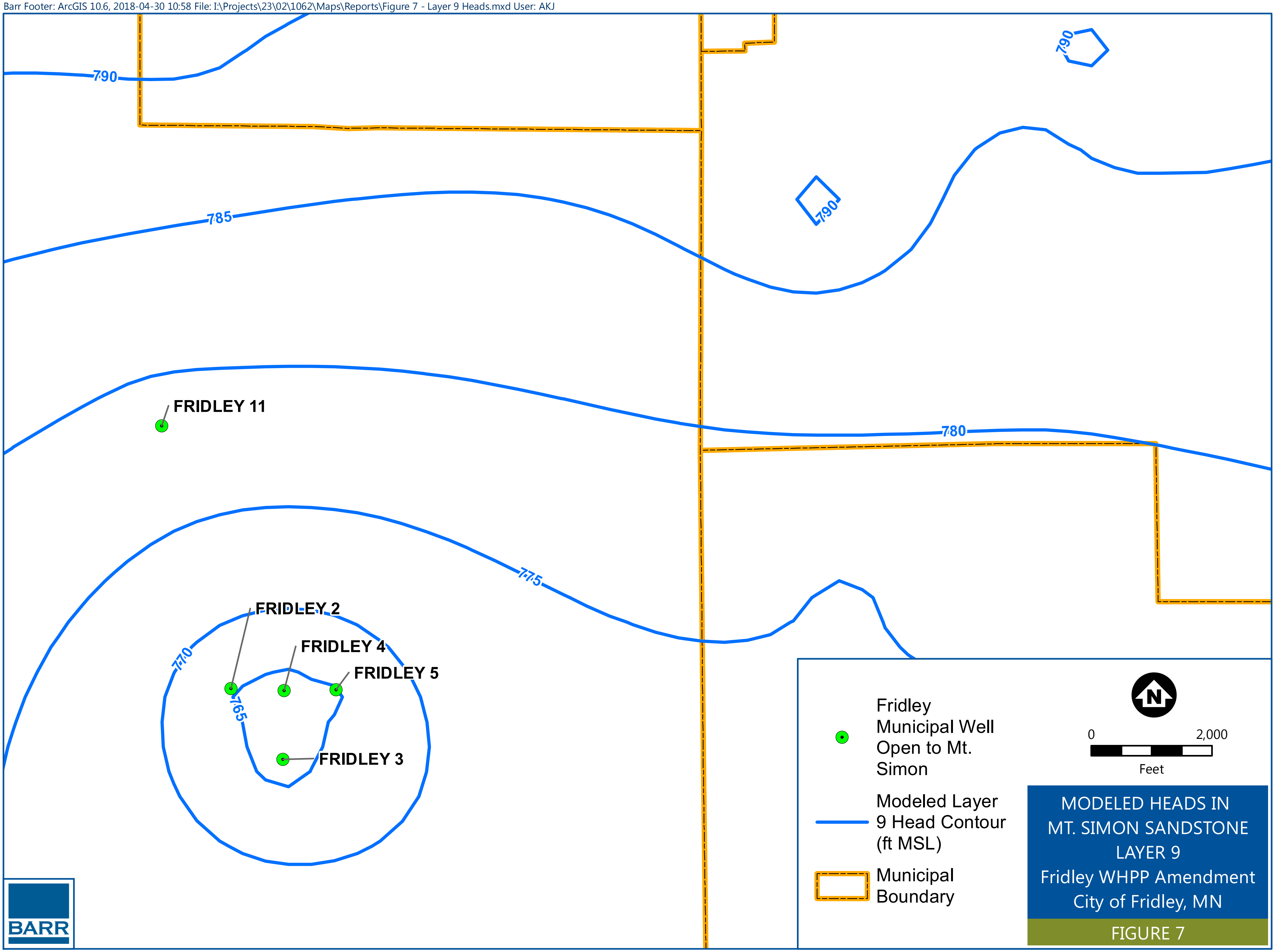


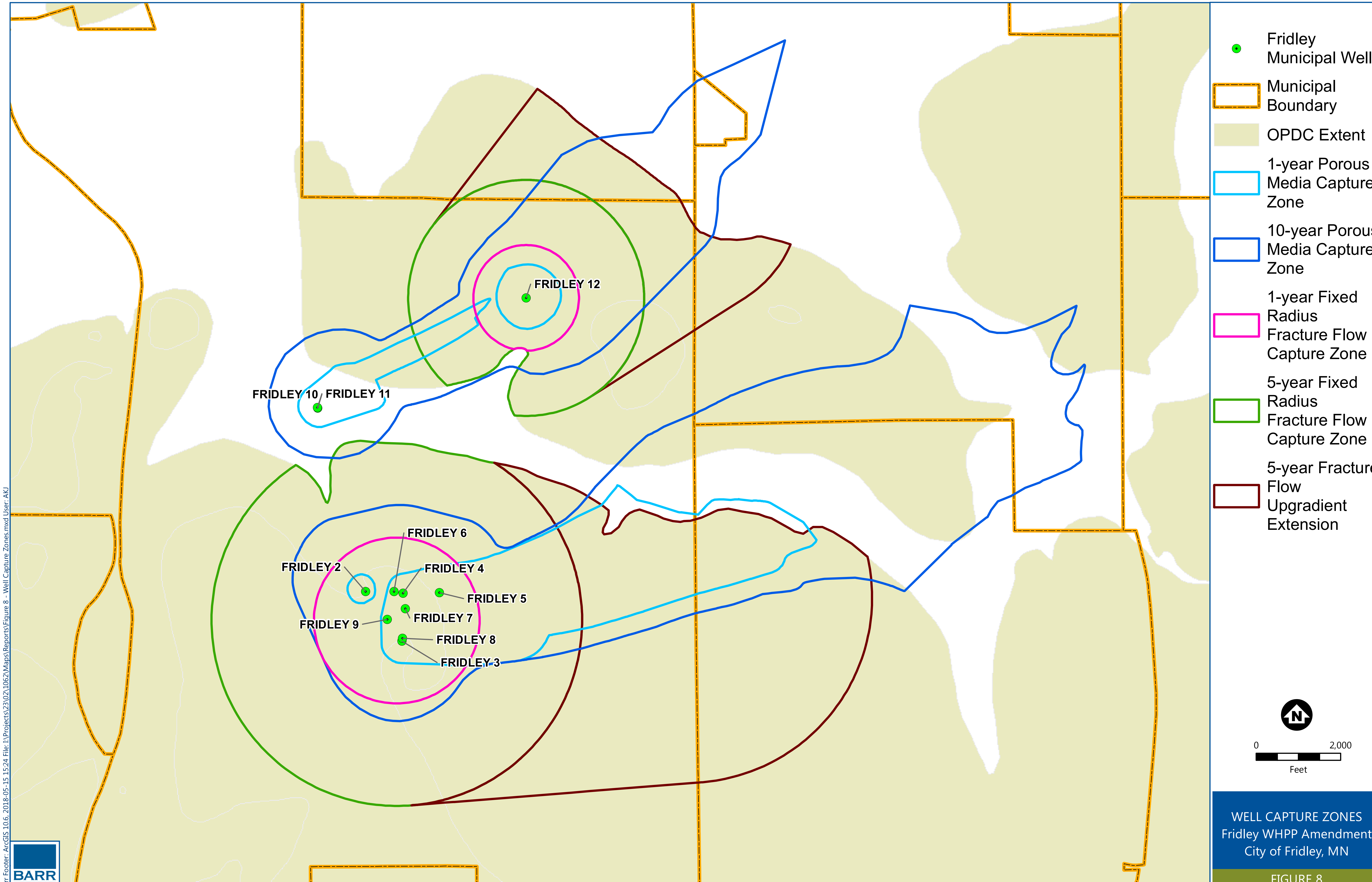
MODELED HEADS IN JORDAN SANDSTONE LAYER 4
Fridley WHPP Amendment
City of Fridley, MN

FIGURE 5


FRIDLEY 11
810
805
815
820
825
830
835
840
845
850
800
Fridley Municipal Well Open to TCW
Modeled Layer 6 Head Contour (ft MSL)
Modeled Layer 7 Head Contour (ft MSL)
Municipal Boundary
N
0
2,000
Feet
MODELED HEADS IN TUNNEL CITY GROUP AND WONEWOC SANDSTONE LAYERS 6 AND 7
Fridley WHPP Amendment
City of Fridley, MN
FIGURE 6
BARR

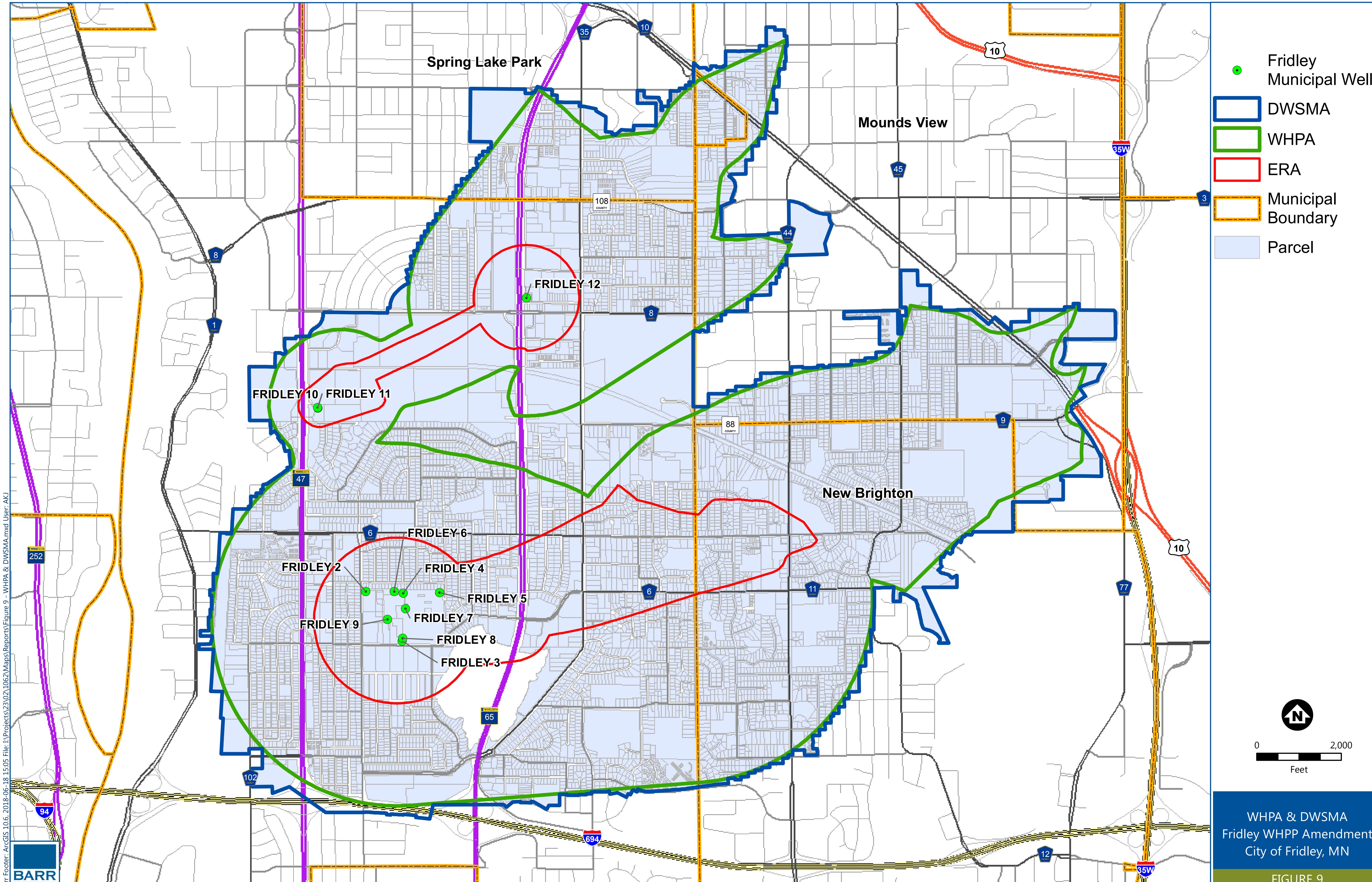
Barr Footer: ArcGIS 10.6, 2018-04-30 10:58 File: I:\Projects\23\02\1062\Maps\Reports\Figure 7 - Layer 9 Heads.mxd User: AKJ





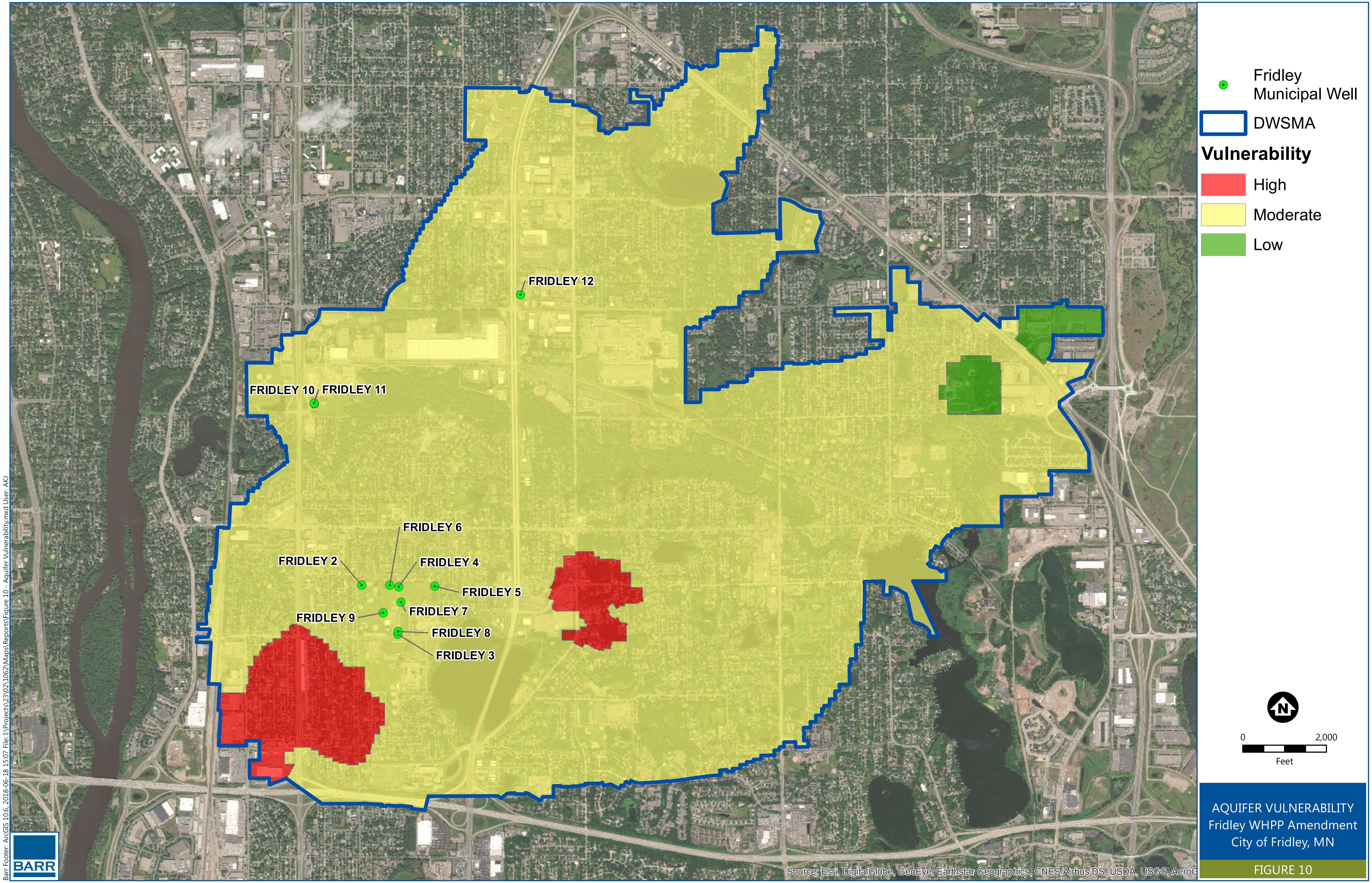
WELL CAPTURE ZONES
Fridley WHPP Amendment
City of Fridley, MN

FIGURE 8



WHPA & DWSMA
Fridley WHPP Amendment
City of Fridley, MN

FIGURE 9



AQUIFER VULNERABILITY
Fridley WHPP Amendment
City of Fridley, MN

FIGURE 10

Appendix A

Well Construction Records

Minnesota Unique Well Number

206674

County Anoka
Quad Minneapolis
Quad ID 120D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING REPORT

Minnesota Statutes Chapter 1031

Entry Date 04/15/1991
Update Date 11/15/2016
Received Date

Well Name	Township	Range	Dir Section	Subsection
FRIDLEY 2	30	24	W 14	DCBBBB

Elevation 865 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet)

Address

C/W 6251 7TH ST NE FRIDLEY MN

Stratigraphy Information

Geological Material	From	To (ft.)	Color	Hardness
SAND & GRAVEL	0	120		
SAND & GRAVEL	120	131		
DOLOMITE ROCK	131	243		
JORDAN SANDSTONE	243	312		
DOLOMITE & SHALE	312	347		
DOLOMITE & SHALE	347	390		
FRANCONIA SHALE	390	452		
SANDSTONE	452	500		
SANDSTONE	500	510		
SANDSTONE & RED	510	550		
SANDSTONE & RED	550	635		
SANDSTONE & RED	635	654		
MT. SIMON	654	718		
HINCKLEY	718	838		
HINCKLEY	838	840		
FOND DU LAC	840	842		

Remarks

M.G.S. NO.192 , INFERRED CABLE TOOL METHOD, BASED ON OTHER WELLS DRILLED 1960-61
BY LAYNE

Well Depth	Depth Completed	Date Well Completed
842 ft.	842 ft.	12/15/1960

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**

16 in. To 675 ft. lbs./ft.

24 in. To 131 ft. lbs./ft.

Open Hole From 675 ft. To 842 ft.

Screen? ☐ **Type** **Make**

Static Water Level

131 ft. land surface Measure 12/15/1960

Pumping Level (below land surface)

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
	0	Sacks	0 ft.	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 Mt.Simon

Last Strat Mid.Prot. sed. undivided Depth to Bedrock 131 ft

Located by Minnesota Department of Health

Locate Method GPS Differentially Corrected

System UTM - NAD83, Zone 15, Meters X 479719 Y 4992127

Unique Number Verification Input Date 07/27/1999

Angled Drill Hole

Well Contractor

Licensee Business	Lic. or Reg. No.	Name of Driller
Layne Well Co.	27010	

Minnesota Unique Well No.

206674

County	Anoka
Quad	Minneapolis North
Quad ID	120D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Entry Date	04/15/1991
Update	
Received Date	11/15/2016

Well Name	Township	Range	Dir	Section	Subsection	Use	Status	Well Depth	Depth Completed	Date Well Completed	Lic/Reg. No.
FRIDLEY 2	30	24	W	14	DCBBBB	community supply	A	842 ft.	842 ft.	12/15/1960	27010

Elevation 865 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet) **Aquifer** Mt.Simon **Depth to Bedrock** 131 ft **Open Hole** 675 - 842 ft **Static Water Level** 131 ft

Field Located By Minnesota Department of
Unique No. Verified
Geological Interpretation John Mossler
Agency (Interpretation)

Locate Method GPS Differentially Corrected
Input Source Minnesota Department of Health
Input Date 07/27/1999

Universal Transverse Mercator (UTM) - NAD83 - Zone 15 -
UTM Easting (X) 479719
UTM Northing (Y) 499212
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	120	120	865	745	sand +larger	sand	gravel	
SAND & GRAVEL			120	131	11	745	734	sand +larger	sand	gravel	
DOLOMITE ROCK			131	243	112	734	622	Prairie Du Chien	dolomite		
JORDAN SANDSTONE			243	312	69	622	553	Jordan Sandstone	sandstone		
DOLOMITE & SHALE			312	347	35	553	518	St.Lawrence	sandstone	siltstone	dolomite
DOLOMITE & SHALE			347	390	43	518	475	Tunnel City Group	sandstone	siltstone	dolomite
FRANCONIA SHALE			390	452	62	475	413	Tunnel City Group	sandstone	shale	siltstone
SANDSTONE			452	500	48	413	365	Tunnel City Group	sandstone	siltstone	
SANDSTONE			500	510	10	365	355	Wonewoc Sandstone	sandstone		
SANDSTONE & RED SHALE			510	550	40	355	315	Wonewoc Sandstone	sandstone		
SANDSTONE & RED SHALE			550	635	85	315	230	Eau Claire Formation	siltstone		
SANDSTONE & RED SHALE			635	654	19	230	211	Mt.Simon Sandstone	sandstone		
MT. SIMON SANDSTONE			654	718	64	211	147	Mt.Simon Sandstone	sandstone		
HINCKLEY SANDSTONE			718	838	120	147	27	Mt.Simon Sandstone	sandstone		
HINCKLEY SANDSTONE			838	840	2	27	25	Mid.Prot. sed.	shale		
FOND DU LAC			840	842	2	25	23	Mid.Prot. sed.	shale		

Minnesota Unique Well Number

206670

County: Anoka
Quad: Minneapolis
Quad ID: 120D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING REPORT

Minnesota Statutes Chapter 1031

Entry Date: 04/15/1991
Update Date: 11/15/2016
Received Date:

Well Name	Township	Range	Dir Section	Subsection
FRIDLEY 3	30	24	W 14	DCDCDD

Elevation 885 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet)

Address

C/W 611 61ST AV NE FRIDLEY MN

Stratigraphy Information

Geological Material	From	To (ft.)	Color	Hardness
DRIFT	0	140		
ST. PETER	140	145		
SHAKOPEE-ONEOTA	145	232		
SHAKOPEE-ONEOTA	232	283		
JORDAN	283	324		
JORDAN	324	360		
JORDAN	360	363		
ST. LAWRENCE	363	380		
ST. LAWRENCE	380	435		
FRANCONIA	435	522		
FRANCONIA	522	536		
GALESVILLE	536	574		
GALESVILLE	574	580		
EAU CLAIRE	580	660		
EAU CLAIRE	660	728		
MT. SIMON	728	831		
HINCKLEY BOTTOM	831	870		

Remarks

M.G.S. NO.195, ON 62ND AVE HALF WAY BETWEEN UNIVERSITY & CENTRAL

NO DATE ON GAMMA LOG. INFERRED CABLE TOOL METHOD, BASED ON OTHER WELLS DRILLED
1960-61 BY LAYNE, GAMMA LOGGED 10-20-2015 BY JIM TRAEN.
REVISED BEDROCK CONTACTS.

Well Depth	Depth Completed	Date Well Completed
870 ft.	836 ft.	03/03/1961

Drill Method Cable Tool **Drill Fluid**

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

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

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

Casing Diameter **Weight**

24 in. To 145 ft. lbs./ft.
16 in. To 752 ft. lbs./ft.
10 in. To 784 ft. lbs./ft.

Open Hole From 752 ft. To 870 ft.
Screen? ☐ **Type** **Make**

Static Water Level
63 ft. land surface Measure 03/03/1961

Pumping Level (below land surface)

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.	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: Mt.Simon
Last Strat: Mt.Simon Sandstone Depth to Bedrock: 140 ft
Located by: Minnesota Department of Health
Locate Method: GPS Differentially Corrected
System: UTM - NAD83, Zone 15, Meters X 479981 Y 4991769
Unique Number Verification Input Date 07/27/1999

Angled Drill Hole

Well Contractor
Layne Well Co. 27010

Licensee Business | Lic. or Reg. No. | Name of Driller

Minnesota Well Index Report

206670

Minnesota Unique Well No.

206670

County	Anoka
Quad	Minneapolis North
Quad ID	120D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Entry Date	04/15/1991
Update	
Received Date	11/15/2016

Well Name	Township	Range	Dir	Section	Subsection	Use	Status	Well Depth	Depth Completed	Date Well Completed	Lic/Reg. No.
FRIDLEY 3	30	24	W	14	DCDCDD	community supply	A	870 ft.	836 ft.	03/03/1961	27010

Elevation 885 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet) **Aquifer** Mt.Simon **Depth to Bedrock** 140 ft **Open Hole** 752 - 870 ft **Static Water Level** 331 ft

Field Located By	Minnesota Department of	**Locate Method**	GPS Differentially Corrected	**Universal Transverse Mercator (UTM) - NAD83 - Zone 15 -**	
Unique No. Verified		**Input Source**	Minnesota Department of Health	**UTM Easting (X)**	479981
Geological Interpretation	Andrew Retzler	**Input Date**	07/27/1999	**UTM Northing (Y)**	499176
Agency (Interpretation)				**Interpretaion Method**	Cuttings + geophysical log

			Depth (ft.)			Elevation (ft.)					
Geological Material	**Color**	**Hardness**	**From**	**To**	**Thickness**	**From**	**To**	**Stratigraphy**	**Primary Lithology**	**Secondary**	**Minor Lithology**
DRIFT			0	140	140	885	745	Quaternary deposit	drift		
ST. PETER			140	145	5	745	740	Prairie Du Chien	dolomite	sandstone	
SHAKOPEE-ONEOTA			145	232	87	740	653	Prairie Du Chien	dolomite		
SHAKOPEE-ONEOTA			232	283	51	653	602	Jordan Sandstone	sandstone		
JORDAN			283	324	41	602	561	Jordan Sandstone	sandstone		
JORDAN			324	360	36	561	525	St.Lawrence	siltstone	dolomite	
JORDAN			360	363	3	525	522	Tunnel City Group	sandstone	shale	dolomite
ST. LAWRENCE			363	380	17	522	505	Tunnel City Group	sandstone	shale	dolomite
ST. LAWRENCE			380	435	55	505	450	Tunnel City Group	sandstone	dolomite	
FRANCONIA			435	522	87	450	363	Tunnel City Group	sandstone	siltstone	dolomite
FRANCONIA			522	536	14	363	349	Wonewoc Sandstone	sandstone		
GALESVILLE			536	574	38	349	311	Wonewoc Sandstone	sandstone		
GALESVILLE			574	580	6	311	305	Eau Claire Formation	siltstone	sandstone	
EAU CLAIRE			580	660	80	305	225	Eau Claire Formation	siltstone	sandstone	
EAU CLAIRE			660	728	68	225	157	Mt.Simon Sandstone	sandstone		
MT. SIMON			728	831	103	157	54	Mt.Simon Sandstone	sandstone		
HINCKLEY BOTTOM			831	870	39	54	15	Mt.Simon Sandstone	sandstone		

Minnesota Unique Well Number

201158

County Anoka
Quad Minneapolis
Quad ID 120D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING REPORT

Minnesota Statutes Chapter 1031

Entry Date 04/15/1991
Update Date 11/15/2016
Received Date

Well Name	Township	Range	Dir Section	Subsection
FRIDLEY 4	30	24	W 14	DCABAD

Elevation 883 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet)

Address

C/W 631 63RD AV NE FRIDLEY MN

Stratigraphy Information

Geological Material	From	To (ft.)	Color	Hardness
FINE SAND	0	19		
CLAY & BOULDERS	19	70		
SAND & BOULDERS	70	120		
SAND & BOULDERS	120	123		
ST. PETER	123	138		
SHAKOPEE LIMESTONE	138	235		
SHAKOPEE LIMESTONE	235	253		
JORDAN SANDSTONE	253	320		
SHALE & SAND	320	364		
SHALE & SAND	364	500		
SANDSTONE & SHALE	500	504		
SANDSTONE & SHALE	504	525		
GALESVILLE SAND	525	550		
HARD SANDSTONE &	550	552		
HARD SANDSTONE &	552	640		
HARD SANDSTONE &	640	665		
HINCKLEY	665	830		
HINCKLEY	830	831		

Remarks

M.G.S. NO.194 INFERRED CABLE TOOL METHOD & PRESENCE OF GROUT BASED ON OTHER WELLS DRILLED 1960-61 BY LAYNE
GAMMA LOGGED 5-9-2016 BY JIM TRAEN.

Well Depth	Depth Completed	Date Well Completed
831 ft.	831 ft.	02/20/1961

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** 0 ft.

Casing Diameter **Weight**
16 in. To 663 ft. lbs./ft.
24 in. To 138 ft. lbs./ft.

Open Hole From 663 ft. To 830 ft.
Screen? ☐ **Type** **Make**

Static Water Level
160 ft. land surface Measure 02/20/1961

Pumping Level (below land surface)

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

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 St.Peter Sandstone Aquifer Mt.Simon
Last Strat Mid.Prot. sed. undivided Depth to Bedrock 120 ft
Located by Minnesota Department of Health
Locate Method GPS Differentially Corrected
System UTM - NAD83, Zone 15, Meters X 479988 Y 4992116
Unique Number Verification Information from Input Date 07/27/1999

Angled Drill Hole

Well Contractor

Licensee Business	Lic. or Reg. No.	Name of Driller
Layne Well Co.	27010	SHUEY, P.

Minnesota Unique Well No.

201158

County Anoka
Quad Minneapolis North
Quad ID 120D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Entry Date 04/15/1991
Update
Received Date 11/15/2016

Well Name	Township	Range	Dir	Section	Subsection	Use	Status	Well Depth	Depth Completed	Date Well Completed	Lic/Reg. No.
FRIDLEY 4	30	24	W	14	DCABAD	community supply	A	831 ft.	831 ft.	02/20/1961	27010

Elevation 883 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet) **Aquifer** Mt.Simon **Depth to Bedrock** 120 ft **Open Hole** 663 - 830 ft **Static Water Level** 160 ft

Field Located By Minnesota Department of
Unique No. Verified Information from owner
Geological Interpretation Andrew Retzler
Agency (Interpretation)

Locate Method GPS Differentially Corrected
Input Source Minnesota Department of Health
Input Date 07/27/1999

Universal Transverse Mercator (UTM) - NAD83 - Zone 15 -
UTM Easting (X) 479988
UTM Northing (Y) 499211
Interpretaion Method Cuttings + geophysical log

			Depth (ft.)			Elevation (ft.)					
Geological Material	**Color**	**Hardness**	**From**	**To**	**Thickness**	**From**	**To**	**Stratigraphy**	**Primary Lithology**	**Secondary**	**Minor Lithology**
FINE SAND			0	19	19	883	864	sand	sand		
CLAY & BOULDERS			19	70	51	864	813	pebbly sand/silt/clay	clay	boulder	
SAND & BOULDERS			70	120	50	813	763	sand +larger	sand	boulder	
SAND & BOULDERS			120	123	3	763	760	St.Peter Sandstone	sandstone		
ST. PETER SANDSTONE			123	138	15	760	745	St.Peter Sandstone	sandstone		
SHAKOPEE LIMESTONE			138	235	97	745	648	Prairie Du Chien	dolomite		
SHAKOPEE LIMESTONE			235	253	18	648	630	Jordan Sandstone	sandstone		
JORDAN SANDSTONE			253	320	67	630	563	Jordan Sandstone	sandstone		
SHALE & SAND			320	364	44	563	519	St.Lawrence	dolomite	flint	
SHALE & SAND			364	500	136	519	383	Tunnel City Group	sandstone	shale	dolomite
SANDSTONE & SHALE			500	504	4	383	379	Tunnel City Group	sandstone	shale	dolomite
SANDSTONE & SHALE			504	525	21	379	358	Wonewoc Sandstone	sandstone		
GALESVILLE SAND			525	550	25	358	333	Wonewoc Sandstone	sandstone		
HARD SANDSTONE & SHALE			550	552	2	333	331	Wonewoc Sandstone	sandstone		
HARD SANDSTONE & SHALE			552	640	88	331	243	Eau Claire Formation	shale	sandstone	
HARD SANDSTONE & SHALE			640	665	25	243	218	Mt.Simon Sandstone	sandstone		
HINCKLEY SANDSTONE			665	830	165	218	53	Mt.Simon Sandstone	sandstone		
HINCKLEY SANDSTONE			830	831	1	53	52	Mid.Prot. sed.	shale		

Minnesota Unique Well Number

206675

County Anoka
Quad Minneapolis
Quad ID 120D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING REPORT

Minnesota Statutes Chapter 1031

Entry Date 04/15/1991
Update Date 11/15/2016
Received Date

Well Name	Township	Range	Dir Section	Subsection
FRIDLEY 5	30	24	W 14	DDBABD

Elevation 879 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet)

Address

C/W 770 63RD AV NE FRIDLEY MN

Stratigraphy Information

Geological Material	From	To (ft.)	Color	Hardness
FINE TO MED.	0	25	BROWN	
TILL-CLAY TO PEBBLES	25	60	GRAY	
GRAVEL-GRANULES	60	65	GRAY	
TILL-GRANULES TO	65	80	RED	
SAND-COARSE TO	80	114	BROWN	
SAND, CARB.-CLAY TO	114	118	TAN	
SAND-VERY COARSE	118	122	BROWN	
DOLOMITE	122	250	BRN/RED	
SANDSTONE	250	295	BRN/TAN	
DOLOMITE, SILTSTONE	295	335	LT. PNK	
SHALE, SILTSTONE	335	400	VARIED	
SANDSTONE	400	420	GREEN	
SHALE, SILTSTONE	420	450	GREEN	
SHALE	450	500	GRAY	
SANDSTONE	500	510	GREEN	
SHALE	510	525	GRAY	
SANDSTONE	525	550	GRAY	
SHALE	550	560	GRAY	
SANDSTONE	560	570	GRAY	
SHALE	570	650	VARIED	
SANDSTONE	650	842	TAN/PNK	
SILTSTONE,	842	845	RED/BRN	

Remarks

M.G.S. NO. 193 G.W.Q. NO. 0224, INFERRED CABLE TOOL METHOD & PRESENCE OF GROUT,
BASED ON OTHER WELLS DRILLED FOR FRIDLEY 1960-61 BY LAYNE

Well Depth	Depth Completed	Date Well Completed
845 ft.	845 ft.	00/00/1961

Drill Method Cable Tool **Drill Fluid**

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

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

Casing Type Single casing **Joint**

Drive Shoe? **Yes** ☐ **No** ☐ **Above/Below** 0 ft.

Casing Diameter **Weight**

16 in. To 656 ft. lbs./ft.

Open Hole From 656 ft. To 845 ft.

Screen? ☐ **Type** **Make**

Static Water Level

Pumping Level (below land surface)

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

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 Submersible

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 Mt.Simon

Last Strat Mid.Prot. sed. undivided Depth to Bedrock 122 ft

Located by Minnesota Department of Health

Locate Method GPS Differentially Corrected

System UTM - NAD83, Zone 15, Meters X 480250 Y 4992120

Unique Number Verification Input Date 07/27/1999

Angled Drill Hole

Well Contractor

Layne Well Co. 27010

Licensee Business Lic. or Reg. No. Name of Driller

Minnesota Well Index Report

206675

Printed on 01/09/2018
HE-01205-15

Minnesota Unique Well No.

206675

County	Anoka
Quad	Minneapolis North
Quad ID	120D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Entry Date	04/15/1991
Update	
Received Date	11/15/2016

Well Name	**Township**	**Range**	**Dir**	**Section**	**Subsection**	**Use**	**Status**	**Well Depth**	**Depth Completed**	**Date Well Completed**	**Lic/Reg. No.**
FRIDLEY 5	30	24	W	14	DDBABD	community supply	A	845 ft.	845 ft.	00/00/1961	27010

Elevation 879 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet) **Aquifer** Mt.Simon **Depth to Bedrock** 122 ft **Open Hole** 656 - 845 ft **Static Water Level** ft

Field Located By	Minnesota Department of	**Locate Method**	GPS Differentially Corrected	**Universal Transverse Mercator (UTM) - NAD83 - Zone 15 -**	
Unique No. Verified		**Input Source**	Minnesota Department of Health	**UTM Easting (X)**	480250
Geological Interpretation	John Mossler	**Input Date**	07/27/1999	**UTM Northing (Y)**	499212
Agency (Interpretation)				**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**
FINE TO MED. OUTWASH	BROWN		0	25	25	879	854	sand-brown	sand		
TILL-CLAY TO PEBBLES	GRAY		25	60	35	854	819	till-gray	till	clay	pebbles
GRAVEL-GRANULES TO FINE	GRAY		60	65	5	819	814	gravel (+larger)-gray	gravel		
TILL-GRANULES TO CLAY	RED		65	80	15	814	799	till-red	till		
SAND-COARSE TO MEDIUM	BROWN		80	114	34	799	765	sand-brown	sand		
SAND, CARB.-CLAY TO	TAN		114	118	4	765	761	clay+sand	sand	clay	
SAND-VERY COARSE	BROWN		118	122	4	761	757	sand-brown	sand		
DOLOMITE	BRN/RED		122	250	128	757	629	Prairie Du Chien	dolomite		
SANDSTONE	BRN/TAN		250	295	45	629	584	Jordan Sandstone	sandstone		
DOLOMITE, SILTSTONE	LT. PNK		295	335	40	584	544	St.Lawrence	dolomite	siltstone	
SHALE, SILTSTONE	VARIED		335	400	65	544	479	Tunnel City Group	shale	siltstone	
SANDSTONE	GREEN		400	420	20	479	459	Tunnel City Group	sandstone		
SHALE, SILTSTONE	GREEN		420	450	30	459	429	Tunnel City Group	shale	siltstone	
SHALE	GRAY		450	500	50	429	379	Tunnel City Group	shale		
SANDSTONE	GREEN		500	510	10	379	369	Tunnel City Group	sandstone		
SHALE	GRAY		510	525	15	369	354	Tunnel City Group	shale		
SANDSTONE	GRAY		525	550	25	354	329	Wonewoc Sandstone	sandstone		
SHALE	GRAY		550	560	10	329	319	Wonewoc Sandstone	shale		
SANDSTONE	GRAY		560	570	10	319	309	Wonewoc Sandstone	sandstone		
SHALE	VARIED		570	650	80	309	229	Eau Claire Formation	shale		
SANDSTONE	TAN/PNK		650	842	192	229	37	Mt.Simon Sandstone	sandstone		
SILTSTONE, SANDSTONE	RED/BRN		842	845	3	37	34	Mid.Prot. sed.	siltstone	sandstone	

Minnesota Unique Well Number

206673

County Anoka
Quad Minneapolis
Quad ID 120D

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING REPORT
Minnesota Statutes Chapter 1031

Entry Date 04/15/1991
Update Date 05/13/2016
Received Date

Well Name	**Township**	**Range**	**Dir Section**	**Subsection**
FRIDLEY 6	30	24	W 14	DCABBB

Elevation 877 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet)

Address

Well 600 63RD AV NE FRIDLEY MN 55432
Contact FRIDLEY MN 55432

Stratigraphy Information

Geological Material	From	To (ft.)	Color	Hardness
MEDIUM SAND	0	13		
SILT & CLAY	13	65		
SAND & GRAVEL	65	115		
ST. PETER	115	125		
ST. PETER	125	130		
SHAKOPEE LIMESTONE	130	233		
SHAKOPEE LIMESTONE	233	248		
JORDAN SANDSTONE	248	255		

Remarks
GAMMA LOGGED 5-9-2016 BY JIM TRAEN.
JIM TRAEN HAS 24 IN. CASING ENDING AT 144.3 FT.

Well Depth	**Depth Completed**	**Date Well Completed**
255 ft.	255 ft.	08/00/1972

Drill Method Cable Tool **Drill Fluid**

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

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

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

Casing Diameter **Weight**
24 in. To 153 ft. lbs./ft.

Open Hole From 153 ft. To 255 ft.
Screen? ☐ **Type** **Make**

Static Water Level
56.5 ft. land surface Measure 08/00/1972

Pumping Level (below land surface)

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	7	Cubic yards	0 ft.	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 Prairie Du Chien-
Last Strat Jordan Sandstone Depth to Bedrock 125 ft
Located by Minnesota Department of Health
Locate Method GPS Differentially Corrected
System UTM - NAD83, Zone 15, Meters X 479923 Y 4992127
Unique Number Verification Input Date 07/27/1999

Angled Drill Hole

Well Contractor
Layne Well Co. 27010
Licensee Business Lic. or Reg. No. Name of Driller

Minnesota Unique Well No.

206673

County Anoka
Quad Minneapolis North
Quad ID 120D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Entry Date 04/15/1991
Update
Received Date 05/13/2016

Well Name	Township	Range	Dir	Section	Subsection	Use	Status	Well Depth	Depth Completed	Date Well Completed	Lic/Reg. No.
FRIDLEY 6	30	24	W	14	DCABBB	community supply	A	255 ft.	255 ft.	08/00/1972	27010

Elevation 877 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet) **Aquifer** Prairie Du Chien- **Depth to Bedrock** 125 ft **Open Hole** 153 - 255 ft **Static Water Level** 56.5 ft

Field Located By Minnesota Department of
Unique No. Verified
Geological Interpretation Andrew Retzler
Agency (Interpretation)

Locate Method GPS Differentially Corrected
Input Source Minnesota Department of Health
Input Date 07/27/1999

Universal Transverse Mercator (UTM) - NAD83 - Zone 15 -
UTM Easting (X) 479923
UTM Northing (Y) 499212
Interpretaion Method Inferred from geophysical log

			Depth (ft.)			Elevation (ft.)					
Geological Material	**Color**	**Hardness**	**From**	**To**	**Thickness**	**From**	**To**	**Stratigraphy**	**Primary Lithology**	**Secondary**	**Minor Lithology**
MEDIUM SAND			0	13	13	877	864	sand	sand		
SILT & CLAY			13	65	52	864	812	silt+clay	silt	clay	
SAND & GRAVEL			65	115	50	812	762	sand +larger	sand	gravel	
ST. PETER SANDSTONE			115	125	10	762	752	Quaternary deposit	sand	gravel	
ST. PETER SANDSTONE			125	130	5	752	747	Prairie Du Chien	dolomite		
SHAKOPEE LIMESTONE			130	233	103	747	644	Prairie Du Chien	dolomite		
SHAKOPEE LIMESTONE			233	248	15	644	629	Jordan Sandstone	sandstone		
JORDAN SANDSTONE			248	255	7	629	622	Jordan Sandstone	sandstone		

Minnesota Unique Well Number

206678

County Anoka
Quad Minneapolis
Quad ID 120D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING REPORT

Minnesota Statutes Chapter 1031

Entry Date 04/15/1991
Update Date 11/15/2016
Received Date

Well Name	Township	Range	Dir Section	Subsection
FRIDLEY 7	30	24	W 14	DCADBC

Elevation 885 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet)

Address

C/W 680 63RD AV NE FRIDLEY MN

Stratigraphy Information

Geological Material	From	To (ft.)	Color	Hardness
FINE SAND	0	26		
BLUE CLAY, LITTLE	26	60		
GOOD WATER GRAVEL	60	73		
MUDDY SAND	73	75		
GRAVEL	75	110	LIGHT	
ST. PETER	110	128	YELLOW	
SHAKOPEE	128	136	RED	
SHAKOPEE & ST.	136	150	WHITE	
SHAKOPEE	150	262	TAN	

Remarks

ORIGINAL NO. 206671 - COMPLETED IN DRIFT, DEEPENED 1970 BY KEYS INTO BEDROCK
GAMMA LOGGED 10-20-2015 BY JIM TRAEN.

Well Depth	Depth Completed	Date Well Completed
262 ft.	262 ft.	01/14/1970

Drill Method **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**

16 in. To 67 ft. lbs./ft.
12 in. To 138 ft. lbs./ft.
24 in. To 27.7 ft. lbs./ft.

Open Hole From 138 ft. To 262 ft.
Screen? ☐ **Type** **Make**

Static Water Level
65 ft. land surface Measure 01/14/1970

Pumping Level (below land surface)
73 ft. hrs. Pumping at 1600 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

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

Pump ☐ Not Installed Date Installed
Manufacturer's name JACUZZI
Model Number SVB00 HP 75 Volt
Length of drop pipe 71 ft Capacity 1100 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 St.Peter Sandstone Aquifer Prairie Du Chien
Last Strat Prairie Du Chien Group Depth to Bedrock 110 ft
Located by Minnesota Department of Health
Locate Method GPS Differentially Corrected
System UTM - NAD83, Zone 15, Meters X 480005 Y 4992003
Unique Number Verification Information from Input Date 07/27/1999

Angled Drill Hole

Well Contractor
Renner E.H. & Sons 02015
Licensee Business Lic. or Reg. No. Name of Driller

Minnesota Unique Well No.

206678

County	Anoka
Quad	Minneapolis North
Quad ID	120D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Entry Date	04/15/1991
Update	
Received Date	11/15/2016

Well Name	Township	Range	Dir	Section	Subsection	Use	Status	Well Depth	Depth Completed	Date Well Completed	Lic/Reg. No.
FRIDLEY 7	30	24	W	14	DCADBC	community supply	A	262 ft.	262 ft.	01/14/1970	02015

Elevation 885 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet) **Aquifer** Prairie Du Chien **Depth to Bedrock** 110 ft **Open Hole** 138 - 262 ft **Static Water Level** 65 ft

Field Located By	Minnesota Department of	**Locate Method**	GPS Differentially Corrected	**Universal Transverse Mercator (UTM) - NAD83 - Zone 15 -**	
Unique No. Verified	Information from owner	**Input Source**	Minnesota Department of Health	**UTM Easting (X)**	480005
Geological Interpretation	John Mossler	**Input Date**	07/27/1999	**UTM Northing (Y)**	499200
Agency (Interpretation)				**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**
FINE SAND			0	26	26	885	859	sand	sand		
BLUE CLAY, LITTLE GRAVEL			26	60	34	859	825	pebbly sand/silt/clay-	clay	gravel	
GOOD WATER GRAVEL			60	73	13	825	812	gravel (+larger)	gravel		
MUDDY SAND			73	75	2	812	810	sand+silt	sand	mud	
GRAVEL	LIGHT		75	110	35	810	775	gravel (+larger)	gravel		
ST. PETER	YELLOW		110	128	18	775	757	St.Peter Sandstone	sandstone		
SHAKOPEE	RED		128	136	8	757	749	Prairie Du Chien	dolomite		
SHAKOPEE & ST. PETER	WHITE		136	150	14	749	735	Prairie Du Chien	dolomite	sandstone	
SHAKOPEE	TAN		150	262	112	735	623	Prairie Du Chien	dolomite		

Minnesota Unique Well Number

206669

County Anoka
Quad Minneapolis
Quad ID 120D

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING REPORT
Minnesota Statutes Chapter 1031

Entry Date 04/15/1991
Update Date 03/10/2014
Received Date

Well Name	Township	Range	Dir Section	Subsection
FRIDLEY 8	30	24	W 14	DCDCDA

Elevation 885 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet)

Address

C/W 613 61ST AV NE FRIDLEY MN

Stratigraphy Information

Geological Material	From	To (ft.)	Color	Hardness
NO RECORD	0	64		
GRAVEL & STONES	64	122	GRAY	
SHALE	122	126	BLACK	
ST. PETER, DUSTY	126	130	WHITE	
ST. PETER, SHAKOPEE	130	186	YELLOW	
SHAKOPEE	186	195	TAN	
SHAKOPEE	195	265	TAN	
JORDAN	265	265	YELLOW	

Remarks

M.G.S. NO. 526
0 TO 64 FEET IS 16" CASE HOLE, DRILLED BY OTHERS.

Well Depth	Depth Completed	Date Well Completed
265 ft.	265 ft.	12/17/1969

Drill Method **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**

12 in. To 138 ft. lbs./ft.
16 in. To 64 ft. lbs./ft.

Open Hole From 138 ft. To 265 ft.
Screen? ☐ **Type** **Make**

Static Water Level

70 ft. land surface Measure 12/17/1969

Pumping Level (below land surface)

74 ft. hrs. Pumping at 1160 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

Nearest Known Source of Contamination

feet Direction Type
Well disinfected upon completion? ☐ Yes ☐ No

Pump ☐ Not Installed Date Installed
Manufacturer's name JACUZZI
Model Number 12MC24 HP 75 Volt
Length of drop pipe 125 ft Capacity 1150 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 St.Peter Sandstone Aquifer Prairie Du Chien
Last Strat Jordan Sandstone Depth to Bedrock 126 ft
Located by Minnesota Department of Health
Locate Method GPS Differentially Corrected
System UTM - NAD83, Zone 15, Meters X 479984 Y 4991790
Unique Number Verification Input Date 07/27/1999

Angled Drill Hole

Well Contractor

Licensee Business	Lic. or Reg. No.	Name of Driller
Renner E.H. & Sons	02015	

Minnesota Unique Well No.

206669

County Anoka
Quad Minneapolis North
Quad ID 120D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Entry Date 04/15/1991
Update
Received Date 03/10/2014

Well Name	Township	Range	Dir	Section	Subsection	Use	Status	Well Depth	Depth Completed	Date Well Completed	Lic/Reg. No.
FRIDLEY 8	30	24	W	14	DCDCDA	community supply	A	265 ft.	265 ft.	12/17/1969	02015

Elevation 885 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet) **Aquifer** Prairie Du Chien **Depth to Bedrock** 126 ft **Open Hole** 138 - 265 ft **Static Water Level** 70 ft

Field Located By Minnesota Department of
Unique No. Verified
Geological Interpretation John Mossler
Agency (Interpretation)

Locate Method GPS Differentially Corrected
Input Source Minnesota Department of Health
Input Date 07/27/1999

Universal Transverse Mercator (UTM) - NAD83 - Zone 15 -
UTM Easting (X) 479984
UTM Northing (Y) 499179
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**
NO RECORD			0	64	64	885	821	Quaternary deposit	drift		
GRAVEL & STONES	GRAY		64	122	58	821	763	gravel (+larger)-gray	gravel	pebbles	
SHALE	BLACK		122	126	4	763	759	clay-black	clay		
ST. PETER, DUSTY	WHITE		126	130	4	759	755	St.Peter Sandstone	sandstone		
ST. PETER, SHAKOPEE	YELLOW		130	186	56	755	699	Prairie Du Chien	sandstone	dolomite	
SHAKOPEE	TAN		186	195	9	699	690	Prairie Du Chien	dolomite		
SHAKOPEE	TAN		195	265	70	690	620	Prairie Du Chien	dolomite		
JORDAN	YELLOW		265	265	0	620	620	Jordan Sandstone	sandstone		

Minnesota Unique Well Number

206672

County Anoka
Quad Minneapolis
Quad ID 120D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING REPORT

Minnesota Statutes Chapter 1031

Entry Date 04/15/1991
Update Date 03/10/2014
Received Date

Well Name	**Township**	**Range**	**Dir Section**	**Subsection**
FRIDLEY 9	30	24	W 14	DCCAAB

Elevation 882 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet)

Address

C/W 603 61ST AV NE FRIDLEY MN

Stratigraphy Information

Geological Material	From	To (ft.)	Color	Hardness
SAND	0	15		
SILT & CLAY	15	67		
SAND & GRAVEL	67	117		
ST. PETER	117	132		
DOLOMITE	132	250		
JORDAN SANDROCK	250	255		SOFT

Remarks

DEEPENED BY LAYNE MINN. CO. TO 255 FT. IN 1972.

Well Depth	**Depth Completed**	**Date Well Completed**
255 ft.	255 ft.	12/22/1965

Drill Method **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**
24 in. To 153 ft. lbs./ft.
30 in. To 67 ft. lbs./ft.

Open Hole From 153 ft. To 255 ft.
Screen? ☐ **Type** **Make**

Static Water Level
56 ft. land surface Measure 12/22/1965

Pumping Level (below land surface)
59 ft. 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

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

Pump ☐ Not Installed Date Installed
Manufacturer's name JACUZZI
Model Number HP 75 Volt 220
Length of drop pipe ft Capacity 1100 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 St.Peter Sandstone Aquifer Prairie Du Chien-
Last Strat Jordan Sandstone Depth to Bedrock 117 ft
Located by Minnesota Department of Health
Locate Method GPS Differentially Corrected
System UTM - NAD83, Zone 15, Meters X 479875 Y 4991927
Unique Number Verification Information from Input Date 07/27/1999

Angled Drill Hole

Well Contractor

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

Minnesota Unique Well No.

206672

County Anoka
Quad Minneapolis North
Quad ID 120D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Entry Date 04/15/1991
Update
Received Date 03/10/2014

Well Name	Township	Range	Dir	Section	Subsection	Use	Status	Well Depth	Depth Completed	Date Well Completed	Lic/Reg. No.
FRIDLEY 9	30	24	W	14	DCCAAB	community supply	A	255 ft.	255 ft.	12/22/1965	62012

Elevation 882 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet) **Aquifer** Prairie Du Chien- **Depth to Bedrock** 117 ft **Open Hole** 153 - 255 ft **Static Water Level** 56 ft

Field Located By Minnesota Department of
Unique No. Verified Information from owner
Geological Interpretation John Mossler
Agency (Interpretation)

Locate Method GPS Differentially Corrected
Input Source Minnesota Department of Health
Input Date 07/27/1999

Universal Transverse Mercator (UTM) - NAD83 - Zone 15 -
UTM Easting (X) 479875
UTM Northing (Y) 499192
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			0	15	15	882	867	sand	sand		
SILT & CLAY			15	67	52	867	815	silt+clay	silt	clay	
SAND & GRAVEL			67	117	50	815	765	sand +larger	sand	gravel	
ST. PETER SANDSTONE			117	132	15	765	750	St.Peter Sandstone	sandstone		
DOLOMITE			132	250	118	750	632	Prairie Du Chien	dolomite		
JORDAN SANDROCK		SOFT	250	255	5	632	627	Jordan Sandstone	sandstone		

Minnesota Unique Well Number

206658

County Anoka
Quad Minneapolis
Quad ID 120D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING REPORT

Minnesota Statutes Chapter 1031

Entry Date 04/15/1991
Update Date 03/26/2015
Received Date

Well Name	Township	Range	Dir Section	Subsection
FRIDLEY 10	30	24	W 11	CDCCAA

Elevation 861 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet)

Address

C/W 6911 UNIVERSITY AV NE FRIDLEY MN

Stratigraphy Information

Geological Material	From	To (ft.)	Color	Hardness
SAND	0	8		
CLAY	8	35		
GRAVEL	35	42		
SAND, GRAVEL & CLAY	42	95		
SAND	95	123		
SAND & GRAVEL	123	173		
SAND	173	199		

Remarks

SOUTH WELL. M.G.S. NO. 547.
GAMMA LOGGED 3-19-2015 BY JIM TRAEN.

Well Depth	Depth Completed	Date Well Completed
199 ft.	199 ft.	12/29/1969

Drill Method **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**
16 in. To 128 ft. lbs./ft.
24 in. To 16 ft. lbs./ft.

Open Hole From ft. To ft.
Screen? ☒ **Type** stainless **Make**

Diameter	Slot/Gauze	Length	Set	
16 in.		73 ft.	128 ft.	199 ft.

Static Water Level
38 ft. top of breather pipe Measure 12/29/1969

Pumping Level (below land surface)
43.2 ft. 2 hrs. Pumping at 800 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	130	Cubic yards	0 ft.	35 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 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 Aquifer Quat. buried
Last Strat sand Depth to Bedrock ft
Located by Minnesota Department of Health
Locate Method GPS SA On (averaged)
System UTM - NAD83, Zone 15, Meters X 479373 Y 4993450
Unique Number Verification Input Date 04/07/1999

Angled Drill Hole

Well Contractor

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

Minnesota Unique Well No.

206658

County Anoka
Quad Minneapolis North
Quad ID 120D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Entry Date 04/15/1991
Update
Received Date 03/26/2015

Well Name	Township	Range	Dir	Section	Subsection	Use	Status	Well Depth	Depth Completed	Date Well Completed	Lic/Reg. No.
FRIDLEY 10	30	24	W	11	CDCCAA	community supply	A	199 ft.	199 ft.	12/29/1969	62012

Elevation 861 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet) **Aquifer** Quat. buried artes. **Depth to Bedrock** ft **Open Hole** - ft **Static Water Level** 38 ft

Field Located By Minnesota Department of
Unique No. Verified
Geological Interpretation Emily Bauer
Agency (Interpretation)

Locate Method GPS SA On (averaged)
Input Source Minnesota Department of Health
Input Date 04/07/1999

Universal Transverse Mercator (UTM) - NAD83 - Zone 15 -
UTM Easting (X) 479373
UTM Northing (Y) 499345
Interpretaion Method Cuttings + geophysical log

			Depth (ft.)			Elevation (ft.)					
Geological Material	**Color**	**Hardness**	**From**	**To**	**Thickness**	**From**	**To**	**Stratigraphy**	**Primary Lithology**	**Secondary**	**Minor Lithology**
SAND			0	8	8	861	853	sand	sand		
CLAY			8	35	27	853	826	clay	clay		
GRAVEL			35	42	7	826	819	gravel (+larger)	gravel		
SAND, GRAVEL & CLAY			42	95	53	819	766	pebbly sand/silt/clay	sand	gravel	clay
SAND			95	123	28	766	738	sand	sand		
SAND & GRAVEL			123	173	50	738	688	sand +larger	sand	gravel	
SAND			173	199	26	688	662	sand	sand		

Minnesota Unique Well Number

206657

County Anoka
Quad Minneapolis
Quad ID 120D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING REPORT

Minnesota Statutes Chapter 1031

Entry Date 04/15/1991
Update Date 03/26/2015
Received Date

Well Name	Township	Range	Dir	Section	Subsection
FRIDLEY 11	30	24	W	11	CDCCAA

Elevation 861 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet)

Address

C/W 6911 UNIVERSITY AV FRIDLEY MN

Stratigraphy Information

Geological Material	From	To (ft.)	Color	Hardness
DRIFT	0	221		
SAND, GRAVEL &	221	225		
SHAKOPEE LIMEROCK	225	235		
SHAKOPEE LIMEROCK	235	236		
JORDAN	236	245		SOFT
JORDAN SANDROCK	245	320		
JORDAN SANDROCK	320	350		
JORDAN SANDROCK	350	355		
ST. LAWRENCE SHALE	355	490		
FRANCONIA	490	548		
FRANCONIA	548	618		
FRANCONIA	618	669		

Remarks

M.G.S. NO 523. NORTH WELL.
GAMMA LOGGED 3-19-2015 BY JIM TRAEN.

Well Depth	Depth Completed	Date Well Completed
669 ft.	669 ft.	04/20/1970

Drill Method **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 325 ft. lbs./ft. 23 in. To 344 ft.
30 in. To 225 ft. lbs./ft.

Open Hole From 325 ft. To 669 ft.
Screen? ☐ **Type** **Make**

Static Water Level
52 ft. land surface Measure 04/20/1970

Pumping Level (below land surface)
144 ft. 16 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	300	Sacks	0 ft.	248 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 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-Mt.Simon
Last Strat Mt.Simon Sandstone Depth to Bedrock 225 ft
Located by Minnesota Department of Health
Locate Method GPS Differentially Corrected
System UTM - NAD83, Zone 15, Meters X 479371 Y 4993454
Unique Number Verification Information from Input Date 07/27/1999

Angled Drill Hole

Well Contractor

Licensee Business	Lic. or Reg. No.	Name of Driller
Keys Well Co.	62012	HALEY, R.

Minnesota Unique Well No.

206657

County	Anoka
Quad	Minneapolis North
Quad ID	120D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Entry Date	04/15/1991
Update	
Received Date	03/26/2015

Well Name	Township	Range	Dir	Section	Subsection	Use	Status	Well Depth	Depth Completed	Date Well Completed	Lic/Reg. No.
FRIDLEY 11	30	24	W	11	CDCCAA	community supply	A	669 ft.	669 ft.	04/20/1970	62012

Elevation 861 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet) **Aquifer** Jordan-Mt.Simon **Depth to Bedrock** 225 ft **Open Hole** 325 - 669 ft **Static Water Level** 52 ft

Field Located By	Minnesota Department of	**Locate Method**	GPS Differentially Corrected	**Universal Transverse Mercator (UTM) - NAD83 - Zone 15 -**	
Unique No. Verified	Information from owner	**Input Source**	Minnesota Department of Health	**UTM Easting (X)**	479371
Geological Interpretation	Julia Steenberg	**Input Date**	07/27/1999	**UTM Northing (Y)**	499345
Agency (Interpretation)				**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
DRIFT			0	221	221	861	640	Quaternary deposit	drift		
SAND, GRAVEL & BROKEN			221	225	4	640	636	sand	sand	gravel	boulder
SHAKOPEE LIMEROCK			225	235	10	636	626	Prairie Du Chien	dolomite	sandstone	
SHAKOPEE LIMEROCK			235	236	1	626	625	Jordan Sandstone	sandstone		
JORDAN		SOFT	236	245	9	625	616	Jordan Sandstone	sandstone		
JORDAN SANDROCK			245	320	75	616	541	Jordan Sandstone	sandstone		
JORDAN SANDROCK			320	350	30	541	511	St.Lawrence	shale	dolomite	sandstone
JORDAN SANDROCK			350	355	5	511	506	Tunnel City Group	sandstone	shale	dolomite
ST. LAWRENCE SHALE			355	490	135	506	371	Tunnel City Group	sandstone	shale	dolomite
FRANCONIA SANDROCK &			490	548	58	371	313	Wonewoc Sandstone	sandstone		
FRANCONIA SANDROCK &			548	618	70	313	243	Eau Claire Formation	shale	sandstone	
FRANCONIA SANDROCK &			618	669	51	243	192	Mt.Simon Sandstone	sandstone		

Minnesota Unique Well Number

209207

County Anoka
Quad New
Quad ID 119C

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING REPORT

Minnesota Statutes Chapter 1031

Entry Date 04/15/1991
Update Date 05/22/2014
Received Date

Well Name	Township	Range	Dir Section	Subsection
FRIDLEY 12	30	24	W 12	BCDDAA

Elevation 890 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet)

Address

C/W 7345 65 HY FRIDLEY MN

Stratigraphy Information

Geological Material	From	To (ft.)	Color	Hardness
SAND	0	20		
CLAY	20	55		
CLAY & GRAVEL	55	72		
SAND	72	86		
CLAY	86	93		
CLAY & GRAVEL	93	95		
SAND & GRAVEL	95	153		
SHAKOPEE	153	225		
JORDAN	225	276		

Remarks

M.G.S. NO. 524

Well Depth	Depth Completed	Date Well Completed
276 ft.	276 ft.	00/00/1970

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**

24 in. To 234 ft. lbs./ft.

30 in. To 153 ft. lbs./ft.

Open Hole From 234 ft. To 276 ft.

Screen? ☐ **Type** **Make**

Static Water Level

53.5 ft. land surface Measure 00/00/1970

Pumping Level (below land surface)

73.5 ft. hrs. Pumping at 1212 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

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 150 Volt

Length of drop pipe ft Capacity 1200 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 Jordan Sandstone Depth to Bedrock 153 ft

Located by Minnesota Department of Health

Locate Method GPS Differentially Corrected

System UTM - NAD83, Zone 15, Meters X 480877 Y 4994245

Unique Number Verification Information from Input Date 07/27/1999

Angled Drill Hole

Well Contractor

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

Minnesota Unique Well No.

209207

County Anoka
Quad New Brighton
Quad ID 119C

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Entry Date 04/15/1991
Update
Received Date 05/22/2014

Well Name	Township	Range	Dir	Section	Subsection	Use	Status	Well Depth	Depth Completed	Date Well Completed	Lic/Reg. No.
FRIDLEY 12	30	24	W	12	BCDDAA	community supply	A	276 ft.	276 ft.	00/00/1970	62012

Elevation 890 ft. **Elev. Method** 7.5 minute topographic map (+/- 5 feet) **Aquifer** Jordan **Depth to Bedrock** 153 ft **Open Hole** 234 - 276 ft **Static Water Level** 53.5 ft

Field Located By Minnesota Department of
Unique No. Verified Information from owner
Geological Interpretation John Mossler
Agency (Interpretation)

Locate Method GPS Differentially Corrected
Input Source Minnesota Department of Health
Input Date 07/27/1999

Universal Transverse Mercator (UTM) - NAD83 - Zone 15 -
UTM Easting (X) 480877
UTM Northing (Y) 499424
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			0	20	20	890	870	sand	sand		
CLAY			20	55	35	870	835	clay	clay		
CLAY & GRAVEL			55	72	17	835	818	pebbly sand/silt/clay	clay	gravel	
SAND			72	86	14	818	804	sand	sand		
CLAY			86	93	7	804	797	clay	clay		
CLAY & GRAVEL			93	95	2	797	795	pebbly sand/silt/clay	clay	gravel	
SAND & GRAVEL			95	153	58	795	737	sand +larger	sand	gravel	
SHAKOPEE			153	225	72	737	665	Prairie Du Chien	dolomite		
JORDAN			225	276	51	665	614	Jordan Sandstone	sandstone		

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

MINNESOTA MDH DEPARTMENT OF HEALTH

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

Public Water Supply ID:	1020031	PWS Name:	Fridley

Contact Information for Person Completing this Form

Name:	Adam Janzen
Address:	4300 MarketPointe Drive Suite 200
City, State, Zip:	Bloomington, MN, 55435
Phone, Fax, e-mail:	(952) 842-3596 (p), (952) 832-2601 (f), ajanzen@barr.com

Aquifer Properties Determination Methods

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

- ☐ 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

206658					

Submitted by: Adam Janzen	Prof. License: 53665	Date: 2/26/2018
Reviewed by: Amal Djerrari	Approved: ◉ Yes ○ No	Approval Date: 4/16/2018

Summary of Aquifer Properties Based on Existing Data

Aquifer Name: Quaternary Buried Unconfined | **Aquifer Code:** QBUA

Hydraulic Confinement ☐ Confined ☑ Unconfined ☐ Fractured Rock

Aquifer Test Number of test(s) on file used to compile the information tabulated below:
1

Aquifer Properties Summary Table

Representative Values		Unit	Range		+/- %
			Minimum	Maximum	
Top Stratigraphic Elev.	826	feet (MSL)			
Bottom Stratigraphic Elev.	662	feet (MSL)			
Transmissivity (T)	6.40E+04	ft^2/day			
Aquifer Thickness (b)	164	feet			
Saturated Thickness* (b)	161	feet			
Hydraulic Conductivity (k)	397	ft/day	199	596	+50/-50
Primary Porosity (e_p)	0.25	0.00 %			
Secondary Porosity** (e_s)		0.00 %			
Storativity (S)	8.9E-3	dimensionless			
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.

One specific capacity test was conducted on Fridley Well 10 (Unique Number 206658) in 1969. The result of the test was analyzed using the TGuess method (see attached). The log for Fridley Well 10 shows a clay unit from 8-35 feet below grade and then sand and gravel to the bottom of the well. The log includes a static water level of 38 feet below the "top of breather pipe." This measuring point was assumed to be near the ground surface, and therefore the hydrogeologic setting was interpreted as buried unconfined.

Below is a summary of the results from Fridley Well 10 (Unique Number 206658):

Flow Rate (gpm)	T(ft**2/day)
800	6.40E+04

For the model sensitivity analysis, the hydraulic conductivities of the QBUA will be adjusted +/- 50%. The QBUA hydraulic conductivity range will therefore be 199-596 ft/day

Quaternary

Worksheet for Estimating Transmissivity and Hydraulic Conductivity from Specific Capacity Test Data

Explanation and notes attached.

Maximum iterations	20	
Error tolerance (as drawdown)	0.001	feet

	Field Data							Estimated Parameters			Calculated Results							Diagnostics					
		Depth to Water				Screened Interval												***Solution Integrity***			***Sensitivity of T:***		
Location	Well Diam.	Initial	Final	Test Duration	Mean Pumping Rate	Depth to Top	Depth to Bottom	Storage Coeff. (S)	Well loss Coeff. (C)	Aquifer Thickness (b)	Measured Drawdown (s_m)	Saturated Screen Length (L)	Well loss (s_w)	Partial Penetration Parameter (s_p)	Specific Capacity	**Transmissivity (T)**	**Conductivity (K)**	Calculated Drawdown	Error as Drawdown	Well Bore Storage Test	to S at ± 1 factor of 10	to s_w at 10% of s_m	to b at ± 25%
	inches	feet	feet	hours	gpm	feet	feet	-	sec^2/ft^5	feet	feet	feet	feet	-	gpm/ft	**sq ft/sec**	**ft/day**	feet			sq ft/sec	sq ft/sec	sq ft/sec
Fridley10_206658	16	38.0	43.2	2	800.0	128.0	199.0	0.001	0	161.0	5.20	71.0	0.0E+00	5.02	153.85	**7.4E-01**	**4.0E+02**	5.20	0.01%	pass	6.5E-02	8.6E-02	2.9E-01

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:	1020031	PWS Name:	Fridley

Contact Information for Person Completing this Form

Name:	Adam Janzen
Address:	4300 MarketPointe Drive Suite 200
City, State, Zip:	Bloomington, MN, 55435
Phone, Fax, e-mail:	(952) 842-3596 (p), (952) 832-2601 (f), ajanzen@barr.com

Aquifer Properties Determination Methods

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

☑	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

206673					
206678					
206669					
206672					

Submitted by: Adam Janzen	Prof. License: 53665	Date: 5/1/2018
Reviewed by: Amal Djerrari	Approved: ◉ Yes ○ No	Approval Date: 5/2/2018

Summary of Aquifer Properties Based on Existing Data

Aquifer Name: Prairie du Chien | **Aquifer Code:** OPDC

Hydraulic Confinement ☑ Confined ☐ Unconfined ☑ Fractured Rock

Aquifer Test Number of test(s) on file used to compile the information tabulated below:
2

Aquifer Properties Summary Table

Representative Values		Unit	Range		+/- %
			Minimum	Maximum	
Top Stratigraphic Elev.	755	feet (MSL)	734	757	+0.3/-2.8
Bottom Stratigraphic Elev.	620	feet (MSL)	620	653	+5.3/-0
Transmissivity (T)	149,000	ft^2/day	18,860	168,750	+13/-87
Aquifer Thickness (b)	135	feet	92	135	+0/-32
Saturated Thickness* (b)		feet			
Hydraulic Conductivity (k)	1100	ft/day	205	1250	+14/-81
Primary Porosity (e_p)	0.05	0.00 %			
Secondary Porosity** (e_s)	?	0.00 %	Cavernous interconnections present		
Storativity (S)	3.0E-04	dimensionless	2.0E-04	3.5E-04	
Characteristic Leakage (L)	7480	feet			
Hydraulic Resistance (c)	390	days	390	505	

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.

Aquifer tests were performed on both Fridley Well 6 (206673) and Fridley Well 8 (206669) in 1993. The results of the pumping tests were analyzed by the MDH (see attachments). Both tests satisfy the requirements of rule 4720.5520.

Though Fridley Well 6 (206673) extends into the CJDN for a limited distance (~22 ft), the contribution of the CJDN to the properties of the screen aquifer is considered insignificant (see attachments). Fridley Well 8 (206669) is open only to the OPDC. Analysis of the aquifer tests at Fridley Well 6 and Fridley Well 8 estimated an OPDC transmissivity of 149,000 ft**2/day. The thickness of the OPDC at Well 8 is 135 ft, resulting in an estimated OPDC hydraulic conductivity of 1,100 ft/day. Both results for Fridley Well 6 and Fridley Well 8 indicated that cavernous porosity was present in the OPDC.

For the model sensitivity analysis, the lower bound hydraulic conductivity of the OPDC will be set to the 205 ft/day existing Metro Model 3 hydraulic conductivity at Well 6 and the upper bound will be set to the 1,250 ft/day maximum from the Well 6 test.

The logs for Fridley Wells 2, 3, 4, 5, 6, 7, 8, and 9 were used to determine the range of OPDC thicknesses and contact elevations. The representative values shown are from Well 8, consistent with the attached summary tables from both tests.

Memo

Minnesota Department of Health

Date: November 15, 2016

To: Fridley WHP Project File (PWSID: 1020031)

From: Justin Blum

Subject: Analysis of the Fridley 6 (206673) Pumping Test, July 1, 1993, Confined Prairie du Chien Aquifer

Test No. 2585

This test is one of two tests performed in 1993 at the Fridley Commons Park well field by B.A. Liesch and Associates. Inc. The first test, performed on Fridley 6 (206673), was conducted as described below. The specifics of test location, scope, and timing are presented in Tables 2 and 3. Data were analyzed using standard methods cited in references. Individual analyses are presented in Appendix 1 and are summarized in Table 4. Appendix 2 includes maps, field notes, and any other test documentation.

Table 1. Summary of Results

Conceptual model: leaky-confined, radial porous-media flow, water-table aquifer is source of water to the pumped aquifer. The pumped aquifer is karsted dolostone and minor sandstone.

Aquifer Properties Summary					
Representative Values		Unit	Range		+/- %
			Minimum	Maximum	
Top Stratigraphic Elev.	755	feet (MSL)			
Bottom Stratigraphic Elev.	620	feet (MSL)			
Transmissivity (T)	149,000	ft^2/day	108,000	169,000	
Aquifer Thickness (b)	135	Feet			
Saturated Thickness* (b)		Feet			
Hydraulic Conductivity (k)	1100	ft/day	800	1250	
Primary Porosity (e_p)	0.05	0.00 %			
Secondary Porosity** (e_s)	?	0.00 %	Cavernous interconnections present		
Storativity (S)	3.0E-04	dimensionless	2.0E-04	3.5E-04	
Characteristic Leakage (L)	7480	Feet			
Hydraulic Resistance (c)	390	Days	390	505	
Effective Well Radius (r_e)	100	Feet	80	120	
* hydraulically unconfined aquifer, ** dual porosity aquifer because of fractures or solution weathering					

Boundaries: leakage, enlarged effective borehole radius resulting from conduit flow.

Remarks: high quality test, lack of early-time data (< 1 minute) does not materially affect results. Anomalous hydraulic response of observation wells and over-efficiency of the pumped well are attributed to flow in cavernous secondary-porosity developed in the dolostone of the Prairie du Chien.

Table 2. Aquifer Test Information

Aquifer Test Number	2585
Test Location	Fridley 6 (206673)
Well Owner	City of Fridley
Test Conducted By / For	B.A. Liesch Assoc. for MPCA
Aquifer	OPDC
Confined / Unconfined	Confined
Date/Time Monitoring Start	--
Date/Time Pump off Before Test	--
Date/Time Pumping Start	7/1/1993 09:00
Date/Time Recovery Start	7/2/1993 09:00
Date/Time Test Finish	7/2/1993 16:00
Flow Rate	1326 gpm
Data Collection Methods	Manual
Number of Observation Wells	4

Table 3. Wells Monitored During the Test

Well Name (Unique Well No.)	Radial Distance (feet)	Static Water Levels (feet below measuring point)			Change in Water Level (feet)	Aquifer
		Start	Mid-test	End		
Pumped Well:						
Fridley 6 (206673)	1				3.69	OPDC
Ob Wells:						
7 (206678)	488				2.67	OPDC
9 (206672)	675				2.51	OPDC
8 (206669)	1124				2.34	OPDC
MW-2 (509090)	601				0.3	QBAA

Table 4. Graphical Analysis Results					
Transient Analysis					
Well Name (Unique Well No.)	**Transmissivity, T (ft^2/day)**	**Storage Coefficient, S**	**Analysis Method**	**Characteristic Leakage Factor, L (feet)**	**Plot No. Remarks**
Pumped Well:					
Fridley 6 (206673)	41,400	--	Theis		1
	46,100	3.8E-04	Agarwal		10
	169,000	3.0E-04	Hunt-Scott	8,070 [c=390 days]	11 - effective borehole radius ~100 ft.
Ob Wells:					
F-7 (206678)	38,300	2.0E-04	Theis		2
"	149,000	3.5E-04	Hunt-Scott	7,600 [c=390 days]	12 – radius of 490 ft.
F-9 (206672)	50,700	2.6E-05	Theis		3
"	**140,000**	**2.0E-04**	**Hunt-Scott**	**7,480 [c=400 days]**	13 – radius of 675 ft.
F-8 (206669)	45,100	8.0E-05	Theis		4
"	108,000	3.0E-04	Hunt-Scott	5,810 [c=310 days]	14 – radius of 1100 ft.
MW-1 (509090)	170,000	3.4E-02	Theis		5 - Poor match
Distance – Drawdown	47,200	1.4E-04	Walton t/r^2		6 – over-efficient pumping well
	47,200	1.4E-04	Walton t/r^2	5000 to 9800 [c=530 to 2040 days]	7 – effective borehole radius ~100 ft.
	32,500	5.6E-05	Cooper-Jacob		8 – S is too small for this setting
Steady-state Analysis					
Transmissivity, T (ft2/day)	**Characteristic Leakage, L (feet)**	**Hydraulic Resistance, c (days)**	**Analysis Method**	**Plot No. Remarks**	
32,500	32,100	31,800	Hantush-Jacob	8 – L is unreasonably large for setting – not physically possible	
50,700	12,000	2850	de Glee	9 - L is too large for setting – does not permit observed response in drift obwell	

Test Description

Purpose of Test

The test was conducted to investigate the source and concentration of VOC contamination in the public water supply (PWS) wells at the Fridley Commons Park well field. The location and aquifer completion of the wells is shown on Figure 1, Appendix 2.

Hydrogeologic Setting

The test is documented in the B.A, Liesch & Assoc. report to Fridley and the MPCA dated September, 1993 – see references. The wells are constructed primarily as Prairie du Chien (PdC) wells. If they extend into the Jordan Sandstone, it is for a limited distance. Therefore, it is assumed that the contribution of the Jordan to the production of these wells is insignificant.

Qualitative Aquifer Hydraulic Response:

Theis-curve matches are made to all wells, plots 1 to 5, to identify any possible boundaries and provide apparent aquifer properties based on the perspective of each well. The individual plots show the influence of leakage in late-time and no other boundaries were identified. The drift observation well, plot 5, clearly responded to pumping but data collection at that well was limited for this test and the curve-match was poor.

A distance-drawdown plot, t/r^2, is used to view all data from the test on one graph. Plot 6 shows that the pumped well is over-efficient relative to the Theis-curve based on a match to the nearest observation well. A reasonable explanation for the high hydraulic efficiency of this well is that it is open to one or more intervals of cavernous secondary porosity developed within the PdC. In addition, the response of the pumped well appears slightly leaky. With respect to the hydraulic response at the two more distant observation wells, Plot 6 shows that the early-time drawdowns are too large relative to the Theis-curve and the later-time drawdowns converge on a single leaky curve. [Rather than individual curves according to the radial distance of each observation well, as is normal in a porous media aquifer.] This is a strong indication that the cavernous interval extends throughout the Commons Park well field; causing these wells to be highly productive and distributing the hydraulic stress of pumping very efficiently relative to a porous-media aquifer.

Storativities calculated by the transient techniques, plots 1 through 8, are within the range for a highly confined aquifer, 10^{-5}, even though the drift monitoring well, completed in the layer above, clearly responded within 24 hours of pumping. The response of the drift monitoring well indicates a very leaky system. If the system is leaky, values for storativity should be in the range of 10^{-3} to 10^{-4}, not 10^{-4} to 10^{-5}, as seen from these analyses.

An iterative process is used to fit the pumped well data to the Theis curve by adjusting the nominal radius of the well. The effective borehole radius for Well 6 appears to be about 100 feet, plot 7. Once the large effective radius of the pumped well is taken into account, steady-state analyses show similar values for transmissivity as from the transient analyses, plots 8 and 9. The values for the characteristic leakage factor from the steady-state analyses are quite large, in the range of a tightly confined aquifer system. From the observed effect on the drift monitoring well, it would be expected that the hydraulic resistance should be in the range of hundreds of days (leakage factor^2/transmissivity, [L^2/T]) and the corresponding leakage factor should be in the range of 5,000 feet – not 12,000 feet and greater. Therefor the Walton t/r^2 leakage factor is more appropriate, plot 7; even though it is only based on the match to the nearest observation well.

These qualitative relationships between interdependent parameters; transmissivity, hydraulic confinement and leakiness are contradictory and indicate problems with the conceptual model of the flow system. It is a fact that the system is sufficiently leaky that the water table is affected by pumping in the PdC. This violates a primary assumption of the source of water for both transient and steady-state analysis techniques. Therefore, a slightly different conceptual model; in which the water table is contained within the leaky layer, after Hunt-Scott (2007) - should be used to calculate the aquifer properties.[1]

Quantitative Analysis

Conceptual Model

The conceptual model is of porous radial flow to a well in a leaky two-layered system; the pumped aquifer and an overlying leaky confining layer that contains the water table.

Analysis Results

The Hunt-Scott analyses, plots 11 through 14, show an extraordinarily large transmissivity, a corresponding large leakage factor, along with a reasonable storativity. The hydraulic resistance of the confining layer calculated from these parameters [L^2/T] is in the range of 300 to 400 days; consistent with the leaky response of the drift observation well. Plot 11 is of data from the pumped well only so as to test the large effective borehole radius. A large effective borehole radius of 100 feet is required for the pumped well in order to provide a transmissivity value that is within the range of those provided by the other wells.

Hydraulic response affected by:

Flow within cavernous secondary-porosity.

Consistency with conceptual model:

Data from the PdC observation wells, modeled on plots 12, 13 and 14, show fairly consistent aquifer properties. Unfortunately, the length of the test was insufficient to confirm that the Hunt-Scott conceptual model is correct for this setting. An additional day of pumping would provide the data needed to differentiate between the late-time curves. Nevertheless, the most consistent set of aquifer parameters is provided by this method; in which the interdependent relationships between T, S, L and c are maintained – consistent with the hydrogeologic setting.

The results from the pumped well and the three PdC observation wells are quite consistent once the appropriate conceptual flow model was identified. Only the large effective borehole radius is needed to compensate for differences with the Hunt-Scott conceptual model of the flow system.

Representative aquifer properties best shown by:

Plots 11 through 14; nominal aquifer properties are shown in Table 1.

Selected References

Agarwal, R.G. 1980. A new method to account for producing time effects when drawdown type curves are used to analyze pressure buildup and other test data. SPE Paper 9289, presented at the 55th SPE Annual Technical Conference and Exhibition, Dallas, Texas, September 21–24, 1980.

Cooper, H.H. and Jacob, C.E. (1946) A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well-filed History, Trans. American Geophysical Union, V. 27, pp. 526 – 534.

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[1] No criticism of the work performed by B.A. Liesch & Assoc. is expressed or implied; datasets that were carefully collected and appropriately documented may be re-examined by newer methods. This technique was not available at the time that the tests were performed in 1993.

de Glee, G. (1930) Over grondwaterstroomingen bij wateronttrekking door middle van putten. Ph.D. thesis, Delft Technische Hogeschool, Delft.

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Kruseman and De Ridder, (1991) Analysis and Evaluation of Pumping Test Data (2nd Edition), Publication 47, International Institute for Land Reclamation and Improvement, P.O. Box 45, 6700 AA Wageningen, The Netherlands, pp. 76-78.

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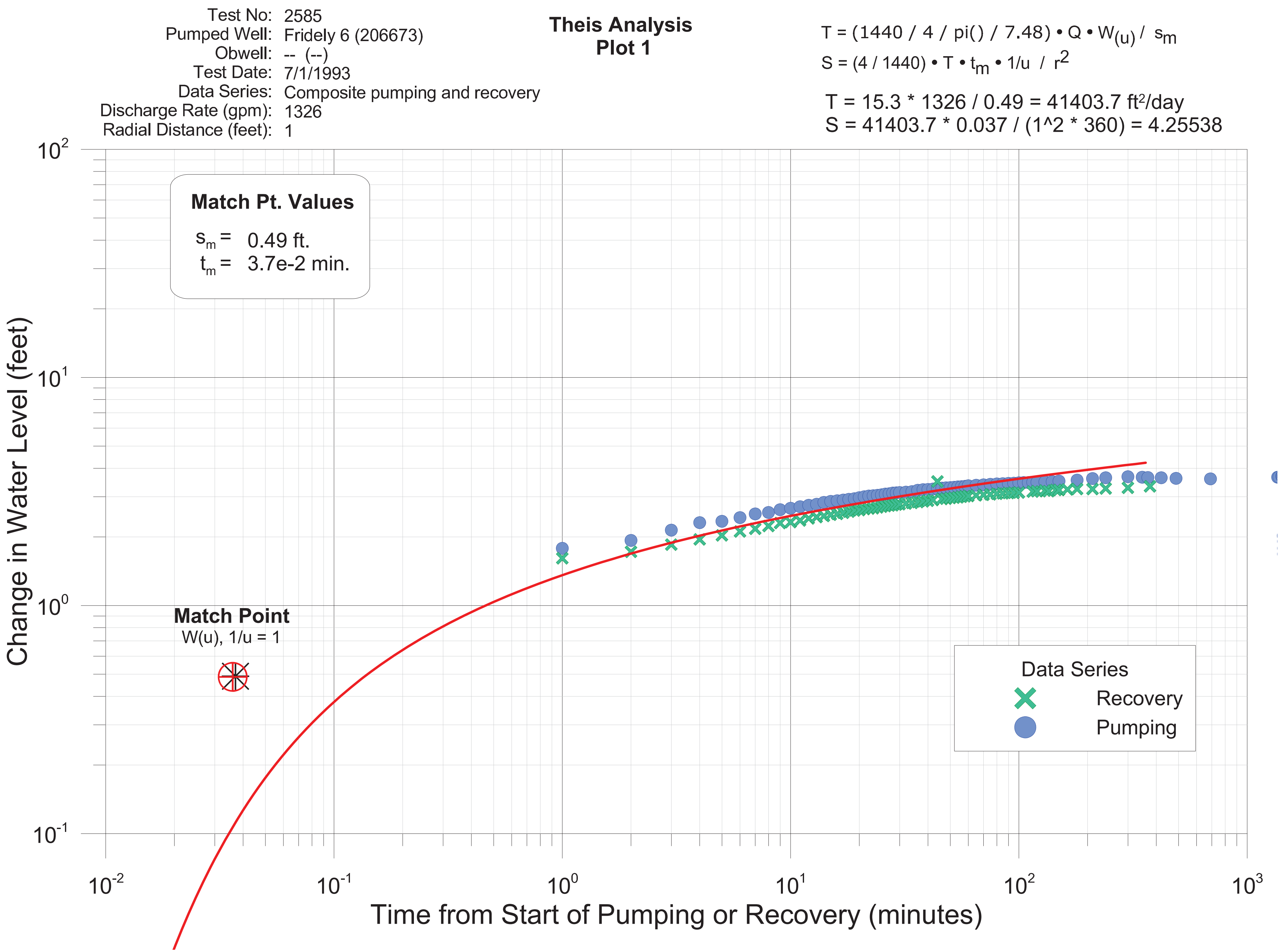
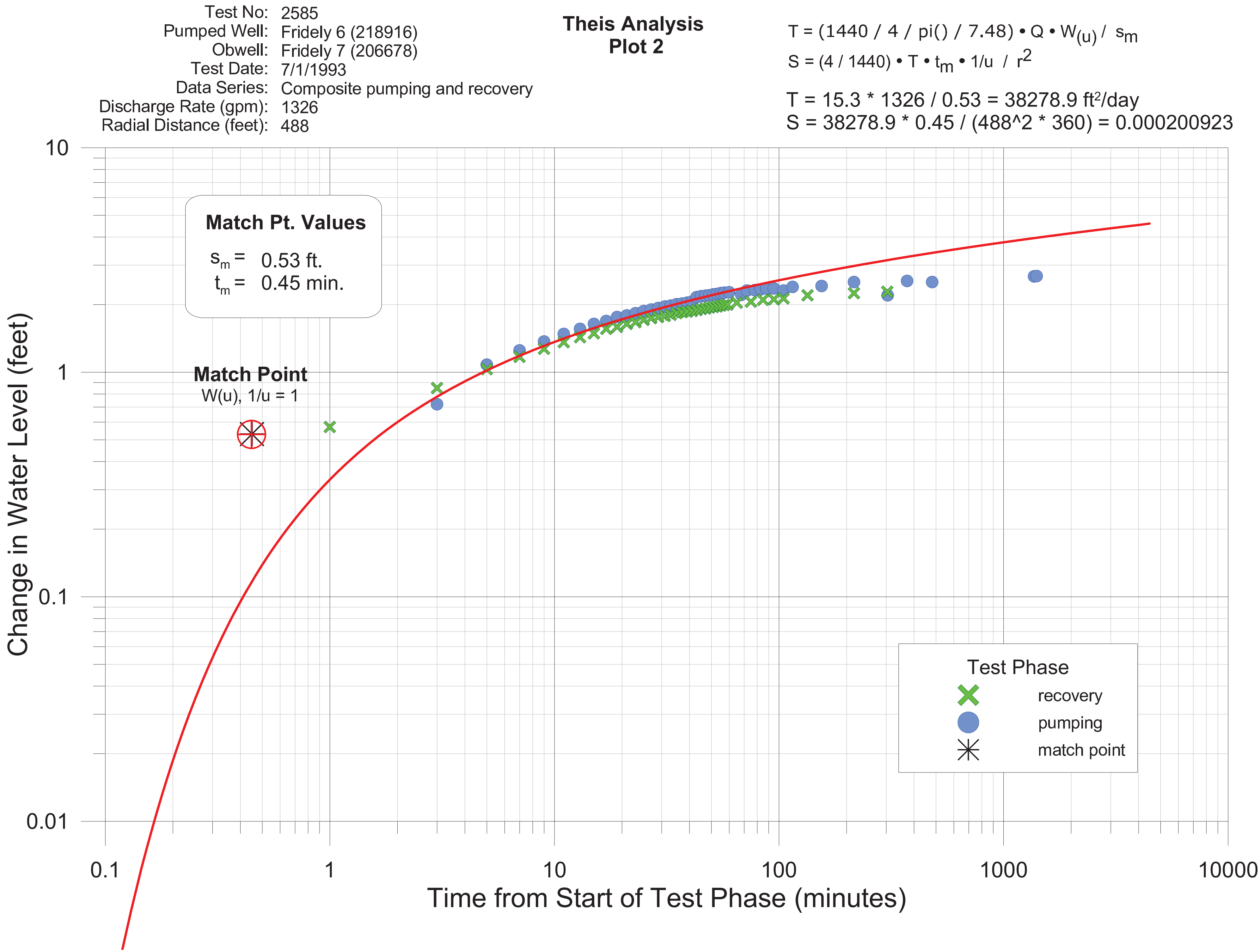
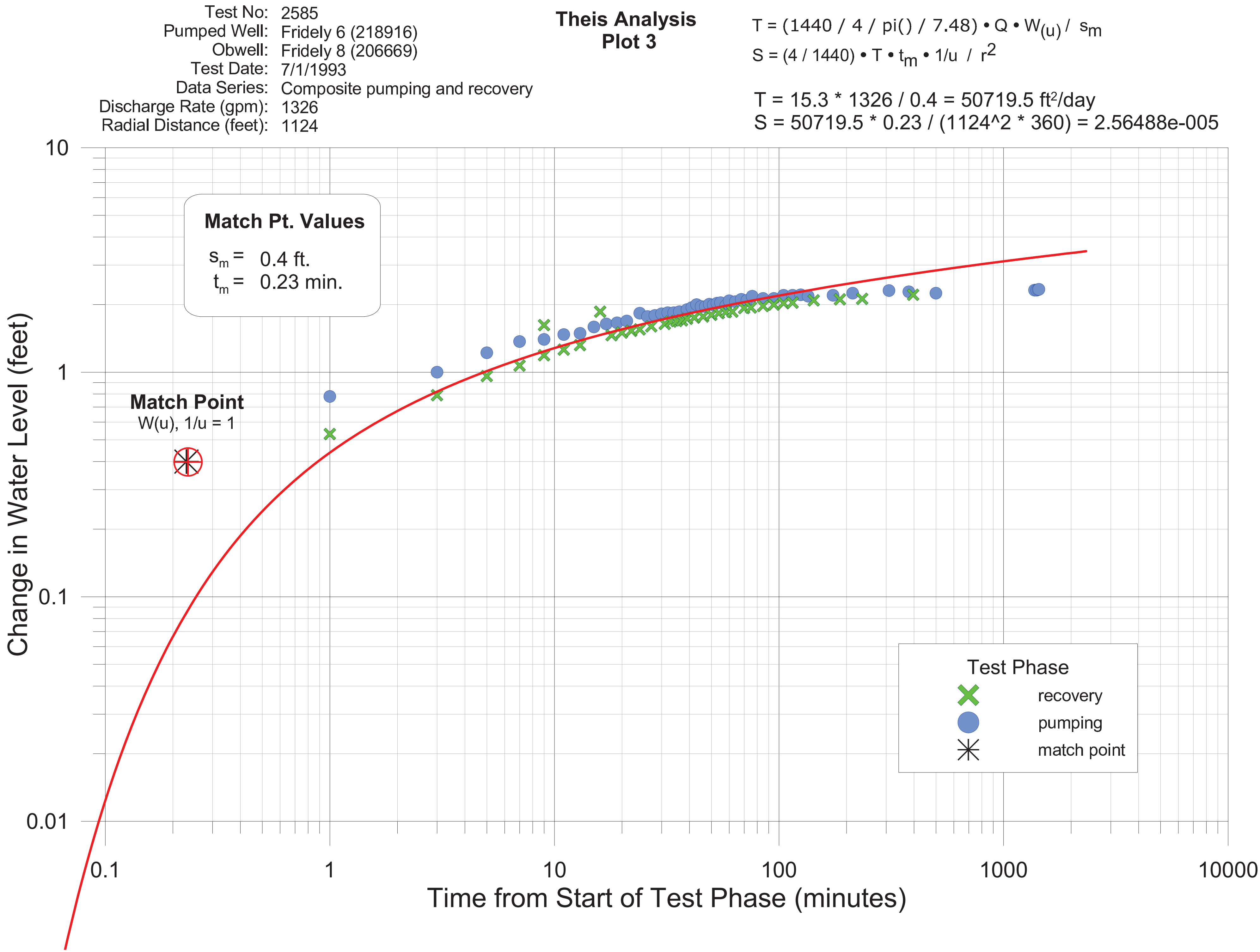
Theis, C. V. (1935) The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Ground-Water Storage, Trans. American Geophysical Union, 16th Annual Meeting, April, 1935, pp. 519-24.

Walton, W.C. (1960) Leaky Artesian Aquifer Conditions In Illinois, Illinois State Water Survey, Bulletin 39, pp. 27.

Appendix 1 – Graphical Analysis


Test No: 2585
Pumped Well: Fridely 6 (206673)
Obwell: -- (--)
Test Date: 7/1/1993
Data Series: Composite pumping and recovery
Discharge Rate (gpm): 1326
Radial Distance (feet): 1
Theis Analysis
Plot 1
T = (1440 / 4 / pi() / 7.48) • Q • W(u) / sm
S = (4 / 1440) • T • tm • 1/u / r2
T = 15.3 * 1326 / 0.49 = 41403.7 ft²/day
S = 41403.7 * 0.037 / (1^2 * 360) = 4.25538
Match Pt. Values
sm = 0.49 ft.
tm = 3.7e-2 min.
Match Point
W(u), 1/u = 1
Data Series
Recovery
Pumping
Change in Water Level (feet)
Time from Start of Pumping or Recovery (minutes)
10-2
10-1
100
101
102
103


Test No: 2585
Pumped Well: Fridely 6 (218916)
Obwell: Fridely 7 (206678)
Test Date: 7/1/1993
Data Series: Composite pumping and recovery
Discharge Rate (gpm): 1326
Radial Distance (feet): 488
Theis Analysis
Plot 2
T = (1440 / 4 / pi() / 7.48) • Q • W(u) / sm
S = (4 / 1440) • T • tm • 1/u / r2
T = 15.3 * 1326 / 0.53 = 38278.9 ft2/day
S = 38278.9 * 0.45 / (488^2 * 360) = 0.000200923
Match Pt. Values
sm = 0.53 ft.
tm = 0.45 min.
Match Point
W(u), 1/u = 1
Test Phase
recovery
pumping
match point
Change in Water Level (feet)
Time from Start of Test Phase (minutes)
10
1
0.1
0.01
0.1
1
10
100
1000
10000



Test No: 2585
Pumped Well: Fridely 6 (218916)
Obwell: Fridely 8 (206669)
Test Date: 7/1/1993
Data Series: Composite pumping and recovery
Discharge Rate (gpm): 1326
Radial Distance (feet): 1124
Theis Analysis
Plot 3
T = (1440 / 4 / pi() / 7.48) • Q • W(u) / sm
S = (4 / 1440) • T • tm • 1/u / r2
T = 15.3 * 1326 / 0.4 = 50719.5 ft2/day
S = 50719.5 * 0.23 / (1124^2 * 360) = 2.56488e-005
Match Pt. Values
sm = 0.4 ft.
tm = 0.23 min.
Match Point
W(u), 1/u = 1
Test Phase
recovery
pumping
match point
Change in Water Level (feet)
10
1
0.1
0.01
0.1
1
10
100
1000
10000
Time from Start of Test Phase (minutes)

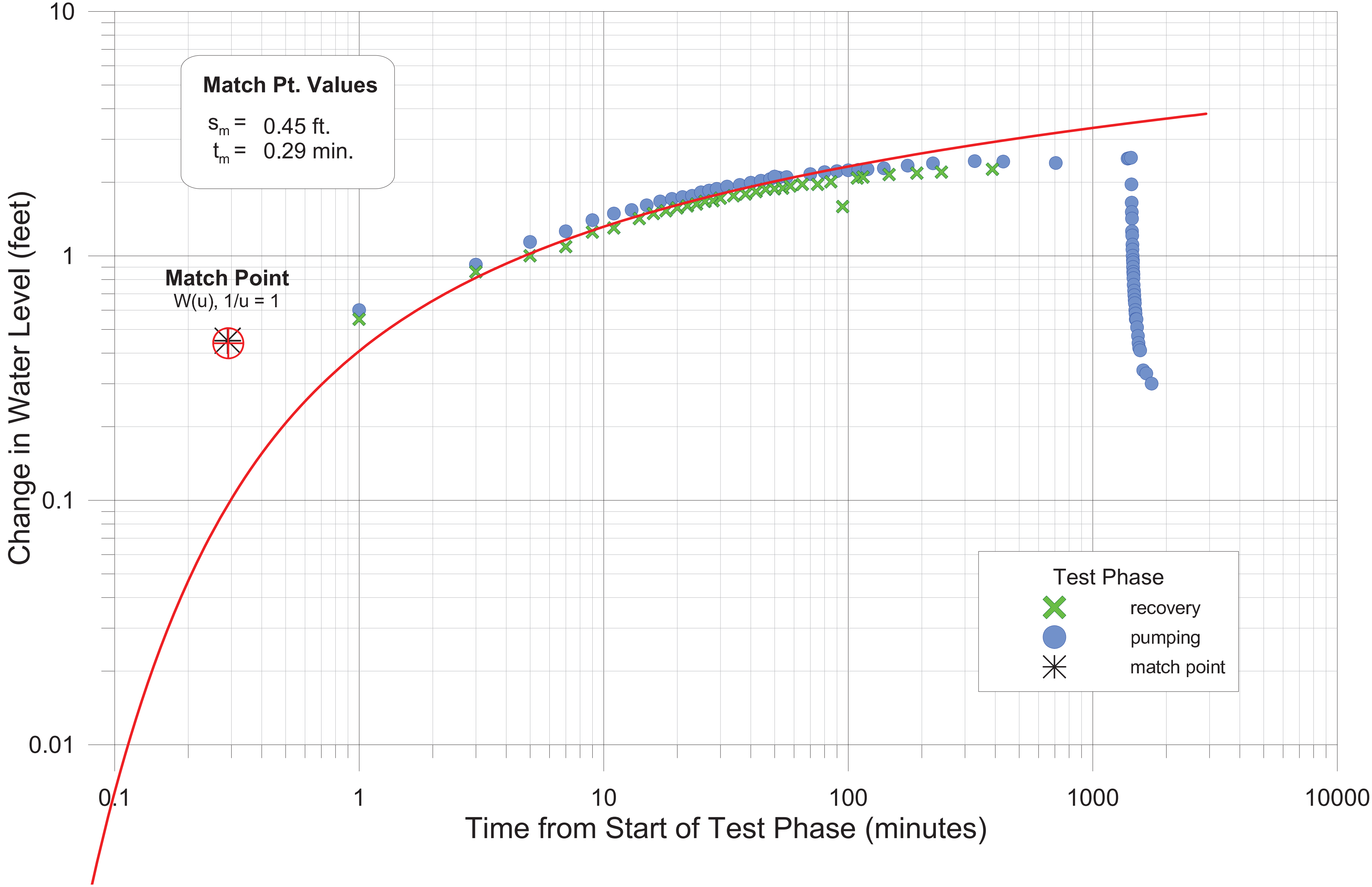
Test No: 2585
Pumped Well: Fridely 6 (218916)
Obwell: Fridely 9 (206672)
Test Date: 7/1/1993
Data Series: Composite pumping and recovery
Discharge Rate (gpm): 1326
Radial Distance (feet): 675

Theis Analysis
Plot 4

$T = (1440 / 4 / pi() / 7.48) \cdot Q \cdot W_{(u)} / s_m$

$S = (4 / 1440) \cdot T \cdot t_m \cdot 1/u \; / \; r^2$

T = 15.3 * 1326 / 0.45 = 45084 ft^2/day
S = 45084 * 0.29 / (675^2 * 360) = 7.97096e-005



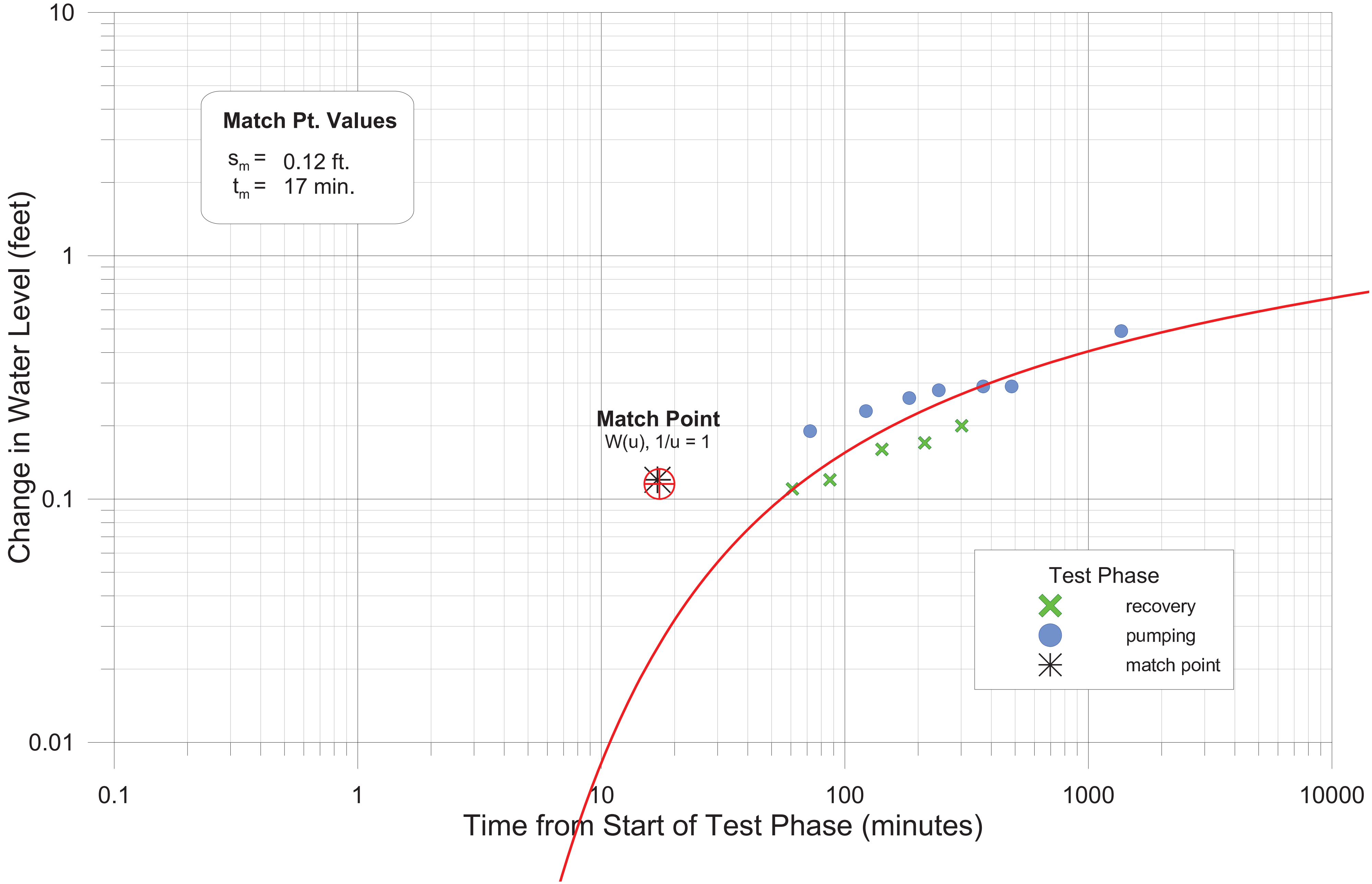
Test No: 2585
Pumped Well: Fridely 6 (218916)
Obwell: MW-2 (509090)
Test Date: 7/1/1993
Data Series: Composite pumping
Discharge Rate (gpm): 1326
Radial Distance (feet): 488

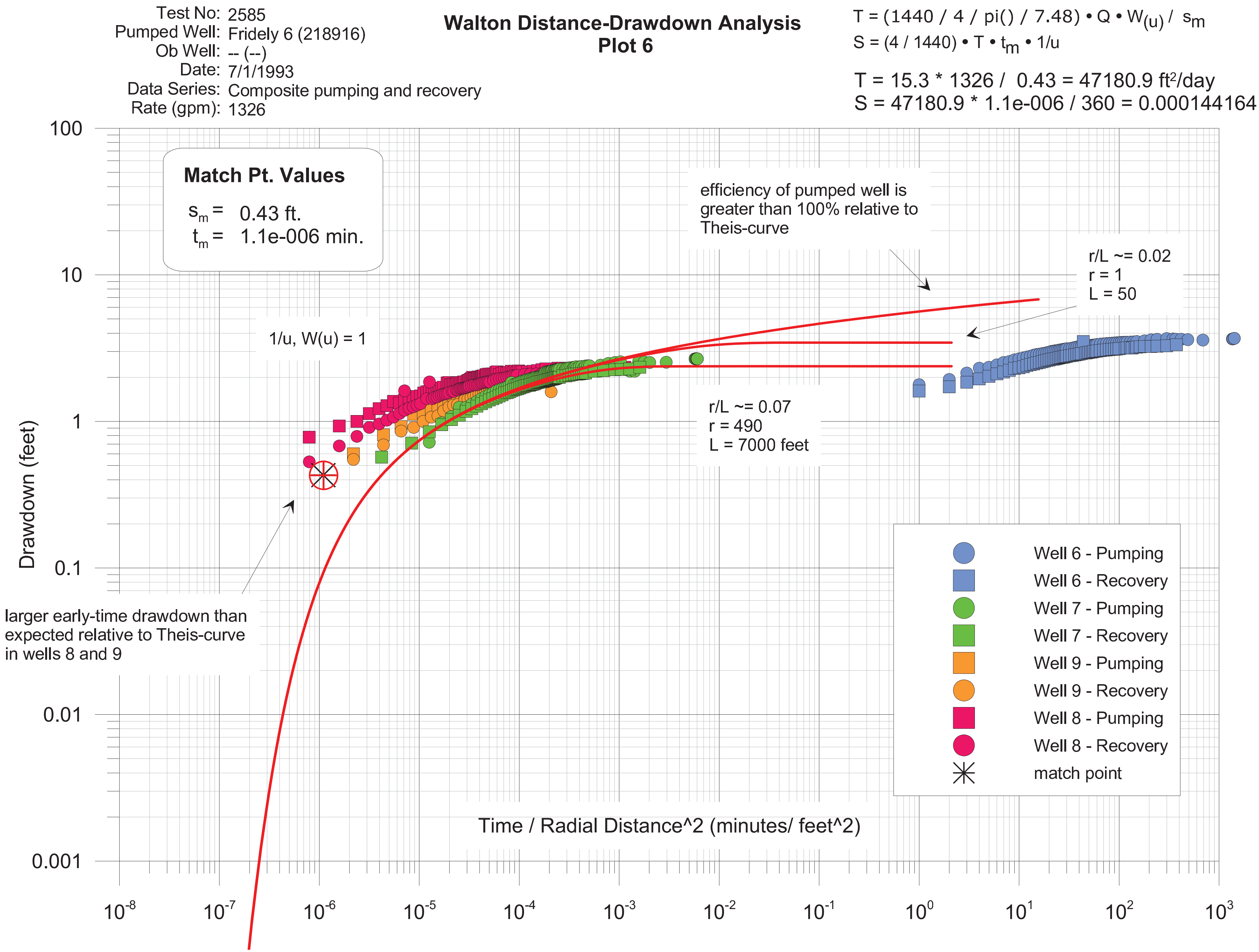
Theis Analysis
Plot 5

$T = (1440 / 4 / pi() / 7.48) \cdot Q \cdot W_{(u)} / s_m$

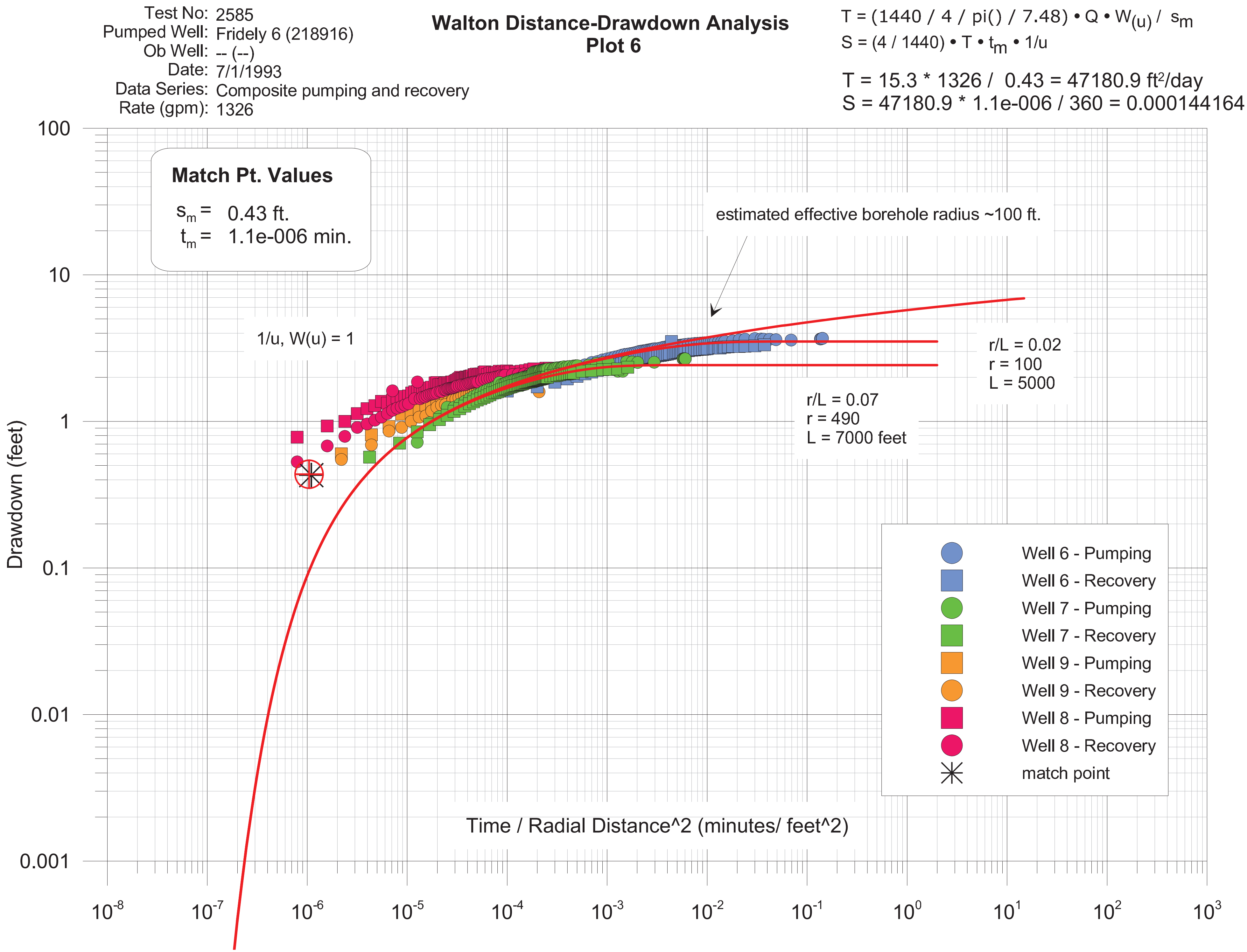
$S = (4 / 1440) \cdot T \cdot t_m \cdot 1/u / r^2$

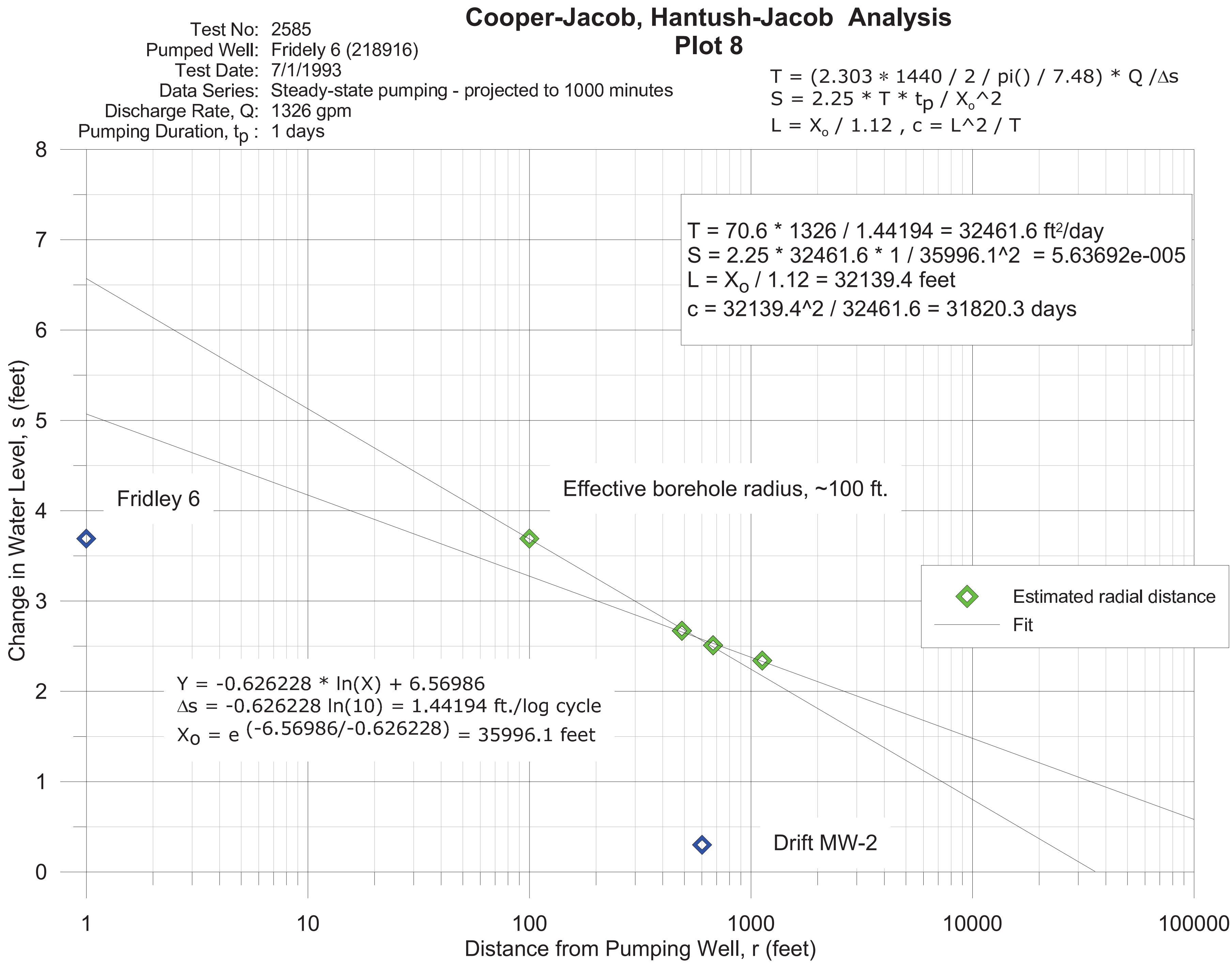
T = 15.3 * 1326 / 0.12 = 169065 ft^2/day
S = 169065 * 17 / (488^2 * 360) = 0.0335244



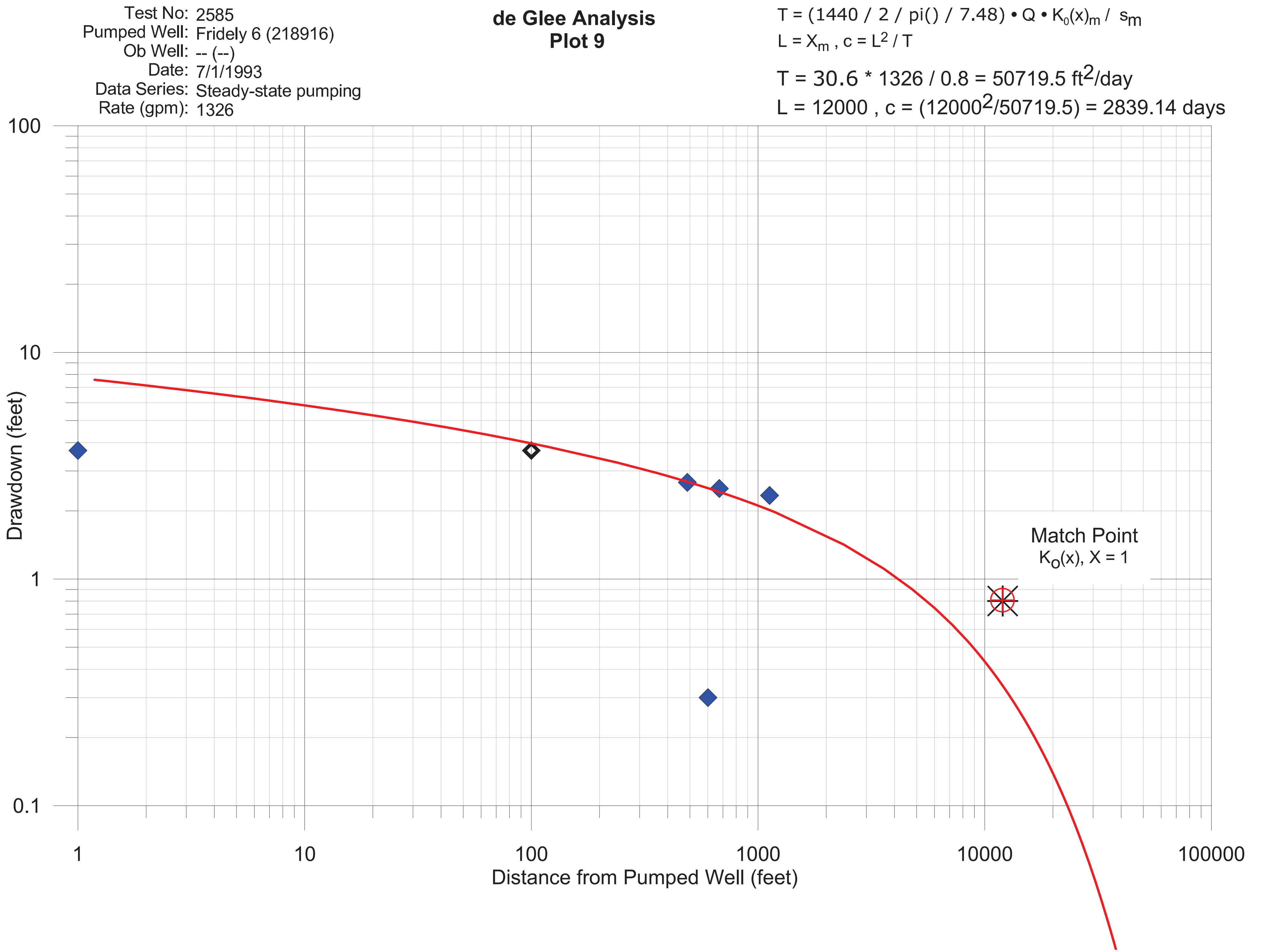


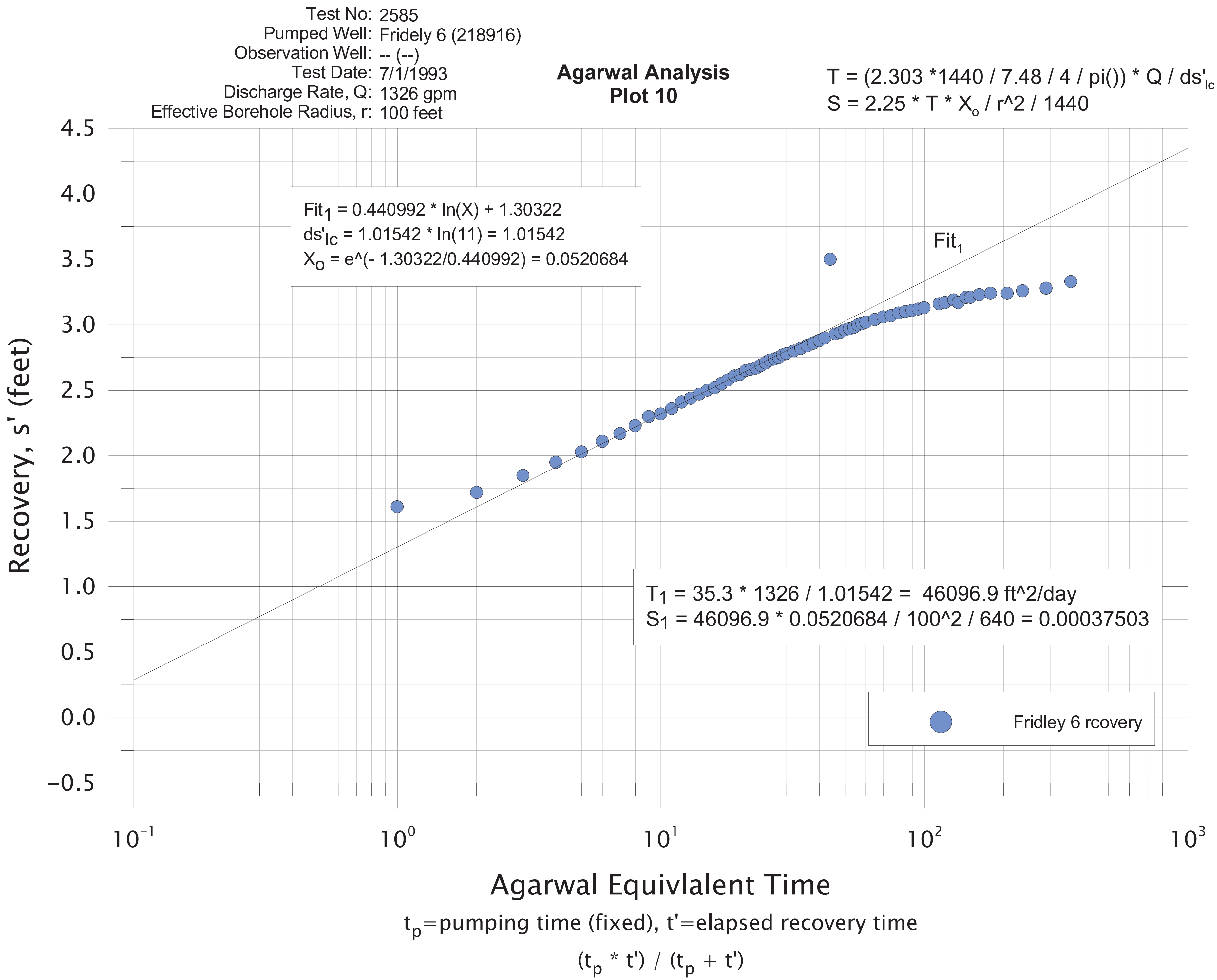
Test No: 2585
Pumped Well: Fridely 6 (218916)
Ob Well: -- (--)
Date: 7/1/1993
Data Series: Composite pumping and recovery
Rate (gpm): 1326
Walton Distance-Drawdown Analysis
Plot 6
T = (1440 / 4 / pi() / 7.48) • Q • W(u) / sm
S = (4 / 1440) • T • tm • 1/u
T = 15.3 * 1326 / 0.43 = 47180.9 ft²/day
S = 47180.9 * 1.1e-006 / 360 = 0.000144164
Match Pt. Values
sm = 0.43 ft.
tm = 1.1e-006 min.
efficiency of pumped well is greater than 100% relative to Theis-curve
r/L ~= 0.02
r = 1
L = 50
1/u, W(u) = 1
r/L ~= 0.07
r = 490
L = 7000 feet
larger early-time drawdown than expected relative to Theis-curve in wells 8 and 9
Drawdown (feet)
100
10
1
0.1
0.01
0.001
Time / Radial Distance^2 (minutes/ feet^2)
10^-8 10^-7 10^-6 10^-5 10^-4 10^-3 10^-2 10^-1 10^0 10^1 10^2 10^3
Well 6 - Pumping
Well 6 - Recovery
Well 7 - Pumping
Well 7 - Recovery
Well 9 - Pumping
Well 9 - Recovery
Well 8 - Pumping
Well 8 - Recovery
match point


Test No: 2585
Pumped Well: Fridely 6 (218916)
Ob Well: -- (--)
Date: 7/1/1993
Data Series: Composite pumping and recovery
Rate (gpm): 1326
Walton Distance-Drawdown Analysis
Plot 6
T = (1440 / 4 / pi() / 7.48) • Q • W(u) / sm
S = (4 / 1440) • T • tm • 1/u
T = 15.3 * 1326 / 0.43 = 47180.9 ft²/day
S = 47180.9 * 1.1e-006 / 360 = 0.000144164
Match Pt. Values
sm = 0.43 ft.
tm = 1.1e-006 min.
estimated effective borehole radius ~100 ft.
1/u, W(u) = 1
r/L = 0.02
r = 100
L = 5000
r/L = 0.07
r = 490
L = 7000 feet
Well 6 - Pumping
Well 6 - Recovery
Well 7 - Pumping
Well 7 - Recovery
Well 9 - Pumping
Well 9 - Recovery
Well 8 - Pumping
Well 8 - Recovery
match point
Drawdown (feet)
Time / Radial Distance^2 (minutes/ feet^2)
100
10
1
0.1
0.01
0.001
10-8
10-7
10-6
10-5
10-4
10-3
10-2
10-1
100
101
102
103

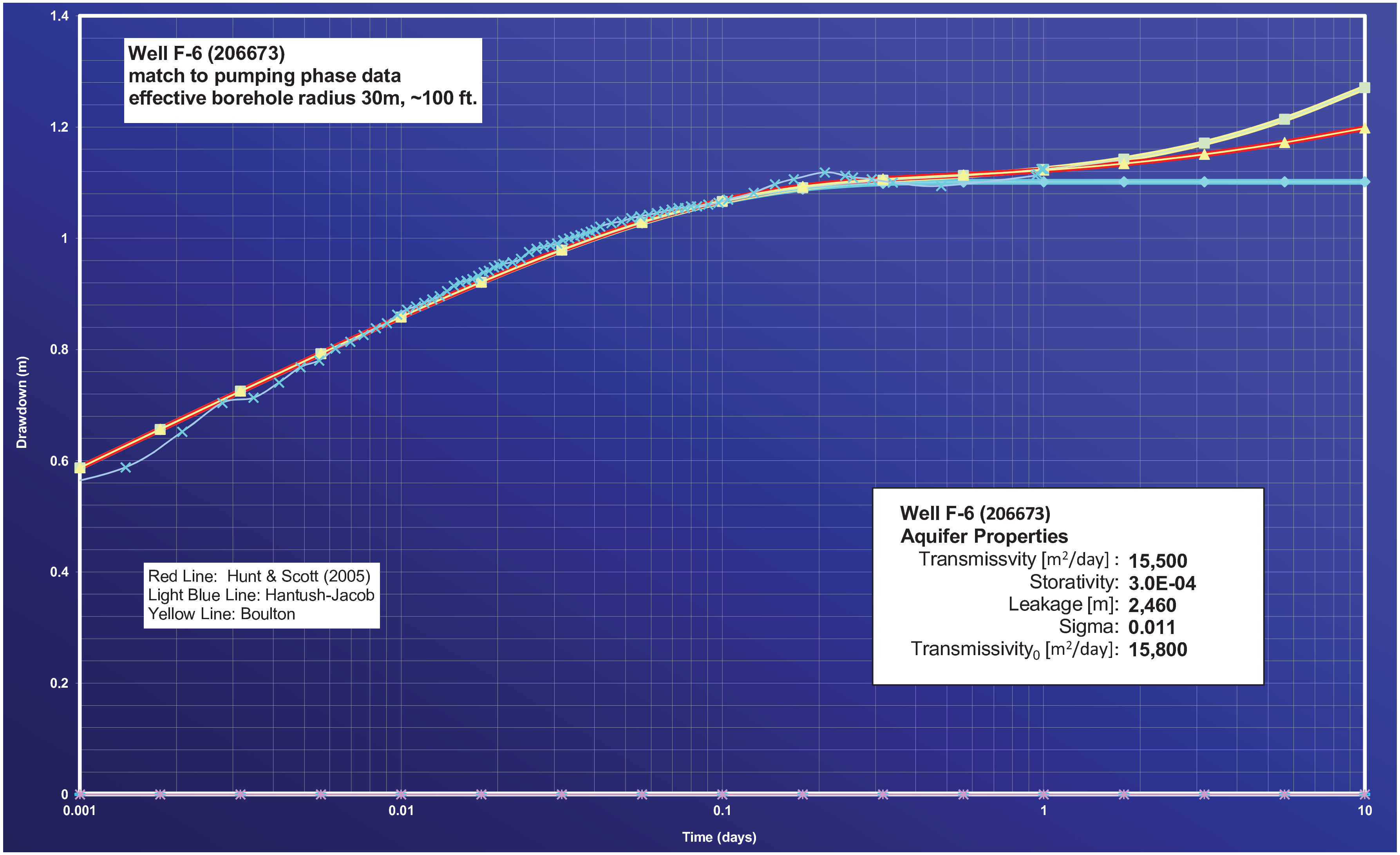


Test No: 2585
Pumped Well: Fridely 6 (218916)
Test Date: 7/1/1993
Data Series: Steady-state pumping - projected to 1000 minutes
Discharge Rate, Q: 1326 gpm
Pumping Duration, tp : 1 days
Cooper-Jacob, Hantush-Jacob Analysis
Plot 8
T = (2.303 * 1440 / 2 / pi() / 7.48) * Q /Δs
S = 2.25 * T * tp / Xo^2
L = Xo / 1.12 , c = L^2 / T
T = 70.6 * 1326 / 1.44194 = 32461.6 ft²/day
S = 2.25 * 32461.6 * 1 / 35996.1^2 = 5.63692e-005
L = Xo / 1.12 = 32139.4 feet
c = 32139.4^2 / 32461.6 = 31820.3 days
Fridley 6
Effective borehole radius, ~100 ft.
Estimated radial distance
Fit
Y = -0.626228 * ln(X) + 6.56986
Δs = -0.626228 ln(10) = 1.44194 ft./log cycle
Xo = e (-6.56986/-0.626228) = 35996.1 feet
Drift MW-2
Change in Water Level, s (feet)
Distance from Pumping Well, r (feet)
0
1
2
3
4
5
6
7
8
1
10
100
1000
10000
100000

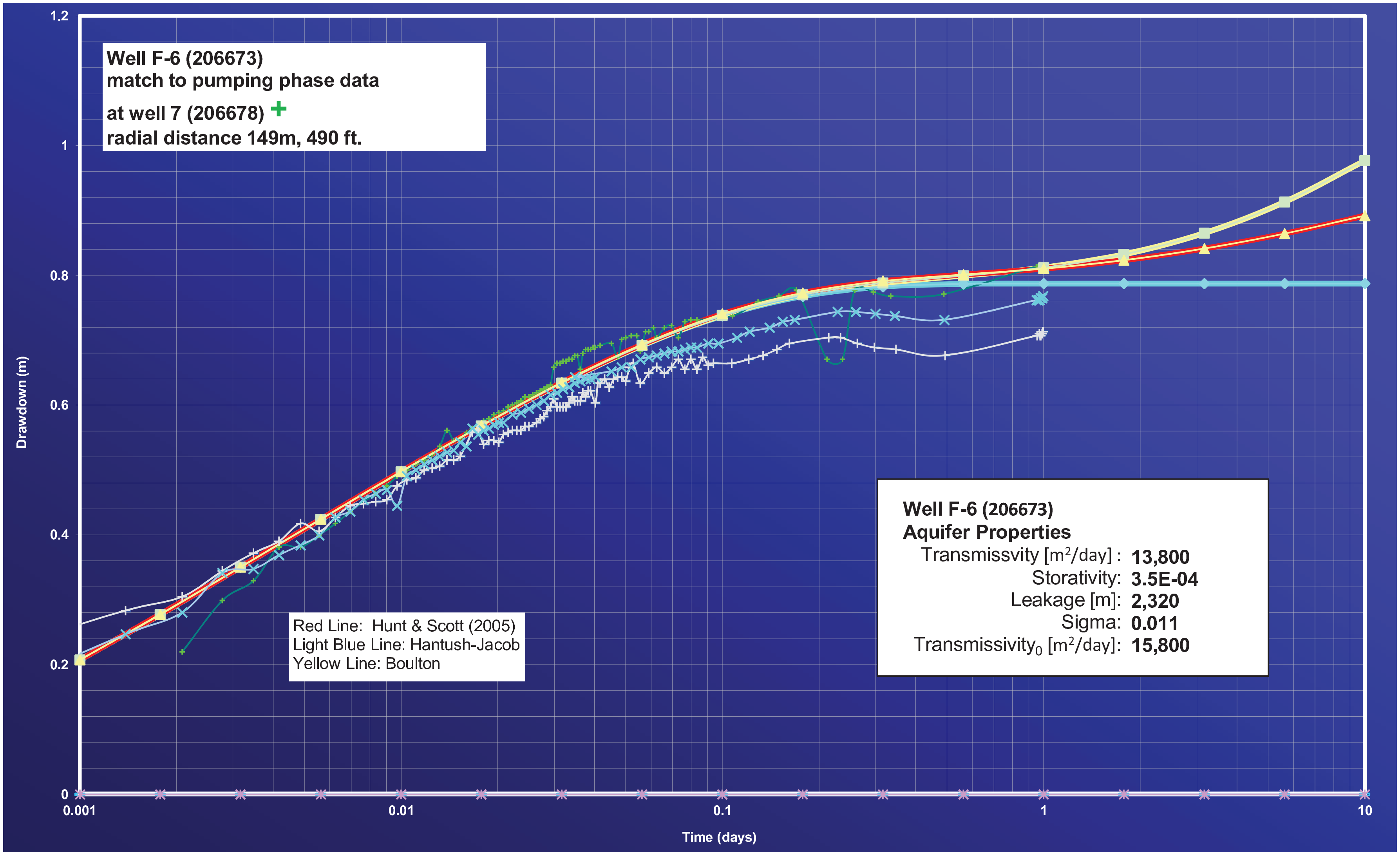

Test No: 2585
Pumped Well: Fridely 6 (218916)
Ob Well: -- (--)
Date: 7/1/1993
Data Series: Steady-state pumping
Rate (gpm): 1326
de Glee Analysis
Plot 9
T = (1440 / 2 / pi() / 7.48) • Q • K0(x)m / sm
L = Xm , c = L2 / T
T = 30.6 * 1326 / 0.8 = 50719.5 ft2/day
L = 12000 , c = (120002/50719.5) = 2839.14 days
Match Point
Ko(x), X = 1
Drawdown (feet)
Distance from Pumped Well (feet)
100
10
1
0.1
1
10
100
1000
10000
100000



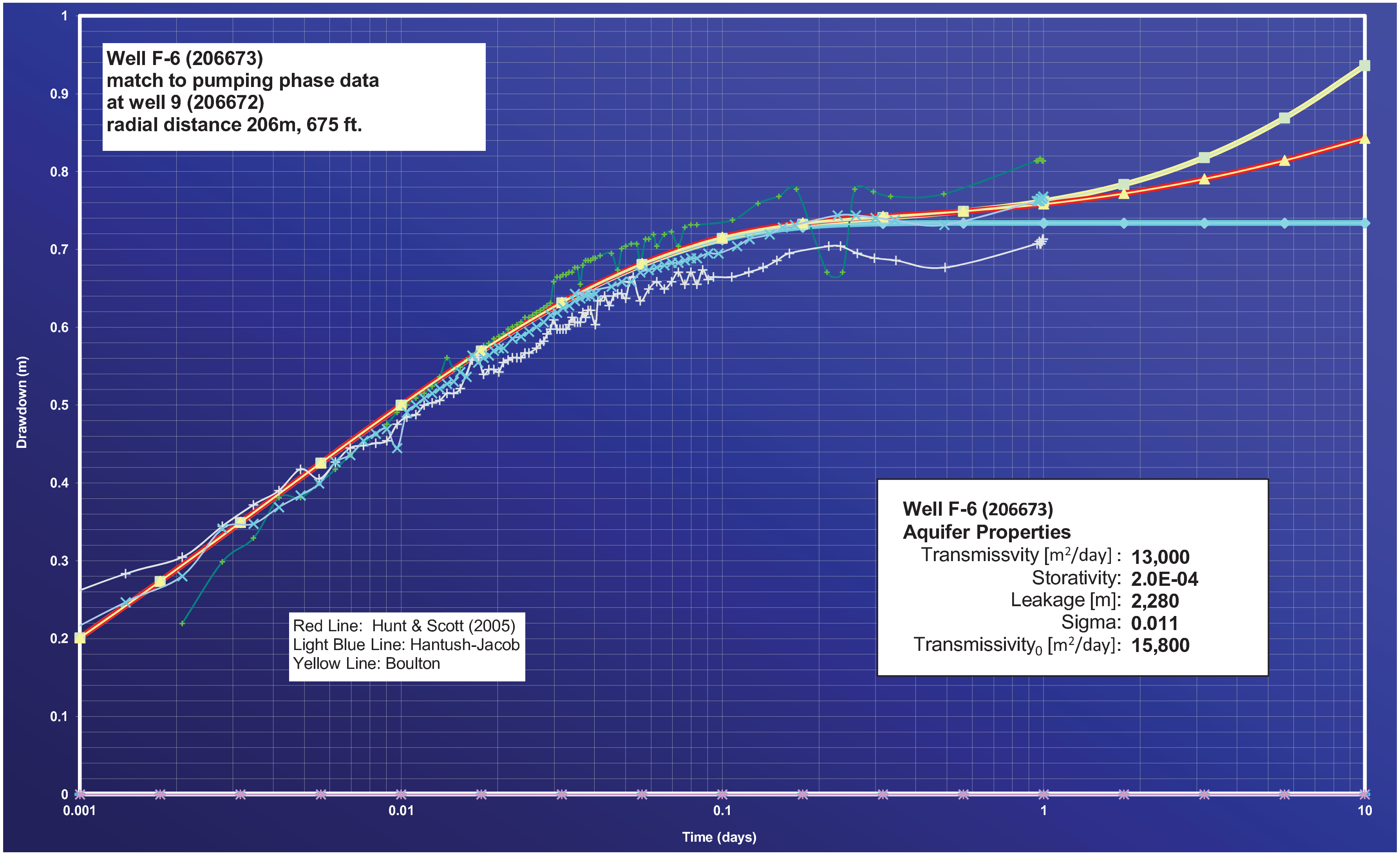
Test No: 2585
Pumped Well: Fridely 6 (218916)
Observation Well: -- (--)
Test Date: 7/1/1993
Discharge Rate, Q: 1326 gpm
Effective Borehole Radius, r: 100 feet
Agarwal Analysis
Plot 10
T = (2.303 *1440 / 7.48 / 4 / pi()) * Q / ds'lc
S = 2.25 * T * Xo / r^2 / 1440
Fit1 = 0.440992 * ln(X) + 1.30322
ds'lc = 1.01542 * ln(11) = 1.01542
Xo = e^(- 1.30322/0.440992) = 0.0520684
Fit1
T1 = 35.3 * 1326 / 1.01542 = 46096.9 ft^2/day
S1 = 46096.9 * 0.0520684 / 100^2 / 640 = 0.00037503
Fridley 6 rcovery
Recovery, s' (feet)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
10^-1
10^0
10^1
10^2
10^3
Agarwal Equivlalent Time
tp=pumping time (fixed), t'=elapsed recovery time
(tp * t') / (tp + t')


Well F-6 (206673)
match to pumping phase data
effective borehole radius 30m, ~100 ft.
Red Line: Hunt & Scott (2005)
Light Blue Line: Hantush-Jacob
Yellow Line: Boulton
Well F-6 (206673)
Aquifer Properties
Transmissvity [m2/day] : 15,500
Storativity: 3.0E-04
Leakage [m]: 2,460
Sigma: 0.011
Transmissivity0 [m2/day]: 15,800
Drawdown (m)
Time (days)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.001
0.01
0.1
1
10

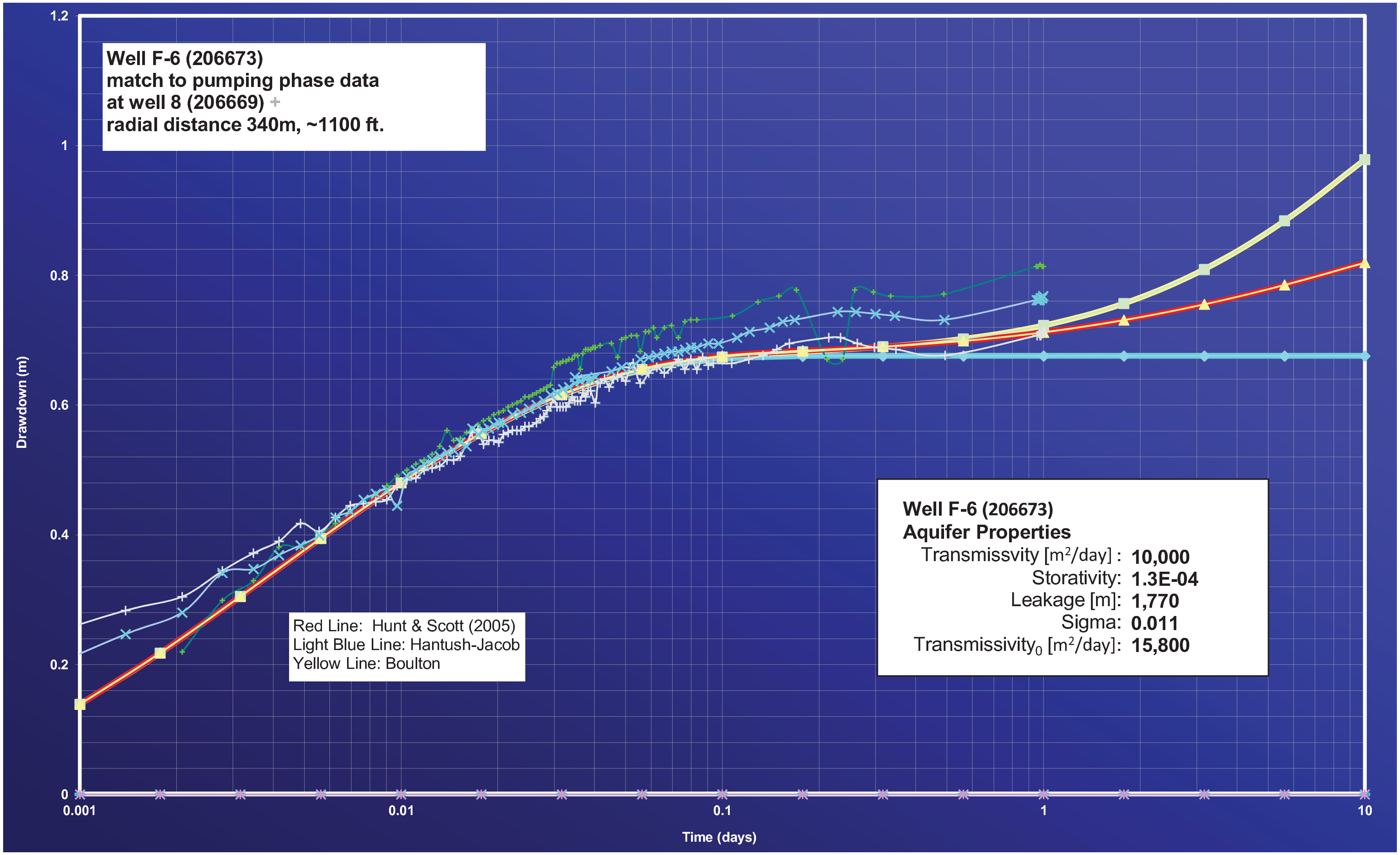
Plot 11


Well F-6 (206673)
match to pumping phase data
at well 7 (206678)
radial distance 149m, 490 ft.
Well F-6 (206673)
Aquifer Properties
Transmissvity [m²/day] : 13,800
Storativity: 3.5E-04
Leakage [m]: 2,320
Sigma: 0.011
Transmissivity0 [m²/day]: 15,800
Red Line: Hunt & Scott (2005)
Light Blue Line: Hantush-Jacob
Yellow Line: Boulton
Drawdown (m)
Time (days)
1.2
1
0.8
0.6
0.4
0.2
0
0.001
0.01
0.1
1
10

Plot 12

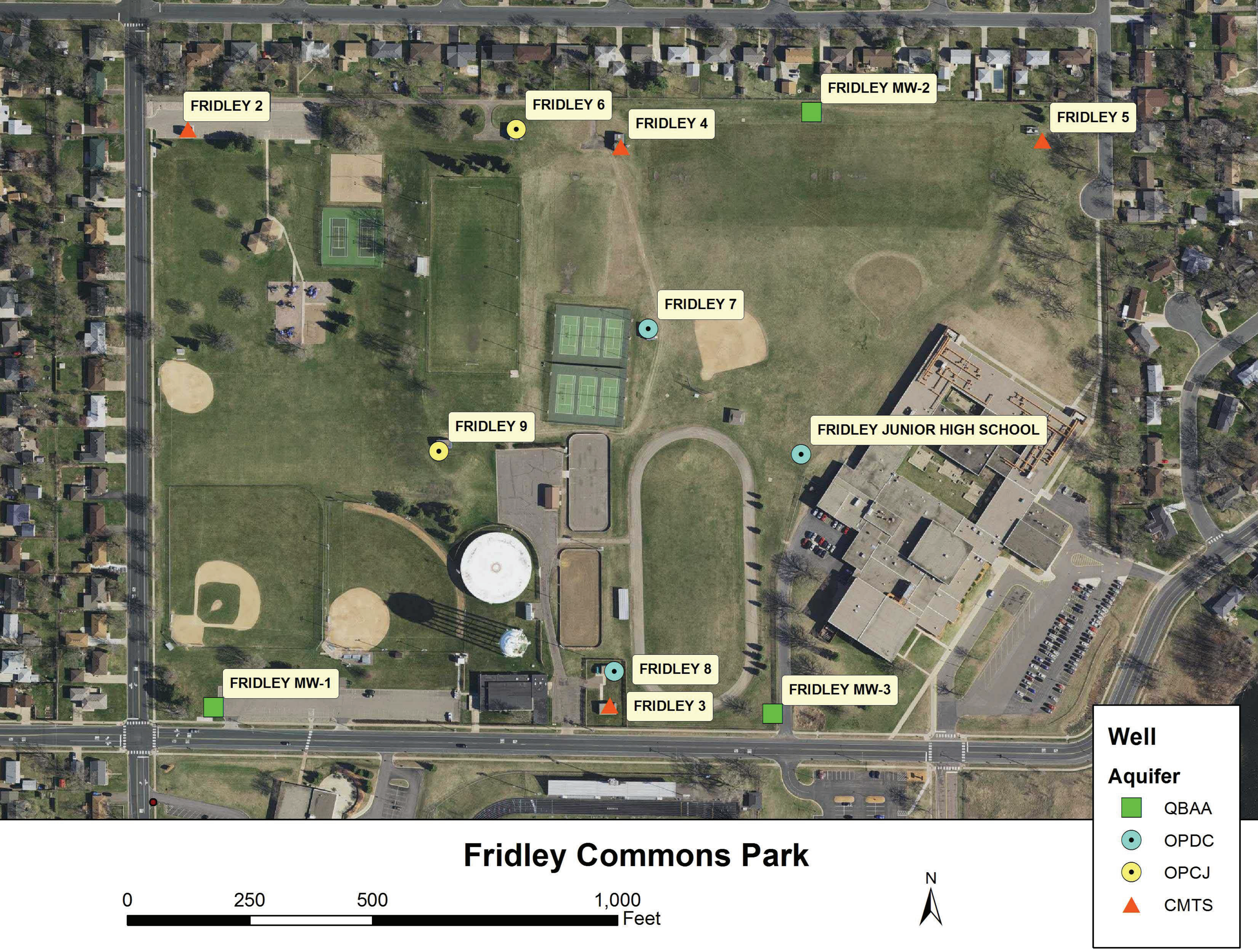

Well F-6 (206673)
match to pumping phase data
at well 9 (206672)
radial distance 206m, 675 ft.
Red Line: Hunt & Scott (2005)
Light Blue Line: Hantush-Jacob
Yellow Line: Boulton
Well F-6 (206673)
Aquifer Properties
Transmissvity [m²/day] : 13,000
Storativity: 2.0E-04
Leakage [m]: 2,280
Sigma: 0.011
Transmissivity0 [m²/day]: 15,800
Drawdown (m)
Time (days)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.001
0.01
0.1
1
10

Plot 13


Well F-6 (206673)
match to pumping phase data
at well 8 (206669) +
radial distance 340m, ~1100 ft.
Red Line: Hunt & Scott (2005)
Light Blue Line: Hantush-Jacob
Yellow Line: Boulton
Well F-6 (206673)
Aquifer Properties
Transmissvity [m2/day] : 10,000
Storativity: 1.3E-04
Leakage [m]: 1,770
Sigma: 0.011
Transmissivity0 [m2/day]: 15,800
Drawdown (m)
1.2
1
0.8
0.6
0.4
0.2
0
0.001
0.01
0.1
1
10
Time (days)

Plot 14

Appendix 2 – Documentation



Fridley Commons Park

WELLID	Name	distance_ft	effective r	drawdown	x-diff^2	y-diff^2	rms_meter	reported distance
206673	6	1	100	3.69	0	0	0.0	1
206678	7	488	488	2.67	6724	15376	148.7	530
206672	9	675	675	2.51	2304	40000	205.7	700
206669	8	1124	1124	2.34	3721	113569	342.5	1000
509090	MW-2	601		0.3	33489	121	183.3	660

datetime	etp	etr	agarwal	wl	dd	rec	t/r^2_p	t/r^2_r	r
7/1/1993 9:00				53.87					100
7/1/1993 9:01	1			55.65	1.78		**0.0001**		**30.4804**
7/1/1993 9:02	2			55.80	1.93		0.0002		
7/1/1993 9:03	3			56.01	2.14		0.0003		
7/1/1993 9:04	4			56.18	2.31		0.0004		
7/1/1993 9:05	5			56.21	2.34		0.0005		
7/1/1993 9:06	6			56.30	2.43		0.0006		
7/1/1993 9:07	7			56.39	2.52		0.0007		
7/1/1993 9:08	8			56.43	2.56		0.0008		
7/1/1993 9:09	9			56.50	2.63		0.0009		
7/1/1993 9:10	10			56.54	2.67		0.001		
7/1/1993 9:11	11			56.58	2.71		0.0011		
7/1/1993 9:12	12			56.62	2.75		0.0012		
7/1/1993 9:13	13			56.65	2.78		0.0013		
7/1/1993 9:14	14			56.70	2.83		0.0014		
7/1/1993 9:15	15			56.73	2.86		0.0015		
7/1/1993 9:16	16			56.75	2.88		0.0016		
7/1/1993 9:17	17			56.77	2.90		0.0017		
7/1/1993 9:18	18			56.79	2.92		0:02		
7/1/1993 9:19	19			56.81	2.94		0.0019		
7/1/1993 9:20	20			56.84	2.97		0.002		
7/1/1993 9:21	21			56.87	3.00		0.0021		
7/1/1993 9:22	22			56.89	3.02		0.0022		
7/1/1993 9:23	23			56.90	3.03		0.0023		
7/1/1993 9:24	24			56.91	3.04		0.0024		
7/1/1993 9:25	25			56.93	3.06		0.0025		
7/1/1993 9:26	26			56.95	3.08		0.0026		
7/1/1993 9:27	27			56.96	3.09		0.0027		
7/1/1993 9:28	28			56.98	3.11		0.0028		
7/1/1993 9:29	29			56.99	3.12		0.0029		
7/1/1993 9:30	30			57.00	3.13		0.003		
7/1/1993 9:32	32			57.01	3.14		0.0032		
7/1/1993 9:34	34			57.03	3.16		0.0034		
7/1/1993 9:36	36			57.07	3.20		0.0036		
7/1/1993 9:38	38			57.09	3.22		0.0038		
7/1/1993 9:40	40			57.10	3.23		0.004		
7/1/1993 9:42	42			57.11	3.24		0.0042		
7/1/1993 9:44	44			57.12	3.25		0.0044		
7/1/1993 9:46	46			57.14	3.27		0.0046		
7/1/1993 9:48	48			57.15	3.28		0:06		
7/1/1993 9:50	50			57.16	3.29		0.005		
7/1/1993 9:52	52			57.17	3.30		0.0052		
7/1/1993 9:54	54			57.18	3.31		0.0054		
7/1/1993 9:56	56			57.19	3.32		0.0056		
7/1/1993 9:58	58			57.20	3.33		0:08		
7/1/1993 10:00	60			57.22	3.35		0:08		

7/1/1993 10:05	65			57.24	3.37		0.0065		
7/1/1993 10:00	70			57.25	3.38		0.007		
7/1/1993 10:15	75			57.27	3.40		0.0075		
7/1/1993 10:20	80			57.28	3.41		0.008		
7/1/1993 10:25	85			57.29	3.42		0.0085		
7/1/1993 10:30	90			57.30	3.43		0.009		
7/1/2009 10:35	95			57.31	3.44		0.0095		
7/1/1993 10:40	100			57.32	3.45		0.01		
7/1/1993 10:45	105			57.33	3.46		0.0105		
7/1/1993 10:50	110			57.33	3.46		0.011		
7/1/1993 10:55	115			57.34	3.47		0.0115		
7/1/1993 11:00	120			57.34	3.47		0.012		
7/1/1993 11:10	130			57.35	3.48		0.013		
7/1/1993 11:20	140			57.36	3.49		0.014		
7/1/2009 11:30	150			57.38	3.51		0.015		
7/1/1993 12:00	180			57.42	3.55		0.018		
7/1/1993 12:30	210			57.47	3.60		0:30		
7/1/1993 1:00	240			57.50	3.63		0.024		
7/1/1993 2:00	300			57.54	3.67		0.03		
7/1/2009 2:47	347			57.52	3.65		0.0347		
7/1/1993 3:07	367			57.51	3.64		0.0367		
7/1/1993 4:00	420			57.50	3.63		0.042		
7/1/1993 5:08	488			57.48	3.61		0.0488		
7/1/1993 8:31	691			57.46	3.59		0.0691		
7/2/1993 7:39	1359			57.52	3.65		0.1359		
7/2/1993 7:57	1377			57.53	3.66		0.1377		
7/2/1993 8:38	1418			57.56	3.69		0.1418		
7/2/1993 8:46	1426			57.56	3.69		0.1426		
7/2/1993 8:59	1439			57.50	3.69		0.1439		
7/2/1993 9:00	1440								
7/2/1993 9:01	1441	1	1.00	55.89	2.02	1.61		0.0001	
7/2/1993 9:02	1442	2	2.00	55.78	1.91	1.72		0.0002	
7/2/1993 9:03	1443	3	3.00	55.65	1.78	1.85		0.0003	
7/2/1993 9:04	1444	4	4.00	55.55	1.68	1.95		0.0004	
7/2/1993 9:05	1445	5	5.00	55.47	1.60	2.03		0.0005	
7/2/1993 9:06	1446	6	6.00	55.39	1.52	2.11		0.0006	
7/2/1993 9:07	1447	7	7.00	55.33	1.46	2.17		0.0007	
7/2/1993 9:08	1448	8	7.99	55.27	1.40	2.23		0.0008	
7/2/1993 9:09	1449	9	8.99	55.20	1.33	2.30		0.0009	
7/2/1993 9:10	1450	10	9.99	55.18	1.31	2.32		0.001	
7/2/1993 9:11	1451	11	10.99	55.14	1.27	2.36		0.0011	
7/2/1993 9:12	1452	12	11.99	55.09	1.22	2.41		0.0012	
7/2/1993 9:13	1453	13	12.99	55.06	1.19	2.44		0.0013	
7/2/1993 9:14	1454	14	13.99	55.03	1.16	2.47		0.0014	
7/2/1993 9:15	1455	15	14.99	55.00	1.13	2.50		0.0015	
7/2/1993 9:16	1456	16	15.99	54.98	1.11	2.52		0.0016	
7/2/1993 9:17	1457	17	16.99	54.95	1.08	2.55		0.0017	

7/2/1993 9:18	1458	18	17.99	54.92	1.05	2.58		0.0018	
7/2/1993 9:19	1459	19	18.99	54.89	1.02	2.61		0.0019	
7/2/1993 9:20	1460	20	19.99	54.88	1.00	2.62		0.002	
7/2/1993 9:21	1461	21	20.99	54.85	0.98	2.65		0.0021	
7/2/1993 9:22	1462	22	21.98	54.84	0.97	2.66		0.0022	
7/2/1993 9:23	1463	23	22.98	54.83	0.96	2.67		0.0023	
7/2/1993 9:24	1464	24	23.98	54.81	0.94	2.69		0.0024	
7/2/1993 9:25	1465	25	24.98	54.79	0.92	2.71		0.0025	
7/2/1993 9:26	1466	26	25.98	54.77	0.90	2.73		0.0026	
7/2/1993 9:27	1467	27	26.98	54.76	0.89	2.74		0.0027	
7/2/1993 9:28	1468	28	27.98	54.75	0.88	2.75		0.0028	
7/2/1993 9:29	1469	29	28.98	54.73	0.86	2.77		0.0029	
7/2/1993 9:30	1470	30	29.98	54.72	0.85	2.78		0.003	
7/2/1993 9:32	1472	32	31.96	54.70	0.83	2.80		0.0032	
7/2/1993 9:34	1474	34	33.95	54.68	0.81	2.82		0.0034	
7/2/1993 9:36	1476	36	35.95	54.66	0.79	2.84		0.0036	
7/2/1993 9:38	1478	38	37.95	54.64	0.77	2.86		0.0038	
7/2/1993 9:40	1480	40	39.95	54.62	0.75	2.88		0.004	
7/2/1993 9:42	1482	42	41.94	54.60	0.73	2.90		0.0042	
7/2/1993 9:44	1484	44	43.94	54.00	0.72	3.50		0.0044	
7/2/1993 9:46	1486	46	45.94	54.57	0.70	2.93		0.0046	
7/2/1993 9:48	1488	48	47.94	54.56	0.69	2.94		0.0048	
7/2/1993 9:50	1490	50	49.93	54.54	0.67	2.96		0.005	
7/2/1993 9:52	1492	52	51.93	54.53	0.66	2.97		0.0052	
7/2/1993 9:54	1494	54	53.93	54.52	0.65	2.98		0.0054	
7/2/1993 9:56	1496	56	55.93	54.50	0.63	3.00		0.0056	
7/2/1993 9:58	1498	58	57.92	54.49	0.62	3.01		0.0058	
7/2/1993 10:00	1500	60	59.92	54.48	0.61	3.02		0.006	
7/2/1993 10:05	1505	65	64.78	54.46	0.59	3.04		0.0065	
7/2/1993 10:10	1510	70	69.77	54.44	0.57	3.06		0.007	
7/2/1993 10:15	1515	75	74.75	54.43	0.56	3.07		0.0075	
7/2/1993 10:20	1520	80	79.74	54.41	0.54	3.09		0.008	
7/2/1993 10:25	1525	85	84.72	54.40	0.53	3.10		0.0085	
7/2/1993 10:30	1530	90	89.71	54.39	0.52	3.11		0.009	
7/2/1993 10:35	1535	95	94.69	54.38	0.51	3.12		0.0095	
7/2/1993 10:40	1540	100	99.68	54.37	0.50	3.13		0.01	
7/2/1993 10:55	1555	115	113.89	54.34	0.47	3.16		0.0115	
7/2/1993 11:00	1560	120	119.62	54.33	0.46	3.17		0.012	
7/2/1993 11:10	1570	130	129.17	54.31	0.44	3.19		0.013	
7/2/1993 11:15	1575	135	134.57	54.33	0.46	3.17		0.0135	
7/2/1993 11:25	1585	145	144.09	54.29	0.42	3.21		0.0145	
7/2/1993 11:30	1590	150	149.53	54.29	0.42	3.21		0.015	
7/2/1993 11:43	1603	163	161.68	54.27	0.40	3.23		0.0163	
7/2/1993 12:00	1620	180	178.11	54.26	0.39	3.24		0.018	
7/2/1993 12:30	1650	210	206.18	54.26	0.39	3.24		0.021	
7/2/1993 13:00	1680	240	235.71	54.24	0.37	3.26		0.024	
7/2/1993 14:00	1740	300	289.66	54.22	0.35	3.28		0.03	

7/2/1993 15:15	1815	375	359.50	54.17	0.30	3.33		0.0375	

datetime	etp	etr	agarwal	wl	dd	rec	t/r^2_p	t/r^2_r	r
7/1/1993 9:00	0			61.84					488
7/1/1993 9:01	1			61.82	-0.02		4.2E-06		**148.744**
7/1/1993 9:03	3			62.56	0.72		1.3E-05		
7/1/1993 9:04	4			62.82	0.98		1.7E-05		
7/1/1993 9:05	5			62.92	1.08		2.1E-05		
7/1/1993 9:06	6			63.09	1.25		2.5E-05		
7/1/1993 9:07	7			63.09	1.25		2.9E-05		
7/1/1993 9:08	8			63.15	1.31		3.4E-05		
7/1/1993 9:09	9			63.21	1.37		3.8E-05		
7/1/1993 9:10	10			63.27	1.43		4.2E-05		
7/1/1993 9:11	11			63.32	1.48		4.6E-05		
7/1/1993 9:12	12			63.36	1.52		5E-05		
7/1/1993 9:13	13			63.40	1.56		5.5E-05		
7/1/1993 9:14	14			63.45	1.61		5.9E-05		
7/1/1993 9:15	15			63.48	1.64		6.3E-05		
7/1/1993 9:16	16			63.51	1.67		6.7E-05		
7/1/1993 9:17	17			63.53	1.69		7.1E-05		
7/1/1993 9:18	18			63.56	1.72		7.6E-05		
7/1/1993 9:19	19			63.60	1.76		8E-05		
7/1/1993 9:20	20			63.68	1.84		8.4E-05		
7/1/1993 9:21	21			63.63	1.79		8.8E-05		
7/1/1993 9:22	22			63.64	1.80		9.2E-05		
7/1/1993 9:23	23			63.67	1.83		9.7E-05		
7/1/1993 9:24	24			63.69	1.85		0.0001		
7/1/1993 9:25	25			63.71	1.87		0.0001		
7/1/1993 9:26	26			63.73	1.89		0.00011		
7/1/1993 9:27	27			63.74	1.90		0.00011		
7/1/1993 9:28	28			63.76	1.92		0.00012		
7/1/1993 9:29	29			63.77	1.93		0.00012		
7/1/1993 9:30	30			63.78	1.94		0.00013		
7/1/1993 9:31	31			63.80	1.96		0.00013		
7/1/1993 9:32	32			63.81	1.97		0.00013		
7/1/1993 9:33	33			63.82	1.98		0.00014		
7/1/1993 9:34	34			63.83	1.99		0.00014		
7/1/1993 9:35	35			63.85	2.01		0.00015		
7/1/1993 9:36	36			63.85	2.01		0.00015		
7/1/1993 9:37	37			63.86	2.02		0.00016		
7/1/1993 9:38	38			63.87	2.03		0.00016		
7/1/1993 9:39	39			63.88	2.04		0.00016		
7/1/1993 9:40	40			63.89	2.05		0.00017		
7/1/1993 9:41	41			63.90	2.06		0.00017		
7/1/1993 9:42	42			63.91	2.07		0.00018		
7/1/1993 9:44	43			64.00	2.16		0.00018		
7/1/1993 9:45	44			64.02	2.18		0.00018		
7/1/1993 9:46	45			64.02	2.18		0.00019		
7/1/1993 9:47	46			64.03	2.19		0.00019		

7/1/1993 9:48	47			64.03	2.19		0.0002		
7/1/1993 9:49	48			64.04	2.20		0.0002		
7/1/1993 9:50	49			64.04	2.20		0.00021		
7/1/1993 9:51	50			64.06	2.22		0.00021		
7/1/1993 9:52	51			64.06	2.22		0.00021		
7/1/1993 9:53	52			63.99	2.15		0.00022		
7/1/1993 9:54	53			64.07	2.23		0.00022		
7/1/1993 9:55	54			64.09	2.25		0.00023		
7/1/1993 9:56	55			64.09	2.25		0.00023		
7/1/1993 9:57	56			64.09	2.25		0.00024		
7/1/1993 9:58	57			64.10	2.26		0.00024		
7/1/1993 9:59	58			64.10	2.26		0.00024		
7/1/1993 10:00	60			64.11	2.27		0.00025		
7/1/1993 10:05	65			64.12	2.28		0.00027		
7/1/1993 10:08	68			64.05	2.21		0.00029		
7/1/1993 10:10	70			64.14	2.30		0.00029		
7/1/1993 10:12	72			64.15	2.31		0.0003		
7/1/1993 10:15	75			64.16	2.32		0.00031		
7/1/1993 10:18	78			64.16	2.32		0.00033		
7/1/1993 10:20	80			64.08	2.24		0.00034		
7/1/1993 10:23	83			64.18	2.34		0.00035		
7/1/1993 10:25	85			64.18	2.34		0.00036		
7/1/1993 10:28	88			64.20	2.36		0.00037		
7/1/1993 10:30	90			64.15	2.31		0.00038		
7/1/1993 10:35	95			64.20	2.36		0.0004		
7/1/1993 10:40	100			64.21	2.37		0.00042		
7/1/1993 10:45	105			64.15	2.31		0.00044		
7/1/1993 10:50	110			64.23	2.39		0.00046		
7/1/1993 10:55	115			64.24	2.40		0.00048		
7/1/1993 11:00	120			64.24	2.40		0.0005		
7/1/1993 11:35	155			64.26	2.42		0.00065		
7/1/1993 12:06	186			64.33	2.49		0.00078		
7/1/1993 12:36	216			64.36	2.52		0.00091		
7/1/1993 13:05	245			64.39	2.55		0.00103		
7/1/1993 14:05	305			64.04	2.20		0.00128		
7/1/1993 14:41	341			64.04	2.20		0.00143		
7/1/1993 15:12	372			64.39	2.55		0.00156		
7/1/1993 16:05	425			64.38	2.54		0.00178		
7/1/1993 17:01	481			64.36	2.52		0.00202		
7/1/1993 20:44	704			64.37	2.53		0.00296		
7/2/1993 7:48	1368			64.51	2.67		0.00574		
7/2/1993 8:05	1385			64.51	2.67		0.00582		
7/2/1993 8:25	1405			64.52	2.68		0.0059		
7/2/1993 8:45	1425			64.51	2.67		0.00598		
7/2/1993 8:55	1435			64.51	2.67		0.00603		
7/2/1993 8:58	1438			64.51	2.67		0.00604		
7/2/1993 9:00	1440	0		64.51	2.67	0.00			

7/2/1993 9:01	1441	1	1.00	63.94	2.10	0.57		4.2E-06	
7/2/1993 9:02	1442	2	2.00	63.80	1.96	0.71		8.4E-06	
7/2/1993 9:03	1443	3	3.00	63.66	1.82	0.85		1.26E-05	
7/2/1993 9:04	1444	4	4.00	63.56	1.72	0.95		1.68E-05	
7/2/1993 9:05	1445	5	5.00	63.48	1.64	1.03		2.1E-05	
7/2/1993 9:06	1446	6	6.00	63.41	1.57	1.10		2.52E-05	
7/2/1993 9:07	1447	7	7.00	63.34	1.50	1.17		2.94E-05	
7/2/1993 9:08	1448	8	7.99	63.29	1.45	1.22		3.36E-05	
7/2/1993 9:09	1449	9	8.99	63.24	1.40	1.27		3.78E-05	
7/2/1993 9:10	1450	10	9.99	63.19	1.35	1.32		4.2E-05	
7/2/1993 9:11	1451	11	10.99	63.15	1.31	1.36		4.62E-05	
7/2/1993 9:12	1452	12	11.99	63.11	1.27	1.40		5.04E-05	
7/2/1993 9:13	1453	13	12.99	63.08	1.24	1.43		5.46E-05	
7/2/1993 9:14	1454	14	13.99	63.05	1.21	1.46		5.88E-05	
7/2/1993 9:15	1455	15	14.99	63.02	1.18	1.49		6.3E-05	
7/2/1993 9:16	1456	16	15.99	62.99	1.15	1.52		6.72E-05	
7/2/1993 9:17	1457	17	16.99	62.95	1.11	1.56		7.14E-05	
7/2/1993 9:18	1458	18	17.99	62.94	1.10	1.57		7.56E-05	
7/2/1993 9:19	1459	19	18.99	62.92	1.08	1.59		7.98E-05	
7/2/1993 9:20	1460	20	19.99	62.89	1.05	1.62		8.4E-05	
7/2/1993 9:21	1461	21	20.99	62.87	1.03	1.64		8.82E-05	
7/2/1993 9:22	1462	22	21.98	62.85	1.01	1.66		9.24E-05	
7/2/1993 9:23	1463	23	22.98	62.84	1.00	1.67		9.66E-05	
7/2/1993 9:24	1464	24	23.98	62.82	0.98	1.69		0.000101	
7/2/1993 9:25	1465	25	24.98	62.80	0.96	1.71		0.000105	
7/2/1993 9:26	1466	26	25.98	62.79	0.95	1.72		0.000109	
7/2/1993 9:27	1467	27	26.98	62.77	0.93	1.74		0.000113	
7/2/1993 9:28	1468	28	27.98	62.76	0.92	1.75		0.000118	
7/2/1993 9:29	1469	29	28.98	62.75	0.91	1.76		0.000122	
7/2/1993 9:30	1470	30	29.98	62.75	0.91	1.76		0.000126	
7/2/1993 9:31	1471	31	30.98	62.73	0.89	1.78		0.00013	
7/2/1993 9:32	1472	32	31.98	62.72	0.88	1.79		0.000134	
7/2/1993 9:33	1473	33	32.98	62.71	0.87	1.80		0.000139	
7/2/1993 9:34	1474	34	33.98	62.70	0.86	1.81		0.000143	
7/2/1993 9:35	1475	35	34.98	62.68	0.84	1.83		0.000147	
7/2/1993 9:36	1476	36	35.98	62.67	0.83	1.84		0.000151	
7/2/1993 9:37	1477	37	36.97	62.66	0.82	1.85		0.000155	
7/2/1993 9:38	1478	38	37.97	62.65	0.81	1.86		0.00016	
7/2/1993 9:39	1479	39	38.97	62.65	0.81	1.86		0.000164	
7/2/1993 9:40	1480	40	39.97	62.64	0.80	1.87		0.000168	
7/2/1993 9:41	1481	41	40.97	62.64	0.80	1.87		0.000172	
7/2/1993 9:42	1482	42	41.97	62.63	0.79	1.88		0.000176	
7/2/1993 9:43	1483	43	42.97	62.62	0.78	1.89		0.000181	
7/2/1993 9:44	1484	44	43.97	62.61	0.77	1.90		0.000185	
7/2/1993 9:45	1485	45	44.97	62.60	0.76	1.91		0.000189	
7/2/1993 9:46	1486	46	45.97	62.60	0.76	1.91		0.000193	
7/2/1993 9:47	1487	47	46.97	62.59	0.75	1.92		0.000197	

7/2/1993 9:48	1488	48	47.97	62.58	0.74	1.93		0.000202	
7/2/1993 9:49	1489	49	48.97	62.57	0.73	1.94		0.000206	
7/2/1993 9:50	1490	50	49.97	62.57	0.73	1.94		0.00021	
7/2/1993 9:51	1491	51	50.97	62.56	0.72	1.95		0.000214	
7/2/1993 9:52	1492	52	51.97	62.56	0.72	1.95		0.000218	
7/2/1993 9:53	1493	53	52.96	62.55	0.71	1.96		0.000223	
7/2/1993 9:54	1494	54	53.96	62.54	0.70	1.97		0.000227	
7/2/1993 9:55	1495	55	54.96	62.53	0.69	1.98		0.000231	
7/2/1993 9:56	1496	56	55.96	62.52	0.68	1.99		0.000235	
7/2/1993 9:57	1497	57	56.96	62.52	0.68	1.99		0.000239	
7/2/1993 9:58	1498	58	57.96	62.51	0.67	2.00		0.000244	
7/2/1993 9:59	1499	59	58.96	62.51	0.67	2.00		0.000248	
7/2/1993 10:00	1500	60	59.96	62.51	0.67	2.00		0.000252	
7/2/1993 10:05	1505	65	64.78	62.47	0.63	2.04		0.000273	
7/2/1993 10:10	1510	70	69.77	62.47	0.63	2.04		0.000294	
7/2/1993 10:15	1515	75	74.75	62.45	0.61	2.06		0.000315	
7/2/1993 10:20	1520	80	79.74	62.43	0.59	2.08		0.000336	
7/2/1993 10:25	1525	85	84.72	62.41	0.57	2.10		0.000357	
7/2/1993 10:30	1530	90	89.71	62.41	0.57	2.10		0.000378	
7/2/1993 10:35	1535	95	94.69	62.40	0.56	2.11		0.000399	
7/2/1993 10:40	1540	100	99.68	62.39	0.55	2.12		0.00042	
7/2/1993 10:45	1545	105	104.66	62.38	0.54	2.13		0.000441	
7/2/1993 10:50	1550	110	109.65	62.37	0.53	2.14		0.000462	
7/2/1993 11:14	1574	134	131.96	62.31	0.47	2.20		0.000563	
7/2/1993 11:46	1606	166	162.69	62.29	0.45	2.22		0.000697	
7/2/1993 12:36	1656	216	209.48	62.26	0.42	2.25		0.000907	
7/2/1993 13:09	1689	249	244.13	62.25	0.41	2.26		0.001046	
7/2/1993 14:04	1744	304	294.41	62.23	0.39	2.28		0.001277	
7/2/1993 15:23	1823	383	366.40	62.17	0.33	2.34		0.001608	

datetime	etp	etr	agarwal	wl	dd	rec	t/r^2_p	t/r^2_r	r
7/1/1993 9:00	0			63.52					1124
7/1/1993 9:01	1			64.30	0.78		7.915E-07		**342.599**
7/1/1993 9:02	2			64.45	0.93		1.583E-06		
7/1/1993 9:03	3			64.52	1.00		2.375E-06		
7/1/1993 9:04	4			64.65	1.13		3.166E-06		
7/1/1993 9:05	5			64.74	1.22		3.958E-06		
7/1/1993 9:06	6			64.80	1.28		4.749E-06		
7/1/1993 9:07	7			64.89	1.37		5.541E-06		
7/1/1993 9:08	8			64.85	1.33		6.332E-06		
7/1/1993 9:09	9			64.92	1.40		7.124E-06		
7/1/1993 9:10	10			64.98	1.46		7.915E-06		
7/1/1993 9:11	11			64.99	1.47		8.707E-06		
7/1/1993 9:12	12			65.00	1.48		9.498E-06		
7/1/1993 9:13	13			65.01	1.49		1.029E-05		
7/1/1993 9:14	14			65.08	1.56		1.108E-05		
7/1/1993 9:15	15			65.11	1.59		1.187E-05		
7/1/1993 9:16	16			65.12	1.60		1.266E-05		
7/1/1993 9:17	17			65.16	1.64		1.346E-05		
7/1/1993 9:18	18			65.17	1.65		1.425E-05		
7/1/1993 9:19	19			65.18	1.66		1.504E-05		
7/1/1993 9:20	20			65.21	1.69		1.583E-05		
7/1/1993 9:21	21			65.21	1.69		1.662E-05		
7/1/1993 9:22	22			65.23	1.71		1.741E-05		
7/1/1993 9:24	24			65.35	1.83		1.9E-05		
7/1/1993 9:25	25			65.36	1.84		1.979E-05		
7/1/1993 9:26	26			65.29	1.77		2.058E-05		
7/1/1993 9:27	27			65.31	1.79		2.137E-05		
7/1/1993 9:28	28			65.31	1.79		2.216E-05		
7/1/1993 9:29	29			65.30	1.78		2.295E-05		
7/1/1993 9:30	30			65.34	1.82		2.375E-05		
7/1/1993 9:31	31			65.35	1.83		2.454E-05		
7/1/1993 9:32	32			65.36	1.84		2.533E-05		
7/1/1993 9:33	33			65.36	1.84		2.612E-05		
7/1/1993 9:34	34			65.36	1.84		2.691E-05		
7/1/1993 9:35	35			65.38	1.86		2.77E-05		
7/1/1993 9:36	36			65.38	1.86		2.85E-05		
7/1/1993 9:38	38			65.40	1.88		3.008E-05		
7/1/1993 9:39	39			65.42	1.90		3.087E-05		
7/1/1993 9:40	40			65.43	1.91		3.166E-05		
7/1/1993 9:41	41			65.46	1.94		3.245E-05		
7/1/1993 9:42	42			65.48	1.96		3.324E-05		
7/1/1993 9:43	43			65.52	2.00		3.404E-05		
7/1/1993 9:44	44			65.48	1.96		3.483E-05		
7/1/1993 9:45	45			65.48	1.96		3.562E-05		
7/1/1993 9:46	46			65.48	1.96		3.641E-05		
7/1/1993 9:47	47			65.48	1.96		3.72E-05		

7/1/1993 9:48	48			65.50	1.98		3.799E-05		
7/1/1993 9:49	49			65.53	2.01		3.878E-05		
7/1/1993 9:50	50			65.51	1.99		3.958E-05		
7/1/1993 9:51	51			65.51	1.99		4.037E-05		
7/1/1993 9:52	52			65.51	1.99		4.116E-05		
7/1/1993 9:53	53			65.55	2.03		4.195E-05		
7/1/1993 9:54	54			65.53	2.01		4.274E-05		
7/1/1993 9:55	55			65.56	2.04		4.353E-05		
7/1/1993 9:56	56			65.56	2.04		4.433E-05		
7/1/1993 9:58	58			65.50	1.98		4.591E-05		
7/1/1993 9:59	59			65.60	2.08		4.67E-05		
7/1/1993 10:00	60			65.60	2.08		4.749E-05		
7/1/1993 10:02	62			65.62	2.10		4.907E-05		
7/1/1993 10:04	64			65.58	2.06		5.066E-05		
7/1/1993 10:06	66			65.62	2.10		5.224E-05		
7/1/1993 10:08	68			65.63	2.11		5.382E-05		
7/1/1993 10:10	70			65.63	2.11		5.541E-05		
7/1/1993 10:12	72			65.61	2.09		5.699E-05		
7/1/1993 10:14	74			65.68	2.16		5.857E-05		
7/1/1993 10:16	76			65.70	2.18		6.016E-05		
7/1/1993 10:20	80			65.60	2.08		6.332E-05		
7/1/1993 10:25	85			65.65	2.13		6.728E-05		
7/1/1993 10:30	90			65.68	2.16		7.124E-05		
7/1/1993 10:35	95			65.65	2.13		7.52E-05		
7/1/1993 10:40	100			65.68	2.16		7.915E-05		
7/1/1993 10:45	105			65.72	2.20		8.311E-05		
7/1/1993 10:50	110			65.67	2.15		8.707E-05		
7/1/1993 10:55	115			65.72	2.20		9.103E-05		
7/1/1993 11:00	120			65.67	2.15		9.498E-05		
7/1/1993 11:05	125			65.73	2.21		9.894E-05		
7/1/1993 11:10	130			65.69	2.17		0.0001029		
7/1/1993 11:15	135			65.70	2.18		0.0001069		
7/1/1993 11:34	154			65.70	2.18		0.0001219		
7/1/1993 11:54	174			65.72	2.20		0.0001377		
7/1/1993 12:13	193			65.74	2.22		0.0001528		
7/1/1993 12:33	213			65.77	2.25		0.0001686		
7/1/1993 12:53	233			65.80	2.28		0.0001844		
7/1/1993 14:09	309			65.83	2.31		0.0002446		
7/1/1993 14:36	336			65.83	2.31		0.000266		
7/1/1993 15:19	379			65.80	2.28		0.0003		
7/1/1993 16:08	428			65.78	2.26		0.0003388		
7/1/1993 17:20	500			65.77	2.25		0.0003958		
7/1/1993 20:51	711			65.74	2.22		0.0005628		
7/2/1993 7:54	1374			65.84	2.32		0.0010876		
7/2/1993 8:18	1398			65.85	2.33		0.0011066		
7/2/1993 8:25	1405			65.84	2.32		0.0011121		
7/2/1993 8:32	1412			65.84	2.32		0.0011176		

7/2/1993 8:45	1425			65.85	2.33		0.0011279		
7/2/1993 8:51	1431			65.86	2.34		0.0011327		
7/2/1993 8:57	1437			65.86	2.34		0.0011374		
7/2/1993 9:00	1440	0		65.86	2.34	0.00			
7/2/1993 9:01	1441	1	1.00	65.33	1.81	0.53		7.9E-07	
7/2/1993 9:02	1442	2	2.00	65.18	1.66	0.68		1.6E-06	
7/2/1993 9:03	1443	3	3.00	65.07	1.55	0.79		2.4E-06	
7/2/1993 9:04	1444	4	4.00	64.95	1.43	0.91		3.2E-06	
7/2/1993 9:05	1445	5	5.00	64.90	1.38	0.96		4E-06	
7/2/1993 9:06	1446	6	6.00	64.84	1.32	1.02		4.7E-06	
7/2/1993 9:07	1447	7	7.00	64.79	1.27	1.07		5.5E-06	
7/2/1993 9:08	1448	8	7.99	64.73	1.21	1.13		6.3E-06	
7/2/1993 9:09	1449	9	8.99	64.67	1.15	1.19		7.1E-06	
7/2/1993 9:10	1450	10	9.99	64.63	1.11	1.23		7.9E-06	
7/2/1993 9:11	1451	11	10.99	64.60	1.08	1.26		8.7E-06	
7/2/1993 9:12	1452	12	11.99	64.57	1.05	1.29		9.5E-06	
7/2/1993 9:13	1453	13	12.99	64.54	1.02	1.32		1E-05	
7/2/1993 9:15	1455	15	14.98	64.43	0.91	1.43		1.2E-05	
7/2/1993 9:16	1456	16	15.99	64.00	0.48	1.86		1.3E-05	
7/2/1993 9:17	1457	17	16.99	64.43	0.91	1.43		1.3E-05	
7/2/1993 9:18	1458	18	17.99	64.40	0.88	1.46		1.4E-05	
7/2/1993 9:19	1459	19	18.99	64.39	0.87	1.47		1.5E-05	
7/2/1993 9:20	1460	20	19.99	64.36	0.84	1.50		1.6E-05	
7/2/1993 9:21	1461	21	20.99	64.34	0.82	1.52		1.7E-05	
7/2/1993 9:22	1462	22	21.98	64.33	0.81	1.53		1.7E-05	
7/2/1993 9:23	1463	23	22.98	64.32	0.80	1.54		1.8E-05	
7/2/1993 9:24	1464	24	23.98	64.31	0.79	1.55		1.9E-05	
7/2/1993 9:25	1465	25	24.98	64.29	0.77	1.57		2E-05	
7/2/1993 9:27	1467	27	26.96	64.26	0.74	1.60		2.1E-05	
7/2/1993 9:28	1468	28	27.98	64.26	0.74	1.60		2.2E-05	
7/2/1993 9:09	1449	9	9.12	64.24	0.72	1.62		7.1E-06	
7/2/1993 9:30	1470	30	29.57	64.22	0.70	1.64		2.4E-05	
7/2/1993 9:31	1471	31	30.98	64.22	0.70	1.64		2.5E-05	
7/2/1993 9:32	1472	32	31.98	64.19	0.67	1.67		2.5E-05	
7/2/1993 9:33	1473	33	32.98	64.18	0.66	1.68		2.6E-05	
7/2/1993 9:34	1474	34	33.98	64.18	0.66	1.68		2.7E-05	
7/2/1993 9:35	1475	35	34.98	64.17	0.65	1.69		2.8E-05	
7/2/1993 9:36	1476	36	35.98	64.17	0.65	1.69		2.8E-05	
7/2/1993 9:37	1477	37	36.97	64.16	0.64	1.70		2.9E-05	
7/2/1993 9:38	1478	38	37.97	64.15	0.63	1.71		3E-05	
7/2/1993 9:39	1479	39	38.97	64.13	0.61	1.73		3.1E-05	
7/2/1993 9:40	1480	40	39.97	64.12	0.60	1.74		3.2E-05	
7/2/1993 9:42	1482	42	41.94	64.11	0.59	1.75		3.3E-05	
7/2/1993 9:44	1484	44	43.94	64.09	0.57	1.77		3.5E-05	
7/2/1993 9:46	1486	46	45.94	64.09	0.57	1.77		3.6E-05	
7/2/1993 9:48	1488	48	47.94	64.08	0.56	1.78		3.8E-05	
7/2/1993 9:50	1490	50	49.93	64.06	0.54	1.80		4E-05	

7/2/1993 9:52	1492	52	51.93	64.04	0.52	1.82		4.1E-05	
7/2/1993 9:54	1494	54	53.93	64.03	0.51	1.83		4.3E-05	
7/2/1993 9:56	1496	56	55.93	64.02	0.50	1.84		4.4E-05	
7/2/1993 9:58	1498	58	57.92	64.01	0.49	1.85		4.6E-05	
7/2/1993 10:00	1500	60	59.92	64.00	0.48	1.86		4.7E-05	
7/2/1993 10:02	1502	62	61.92	64.00	0.48	1.86		4.9E-05	
7/2/1993 10:04	1504	64	63.91	64.00	0.48	1.86		5.1E-05	
7/2/1993 10:10	1510	70	69.72	63.93	0.41	1.93		5.5E-05	
7/2/1993 10:10	1510	70	70.00	63.96	0.44	1.90		5.5E-05	
7/2/1993 10:15	1515	75	74.75	63.92	0.40	1.94		5.9E-05	
7/2/1993 10:20	1520	80	79.74	63.90	0.38	1.96		6.3E-05	
7/2/1993 10:25	1525	85	84.72	63.89	0.37	1.97		6.7E-05	
7/2/1993 10:30	1530	90	89.71	63.88	0.36	1.98		7.1E-05	
7/2/1993 10:35	1535	95	94.69	63.86	0.34	2.00		7.5E-05	
7/2/1993 10:40	1540	100	99.68	63.85	0.33	2.01		7.9E-05	
7/2/1993 10:45	1545	105	104.66	63.83	0.31	2.03		8.3E-05	
7/2/1993 10:50	1550	110	109.65	63.81	0.29	2.05		8.7E-05	
7/2/1993 10:55	1555	115	114.63	63.82	0.30	2.04		9.1E-05	
7/2/1993 11:00	1560	120	119.62	63.80	0.28	2.06		9.5E-05	
7/2/1993 11:23	1583	143	140.92	63.77	0.25	2.09		0.00011	
7/2/1993 11:43	1603	163	160.97	63.76	0.24	2.10		0.00013	
7/2/1993 12:07	1627	187	184.24	63.75	0.23	2.11		0.00015	
7/2/1993 12:31	1651	211	207.93	63.75	0.23	2.11		0.00017	
7/2/1993 12:55	1675	235	231.63	63.74	0.22	2.12		0.00019	
7/2/1993 14:11	1751	311	297.50	63.70	0.18	2.16		0.00025	
7/2/1993 15:36	1836	396	377.67	63.65	0.13	2.21		0.00031	

datetime	etp	etr	agarwal	wl	dd	rec	t/r^2_p	t/r^2_r	r
7/1/1993 9:00	0			62.54					675
7/1/1993 9:01	1			63.14	0.60		2.2E-06		**205.74**
7/1/1993 9:02	2			63.35	0.81		4.4E-06		
7/1/1993 9:03	3			63.46	0.92		6.6E-06		
7/1/1993 9:04	4			63.66	1.12		8.8E-06		
7/1/1993 9:05	5			63.68	1.14		1.1E-05		
7/1/1993 9:06	6			63.75	1.21		1.3E-05		
7/1/1993 9:07	7			63.80	1.26		1.5E-05		
7/1/1993 9:08	8			63.85	1.31		1.8E-05		
7/1/1993 9:09	9			63.94	1.40		2E-05		
7/1/1993 9:10	10			63.97	1.43		2.2E-05		
7/1/1993 9:11	11			64.03	1.49		2.4E-05		
7/1/1993 9:12	12			64.06	1.52		2.6E-05		
7/1/1993 9:13	13			64.08	1.54		2.9E-05		
7/1/1993 9:14	14			64.00	1.46		3.1E-05		
7/1/1993 9:15	15			64.15	1.61		3.3E-05		
7/1/1993 9:16	16			64.18	1.64		3.5E-05		
7/1/1993 9:17	17			64.21	1.67		3.7E-05		
7/1/1993 9:18	18			64.23	1.69		4E-05		
7/1/1993 9:19	19			64.25	1.71		4.2E-05		
7/1/1993 9:20	20			64.27	1.73		4.4E-05		
7/1/1993 9:21	21			64.28	1.74		4.6E-05		
7/1/1993 9:22	22			64.32	1.78		4.8E-05		
7/1/1993 9:23	23			64.30	1.76		5E-05		
7/1/1993 9:24	24			64.39	1.85		5.3E-05		
7/1/1993 9:25	25			64.36	1.82		5.5E-05		
7/1/1993 9:26	26			64.38	1.84		5.7E-05		
7/1/1993 9:27	27			64.39	1.85		5.9E-05		
7/1/1993 9:28	28			64.41	1.87		6.1E-05		
7/1/1993 9:29	29			64.42	1.88		6.4E-05		
7/1/1993 9:30	30			64.42	1.88		6.6E-05		
7/1/1993 9:32	32			64.46	1.92		7E-05		
7/1/1993 9:34	34			64.47	1.93		7.5E-05		
7/1/1993 9:36	36			64.49	1.95		7.9E-05		
7/1/1993 9:38	38			64.51	1.97		8.3E-05		
7/1/1993 9:40	40			64.53	1.99		8.8E-05		
7/1/1993 9:42	42			64.56	2.02		9.2E-05		
7/1/1993 9:44	44			64.57	2.03		9.7E-05		
7/1/1993 9:46	46			64.59	2.05		0.0001		
7/1/1993 9:48	48			64.60	2.06		0.00011		
7/1/1993 9:50	50			64.62	2.08		0.00011		
7/1/1993 9:52	52			64.63	2.09		0.00011		
7/1/1993 9:54	54			64.64	2.10		0.00012		
7/1/1993 9:56	56			64.64	2.10		0.00012		
7/1/1993 9:58	58			64.65	2.11		0.00013		
7/1/1993 10:00	50			64.65	2.11		0.00011		

7/1/1993 10:05	65			64.68	2.14		0.00014		
7/1/1993 10:10	70			64.70	2.16		0.00015		
7/1/1993 10:15	75			64.70	2.16		0.00016		
7/1/1993 10:20	80			64.74	2.20		0.00018		
7/1/1993 10:25	85			64.75	2.21		0.00019		
7/1/1993 10:30	90			64.76	2.22		0.0002		
7/1/1993 10:35	95			64.77	2.23		0.00021		
7/1/1993 10:40	100			64.78	2.24		0.00022		
7/1/1993 10:45	105			64.78	2.24		0.00023		
7/1/1993 10:50	110			64.79	2.25		0.00024		
7/1/1993 10:55	115			64.80	2.26		0.00025		
7/1/1993 11:00	120			64.80	2.26		0.00026		
7/1/1993 11:10	130			64.82	2.28		0.00029		
7/1/1993 11:20	140			64.82	2.28		0.00031		
7/1/1993 11:40	160			64.85	2.31		0.00035		
7/1/1993 11:55	175			64.88	2.34		0.00038		
7/1/1993 12:22	202			64.90	2.36		0.00044		
7/1/1993 12:42	222			64.93	2.39		0.00049		
7/1/1993 13:02	242			64.94	2.40		0.00053		
7/1/1993 14:29	329			64.98	2.44		0.00072		
7/1/1993 15:15	375			64.98	2.44		0.00082		
7/1/1993 16:11	431			64.97	2.43		0.00095		
7/1/1993 17:15	495			64.96	2.42		0.00109		
7/1/1993 20:47	707			64.94	2.40		0.00155		
7/2/1993 7:50	1370			65.04	2.50		0.00301		
7/2/1993 8:08	1388			65.04	2.50		0.00305		
7/2/1993 8:20	1400			65.04	2.50		0.00307		
7/2/1993 8:30	1410			65.05	2.51		0.00309		
7/2/1993 8:45	1425			65.05	2.51		0.00313		
7/2/1993 8:55	1435			65.06	2.52		0.00315		
7/2/1993 9:00	1440	0		65.05	2.51	0.00			
7/2/1993 9:01	1441	1		64.50	1.96	0.55		2.2E-06	
7/2/1993 9:02	1442	2		64.36	1.82	0.69		4.4E-06	
7/2/1993 9:03	1443	3		64.19	1.65	0.86		6.6E-06	
7/2/1993 9:04	1444	4		64.14	1.60	0.91		8.8E-06	
7/2/1993 9:05	1445	5		64.05	1.51	1.00		1.1E-05	
7/2/1993 9:06	1446	6		63.98	1.44	1.07		1.3E-05	
7/2/1993 9:07	1447	7		63.96	1.42	1.09		1.5E-05	
7/2/1993 9:08	1448	8		63.87	1.33	1.18		1.8E-05	
7/2/1993 9:09	1449	9		63.80	1.26	1.25		2E-05	
7/2/1993 9:10	1450	10		63.76	1.22	1.29		2.2E-05	
7/2/1993 9:11	1451	11		63.75	1.21	1.30		2.4E-05	
7/2/1993 9:12	1452	12		65.70	3.16	-0.65		2.6E-05	
7/2/1993 9:13	1453	13		63.65	1.11	1.40		2.9E-05	
7/2/1993 9:14	1454	14		63.63	1.09	1.42		3.1E-05	
7/2/1993 9:15	1455	15		63.60	1.06	1.45		3.3E-05	
7/2/1993 9:16	1456	16		63.56	1.02	1.49		3.5E-05	

7/2/1993 9:17	1457	17		63.54	1.00	1.51		3.7E-05	
7/2/1993 9:18	1458	18		63.52	0.98	1.53		4E-05	
7/2/1993 9:19	1459	19		63.50	0.96	1.55		4.2E-05	
7/2/1993 9:20	1460	20		63.48	0.94	1.57		4.4E-05	
7/2/1993 9:21	1461	21		63.48	0.94	1.57		4.6E-05	
7/2/1993 9:22	1462	22		63.45	0.91	1.60		4.8E-05	
7/2/1993 9:23	1463	23		63.44	0.90	1.61		5E-05	
7/2/1993 9:24	1464	24		63.42	0.88	1.63		5.3E-05	
7/2/1993 9:25	1465	25		63.40	0.86	1.65		5.5E-05	
7/2/1993 9:26	1466	26		63.38	0.84	1.67		5.7E-05	
7/2/1993 9:27	1467	27		63.38	0.84	1.67		5.9E-05	
7/2/1993 9:28	1468	28		63.37	0.83	1.68		6.1E-05	
7/2/1993 9:29	1469	29		63.35	0.81	1.70		6.4E-05	
7/2/1993 9:30	1470	30		63.33	0.79	1.72		6.6E-05	
7/2/1993 9:32	1472	32		63.30	0.76	1.75		7E-05	
7/2/1993 9:34	1474	34		63.29	0.75	1.76		7.5E-05	
7/2/1993 9:36	1476	36		63.26	0.72	1.79		7.9E-05	
7/2/1993 9:38	1478	38		63.26	0.72	1.79		8.3E-05	
7/2/1993 9:40	1480	40		63.23	0.69	1.82		8.8E-05	
7/2/1993 9:42	1482	42		63.22	0.68	1.83		9.2E-05	
7/2/1993 9:44	1484	44		63.20	0.66	1.85		9.7E-05	
7/2/1993 9:46	1486	46		63.18	0.64	1.87		0.0001	
7/2/1993 9:49	1489	49		63.18	0.64	1.87		0.00011	
7/2/1993 9:50	1490	50		63.17	0.63	1.88		0.00011	
7/2/1993 9:52	1492	52		63.14	0.60	1.91		0.00011	
7/2/1993 9:54	1494	54		63.16	0.62	1.89		0.00012	
7/2/1993 9:56	1496	56		63.12	0.58	1.93		0.00012	
7/2/1993 9:58	1498	58		63.12	0.58	1.93		0.00013	
7/2/1993 10:00	1500	60		63.09	0.55	1.96		0.00013	
7/2/1993 10:05	1505	65		63.09	0.55	1.96		0.00014	
7/2/1993 10:10	1510	70		63.09	0.55	1.96		0.00015	
7/2/1993 10:15	1515	75		63.09	0.55	1.96		0.00016	
7/2/1993 10:20	1520	80		63.05	0.51	2.00		0.00018	
7/2/1993 10:25	1525	85		63.04	0.50	2.01		0.00019	
7/2/1993 10:30	1530	90		63.01	0.47	2.04		0.0002	
7/2/1993 10:35	1535	95		63.46	0.92	1.59		0.00021	
7/2/1993 10:40	1540	100		62.98	0.44	2.07		0.00022	
7/2/1993 10:49	1549	109		62.97	0.43	2.08		0.00024	
7/2/1993 10:50	1550	110		62.96	0.42	2.09		0.00024	
7/2/1993 10:55	1555	115		62.95	0.41	2.10		0.00025	
7/2/1993 11:05	1565	125		62.95	0.41	2.10		0.00027	
7/2/1993 11:27	1587	147		62.90	0.36	2.15		0.00032	
7/2/1993 11:48	1608	168		62.88	0.34	2.17		0.00037	
7/2/1993 12:11	1631	191		62.87	0.33	2.18		0.00042	
7/2/1993 12:36	1656	216		62.87	0.33	2.18		0.00047	
7/2/1993 13:01	1681	241		62.85	0.31	2.20		0.00053	
7/2/1993 14:02	1742	302		62.84	0.30	2.21		0.00066	

7/2/1993 15:29	1829	389		62.79	0.25	2.26		0.00085	

datetime	etp	etr	agarwal	wl	dd	rec	t/r^2_p	t/r^2_r	r
07/01/1993 09:00	0			59.5					601
07/01/2093 10:12	72			59.69	0.19		0.0002		
07/01/2093 10:33	93			59.7	0.2		0.00026		
07/01/2093 11:02	122			59.73	0.23		0.00034		
07/01/2093 11:33	153			59.74	0.24		0.00042		
07/01/2093 12:04	184			59.76	0.26		0.00051		
07/01/2093 12:33	213			59.77	0.27		0.00059		
07/01/2093 13:03	243			59.78	0.28		0.00067		
07/01/2093 14:02	302			59.78	0.28		0.00084		
07/01/2093 15:10	370			59.79	0.29		0.00102		
07/01/2093 16:02	422			59.79	0.29		0.00117		
07/01/2093 17:04	484			59.79	0.29		0.00134		
07/01/2093 20:27	687			59.79	0.29		0.0019		
07/02/2093 07:45	1365			59.99	0.49		0.00378		
07/02/2093 08:35	1415			60.01	0.51		0.00392		
07/02/1993 09:00	1440	0							
07/02/1993 10:01	1501	61		59.9	0.4	0.11		0.00017	
07/02/2093 10:12	1512	72		59.9	0.4	0.11		0.0002	
07/02/2093 10:27	1527	87		59.89	0.39	0.12		0.00024	
07/02/2093 10:52	1552	112		59.87	0.37	0.14		0.00031	
07/02/2093 11:22	1582	142		59.85	0.35	0.16		0.00039	
07/02/2093 11:49	1609	169		59.84	0.34	0.17		0.00047	
07/02/2093 12:33	1653	213		59.84	0.34	0.17		0.00059	
07/02/2093 13:12	1692	252		59.83	0.33	0.18		0.0007	
07/02/2093 14:02	1742	302		59.81	0.31	0.2		0.00084	
07/02/2093 15:19	1819	379		59.76	0.26	0.25		0.00105	

Unique Well Number **206673**

County Anoka
Quad Minneapolis North
Quad Id 120D

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING RECORD
MINNESOTA STATUTES CHAPTER 1031

Entry Date 1991/04/15
Update Date 2016/05/13
Received Date

Well Name FRIDLEY 6

Township	Range	Dir	Section	Subsection	Field Located Elevation	MDH
30	24	W	14	DCABBB		877.00 ft.

Well Depth 255.00 ft
Depth Completed 255.00 ft
Date Well Completed 1972/08/00

well address FRIDLEY 6
600 63RD AV NE
FRIDLEY MN 55432 Changed

contact address CITY OF FRIDLEY

FRIDLEY MN 55432

Drillhole Angle

Drilling Method Cable Tool

Drilling Fluid

Well Hydrofractured? ☐ YES ☐ NO From ft. to

Use community supply(municipal)

Casing Type Steel (black or low Drive Shoe? ☐ YES ☐ NO Hole Diameter (in.)
Diameter 24 Depth 153
24.00 in. from 0.00 to 153.00 ft. lbs/ft

Description	Color	Hardness	From	To (ft.)
MEDIUM SAND			0	13
SILT & CLAY			13	65
SAND & GRAVEL			65	115
ST. PETER SANDSTONE			115	125
ST. PETER SANDSTONE			125	130
SHAKOPEE LIMESTONE			130	233
SHAKOPEE LIMESTONE			233	248
JORDAN SANDSTONE			248	255

Screen No
Make
Diamter Slot Length Set

Open Hole(ft.) From 153.0 to 255.0
Type

Static Water Level
56.50 ft. land surface Date measured 1972/08/00

Pumping Level (below land surface)
ft. after hrs. pumping g.p.m.

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

Grouting Information Well grouted? ☒ YES ☐ NO ☐ NOT SPECIFIED
Material neat cement From 0.0 To ft. 7.00 Cubic yards

Nearest Known Source of Contamination
feet Direction Type
Well disinfected upon completion? ☐ YES ☐ NO

Pump
☐ Not Installed Date Installed
Manufacture's name
Model number HP 0.00 Volts
Length of drop pipe Material Capacity g.p.m
Type

Abandoned Wells
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

Well Contractor Cerfication
Layne Well Co. 27010
License Business Name Lic. or Reg No.

Name of Driller Date

Remarks
GAMMA LOGGED 5-9-2016 BY JIM TRAEN. JIM TRAEN HAS 24 IN. CASING ENDING AT 144.3 FT.

First Bedrock OPDC
Last Strat CJDN
Aquifer Prairie Du Chien-Jordan
Depth to Bedrock 125.00 ft.

Unique Well Number	County Anoka Quad Minneapolis North Quad Id 120D	MINNESOTA DEPARTMENT OF HEALTH **WELL AND BORING RECORD** *MINNESOTA STATUTES CHAPTER 1031*	Entry Date 1991/04/15 Update Date 2016/11/15 Received Date
206678			

Well Name FRIDLEY 7

Township	Range	Dir	Section	Subsection	Field Located Elevation	MDH
30	24	W	14	DCADBC		885.00 ft.

well and contact address FRIDLEY 7
680 63RD AV NE
FRIDLEY MN Changed

Description	Color	Hardness	From	To (ft.)
FINE SAND			0	26
BLUE CLAY, LITTLE GRAVEL			26	60
GOOD WATER GRAVEL			60	73
MUDDY SAND			73	75
GRAVEL	LIGHT		75	110
ST. PETER	YELLOW		110	128
SHAKOPEE	RED		128	136
SHAKOPEE & ST. PETER	WHITE		136	150
SHAKOPEE	TAN		150	262

Remarks
ORIGINAL NO. 206671 - COMPLETED IN DRIFT, DEEPENED 1970 BY KEYS INTO BEDROCK GAMMA LOGGED 10-20-2015 BY JIM TRAEN.

First Bedrock OSTP **Aquifer** Prairie Du Chien Group
Last Strat OPDC **Depth to Bedrock** 110.00 ft.

Well Depth 262.00 ft **Depth Completed** 262.00 ft **Date Well Completed** 1970/01/14

Drillhole Angle

Drilling Method

Drilling Fluid **Well Hydrofractured?** ☐ YES ☐ NO From ft. to

Use community supply(municipal)

Casing Type Drive Shoe? ☐ YES ☐ NO Hole Diameter (in.)
Diameter 12 Depth 138

16.00 in. from 0.00 to 67.00 ft. lbs/ft
12.00 in. from 0.00 to 138.00 ft. lbs/ft
24.00 in. from 0.00 to 27.70 ft. lbs/ft

Screen No **Open Hole(ft.) From** 138.0 **to** 262.0
Make Type
Diamter Slot Length Set

Static Water Level
65.00 ft. land surface Date measured 1970/01/14

Pumping Level (below land surface)
73.00 ft. after hrs. pumping 1600.00 g.p.m.

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

Grouting Information Well grouted? ☐ YES ☐ NO ☐ NOT SPECIFIED

Nearest Known Source of Contamination
feet Direction Type
Well disinfected upon completion? ☐ YES ☐ NO

Pump
☐ Not Installed Date Installed
Manufacture's name JACUZZI
Model number SVB00 HP 75.00 Volts
Length of drop pipe 71.0 Material Capacity 1100 g.p.m
Type

Abandoned Wells
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

Well Contractor Cerfication
Renner E.H. & Sons 02015
License Business Name **Lic. or Reg No.**

Name of Driller **Date**

Unique Well Number **206669**

County Anoka
Quad Minneapolis North
Quad Id 120D

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING RECORD
MINNESOTA STATUTES CHAPTER 1031

Entry Date 1991/04/15
Update Date 2014/03/10
Received Date

Well Name FRIDLEY 8

Township	Range	Dir	Section	Subsection	Field Located Elevation	MDH
30	24	W	14	DCDCDA		885.00 ft.

well and contact address FRIDLEY 8
613 61ST AV NE
FRIDLEY MN Changed

Description	Color	Hardness	From	To (ft.)
NO RECORD			0	64
GRAVEL & STONES	GRAY		64	122
SHALE	BLACK		122	126
ST. PETER, DUSTY	WHITE		126	130
ST. PETER, SHAKOPEE	YELLOW		130	186
SHAKOPEE	TAN		186	195
SHAKOPEE	TAN		195	265
JORDAN	YELLOW		265	265

Well Depth 265.00 ft
Depth Completed 265.00 ft
Date Well Completed 1969/12/17

Drillhole Angle

Drilling Method

Drilling Fluid

Well Hydrofractured? ☐ YES ☐ NO
From ft. to

Use community supply(municipal)

Casing Type
Drive Shoe? ☐ YES ☐ NO
Hole Diameter (in.)
Diameter 12 Depth 138
16.00 in. from 0.00 to 64.00 ft. lbs/ft
12.00 in. from 0.00 to 138.00 ft. lbs/ft

Screen No
Open Hole(ft.) From 138.0 to 265.0
Make
Type
Diamter Slot Length Set

Static Water Level
70.00 ft. land surface
Date measured 1969/12/17

Pumping Level (below land surface)
74.00 ft. after hrs. pumping 1160.00 g.p.m.

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

Grouting Information
Well grouted? ☐ YES ☐ NO ☐ NOT SPECIFIED

Nearest Known Source of Contamination
feet Direction Type
Well disinfected upon completion? ☐ YES ☐ NO

Pump
☐ Not Installed
Date Installed
Manufacture's name JACUZZI
Model number 12MC24 HP 75.00 Volts
Length of drop pipe 125.(Material Capacity 1150 g.p.m
Type Turbine

Abandoned Wells
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

Well Contractor Cerfication
Renner E.H. & Sons 02015
License Business Name Lic. or Reg No.

Remarks
M.G.S. NO. 526 0 TO 64 FEET IS 16" CASE HOLE, DRILLED BY OTHERS.

First Bedrock OSTP
Aquifer Prairie Du Chien Group
Last Strat CJDN
Depth to Bedrock 126.00 ft.

Name of Driller
Date

Unique Well Number	County Anoka	MINNESOTA DEPARTMENT OF HEALTH	Entry Date 1991/04/15
206672	Quad Minneapolis North	**WELL AND BORING RECORD**	Update Date 2014/03/10
	Quad Id 120D	*MINNESOTA STATUTES CHAPTER 1031*	Received Date

Well Name FRIDLEY 9

Township	Range	Dir	Section	Subsection	Field Located Elevation	MDH
30	24	W	14	DCCAAB		882.00 ft.

well and contact address FRIDLEY 9
603 61ST AV NE
FRIDLEY MN Changed

Description	Color	Hardness	From	To (ft.)
SAND			0	15
SILT & CLAY			15	67
SAND & GRAVEL			67	117
ST. PETER SANDSTONE			117	132
DOLOMITE			132	250
JORDAN SANDROCK		SOFT	250	255

Remarks
DEEPENED BY LAYNE MINN. CO. TO 255 FT. IN 1972.

First Bedrock OSTP **Aquifer** Prairie Du Chien-Jordan
Last Strat CJDN **Depth to Bedrock** 117.00 ft.

Well Depth 255.00 ft **Depth Completed** 255.00 ft **Date Well Completed** 1965/12/22

Drillhole Angle

Drilling Method

Drilling Fluid

Well Hydrofractured? ☐ YES ☐ NO
From ft. to

Use community supply(municipal)

Casing Type Drive Shoe? ☐ YES ☐ NO **Hole Diameter (in.)**
Diameter 24 Depth 153
30.00 in. from 0.00 to 67.00 ft. lbs/ft
24.00 in. from 0.00 to 153.00 ft. lbs/ft

Screen No **Open Hole(ft.) From** 153.0 **to** 255.0
Make Type
Diamter Slot Length Set

Static Water Level
56.00 ft. land surface Date measured 1965/12/22

Pumping Level (below land surface)
60.00 ft. after hrs. pumping 1200.00 g.p.m.

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

Grouting Information Well grouted? ☐ YES ☐ NO ☐ NOT SPECIFIED

Nearest Known Source of Contamination
feet Direction Type
Well disinfected upon completion? ☐ YES ☐ NO

Pump
☐ Not Installed Date Installed
Manufacture's name JACUZZI
Model number HP 75.00 Volts 220
Length of drop pipe Material Capacity 1100 g.p.m
Type Turbine

Abandoned Wells
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

Well Contractor Cerfication
Keys Well Co. 62012
License Business Name **Lic. or Reg No.**

Name of Driller **Date**

Unique Well Number 509090

County Anoka
Quad Minneapolis North
Quad Id 120D

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING RECORD
MINNESOTA STATUTES CHAPTER 1031

Entry Date 1992/10/01
Update Date 2016/11/15
Received Date

Well Name FRIDLEY MW-2

Township	Range	Dir	Section	Subsection	Field Located Elevation	
30	24	W	14	DDBBBB	MDH 879.30	ft.

Well Depth 107.00 ft
Depth Completed 107.00 ft
Date Well Completed 1990/09/14

well and contact address FRIDLEY MW-2
6431 UNIVERSITY AV
FRIDLEY MN 55432 Changed

Drillhole Angle

Drilling Method Non-specified Rotary

Drilling Fluid Bentonite

Well Hydrofractured? ☐ YES ☐ NO From ft. to

Use monitor well

Casing Type Steel (black or low Drive Shoe? ☐ YES ☒ NO
Diameter 4 Depth 90
4.00 in. from 0.00 to 90.00 ft. 10.79 lbs/ft

Hole Diameter (in.) 9.00 To 107.0

Description	Color	Hardness	From	To (ft.)
SAND	BROWN	SOFT	0	24
CLAY	GRAY	SOFT	24	42
CLAY & GRAVEL	GRAY	SOFT	42	86
SAND & GRAVEL	BROWN	SOFT	86	107

Screen Yes
Make JOHNSON
Diamter Slot 10 Length 10 Set 90 ft. to 100 ft.

Open Hole(ft.) From to
Type

Static Water Level
62.00 ft. land surface Date measured 1990/08/27

Pumping Level (below land surface)
81.00 ft. after 3.00 hrs. pumping 10.00 g.p.m.

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

Grouting Information Well grouted? ☒ YES ☐ NO ☐ NOT SPECIFIED
Material neat cement From ______ To 90.0 ft. 18.00 Sacks

Nearest Known Source of Contamination
100 feet N Direction SDF Type
Well disinfected upon completion? ☐ YES ☒ NO

Pump
☐ Not Installed Date Installed ______
Manufacture's name ______
Model number ______ HP ______ Volts ______
Length of drop pipe ______ Material ______ Capacity ______ g.p.m
Type

Abandoned Wells
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

Remarks
DRILLED FOR B.A LEISCH ASSOCIATES AND ENGINEERS. LOT 4-C 10.

First Bedrock
Last Strat
Aquifer Quat. buried artes. aquifer
Depth to Bedrock ft.

Well Contractor Cerfication
Keys Well Co. 62012
License Business Name **Lic. or Reg No.**
SAMPSON, B.
Name of Driller **Date**

Memo

Minnesota Department *of* Health

Date: November 15, 2016

To: Fridley WHP Project File (PWSID: 1020031)

From: Justin Blum

Subject: Analysis of the Fridley 8 (206669) Pumping Test, July 15, 1993, Confined Prairie du Chien Aquifer

Test No. 2586

This test is the second of two tests performed in 1993 at the Fridley Commons Park well field by B.A. Liesch and Associates. Inc. The test of Fridley 8 (206669), was conducted as described below. The specifics of test location, scope, and timing are presented in Tables 2 and 3. Data were analyzed using standard methods cited in references. Individual analyses are presented in Appendix 1 and are summarized in Table 4. Appendix 2 includes maps, field notes, and any other test documentation.

Table 1. Summary of Results

Conceptual model: leaky-confined, radial porous-media flow, water-table aquifer is source of water to the pumped aquifer

Aquifer Properties Summary					
Representative Values		Unit	Range		+/- %
			Minimum	Maximum	
Top Stratigraphic Elev.	755	feet (MSL)			
Bottom Stratigraphic Elev.	620	feet (MSL)			
Transmissivity (T)	149,000	ft^2/day	147,000	154,000	
Aquifer Thickness (b)	135	Feet			
Saturated Thickness* (b)		Feet			
Hydraulic Conductivity (k)	1100	ft/day	1090	1140	
Primary Porosity (e_p)	0.05	0.00 %			
Secondary Porosity** (e_s)	?	0.00 %	Cavernous porosity indicated		
Storativity (S)	3.0e-4	dimensionless	7.0E-05	4.5E-04	
Characteristic Leakage (L)	7710	Feet	5000	9800	
Hydraulic Resistance (c)	400	Days	180	640	
Effective Well Radius (r_e)	5	Feet	1	5	
* hydraulically unconfined aquifer, ** dual porosity aquifer because of fractures or solution weathering					

Boundaries: leakage and enlarged effective borehole radius (cavernous flow)

Remarks: high quality test, lack of early-time data (< 1 minute) does not materially affect results. Unknown degree of secondary porosity development.

Table 2. Aquifer Test Information

Aquifer Test Number	2586
Test Location	Fridley 8 (206669)
Well Owner	City of Fridley
Test Conducted By / For	B.A. Liesch Assoc. for MPCA and Fridley
Aquifer	OPDC
Confined / Unconfined	Confined
Date/Time Monitoring Start	
Date/Time Pump off Before Test	--
Date/Time Pumping Start	7/15/1993 09:02
Date/Time Recovery Start	7/16/1993 09:00
Date/Time Test Finish	7/16/1993 16:00
Flow Rate	1550 gpm
Data Collection Methods	Manual, transducer in MW-1
Number of Observation Wells	4

Table 3. Wells Monitored During the Test

Well Name (Unique Well No.)	Radial Distance (feet)	Static Water Levels (feet below measuring point)			Change in Water Level (feet)	Aquifer
		Start	Mid-test	End		
Pumped Well:						
Fridley 8 (206669)	1				8.06	OPDC
Ob Wells:						
7 (206678)	574				2.98	OPDC
9 (206672)	702				2.86	OPDC
6 (206673)	1124				2.79	OPDC
MW-1 (509089)	820				0.58	QBAA

Table 4. Graphical Analysis Results

Transient Analysis					
Well Name (Unique Well No.)	**Transmissivity, T (ft^2/day)**	**Storage Coefficient, S**	**Analysis Method**	**Characteristic Leakage Factor, L (feet)**	**Plot No. Remarks**
Pumped Well:					
Fridley 8 (206669)	23,700	--	Theis	--	1
	14,052	1.9E-05	Agarwal	--	10
	154,000	3.0E-04	Hunt-Scott	7840 [c=400 days]	11
Ob Wells:					
F-9 (206672)	53,900	5.9E-05	Theis	--	2
"	**149,000**	**2.5E-04**	Hunt-Scott	**7710 [c=400 days]**	**12**
F-7 (206678)	51,600	7.0E-05	Theis	--	3
"	140,000	3.0E-04	Hunt-Scott	7480 [c=400 days]	13
F-6 (206673)	49,400	3.6E-05	Theis	--	4
"	118,000	3.0E-04	Hunt-Scott	7020 [c=418 days]	14 – influence of cavernous porosity
MW-1 (509089)	198,000	2.0E-02	Theis	--	5 - good match
Distance – Drawdown	52,700	1.0E-04	Walton t/r^2	--	6 – efficient pumping well
	40,900	1.4E-04	Walton t/r^2	5000 to 9800	7 – effective borehole radius ~5 ft.
	22,600	4.5E-04	Cooper-Jacob	--	8 – Smallest credible T
	30,600	7.0E-05			8 – Largest credible T

Steady-state Analysis				
Transmissivity, T (ft2/day)	**Characteristic Leakage, L (feet)**	**Hydraulic Resistance, c (days)**	**Analysis Method**	**Plot No. Remarks**
22,600	32,100	31,800	Hantush-Jacob	8 – L is far outside the reasonable range for setting and does not correspond to S value of 10^{-4}
43,100	8,000	1480	de Glee	9 - L is too large for setting

Representative values are bolded

Test Description

Purpose of Test

The test was conducted to investigate the source and concentration of VOC contamination in the public water supply (PWS) wells at the Fridley Commons Park well field. The distribution and construction of the wells is shown on Figure 1, Appendix 2. The test is documented in the B.A, Liesch & Assoc. report to the MPCA dated September, 1993 – see references.

Qualitative Aquifer Hydraulic Response:

The wells are constructed primarily as Prairie du Chien (PdC) wells. If they extend into the Jordan, it is for a limited distance. Therefore, it is assumed that the contribution of the Jordan to the production of these wells is insignificant.

The pumped well was not obviously over-efficient relative to the Theis-curve, Plot 6. This well is very likely open to one or more intervals of cavernous secondary porosity developed within the PdC but does not appear to be as well-connected to the cavernous porosity as Well 6. The response of the pumped well may also be slightly leaky. However, the hydraulic response at the observation wells is similar to the test of Well 6; as early-time drawdowns are too large relative to the Theis-curve and the later-time drawdowns converge on a leaky curve, Plot 6. This confirms the extent of the cavernous interval throughout the Commons Park well field; even though, it is not evident in the response of Well 8. The effective borehole radius of the pumped well may be as small as that described in the construction record and as great as 5 feet.

The responses of the wells were inspected for hydraulic distortions caused by fracture flow. The fracture flow response was not seen at any well. The only anomalous effect seen was the half-unit slope of the recovery of Well 9, plot 2. A half-unit slope is generally thought to be the result of borehole storage effects. (Gringarten, 2008) In a porous medium, the recovery phase of an observation well should not display this effect… therefore, it is interpreted to be an artifact of the cavernous porosity. Otherwise, the cavernous porosity has an effect on the drawdown observed at Well 6 during this test. The drawdown is too large for the radial distance as shown by the displacement of the well 6 point from the curve on the steady-state analyses, plots 8 and 9. Therefore, well 6 should not be included in these analyses as it skews the results to larger transmissivity, smaller storativity, and larger leakage factor.

Similar to the test of well 6, the storativities calculated by these techniques, plots 1 through 8, are within the range for a highly confined aquifer, even though the drift monitoring well, completed in the layer above, clearly responded to pumping and indicates a strongly leaky system. Values for storativity in a leaky system should be in the range of 10^{-3} to 10^{-4}, not 10^{-4} to 10^{-5}, as seen from analyses that use the Theis assumptions, plots 1 - 8.

All PdC observation wells show a leaky response relative to the Theis-curve. Both the steady-state and transient analyses show similar values for transmissivity. However, the values for the characteristic leakage factor are quite large, in the range of a tightly confined aquifer system. From the observed effect on the drift monitoring well, it would be expected that the hydraulic resistance should be in the range of hundreds of days.

Even though the pumping well is not over-efficient - as was seen in the first test at well 6, the large transmissivities from this test are consistent with one or more zones of cavernous porosity in the PdC. The degree of leakiness of the flow system and the confirmation of water level declines in the drift monitoring well, also requires the application of the Hunt-Scott (2007) conceptual model where the water table is contained in the leaky layer. The Hunt (2012) spreadsheet model was used to quantify the aquifer properties and verify the vertical hydraulic resistance.

The Hunt-Scott analyses, plots 11 through 14, show an extraordinarily large transmissivity, a corresponding large leakage factor, along with a reasonable storativity. The hydraulic resistance of the leaky-confining layer calculated from these parameters, L^2/T, is about 400 days; consistent with the leaky response of the drift observation well.

Quantitative Analysis

Conceptual Model

The conceptual model is of porous radial flow to a well in a leaky two-layered system. The pumped aquifer and an overlying leaky confining layer that contains the water table.

Analysis Results

Hydraulic response affected by:

A large effective borehole radius is used to account for the effects of conduit flow through secondary porosity in the pumped aquifer.

Consistency with conceptual model:

The results from the pumped well and various observation wells are quite consistent once the appropriate conceptual flow model was identified and only the large effective borehole radius is needed to compensate for differences with the Hunt-Scott conceptual model.

Representative aquifer properties best shown by:

Plots 11 through 14; nominal aquifer properties are shown in Table 1.

Selected References

Agarwal, R.G. 1980. A new method to account for producing time effects when drawdown type curves are used to analyze pressure buildup and other test data. SPE Paper 9289, presented at the 55th SPE Annual Technical Conference and Exhibition, Dallas, Texas, September 21–24, 1980.

Cooper, H.H. and Jacob, C.E. (1946) A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well-filed History, Trans. American Geophysical Union, V. 27, pp. 526 – 534.

de Glee, G. (1930) Over grondwaterstroomingen bij wateronttrekking door middle van putten. Ph.D. thesis, Delft Technische Hogeschool, Delft.

deGlee Method in:

Kruseman and De Ridder, (1991) Analysis and Evaluation of Pumping Test Data (2nd Edition), Publication 47, International Institute for Land Reclamation and Improvement, P.O. Box 45, 6700 AA Wageningen, The Netherlands, pp. 76-78.

Duffield, G.M. (2007) AQTESOLV for Windows Version 4.5 User's Guide, HydroSOLVE, Inc., Reston, VA.

Gringarten, A., 2008. From Straight Lines to Deconvolution: The Evolution of the State of the Art in Well Test Analysis. SPE Reservoir Evaluation & Engineering, 11(1).

Jacob, C.E. (1947) Drawdown Test to Determine the Effective Radius of Artesian Wells. Transactions of the American Society of Civil Engineers, 112, pp.1047–1170.

Hantush, M. S. and Jacob, C.E. (1955b) Steady Three-dimensional Flow to a Well in a Two-layered Aquifer, Trans. American Geophysical Union, Vol. 36, pp. 286-292.

Hantush, M. S. (1960) Modification of the Theory of Leaky Aquifers, Journal of Geophysical Research, Vol. 65, pp. 3713-25.

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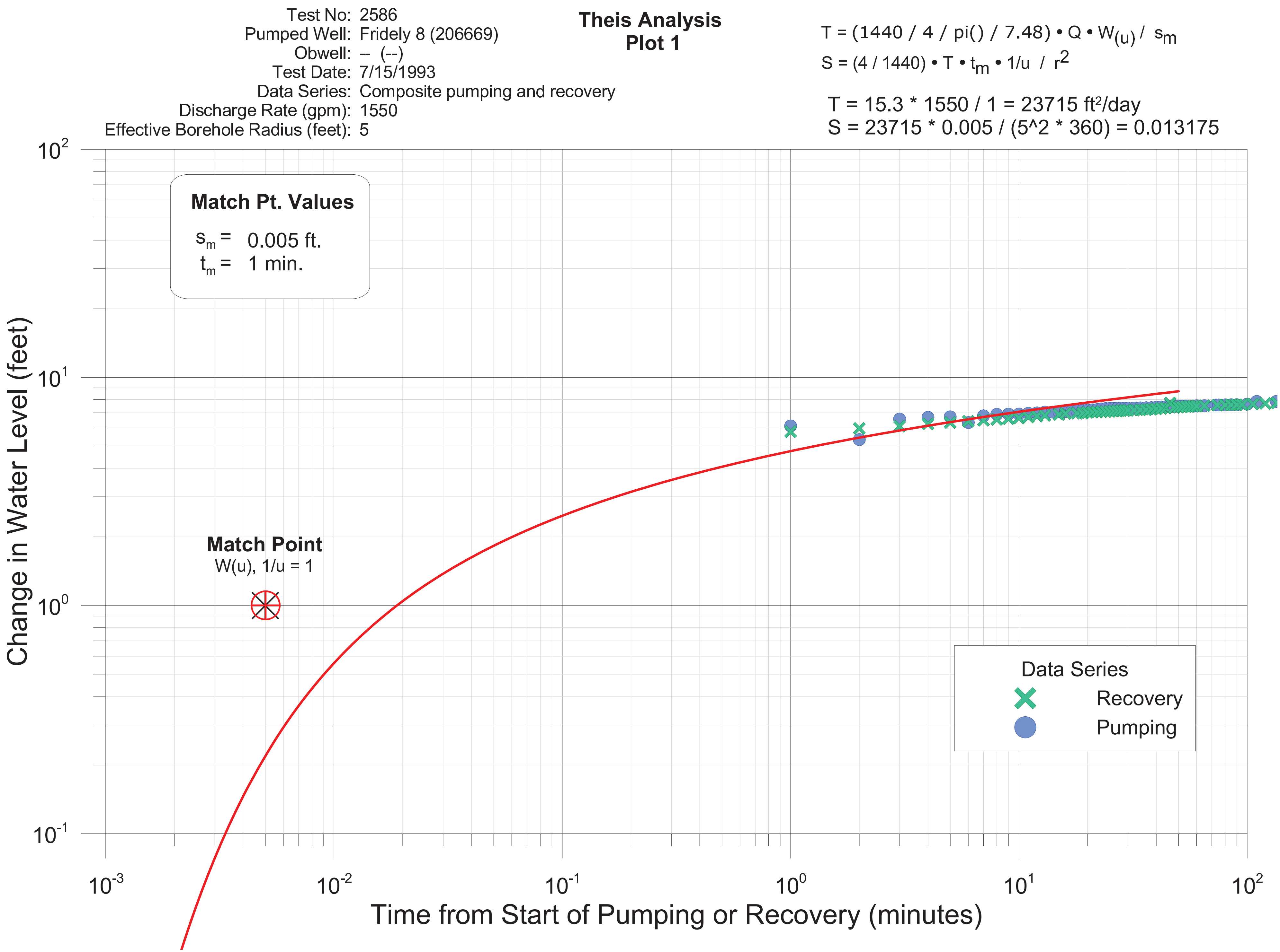
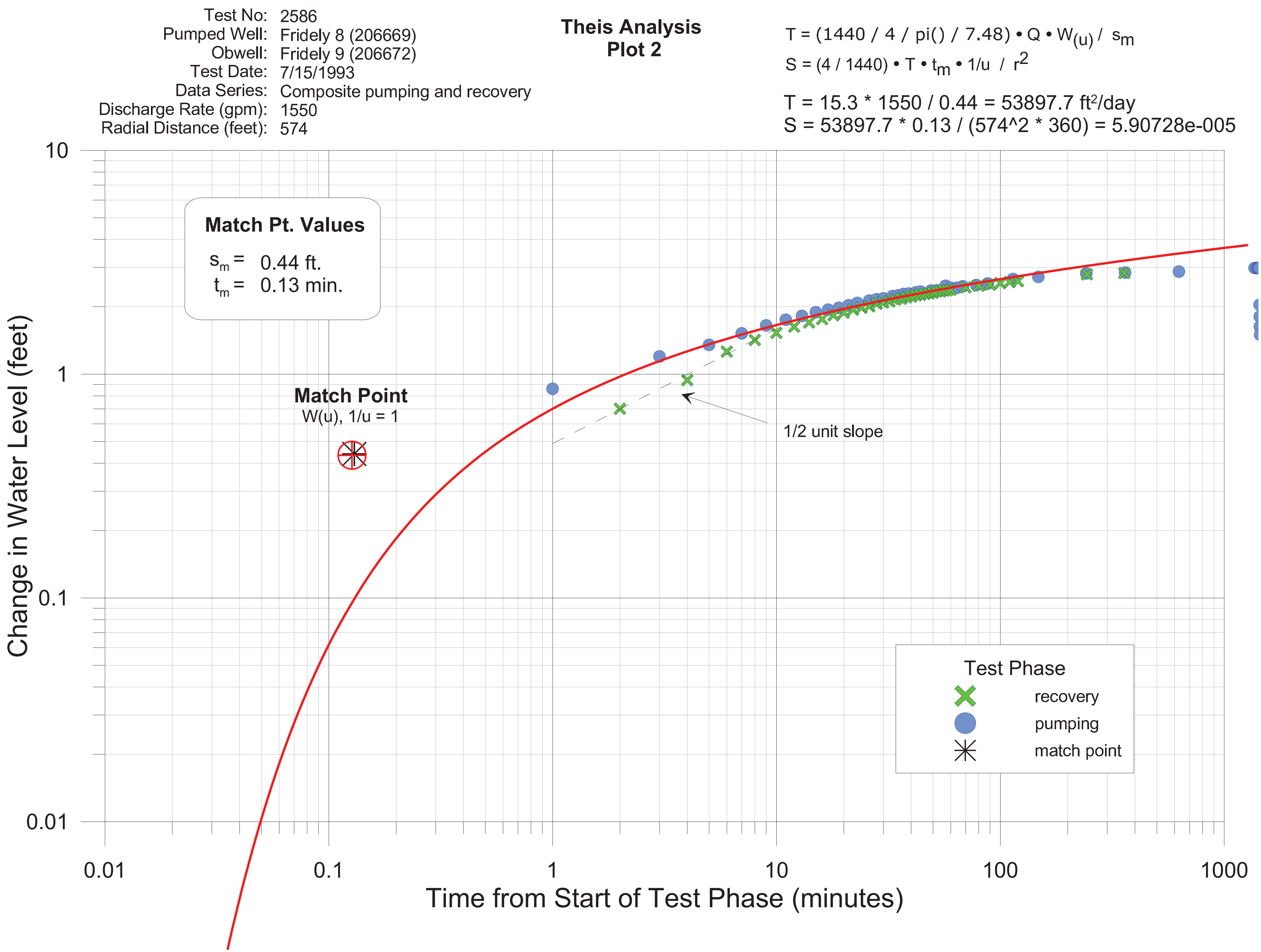
Hunt, B. & Scott, D. (2007) Flow to a Well in a Two-Aquifer System. Journal of Hydrologic Engineering, 12(2), pp.146–155.

Theis, C. V. (1935) The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Ground-Water Storage, Trans. American Geophysical Union, 16th Annual Meeting, April, 1935, pp. 519-24.

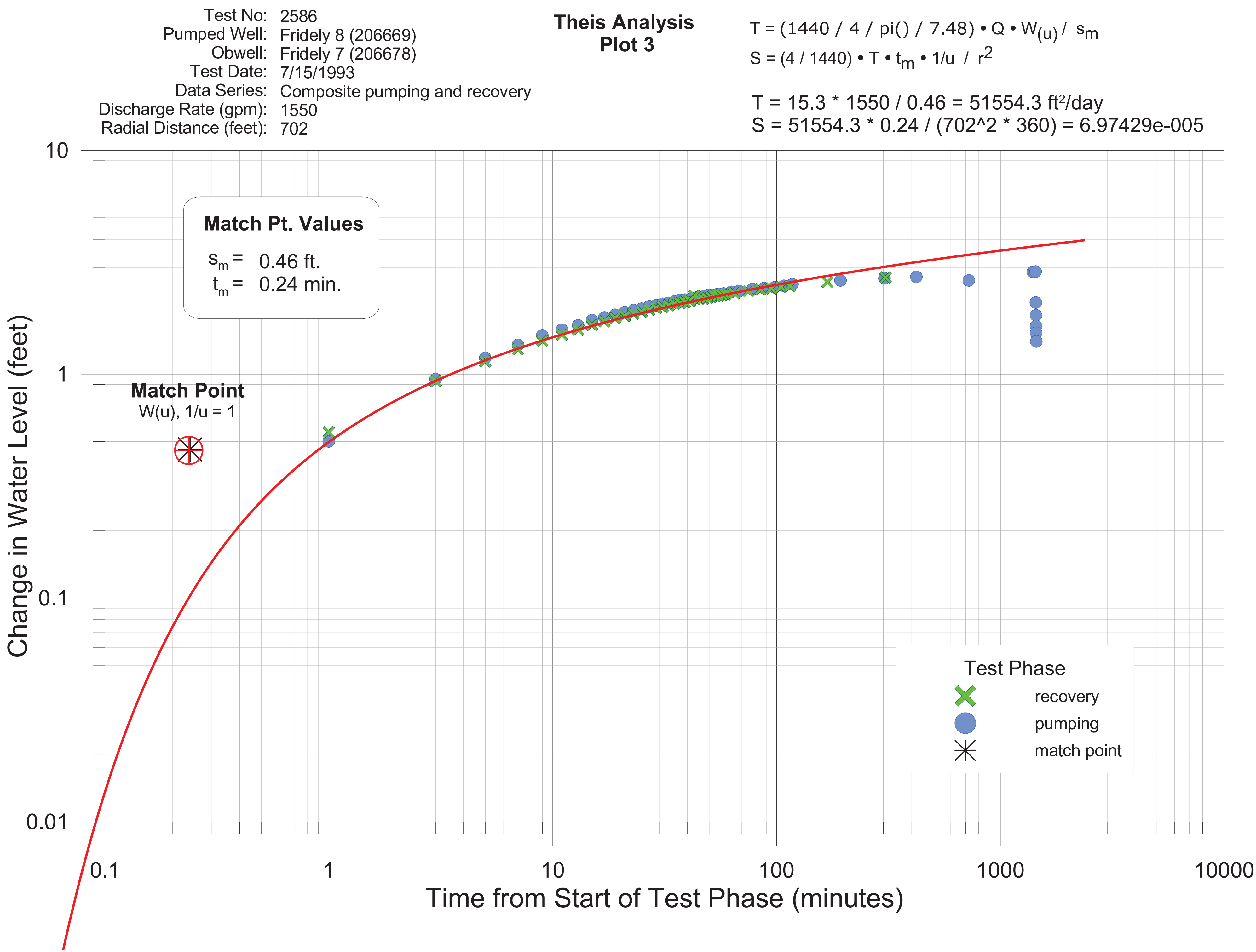
Walton, W.C. (1960) Leaky Artesian Aquifer Conditions In Illinois, Illinois State Water Survey, Bulletin 39, pp. 27.

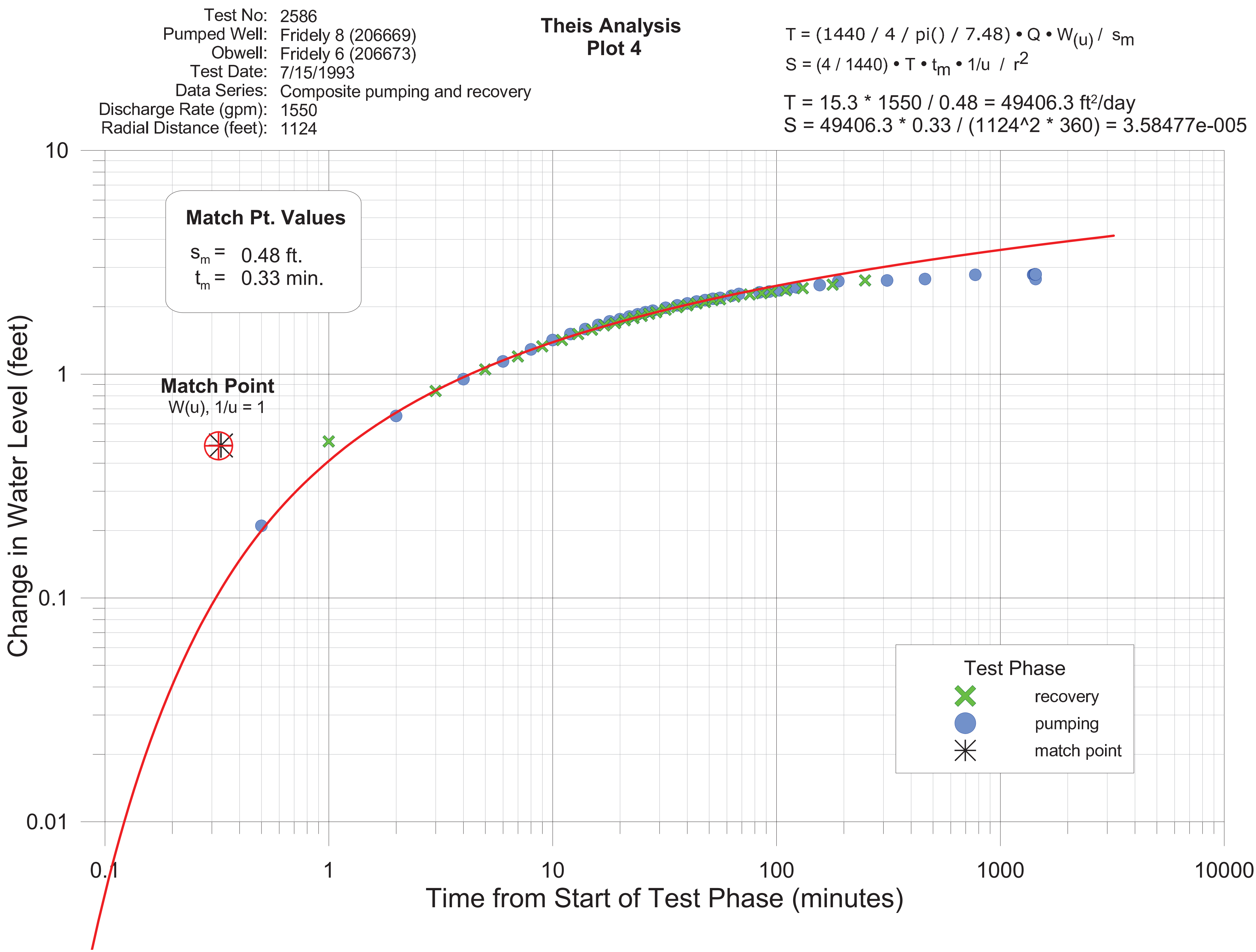
Appendix 1 – Graphical Analysis


Test No: 2586
Pumped Well: Fridely 8 (206669)
Obwell: -- (--)
Test Date: 7/15/1993
Data Series: Composite pumping and recovery
Discharge Rate (gpm): 1550
Effective Borehole Radius (feet): 5
Theis Analysis
Plot 1
T = (1440 / 4 / pi() / 7.48) • Q • W(u) / sm
S = (4 / 1440) • T • tm • 1/u / r2
T = 15.3 * 1550 / 1 = 23715 ft2/day
S = 23715 * 0.005 / (5^2 * 360) = 0.013175
Match Pt. Values
sm = 0.005 ft.
tm = 1 min.
Match Point
W(u), 1/u = 1
Data Series
Recovery
Pumping
Change in Water Level (feet)
Time from Start of Pumping or Recovery (minutes)
10-3
10-2
10-1
100
101
102
10-1

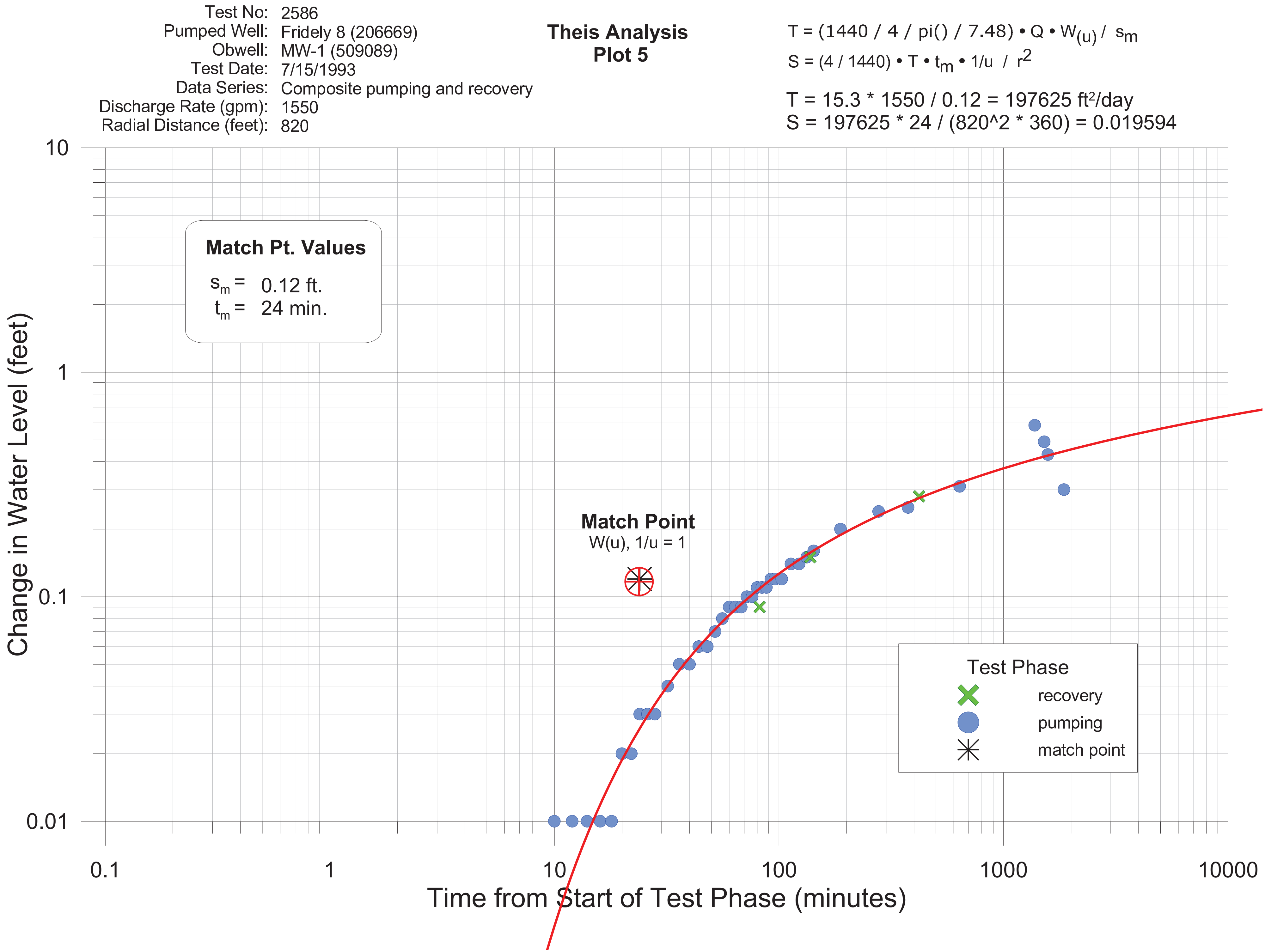


Test No: 2586
Pumped Well: Fridely 8 (206669)
Obwell: Fridely 9 (206672)
Test Date: 7/15/1993
Data Series: Composite pumping and recovery
Discharge Rate (gpm): 1550
Radial Distance (feet): 574
Theis Analysis
Plot 2
T = (1440 / 4 / pi() / 7.48) • Q • W(u) / sm
S = (4 / 1440) • T • tm • 1/u / r2
T = 15.3 * 1550 / 0.44 = 53897.7 ft2/day
S = 53897.7 * 0.13 / (574^2 * 360) = 5.90728e-005
Match Pt. Values
sm = 0.44 ft.
tm = 0.13 min.
Match Point
W(u), 1/u = 1
1/2 unit slope
Test Phase
recovery
pumping
match point
Change in Water Level (feet)
10
1
0.1
0.01
0.01
0.1
1
10
100
1000
Time from Start of Test Phase (minutes)

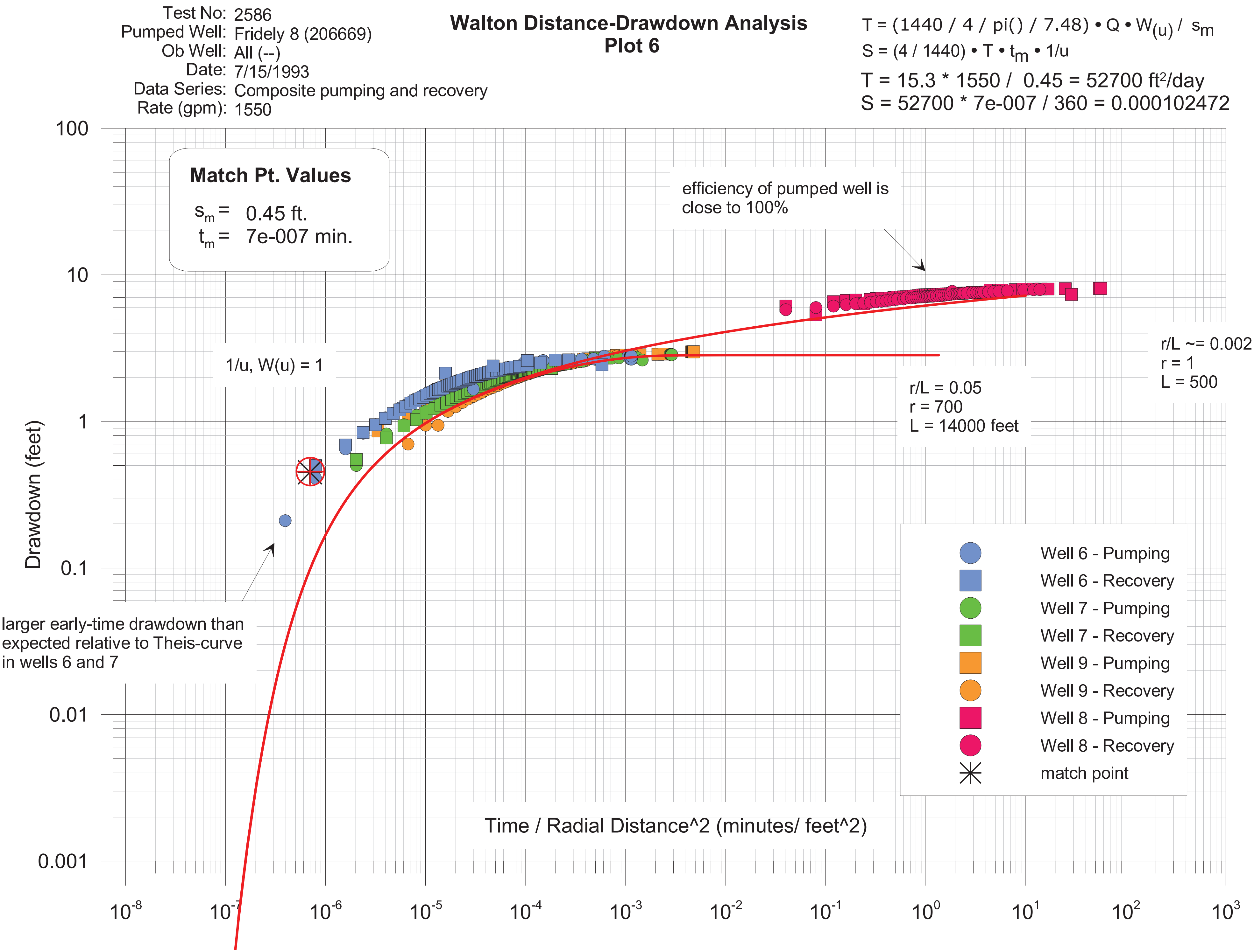

Test No: 2586
Pumped Well: Fridely 8 (206669)
Obwell: Fridely 7 (206678)
Test Date: 7/15/1993
Data Series: Composite pumping and recovery
Discharge Rate (gpm): 1550
Radial Distance (feet): 702
Theis Analysis
Plot 3
T = (1440 / 4 / pi() / 7.48) • Q • W(u) / sm
S = (4 / 1440) • T • tm • 1/u / r2
T = 15.3 * 1550 / 0.46 = 51554.3 ft2/day
S = 51554.3 * 0.24 / (702^2 * 360) = 6.97429e-005
Match Pt. Values
sm = 0.46 ft.
tm = 0.24 min.
Match Point
W(u), 1/u = 1
Test Phase
recovery
pumping
match point
Change in Water Level (feet)
10
1
0.1
0.01
0.1
1
10
100
1000
10000
Time from Start of Test Phase (minutes)



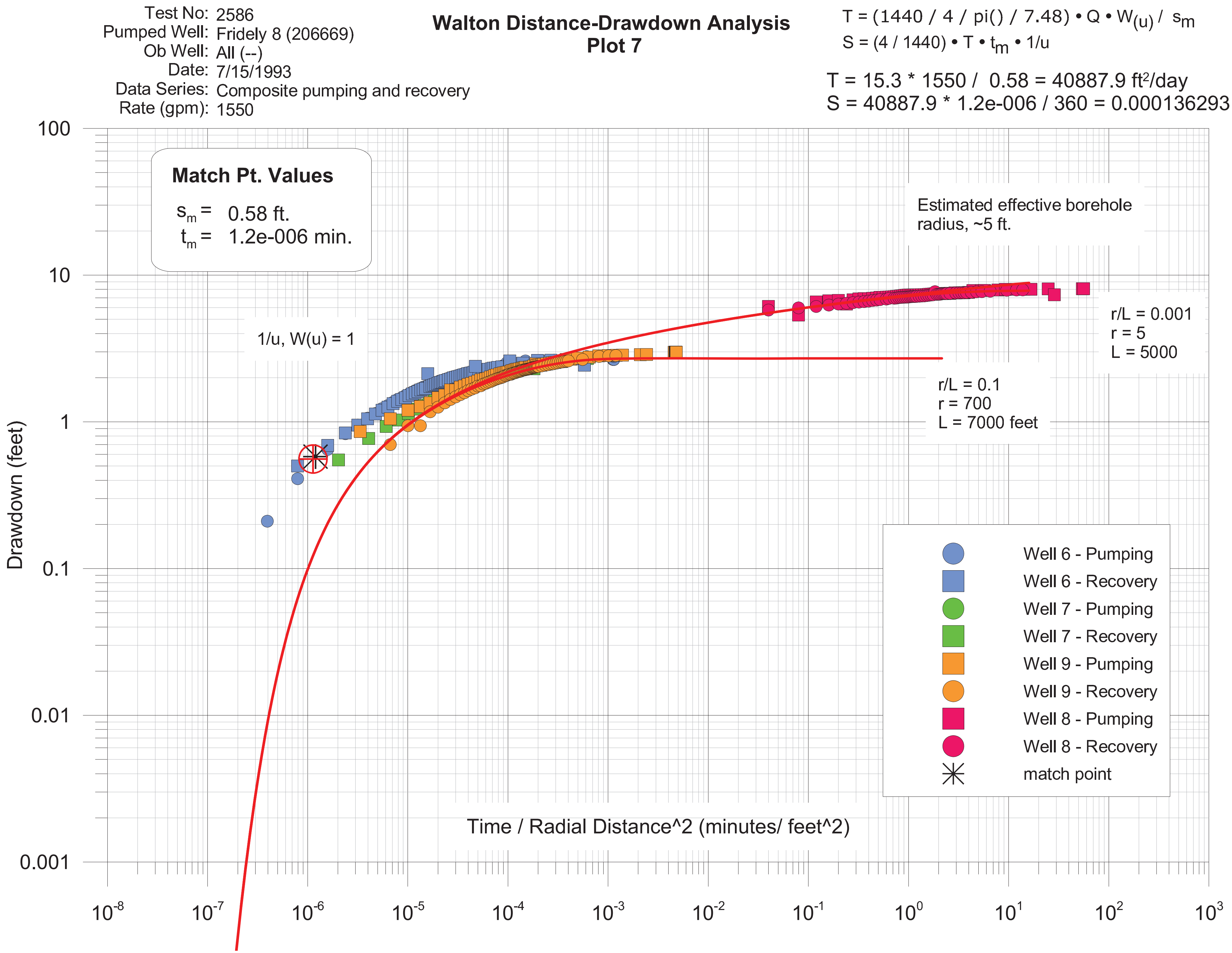
Test No: 2586
Pumped Well: Fridely 8 (206669)
Obwell: Fridely 6 (206673)
Test Date: 7/15/1993
Data Series: Composite pumping and recovery
Discharge Rate (gpm): 1550
Radial Distance (feet): 1124
Theis Analysis
Plot 4
T = (1440 / 4 / pi() / 7.48) • Q • W(u) / sm
S = (4 / 1440) • T • tm • 1/u / r2
T = 15.3 * 1550 / 0.48 = 49406.3 ft2/day
S = 49406.3 * 0.33 / (1124^2 * 360) = 3.58477e-005
Match Pt. Values
sm = 0.48 ft.
tm = 0.33 min.
Match Point
W(u), 1/u = 1
Test Phase
recovery
pumping
match point
Change in Water Level (feet)
Time from Start of Test Phase (minutes)
10
1
0.1
0.01
0.1
1
10
100
1000
10000



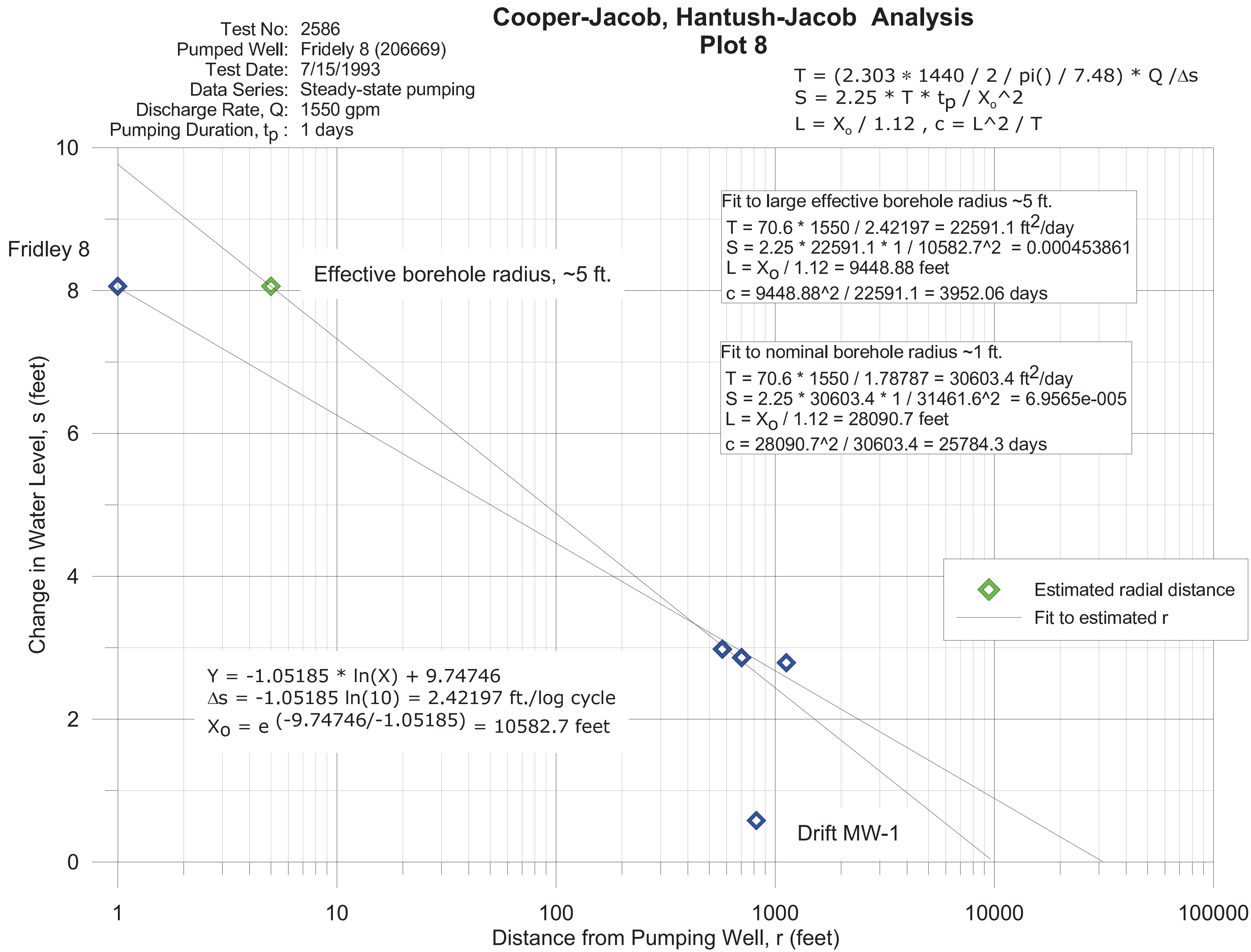
Test No: 2586
Pumped Well: Fridely 8 (206669)
Obwell: MW-1 (509089)
Test Date: 7/15/1993
Data Series: Composite pumping and recovery
Discharge Rate (gpm): 1550
Radial Distance (feet): 820
Theis Analysis
Plot 5
T = (1440 / 4 / pi() / 7.48) • Q • W(u) / sm
S = (4 / 1440) • T • tm • 1/u / r2
T = 15.3 * 1550 / 0.12 = 197625 ft2/day
S = 197625 * 24 / (820^2 * 360) = 0.019594
Match Pt. Values
sm = 0.12 ft.
tm = 24 min.
Match Point
W(u), 1/u = 1
Test Phase
recovery
pumping
match point
Change in Water Level (feet)
Time from Start of Test Phase (minutes)
10
1
0.1
0.01
0.1
1
10
100
1000
10000



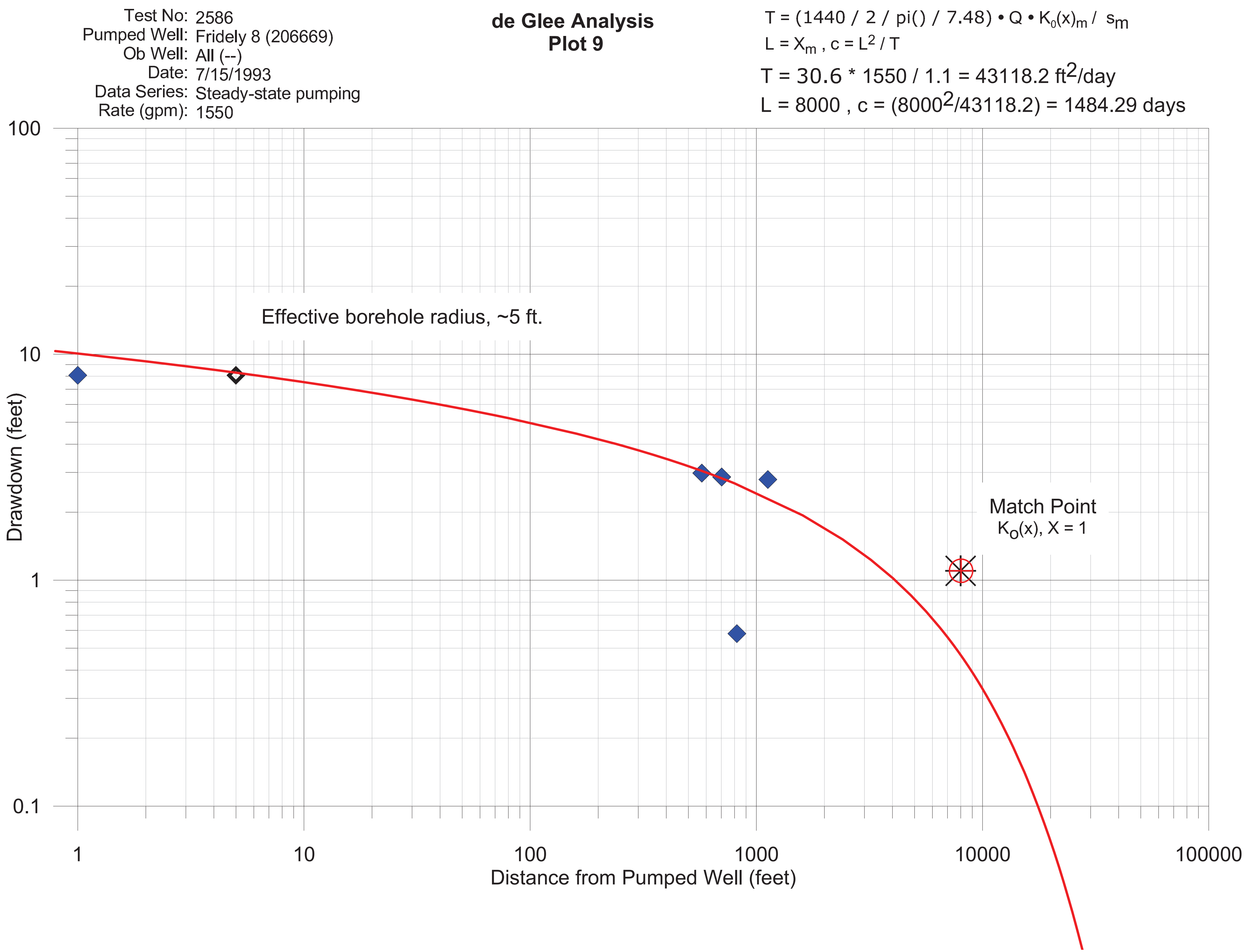
Test No: 2586
Pumped Well: Fridely 8 (206669)
Ob Well: All (--)
Date: 7/15/1993
Data Series: Composite pumping and recovery
Rate (gpm): 1550
Walton Distance-Drawdown Analysis
Plot 6
T = (1440 / 4 / pi() / 7.48) • Q • W(u) / sm
S = (4 / 1440) • T • tm • 1/u
T = 15.3 * 1550 / 0.45 = 52700 ft²/day
S = 52700 * 7e-007 / 360 = 0.000102472
Match Pt. Values
sm = 0.45 ft.
tm = 7e-007 min.
efficiency of pumped well is close to 100%
1/u, W(u) = 1
r/L = 0.05
r = 700
L = 14000 feet
r/L ~= 0.002
r = 1
L = 500
larger early-time drawdown than expected relative to Theis-curve in wells 6 and 7
Well 6 - Pumping
Well 6 - Recovery
Well 7 - Pumping
Well 7 - Recovery
Well 9 - Pumping
Well 9 - Recovery
Well 8 - Pumping
Well 8 - Recovery
match point
Drawdown (feet)
Time / Radial Distance^2 (minutes/ feet^2)
100
10
1
0.1
0.01
0.001
10-8
10-7
10-6
10-5
10-4
10-3
10-2
10-1
100
101
102
103



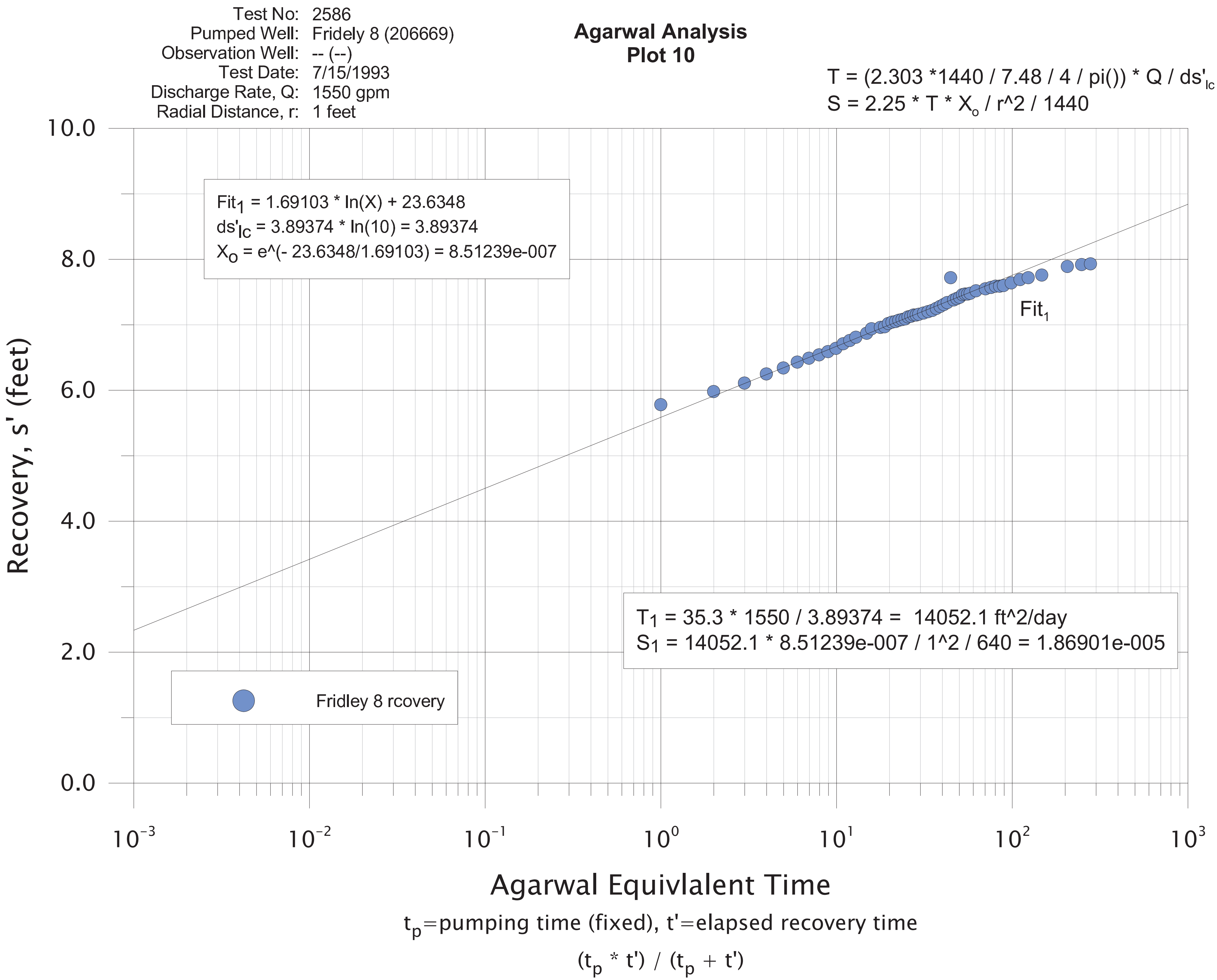
Test No: 2586
Pumped Well: Fridely 8 (206669)
Ob Well: All (--)
Date: 7/15/1993
Data Series: Composite pumping and recovery
Rate (gpm): 1550
Walton Distance-Drawdown Analysis
Plot 7
T = (1440 / 4 / pi() / 7.48) • Q • W(u) / sm
S = (4 / 1440) • T • tm • 1/u
T = 15.3 * 1550 / 0.58 = 40887.9 ft²/day
S = 40887.9 * 1.2e-006 / 360 = 0.000136293
Match Pt. Values
sm = 0.58 ft.
tm = 1.2e-006 min.
Estimated effective borehole radius, ~5 ft.
1/u, W(u) = 1
r/L = 0.001
r = 5
L = 5000
r/L = 0.1
r = 700
L = 7000 feet
Well 6 - Pumping
Well 6 - Recovery
Well 7 - Pumping
Well 7 - Recovery
Well 9 - Pumping
Well 9 - Recovery
Well 8 - Pumping
Well 8 - Recovery
match point
Drawdown (feet)
Time / Radial Distance^2 (minutes/ feet^2)
100
10
1
0.1
0.01
0.001
10-8
10-7
10-6
10-5
10-4
10-3
10-2
10-1
100
101
102
103



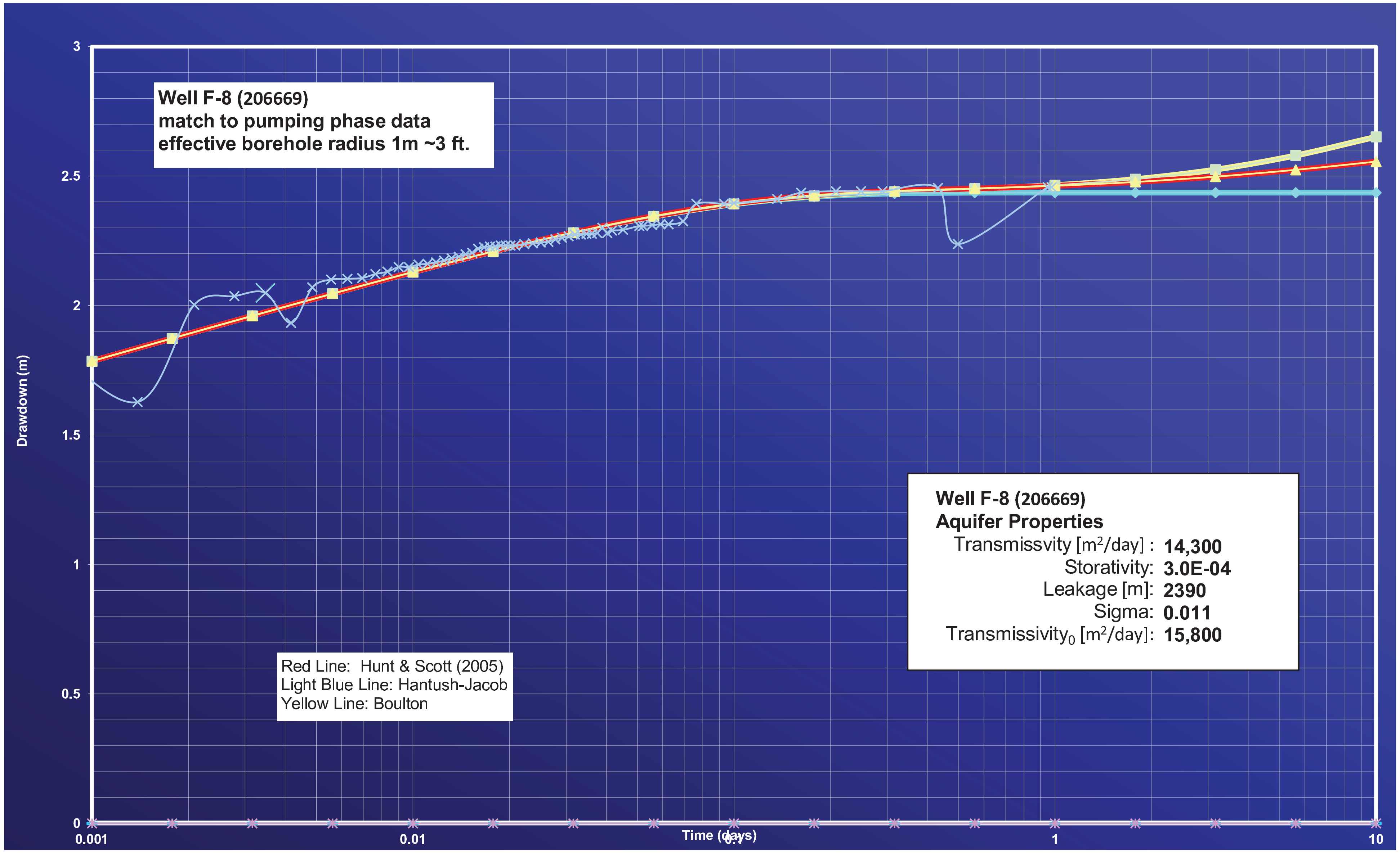
Cooper-Jacob, Hantush-Jacob Analysis
Plot 8
Test No: 2586
Pumped Well: Fridely 8 (206669)
Test Date: 7/15/1993
Data Series: Steady-state pumping
Discharge Rate, Q: 1550 gpm
Pumping Duration, t_p : 1 days
T = (2.303 * 1440 / 2 / pi() / 7.48) * Q / Δs
S = 2.25 * T * t_p / X_o^2
L = X_o / 1.12 , c = L^2 / T
Fit to large effective borehole radius ~5 ft.
T = 70.6 * 1550 / 2.42197 = 22591.1 ft^2/day
S = 2.25 * 22591.1 * 1 / 10582.7^2 = 0.000453861
L = X_o / 1.12 = 9448.88 feet
c = 9448.88^2 / 22591.1 = 3952.06 days
Fit to nominal borehole radius ~1 ft.
T = 70.6 * 1550 / 1.78787 = 30603.4 ft^2/day
S = 2.25 * 30603.4 * 1 / 31461.6^2 = 6.9565e-005
L = X_o / 1.12 = 28090.7 feet
c = 28090.7^2 / 30603.4 = 25784.3 days
Fridley 8
Effective borehole radius, ~5 ft.
Estimated radial distance
Fit to estimated r
Y = -1.05185 * ln(X) + 9.74746
Δs = -1.05185 ln(10) = 2.42197 ft./log cycle
X_o = e $^{(-9.74746/-1.05185)}$ = 10582.7 feet
Drift MW-1
Change in Water Level, s (feet)
Distance from Pumping Well, r (feet)
0
2
4
6
8
10
1
10
100
1000
10000
100000



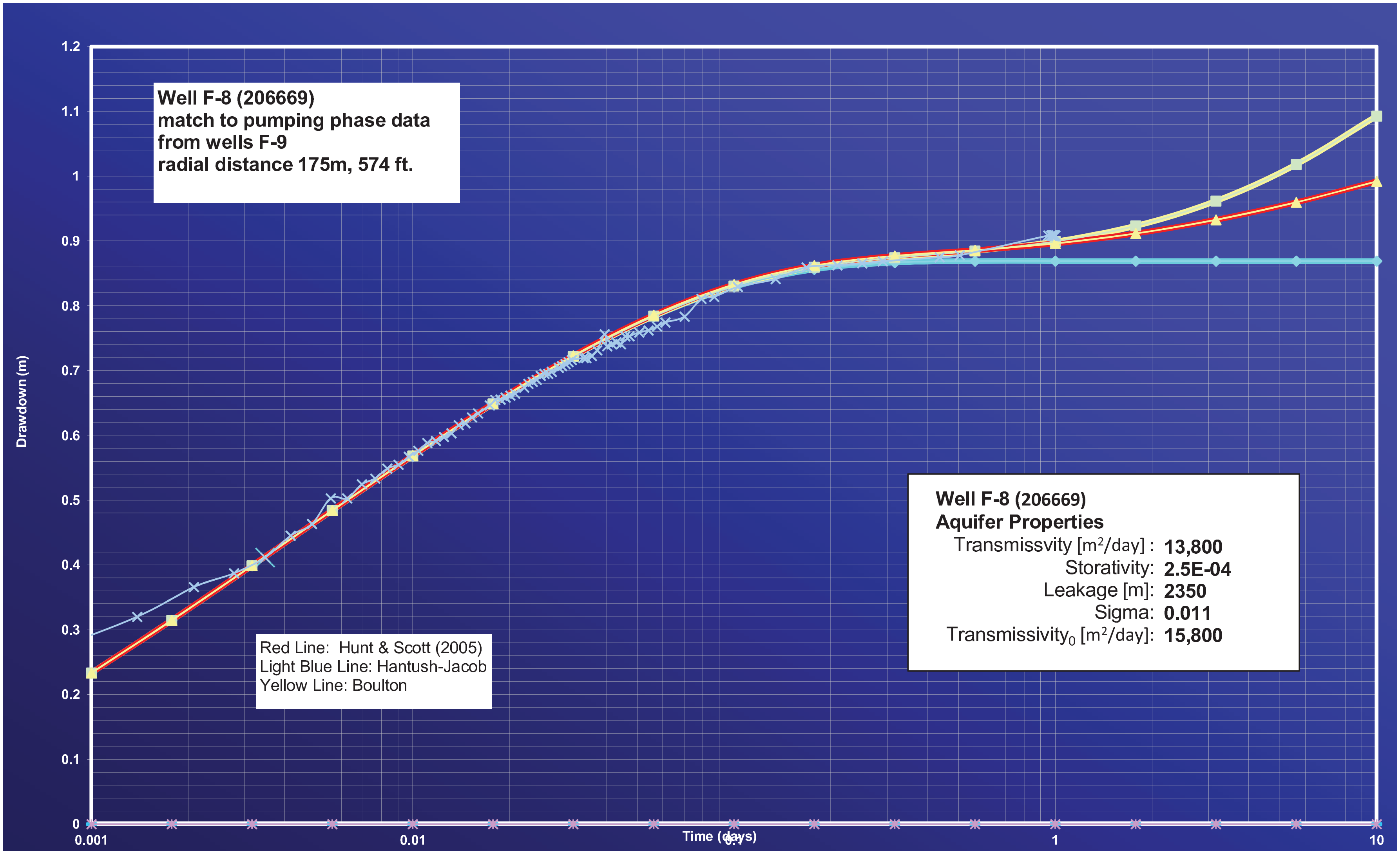
Test No: 2586
Pumped Well: Fridely 8 (206669)
Ob Well: All (--)
Date: 7/15/1993
Data Series: Steady-state pumping
Rate (gpm): 1550
de Glee Analysis
Plot 9
T = (1440 / 2 / pi() / 7.48) • Q • $K_0(x)_m$ / s_m
L = X_m , c = L^2 / T
T = 30.6 * 1550 / 1.1 = 43118.2 ft^2/day
L = 8000 , c = (8000^2/43118.2) = 1484.29 days
Effective borehole radius, ~5 ft.
Match Point
$K_o(x)$, X = 1
Drawdown (feet)
Distance from Pumped Well (feet)
100
10
1
0.1
1
10
100
1000
10000
100000

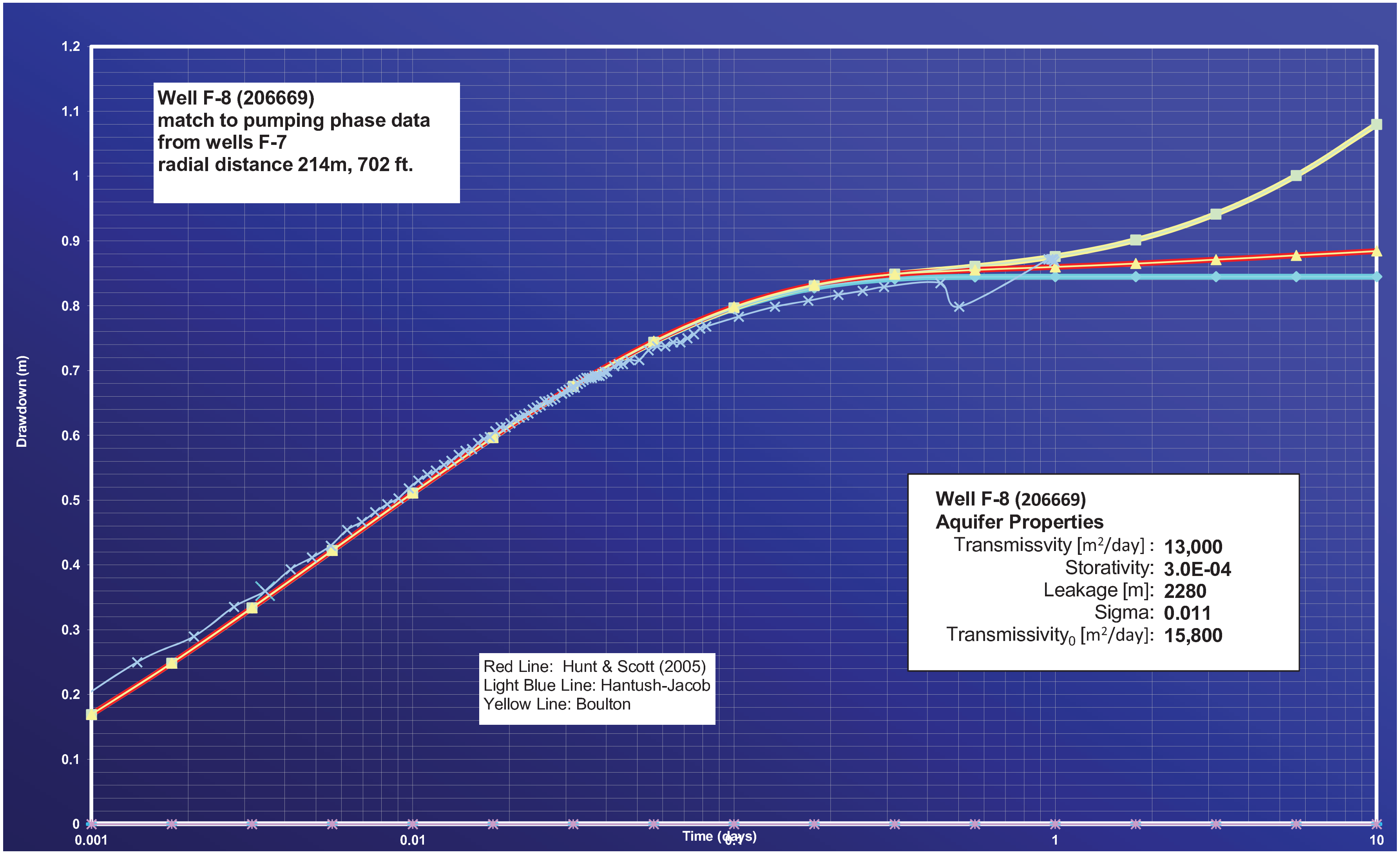


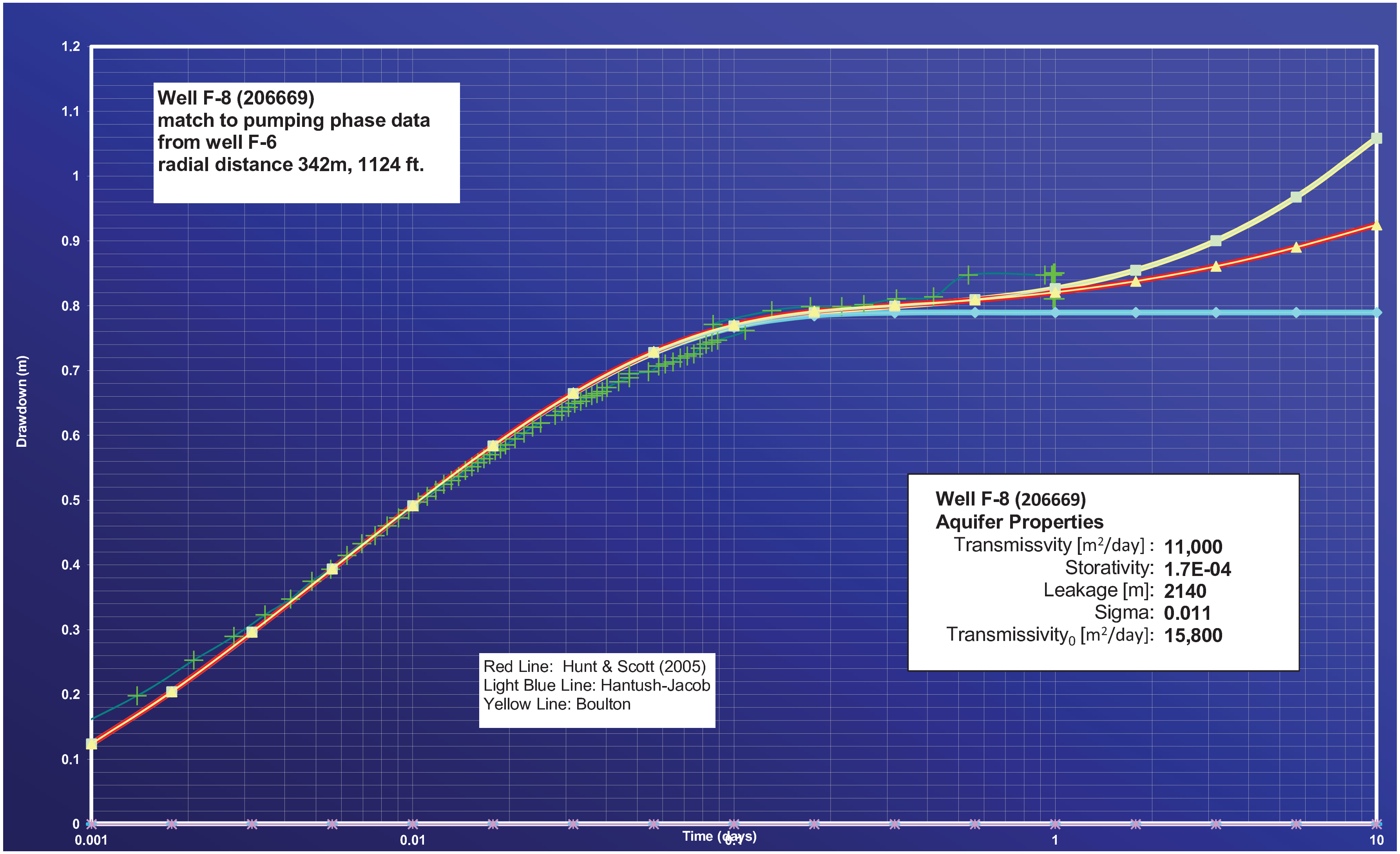
Test No: 2586
Pumped Well: Fridely 8 (206669)
Observation Well: -- (--)
Test Date: 7/15/1993
Discharge Rate, Q: 1550 gpm
Radial Distance, r: 1 feet
Agarwal Analysis
Plot 10
T = (2.303 *1440 / 7.48 / 4 / pi()) * Q / ds'lc
S = 2.25 * T * Xo / r^2 / 1440
Fit1 = 1.69103 * ln(X) + 23.6348
ds'lc = 3.89374 * ln(10) = 3.89374
Xo = e^(- 23.6348/1.69103) = 8.51239e-007
Fit1
T1 = 35.3 * 1550 / 3.89374 = 14052.1 ft^2/day
S1 = 14052.1 * 8.51239e-007 / 1^2 / 640 = 1.86901e-005
Fridley 8 rcovery
Recovery, s' (feet)
10.0
8.0
6.0
4.0
2.0
0.0
10-3
10-2
10-1
100
101
102
103
Agarwal Equivlalent Time
tp=pumping time (fixed), t'=elapsed recovery time
(tp * t') / (tp + t')



Well F-8 (206669)
match to pumping phase data
effective borehole radius 1m ~3 ft.
Well F-8 (206669)
Aquifer Properties
Transmissvity [m²/day] : 14,300
Storativity: 3.0E-04
Leakage [m]: 2390
Sigma: 0.011
Transmissivity₀ [m²/day]: 15,800
Red Line: Hunt & Scott (2005)
Light Blue Line: Hantush-Jacob
Yellow Line: Boulton
Drawdown (m)
Time (days)
3
2.5
2
1.5
1
0.5
0
0.001
0.01
0.1
1
10

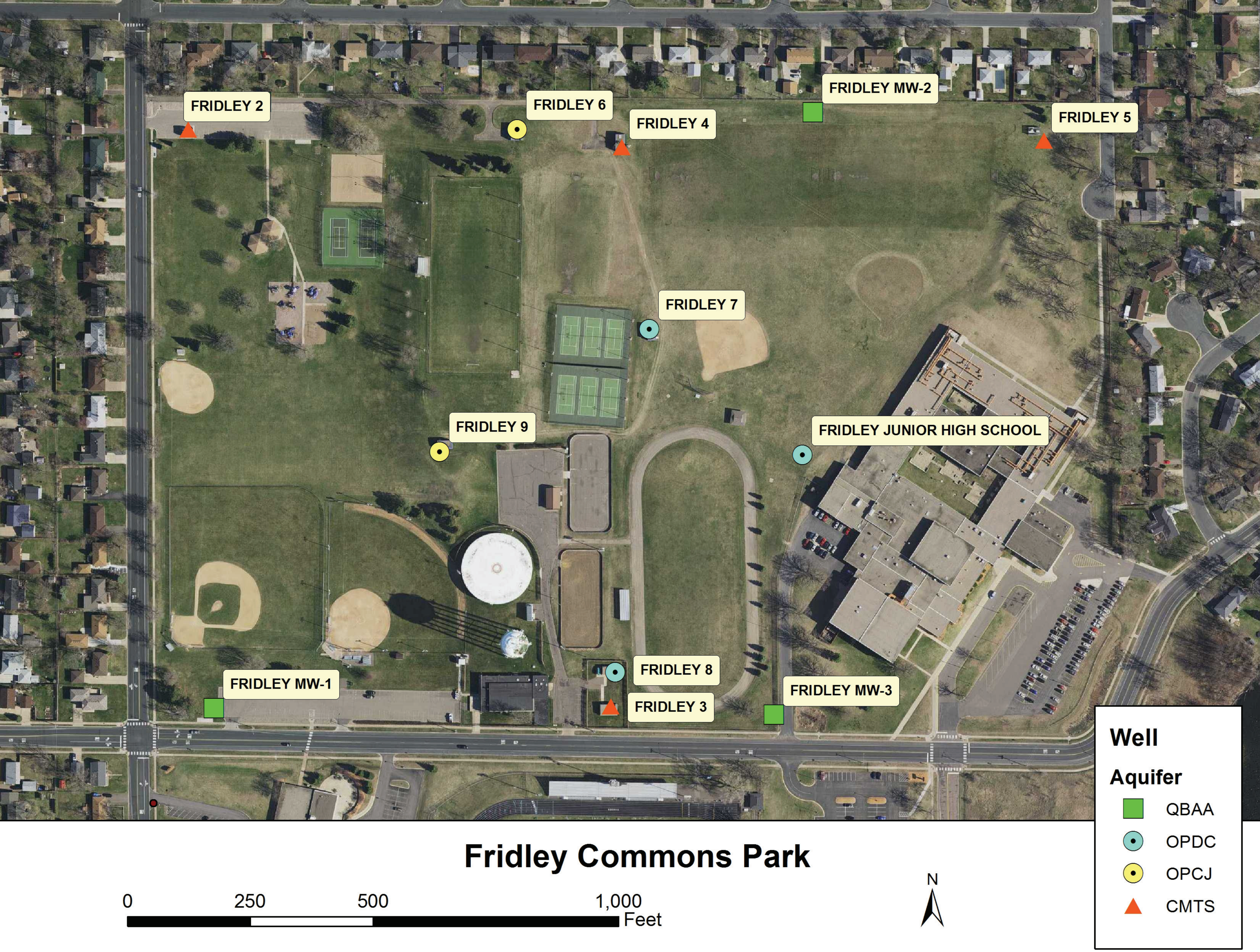

Well F-8 (206669)
match to pumping phase data
from wells F-9
radial distance 175m, 574 ft.
Red Line: Hunt & Scott (2005)
Light Blue Line: Hantush-Jacob
Yellow Line: Boulton
Well F-8 (206669)
Aquifer Properties
Transmissvity [m2/day] : 13,800
Storativity: 2.5E-04
Leakage [m]: 2350
Sigma: 0.011
Transmissivity0 [m2/day]: 15,800
Drawdown (m)
Time (days)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
0.001
0.01
0.1
1
10


Well F-8 (206669)
match to pumping phase data
from wells F-7
radial distance 214m, 702 ft.
Well F-8 (206669)
Aquifer Properties
Transmissvity [m2/day] : 13,000
Storativity: 3.0E-04
Leakage [m]: 2280
Sigma: 0.011
Transmissivity0 [m2/day]: 15,800
Red Line: Hunt & Scott (2005)
Light Blue Line: Hantush-Jacob
Yellow Line: Boulton
Drawdown (m)
Time (days)
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.001
0.01
0.1
1
10



Well F-8 (206669)
match to pumping phase data
from well F-6
radial distance 342m, 1124 ft.
Well F-8 (206669)
Aquifer Properties
Transmissvity [m2/day] : 11,000
Storativity: 1.7E-04
Leakage [m]: 2140
Sigma: 0.011
Transmissivity0 [m2/day]: 15,800
Red Line: Hunt & Scott (2005)
Light Blue Line: Hantush-Jacob
Yellow Line: Boulton
Drawdown (m)
Time (days)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
0.001
0.01
0.1
1
10

Appendix 2 – Documentation



Fridley Commons Park

WELLID		distance	effective r	drawdowr	x-diff^2	y-diff^2	rms_mete	reported dista
206669	8	1	5	8.06			1.5	
206672	9	574	574	2.98	11881	18769	175.0714	574.374295
206678	7	702	702	2.86	441	45369	214.0327	702.198508
206673	6	1124	1124	2.79	3721	113569	342.4763	1123.59617
509089	MW-1	820		0.58	62001	484	249.97	820.10157

datetime	etp	etr	agarwal	wl	dd	rec	t/r^2_p	t/r^2_r	r
07/15/1993 09:02	0			53.34					1124
07/15/1993 09:02:30	0.50			53.55	0.21		3.96E-07		**342.599**
07/15/1993 09:03	1			53.75	0.41		7.92E-07		
07/15/1993 09:04	2			53.99	0.65		1.58E-06		
07/15/1993 09:05	3			54.17	0.83		2.37E-06		
07/15/1993 09:06	4			54.29	0.95		3.17E-06		
07/15/1993 09:07	5			54.40	1.06		3.96E-06		
07/15/1993 09:08	6			54.48	1.14		4.75E-06		
07/15/1993 09:09	7			54.57	1.23		5.54E-06		
07/15/1993 09:10	8			54.63	1.29		6.33E-06		
07/15/1993 09:11	9			54.70	1.36		7.12E-06		
07/15/1993 09:12	10			54.76	1.42		7.92E-06		
07/15/1993 09:13	11			54.80	1.46		8.71E-06		
07/15/1993 09:14	12			54.85	1.51		9.50E-06		
07/15/1993 09:15	13			54.89	1.55		1.03E-05		
07/15/1993 09:16	14			54.93	1.59		1.11E-05		
07/15/1993 09:17	15			54.97	1.63		1.19E-05		
07/15/1993 09:18	16			55.00	1.66		1.27E-05		
07/15/1993 09:19	17			55.03	1.69		1.35E-05		
07/15/1993 09:20	18			55.06	1.72		1.42E-05		
07/15/1993 09:21	19			55.08	1.74		1.50E-05		
07/15/1993 09:22	20			55.10	1.76		1.58E-05		
07/15/1993 09:23	21			55.13	1.79		1.66E-05		
07/15/1993 09:24	22			55.15	1.81		1.74E-05		
07/15/1993 09:25	23			55.17	1.83		1.82E-05		
07/15/1993 09:26	24			55.19	1.85		1.90E-05		
07/15/1993 09:27	25			55.21	1.87		1.98E-05		
07/15/1993 09:28	26			55.23	1.89		2.06E-05		
07/15/1993 09:29	27			55.24	1.90		2.14E-05		
07/15/1993 09:30	28			55.26	1.92		2.22E-05		
07/15/1993 09:32	30			55.29	1.95		2.37E-05		
07/15/1993 09:34	32			55.32	1.98		2.53E-05		
07/15/1993 09:36	34			55.35	2.01		2.69E-05		
07/15/1993 09:38	36			55.37	2.03		2.85E-05		
07/15/1993 09:40	38			55.00	1.66		3.01E-05		
07/15/1993 09:42	40			55.41	2.07		3.17E-05		
07/15/1993 09:44	42			55.43	2.09		3.32E-05		
07/15/1993 09:46	44			55.45	2.11		3.48E-05		
07/15/1993 09:48	46			55.47	2.13		3.64E-05		
07/15/1993 09:50	48			55.48	2.14		3.80E-05		
07/15/1993 09:52	50			55.50	2.16		3.96E-05		
07/15/1993 09:54	52			55.51	2.17		4.12E-05		
07/15/1993 09:56	54			55.52	2.18		4.27E-05		
07/15/1993 09:58	56			55.53	2.19		4.43E-05		
07/15/1993 09:00	58			55.55	2.21		4.59E-05		
07/15/1993 10:05	63			55.58	2.24		4.99E-05		

07/15/1993 10:10	68			55.60	2.26		5.38E-05		
07/15/1993 10:10	68			55.62	2.28		5.38E-05		
07/15/1993 10:20	78			55.63	2.29		6.17E-05		
07/15/1993 10:26	84			55.66	2.32		6.65E-05		
07/15/1993 10:30	88			55.67	2.33		6.97E-05		
07/15/1993 10:35	93			55.68	2.34		7.36E-05		
07/15/1993 10:40	98			55.70	2.36		7.76E-05		
07/15/1993 10:45	103			55.71	2.37		8.15E-05		
07/15/1993 10:50	108			55.72	2.38		8.55E-05		
07/15/1993 10:55	113			55.75	2.41		8.94E-05		
07/15/1993 11:00	118			55.77	2.43		9.34E-05		
07/15/1993 11:05	123			55.78	2.44		9.74E-05		
07/15/1993 11:10	128			55.79	2.45		1.01E-04		
07/15/1993 11:38	156			55.84	2.50		1.23E-04		
07/15/1993 11:06	124			55.87	2.53		9.81E-05		
07/15/1993 12:11	189			55.94	2.60		1.50E-04		
07/15/1993 13:11	249			55.96	2.62		1.97E-04		
07/15/1993 14:14	312			55.96	2.62		2.47E-04		
07/15/1993 15:07	365			55.97	2.63		2.89E-04		
07/15/1993 16:43	461			56.00	2.66		3.65E-04		
07/15/1993 19:04	602			56.01	2.67		4.77E-04		
07/15/1993 21:55	773			56.12	2.78		6.12E-04		
07/16/1993 07:18	1336			56.12	2.78		1.06E-03		
07/16/1993 08:25	1403			56.12	2.78		1.11E-03		
07/16/1993 08:30	1408			56.12	2.78		1.11E-03		
07/16/1993 08:35	1413			56.12	2.78		1.12E-03		
07/16/1993 08:40	1418			56.00	2.66		1.12E-03		
07/16/1993 08:45	1423			56.13	2.79		1.13E-03		
07/16/1993 08:50	1428			56.13	2.79		1.13E-03		
07/16/1993 08:55	1433			56.13	2.79		1.13E-03		
07/16/1993 08:56	1434			56.13	2.79		1.14E-03		
07/16/1993 08:57	1435			56.13	2.79		1.14E-03		
07/16/1993 08:58	1436			56.00	2.66		1.14E-03		
07/16/1993 08:59	1437			56.13	2.79		1.14E-03		
07/16/1993 08:45	1423			56.13	2.79		1.13E-03		
07/16/1993 08:50	1428			56.13	2.79		1.13E-03		
07/16/1993 08:55	1433			56.13	2.79		1.13E-03		
07/16/1993 08:56	1434			56.13	2.79		1.14E-03		
07/16/1993 08:57	1435			56.13	2.79		1.14E-03		
07/16/1993 08:58	1436			56.00	2.66		1.14E-03		
07/16/1993 08:59	1437			56.13	2.79		1.14E-03		
07/16/1993 08:45	1423			56.13	2.79		1.13E-03		
07/16/1993 08:50	1428			56.13	2.79		1.13E-03		
07/16/1993 08:55	1433			56.13	2.79		1.13E-03		
07/16/1993 08:56	1434			56.13	2.79		1.14E-03		
07/16/1993 08:57	1435			56.13	2.79		1.14E-03		
07/16/1993 08:58	1436			56.00	2.66		1.14E-03		

07/16/1993 08:59	1437			56.13	2.79		1.14E-03		
07/16/1993 09:00	1438	0	0.00	56.13	2.79	0.00			
07/16/1993 09:01	1439	1	1.00	55.63	2.29	0.50		7.92E-07	
07/16/1993 09:02	1440	2	2.00	55.44	2.10	0.69		1.58E-06	
07/16/1993 09:03	1441	3	2.99	55.29	1.95	0.84		2.37E-06	
07/16/1993 09:04	1442	4	3.99	55.18	1.84	0.95		3.17E-06	
07/16/1993 09:05	1443	5	4.98	55.08	1.74	1.05		3.96E-06	
07/16/1993 09:06	1444	6	5.97	55.00	1.66	1.13		4.75E-06	
07/16/1993 09:07	1445	7	6.96	54.93	1.59	1.20		5.54E-06	
07/16/1993 09:08	1446	8	7.95	54.87	1.53	1.26		6.33E-06	
07/16/1993 09:09	1447	9	8.94	54.80	1.46	1.33		7.12E-06	
07/16/1993 09:10	1448	10	9.92	54.75	1.41	1.38		7.92E-06	
07/16/1993 09:11	1449	11	10.91	54.71	1.37	1.42		8.71E-06	
07/16/1993 09:12	1450	12	11.89	54.67	1.33	1.46		9.50E-06	
07/16/1993 09:13	1451	13	12.87	54.62	1.28	1.51		1.03E-05	
07/16/1993 09:14	1452	14	13.86	54.58	1.24	1.55		1.11E-05	
07/16/1993 09:15	1453	15	14.83	54.55	1.21	1.58		1.19E-05	
07/16/1993 09:16	1454	16	15.81	54.52	1.18	1.61		1.27E-05	
07/16/1993 09:17	1455	17	16.79	54.48	1.14	1.65		1.35E-05	
07/16/1993 09:18	1456	18	17.77	54.46	1.12	1.67		1.42E-05	
07/16/1993 09:19	1457	19	18.74	54.44	1.10	1.69		1.50E-05	
07/16/1993 09:20	1458	20	19.71	54.00	0.66	2.13		1.58E-05	
07/16/1993 09:21	1459	21	20.68	54.39	1.05	1.74		1.66E-05	
07/16/1993 09:22	1460	22	21.65	54.37	1.03	1.76		1.74E-05	
07/16/1993 09:23	1461	23	22.62	54.35	1.01	1.78		1.82E-05	
07/16/1993 09:24	1462	24	23.59	54.33	0.99	1.80		1.90E-05	
07/16/1993 09:25	1463	25	24.56	54.31	0.97	1.82		1.98E-05	
07/16/1993 09:26	1464	26	25.52	54.29	0.95	1.84		2.06E-05	
07/16/1993 09:27	1465	27	26.48	54.27	0.93	1.86		2.14E-05	
07/16/1993 09:28	1466	28	27.45	54.26	0.92	1.87		2.22E-05	
07/16/1993 09:29	1467	29	28.41	54.24	0.90	1.89		2.30E-05	
07/16/1993 09:30	1468	30	29.37	54.22	0.88	1.91		2.37E-05	
07/16/1993 09:32	1470	32	31.28	54.19	0.85	1.94		2.53E-05	
07/16/1993 09:34	1472	34	33.19	54.17	0.83	1.96		2.69E-05	
07/16/1993 09:36	1474	36	35.10	54.14	0.80	1.99		2.85E-05	
07/16/1993 09:38	1476	38	37.00	54.12	0.78	2.01		3.01E-05	
07/16/1993 09:40	1478	40	38.89	54.10	0.76	2.03		3.17E-05	
07/16/1993 09:42	1480	42	40.78	54.08	0.74	2.05		3.32E-05	
07/16/1993 09:44	1482	44	42.66	54.06	0.72	2.07		3.48E-05	
07/16/1993 09:46	1484	46	44.54	54.04	0.70	2.09		3.64E-05	
07/16/1993 09:48	1486	48	46.42	54.03	0.69	2.10		3.80E-05	
07/16/1993 09:50	1488	50	48.29	54.00	0.66	2.13		3.96E-05	
07/16/1993 09:52	1490	52	50.15	53.99	0.65	2.14		4.12E-05	
07/16/1993 09:54	1492	54	52.01	53.98	0.64	2.15		4.27E-05	
07/16/1993 09:56	1494	56	53.86	53.97	0.63	2.16		4.43E-05	
07/16/1993 09:58	1496	58	55.71	53.95	0.61	2.18		4.59E-05	
07/16/1993 09:00	1438	0	0.00	53.94	0.60	2.19		0.00E+00	

07/16/1993 10:05	1503	65	62.15	53.91	0.57	2.22		5.14E-05	
07/16/1993 10:10	1508	70	66.70	53.89	0.55	2.24		5.54E-05	
07/16/1993 10:16	1514	76	72.13	53.86	0.52	2.27		6.02E-05	
07/16/1993 10:20	1518	80	75.73	53.85	0.51	2.28		6.33E-05	
07/16/1993 10:26	1524	86	81.09	53.83	0.49	2.30		6.81E-05	
07/16/1993 10:30	1528	90	84.64	53.81	0.47	2.32		7.12E-05	
07/16/1993 10:35	1533	95	89.05	53.80	0.46	2.33		7.52E-05	
07/16/1993 10:40	1538	100	93.43	53.78	0.44	2.35		7.92E-05	
07/16/1993 10:50	1548	110	102.11	53.76	0.42	2.37		8.71E-05	
07/16/1993 10:00	1498	60	57.56	53.74	0.40	2.39		4.75E-05	
07/16/1993 11:11	1569	131	119.98	53.71	0.37	2.42		1.04E-04	
07/16/1993 21:15	2173	735	486.05	53.70	0.36	2.43		5.82E-04	
07/16/1993 11:58	1616	178	158.28	53.62	0.28	2.51		1.41E-04	
07/16/1993 11:12	1570	132	120.82	53.53	0.19	2.60		1.04E-04	
07/16/1993 13:09	1687	249	212.10	53.51	0.17	2.62		1.97E-04	
07/16/1993 14:40	1778	339	273.98	53.50	0.16	2.63		2.68E-04	

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07/15/1993 09:03	1			61.88	0.50		2.029E-06		**213.97**
07/15/1993 09:04	2			62.20	0.82		4.058E-06		
07/15/1993 09:05	3			62.33	0.95		6.088E-06		
07/15/1993 09:06	4			62.48	1.10		8.117E-06		
07/15/1993 09:07	5			62.56	1.18		1.015E-05		
07/15/1993 09:08	6			62.67	1.29		1.218E-05		
07/15/1993 09:09	7			62.73	1.35		1.42E-05		
07/15/1993 09:10	8			62.79	1.41		1.623E-05		
07/15/1993 09:11	9			62.87	1.49		1.826E-05		
07/15/1993 09:12	10			62.91	1.53		2.029E-05		
07/15/1993 09:13	11			62.96	1.58		2.232E-05		
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07/15/1993 09:15	13			63.03	1.65		2.638E-05		
07/15/1993 09:16	14			63.08	1.70		2.841E-05		
07/15/1993 09:17	15			63.12	1.74		3.044E-05		
07/15/1993 09:18	16			63.15	1.77		3.247E-05		
07/15/1993 09:19	17			63.17	1.79		3.45E-05		
07/15/1993 09:20	18			63.20	1.82		3.653E-05		
07/15/1993 09:21	19			63.22	1.84		3.855E-05		
07/15/1993 09:22	20			63.25	1.87		4.058E-05		
07/15/1993 09:23	21			63.27	1.89		4.261E-05		
07/15/1993 09:24	22			63.28	1.90		4.464E-05		
07/15/1993 09:25	23			63.31	1.93		4.667E-05		
07/15/1993 09:26	24			63.33	1.95		4.87E-05		
07/15/1993 09:09	25			63.34	1.96		5.073E-05		
07/15/1993 09:28	26			63.37	1.99		5.276E-05		
07/15/1993 09:29	27			63.39	2.01		5.479E-05		
07/15/1993 09:30	28			63.39	2.01		5.682E-05		
07/15/1993 09:31	29			63.41	2.03		5.885E-05		
07/15/1993 09:32	30			63.43	2.05		6.088E-05		
07/15/1993 09:33	31			63.44	2.06		6.291E-05		
07/15/1993 09:34	32			63.45	2.07		6.493E-05		
07/15/1993 09:35	33			63.46	2.08		6.696E-05		
07/15/1993 09:36	34			63.48	2.10		6.899E-05		
07/15/1993 09:37	35			63.49	2.11		7.102E-05		
07/15/1993 09:38	36			63.50	2.12		7.305E-05		
07/15/1993 09:39	37			63.52	2.14		7.508E-05		
07/15/1993 09:40	38			63.52	2.14		7.711E-05		
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07/15/1993 09:42	40			63.54	2.16		8.117E-05		
07/15/1993 09:44	42			63.56	2.18		8.523E-05		
07/15/1993 09:45	43			63.57	2.19		8.726E-05		
07/15/1993 09:46	44			63.58	2.20		8.928E-05		
07/15/1993 09:09	45			63.59	2.21		9.131E-05		
07/15/1993 09:48	46			63.59	2.21		9.334E-05		

07/15/1993 09:49	47			63.61	2.23		9.537E-05		
07/15/1993 09:50	48			63.62	2.24		9.74E-05		
07/15/1993 09:51	49			63.63	2.25		9.943E-05		
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07/15/1993 09:53	51			63.64	2.26		0.0001035		
07/15/1993 09:54	52			63.64	2.26		0.0001055		
07/15/1993 09:55	53			63.65	2.27		0.0001075		
07/15/1993 09:56	54			63.65	2.27		0.0001096		
07/15/1993 09:57	55			63.65	2.27		0.0001116		
07/15/1993 09:58	56			63.66	2.28		0.0001136		
07/15/1993 09:59	57			63.67	2.29		0.0001157		
07/15/1993 10:00	58			63.67	2.29		0.0001177		
07/15/1993 10:03	61			63.70	2.32		0.0001238		
07/15/1993 10:05	63			63.71	2.33		0.0001278		
07/15/1993 10:07	65			63.71	2.33		0.0001319		
07/15/1993 10:10	68			63.73	2.35		0.000138		
07/15/1993 10:15	73			63.73	2.35		0.0001481		
07/15/1993 10:20	78			63.78	2.40		0.0001583		
07/15/1993 10:25	83			63.80	2.42		0.0001684		
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07/15/1993 10:40	98			63.82	2.44		0.0001989		
07/15/1993 10:45	103			63.84	2.46		0.000209		
07/15/1993 10:50	108			63.86	2.48		0.0002192		
07/15/1993 10:55	113			63.89	2.51		0.0002293		
07/15/1993 11:00	118			63.90	2.52		0.0002394		
07/15/1993 11:31	149			63.95	2.57		0.0003024		
07/15/1993 12:15	193			64.00	2.62		0.0003916		
07/15/1993 13:07	245			64.03	2.65		0.0004972		
07/15/1993 14:06	304			64.06	2.68		0.0006169		
07/15/1993 15:04	362			64.08	2.70		0.0007346		
07/15/1993 16:04	422			64.10	2.72		0.0008563		
07/15/1993 19:34	632			64.12	2.74		0.0012825		
07/15/1993 21:05	723			64.00	2.62		0.0014671		
07/16/1993 07:53	1371			64.24	2.86		0.002782		
07/16/1993 08:20	1398			64.24	2.86		0.0028368		
07/16/1993 08:30	1408			64.24	2.86		0.0028571		
07/16/1993 08:40	1418			64.24	2.86		0.0028774		
07/16/1993 08:50	1428			64.23	2.85		0.0028977		
07/16/1993 09:00	1438	0	0.00	64.25	2.87	0.00			
07/16/1993 09:01	1439	1	1.00	63.69	2.31	0.55		2.03E-06	
07/16/1993 09:02	1440	2	2.00	63.47	2.09	0.77		4.06E-06	
07/16/1993 09:03	1441	3	2.99	63.31	1.93	0.93		6.09E-06	
07/16/1993 09:04	1442	4	3.99	63.21	1.83	1.03		8.12E-06	
07/16/1993 09:05	1443	5	4.98	63.10	1.72	1.14		1.01E-05	
07/16/1993 09:06	1444	6	5.98	63.02	1.64	1.22		1.22E-05	
07/16/1993 09:07	1445	7	6.97	62.95	1.57	1.29		1.42E-05	

07/16/1993 09:08	1446	8	7.96	62.91	1.53	1.33		1.62E-05	
07/16/1993 09:09	1447	9	8.94	62.83	1.45	1.41		1.83E-05	
07/16/1993 09:10	1448	10	9.93	62.78	1.40	1.46		2.03E-05	
07/16/1993 09:11	1449	11	10.92	62.74	1.36	1.50		2.23E-05	
07/16/1993 09:12	1450	12	11.90	62.69	1.31	1.55		2.44E-05	
07/16/1993 09:13	1451	13	12.88	62.66	1.28	1.58		2.64E-05	
07/16/1993 09:14	1452	14	13.87	62.61	1.23	1.63		2.84E-05	
07/16/1993 09:15	1453	15	14.85	62.58	1.20	1.66		3.04E-05	
07/16/1993 09:16	1454	16	15.82	62.55	1.17	1.69		3.25E-05	
07/16/1993 09:17	1455	17	16.80	62.52	1.14	1.72		3.45E-05	
07/16/1993 09:18	1456	18	17.78	62.50	1.12	1.74		3.65E-05	
07/16/1993 09:19	1457	19	18.75	62.46	1.08	1.78		3.86E-05	
07/16/1993 09:20	1458	20	19.73	62.44	1.06	1.80		4.06E-05	
07/16/1993 09:21	1459	21	20.70	62.42	1.04	1.82		4.26E-05	
07/16/1993 09:22	1460	22	21.67	62.39	1.01	1.85		4.46E-05	
07/16/1993 09:23	1461	23	22.64	62.38	1.00	1.86		4.67E-05	
07/16/1993 09:24	1462	24	23.61	62.36	0.98	1.88		4.87E-05	
07/16/1993 09:25	1463	25	24.57	62.34	0.96	1.90		5.07E-05	
07/16/1993 09:26	1464	26	25.54	62.32	0.94	1.92		5.28E-05	
07/16/1993 09:27	1465	27	26.50	62.30	0.92	1.94		5.48E-05	
07/16/1993 09:28	1466	28	27.47	62.28	0.90	1.96		5.68E-05	
07/16/1993 09:29	1467	29	28.43	62.26	0.88	1.98		5.88E-05	
07/16/1993 09:30	1468	30	29.39	62.26	0.88	1.98		6.09E-05	
07/16/1993 09:31	1469	31	30.35	62.24	0.86	2.00		6.29E-05	
07/16/1993 09:32	1470	32	31.30	62.22	0.84	2.02		6.49E-05	
07/16/1993 09:33	1471	33	32.26	62.21	0.83	2.03		6.7E-05	
07/16/1993 09:34	1472	34	33.21	62.20	0.82	2.04		6.9E-05	
07/16/1993 09:35	1473	35	34.17	62.18	0.80	2.06		7.1E-05	
07/16/1993 09:36	1474	36	35.12	62.17	0.79	2.07		7.31E-05	
07/16/1993 09:37	1475	37	36.07	62.16	0.78	2.08		7.51E-05	
07/16/1993 09:38	1476	38	37.02	62.14	0.76	2.10		7.71E-05	
07/16/1993 09:39	1477	39	37.97	62.14	0.76	2.10		7.91E-05	
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07/16/1993 09:41	1479	41	39.86	62.12	0.74	2.12		8.32E-05	
07/16/1993 09:42	1480	42	40.81	62.11	0.73	2.13		8.52E-05	
07/16/1993 09:43	1481	43	41.75	62.00	0.62	2.24		8.73E-05	
07/16/1993 09:44	1482	44	42.69	62.00	0.62	2.24		8.93E-05	
07/16/1993 09:45	1483	45	43.63	62.08	0.70	2.16		9.13E-05	
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07/16/1993 09:48	1486	48	46.45	62.06	0.68	2.18		9.74E-05	
07/16/1993 09:49	1487	49	47.39	62.05	0.67	2.19		9.94E-05	
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07/16/1993 09:51	1489	51	49.25	62.03	0.65	2.21		0.000103	
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07/16/1993 09:53	1491	53	51.12	62.01	0.63	2.23		0.000108	
07/16/1993 09:54	1492	54	52.05	62.00	0.62	2.24		0.00011	

07/16/1993 09:55	1493	55	52.97	62.00	0.62	2.24		0.000112	
07/16/1993 09:56	1494	56	53.90	61.99	0.61	2.25		0.000114	
07/16/1993 09:57	1495	57	54.83	61.98	0.60	2.26		0.000116	
07/16/1993 09:58	1496	58	55.75	61.97	0.59	2.27		0.000118	
07/16/1993 09:59	1497	59	56.67	61.97	0.59	2.27		0.00012	
07/16/1993 10:00	1498	60	57.60	61.96	0.58	2.28		0.000122	
07/16/1993 10:05	1503	65	62.19	61.94	0.56	2.30		0.000132	
07/16/1993 10:10	1508	70	66.75	61.91	0.53	2.33		0.000142	
07/16/1993 10:15	1513	75	71.28	61.89	0.51	2.35		0.000152	
07/16/1993 10:20	1518	80	75.78	61.87	0.49	2.37		0.000162	
07/16/1993 10:25	1523	85	80.26	61.85	0.47	2.39		0.000172	
07/16/1993 10:30	1528	90	84.70	61.94	0.56	2.30		0.000183	
07/16/1993 10:35	1533	95	89.11	61.83	0.45	2.41		0.000193	
07/16/1993 10:40	1538	100	93.50	61.81	0.43	2.43		0.000203	
07/16/1993 10:45	1543	105	97.85	61.79	0.41	2.45		0.000213	
07/16/1993 10:50	1548	110	102.18	61.78	0.40	2.46		0.000223	
07/16/1993 10:55	1553	115	106.48	61.77	0.39	2.47		0.000233	
07/16/1993 11:00	1558	120	110.76	61.76	0.38	2.48		0.000244	
07/16/1993 11:49	1607	169	151.23	61.66	0.28	2.58		0.000343	
07/16/1993 13:07	1685	247	210.79	61.55	0.17	2.69		0.000501	
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07/15/1993 09:06	4			69.34	6.68		0.16		
07/15/1993 09:07	5			69.38	6.72		0.2		
07/15/1993 09:08	6			69.00	6.34		0.24		
07/15/1993 09:09	7			69.45	6.79		0.28		
07/15/1993 09:10	8			69.55	6.89		0.32		
07/15/1993 09:11	9			69.56	6.90		0.36		
07/15/1993 09:12	10			69.57	6.91		0.4		
07/15/1993 09:13	11			69.62	6.96		0.44		
07/15/1993 09:14	12			69.65	6.99		0.48		
07/15/1993 09:15	13			69.71	7.05		0.52		
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07/15/1993 09:18	16			69.75	7.09		0.64		
07/15/1993 09:19	17			69.77	7.11		0.68		
07/15/1993 09:20	18			69.79	7.13		0.72		
07/15/1993 09:21	19			69.82	7.16		0.76		
07/15/1993 09:22	20			69.84	7.18		0.8		
07/15/1993 09:23	21			69.87	7.21		0.84		
07/15/1993 09:24	22			69.89	7.23		0.88		
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07/15/1993 09:29	27			69.98	7.32		1.08		
07/15/1993 09:30	28			69.98	7.32		1.12		
07/15/1993 09:31	29			69.98	7.32		1.16		
07/15/1993 09:32	30			69.98	7.32		1.2		
07/15/1993 09:34	32			70.00	7.34		1.28		
07/15/1993 09:36	34			70.01	7.35		1.36		
07/15/1993 09:38	36			70.02	7.36		1.44		
07/15/1993 09:40	38			70.03	7.37		1.52		
07/15/1993 09:42	40			70.06	7.40		1.6		
07/15/1993 09:44	42			70.08	7.42		1.68		
07/15/1993 09:46	44			70.10	7.44		1.76		
07/15/1993 09:48	46			70.12	7.46		1.84		
07/15/1993 09:50	48			70.12	7.46		1.92		
07/15/1993 09:52	50			70.13	7.47		2		
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07/15/1993 09:56	54			70.14	7.48		2.16		
07/15/1993 09:58	56			56.00	-6.66		2.24		
07/15/1993 10:00	58			70.14	7.48		2.32		

07/15/1993 10:02	60			70.17	7.51		2.4		
07/15/1993 10:07	65			70.18	7.52		2.6		
07/15/1993 10:15	73			70.23	7.57		2.92		
07/15/1993 10:17	75			70.23	7.57		3		
07/15/1993 10:22	80			70.24	7.58		3.2		
07/15/1993 10:27	85			70.25	7.59		3.4		
07/15/1993 10:32	90			70.25	7.59		3.6		
07/15/1993 10:42	100			70.29	7.63		4		
07/15/1993 10:52	110			70.51	7.85		4.4		
07/15/1993 11:16	134			70.51	7.85		5.36		
07/15/1993 11:26	144			70.52	7.86		5.76		
07/15/1993 12:18	196			70.57	7.91		7.84		
07/15/1993 12:55	233			70.65	7.99		9.32		
07/15/1993 14:01	299			70.67	8.01		11.96		
07/15/1993 15:00	358			70.67	8.01		14.32		
07/15/1993 16:00	418			70.67	8.01		16.72		
07/15/1993 19:24	622			70.71	8.05		24.88		
07/15/1993 21:00	718			70.00	7.34		28.72		
07/16/1993 07:48	1366			70.72	8.06		54.64		
07/16/1993 08:28	1406			70.72	8.06		56.24		
07/16/1993 09:00	1438								
07/16/1993 09:01	1439	1	1.00	64.94	2.28	5.78		0.04	
07/16/1993 09:02	1440	2	2.00	64.74	2.08	5.98		0.08	
07/16/1993 09:03	1441	3	2.99	64.61	1.95	6.11		0.12	
07/16/1993 09:04	1442	4	3.99	64.47	1.81	6.25		0.16	
07/16/1993 09:05	1443	5	4.98	64.38	1.72	6.34		0.2	
07/16/1993 09:06	1444	6	5.98	64.29	1.63	6.43		0.24	
07/16/1993 09:07	1445	7	6.97	64.23	1.57	6.49		0.28	
07/16/1993 09:08	1446	8	7.96	64.18	1.52	6.54		0.32	
07/16/1993 09:09	1447	9	8.94	64.13	1.47	6.59		0.36	
07/16/1993 09:10	1448	10	9.93	64.08	1.42	6.64		0.4	
07/16/1993 09:11	1449	11	10.92	64.01	1.35	6.71		0.44	
07/16/1993 09:12	1450	12	11.90	63.96	1.30	6.76		0.48	
07/16/1993 09:13	1451	13	12.88	63.91	1.25	6.81		0.52	
07/16/1993 09:15	1453	15	14.85	63.85	1.19	6.87		0.6	
07/16/1993 09:16	1454	16	15.82	63.78	1.12	6.94		0.64	
07/16/1993 09:18	1456	18	17.78	63.76	1.10	6.96		0.72	
07/16/1993 09:19	1457	19	18.75	63.75	1.09	6.97		0.76	
07/16/1993 09:20	1458	20	19.73	63.70	1.04	7.02		0.8	
07/16/1993 09:21	1459	21	20.70	63.68	1.02	7.04		0.84	
07/16/1993 09:22	1460	22	21.67	63.67	1.01	7.05		0.88	
07/16/1993 09:23	1461	23	22.64	63.65	0.99	7.07		0.92	
07/16/1993 09:24	1462	24	23.61	63.64	0.98	7.08		0.96	
07/16/1993 09:25	1463	25	24.57	63.63	0.97	7.09		1	
07/16/1993 09:26	1464	26	25.54	63.60	0.94	7.12		1.04	
07/16/1993 09:27	1465	27	26.50	63.59	0.93	7.13		1.08	
07/16/1993 09:28	1466	28	27.47	63.57	0.91	7.15		1.12	

07/16/1993 09:29	1467	29	28.43	63.57	0.91	7.15		1.16	
07/16/1993 09:30	1468	30	29.39	63.56	0.90	7.16		1.2	
07/16/1993 09:32	1470	32	31.30	63.54	0.88	7.18		1.28	
07/16/1993 09:34	1472	34	33.21	63.52	0.86	7.20		1.36	
07/16/1993 09:36	1474	36	35.12	63.50	0.84	7.22		1.44	
07/16/1993 09:38	1476	38	37.02	63.47	0.81	7.25		1.52	
07/16/1993 09:40	1478	40	38.92	63.44	0.78	7.28		1.6	
07/16/1993 09:42	1480	42	40.81	63.41	0.75	7.31		1.68	
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07/16/1993 09:46	1484	46	44.57	63.00	0.34	7.72		1.84	
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07/16/1993 09:54	1492	54	52.05	63.26	0.60	7.46		2.16	
07/16/1993 09:56	1494	56	53.90	63.25	0.59	7.47		2.24	
07/16/1993 09:58	1496	58	55.75	63.25	0.59	7.47		2.32	
07/16/1993 10:00	1498	60	57.60	63.24	0.58	7.48		2.4	
07/16/1993 10:05	1503	65	62.19	63.20	0.54	7.52		2.6	
07/16/1993 10:14	1512	74	70.38	63.17	0.51	7.55		2.96	
07/16/1993 10:20	1518	80	75.78	63.15	0.49	7.57		3.2	
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07/16/1993 10:35	1533	95	89.11	63.12	0.46	7.60		3.8	
07/16/1993 10:46	1544	106	98.72	63.08	0.42	7.64		4.24	
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07/16/1993 09:06	1444	6	5.98	63.90	1.72	1.26		2E-05	
07/16/1993 09:07	1445	7	6.97	63.81	1.63	1.35		2.3E-05	
07/16/1993 09:08	1446	8	7.96	63.74	1.56	1.42		2.7E-05	
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07/16/1993 09:10	1448	10	9.93	63.63	1.45	1.53		3.3E-05	
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07/16/1993 09:13	1451	13	12.88	63.49	1.31	1.67		4.3E-05	

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07/16/1993 09:16	1454	16	15.82	63.40	1.22	1.76		5.3E-05	
07/16/1993 09:17	1455	17	16.80	63.35	1.17	1.81		5.7E-05	
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07/16/1993 09:19	1457	19	18.75	63.30	1.12	1.86		6.4E-05	
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07/16/1993 09:29	1467	29	28.43	63.09	0.91	2.07		9.7E-05	
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07/15/1993 09:56	54		45.54	0.08	
07/15/1993 09:58	56		45.54	0.08	
07/15/1993 10:00	58		45.54	0.08	
07/15/1993 10:02	60		45.55	0.09	
07/15/1993 10:04	62		45.55	0.09	

07/15/1993 10:06	64		45.55	0.09	
07/15/1993 10:08	66		45.55	0.09	
07/15/1993 10:10	68		45.55	0.09	
07/15/1993 10:12	70		45.56	0.10	
07/15/1993 10:14	72		45.56	0.10	
07/15/1993 10:16	74		45.56	0.10	
07/15/1993 10:18	76		45.56	0.10	
07/15/1993 10:20	78		45.56	0.10	
07/15/1993 10:22	80		45.57	0.11	
07/15/1993 10:24	82		45.57	0.11	
07/15/1993 10:26	84		45.57	0.11	
07/15/1993 10:28	86		45.57	0.11	
07/15/1993 10:30	88		45.57	0.11	
07/15/1993 10:32	90		45.57	0.11	
07/15/1993 10:34	92		45.58	0.12	
07/15/1993 10:36	94		45.58	0.12	
07/15/1993 10:38	96		45.58	0.12	
07/15/1993 10:40	98		45.58	0.12	
07/15/1993 10:45	103		45.58	0.12	
07/15/1993 10:50	108		45.59	0.13	
07/15/1993 10:55	113		45.60	0.14	
07/15/1993 11:00	118		45.60	0.14	
07/15/1993 11:05	123		45.60	0.14	
07/15/1993 11:10	128		45.61	0.15	
07/15/1993 11:15	133		45.61	0.15	
07/15/1993 11:20	138		45.61	0.15	
07/15/1993 11:25	143		45.62	0.16	
07/15/1993 11:30	148		45.62	0.16	
07/15/1993 12:10	188		45.66	0.20	
07/15/1993 13:14	252		45.69	0.23	
07/15/1993 13:40	278		45.70	0.24	
07/15/1993 14:15	313		45.70	0.24	
07/15/1993 15:18	376		45.71	0.25	
07/15/1993 16:11	429		45.71	0.25	
07/15/1993 19:40	638		45.77	0.31	
07/15/1993 21:02	720		45.79	0.33	
07/16/1993 07:59	1377		46.04	0.58	
07/16/1993 08:49	1427		46.04	0.58	
07/16/1993 09:00	1438				
07/16/1993 10:22	1520	82	45.95	0.49	0.09
07/16/1993 10:50	1548	110	45.93	0.47	0.11
07/16/1993 11:18	1576	138	45.89	0.43	0.15
07/16/1993 12:02	1620	182	45.84	0.38	0.20
07/16/1993 16:01	1859	421	45.76	0.30	0.28
07/16/1993 14:12	1750	312	45.75	0.29	0.29

Unique Well Number **206673**

County Anoka
Quad Minneapolis North
Quad Id 120D

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING RECORD
MINNESOTA STATUTES CHAPTER 1031

Entry Date 1991/04/15
Update Date 2016/05/13
Received Date

Well Name FRIDLEY 6

Township	Range	Dir	Section	Subsection	Field Located Elevation	MDH
30	24	W	14	DCABBB		877.00 ft.

Well Depth 255.00 ft
Depth Completed 255.00 ft
Date Well Completed 1972/08/00

well address FRIDLEY 6
600 63RD AV NE
FRIDLEY MN 55432 Changed

contact address CITY OF FRIDLEY

FRIDLEY MN 55432

Drillhole Angle

Drilling Method Cable Tool

Drilling Fluid

Well Hydrofractured? ☐ YES ☐ NO From ft. to

Use community supply(municipal)

Casing Type Steel (black or low Drive Shoe? ☐ YES ☐ NO Hole Diameter (in.)
Diameter 24 Depth 153
24.00 in. from 0.00 to 153.00 ft. lbs/ft

Description	Color	Hardness	From	To (ft.)
MEDIUM SAND			0	13
SILT & CLAY			13	65
SAND & GRAVEL			65	115
ST. PETER SANDSTONE			115	125
ST. PETER SANDSTONE			125	130
SHAKOPEE LIMESTONE			130	233
SHAKOPEE LIMESTONE			233	248
JORDAN SANDSTONE			248	255

Screen No
Open Hole(ft.) From 153.0 to 255.0
Make Type
Diamter Slot Length Set

Static Water Level
56.50 ft. land surface Date measured 1972/08/00

Pumping Level (below land surface)
ft. after hrs. pumping g.p.m.

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

Grouting Information Well grouted? ☒ YES ☐ NO ☐ NOT SPECIFIED
Material neat cement From 0.0 To ft. 7.00 Cubic yards

Nearest Known Source of Contamination
feet Direction Type
Well disinfected upon completion? ☐ YES ☐ NO

Pump
☐ Not Installed Date Installed
Manufacture's name
Model number HP 0.00 Volts
Length of drop pipe Material Capacity g.p.m
Type

Abandoned Wells
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

Well Contractor Cerfication
Layne Well Co. 27010
License Business Name Lic. or Reg No.

Remarks
GAMMA LOGGED 5-9-2016 BY JIM TRAEN. JIM TRAEN HAS 24 IN. CASING ENDING AT 144.3 FT.

First Bedrock OPDC Aquifer Prairie Du Chien-Jordan
Last Strat CJDN Depth to Bedrock 125.00 ft.

Name of Driller Date

Unique Well Number
206678

County Anoka
Quad Minneapolis North
Quad Id 120D

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING RECORD
MINNESOTA STATUTES CHAPTER 1031

Entry Date 1991/04/15
Update Date 2016/11/15
Received Date

Well Name FRIDLEY 7

Township	Range	Dir	Section	Subsection	Field Located Elevation	MDH
30	24	W	14	DCADBC		885.00 ft.

Well Depth 262.00 ft
Depth Completed 262.00 ft
Date Well Completed 1970/01/14

well and contact address FRIDLEY 7
680 63RD AV NE
FRIDLEY MN Changed

Drillhole Angle

Drilling Method

Drilling Fluid

Well Hydrofractured? ☐ YES ☐ NO
From ft. to

Use community supply(municipal)

Casing Type Drive Shoe? ☐ YES ☐ NO Hole Diameter (in.)
Diameter 12 Depth 138

Diameter	From	To	lbs/ft
16.00 in.	0.00	67.00 ft.	
12.00 in.	0.00	138.00 ft.	
24.00 in.	0.00	27.70 ft.	

Description	Color	Hardness	From	To (ft.)
FINE SAND			0	26
BLUE CLAY, LITTLE GRAVEL			26	60
GOOD WATER GRAVEL			60	73
MUDDY SAND			73	75
GRAVEL	LIGHT		75	110
ST. PETER	YELLOW		110	128
SHAKOPEE	RED		128	136
SHAKOPEE & ST. PETER	WHITE		136	150
SHAKOPEE	TAN		150	262

Screen No
Make
Diamter Slot Length Set

Open Hole(ft.) From 138.0 to 262.0
Type

Static Water Level
65.00 ft. land surface Date measured 1970/01/14

Pumping Level (below land surface)
73.00 ft. after hrs. pumping 1600.00 g.p.m.

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

Grouting Information Well grouted? ☐ YES ☐ NO ☐ NOT SPECIFIED

Nearest Known Source of Contamination
feet Direction Type
Well disinfected upon completion? ☐ YES ☐ NO

Pump
☐ Not Installed Date Installed
Manufacture's name JACUZZI
Model number SVB00 HP 75.00 Volts
Length of drop pipe 71.0 Material Capacity 1100 g.p.m
Type

Abandoned Wells
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

Well Contractor Cerfication
Renner E.H. & Sons 02015
License Business Name Lic. or Reg No.

Name of Driller Date

Remarks
ORIGINAL NO. 206671 - COMPLETED IN DRIFT, DEEPENED 1970 BY KEYS INTO BEDROCK GAMMA LOGGED 10-20-2015 BY JIM TRAEN.

First Bedrock OSTP
Last Strat OPDC
Aquifer Prairie Du Chien Group
Depth to Bedrock 110.00 ft.

Unique Well Number **206669**

County Anoka
Quad Minneapolis North
Quad Id 120D

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING RECORD
MINNESOTA STATUTES CHAPTER 1031

Entry Date 1991/04/15
Update Date 2014/03/10
Received Date

Well Name FRIDLEY 8

Township	Range	Dir	Section	Subsection	Field Located	MDH
30	24	W	14	DCDCDA	Elevation	885.00 ft.

Well Depth 265.00 ft
Depth Completed 265.00 ft
Date Well Completed 1969/12/17

well and contact address FRIDLEY 8
613 61ST AV NE
FRIDLEY MN Changed

Drillhole Angle

Drilling Method

Drilling Fluid

Well Hydrofractured? ☐ YES ☐ NO From ft. to

Use community supply(municipal)

Casing Type Drive Shoe? ☐ YES ☐ NO Hole Diameter (in.)
Diameter 12 Depth 138
16.00 in. from 0.00 to 64.00 ft. lbs/ft
12.00 in. from 0.00 to 138.00 ft. lbs/ft

Description	Color	Hardness	From	To (ft.)
NO RECORD			0	64
GRAVEL & STONES	GRAY		64	122
SHALE	BLACK		122	126
ST. PETER, DUSTY	WHITE		126	130
ST. PETER, SHAKOPEE	YELLOW		130	186
SHAKOPEE	TAN		186	195
SHAKOPEE	TAN		195	265
JORDAN	YELLOW		265	265

Screen No
Open Hole(ft.) From 138.0 to 265.0
Make Type
Diamter Slot Length Set

Static Water Level
70.00 ft. land surface Date measured 1969/12/17

Pumping Level (below land surface)
74.00 ft. after hrs. pumping 1160.00 g.p.m.

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

Grouting Information Well grouted? ☐ YES ☐ NO ☐ NOT SPECIFIED

Nearest Known Source of Contamination
feet Direction Type
Well disinfected upon completion? ☐ YES ☐ NO

Pump
☐ Not Installed Date Installed
Manufacture's name JACUZZI
Model number 12MC24 HP 75.00 Volts
Length of drop pipe 125.(Material Capacity 1150 g.p.m
Type Turbine

Abandoned Wells
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

Remarks
M.G.S. NO. 526 0 TO 64 FEET IS 16" CASE HOLE, DRILLED BY OTHERS.

Well Contractor Cerfication
Renner E.H. & Sons 02015
License Business Name Lic. or Reg No.

First Bedrock OSTP
Last Strat CJDN
Aquifer Prairie Du Chien Group
Depth to Bedrock 126.00 ft.

Name of Driller Date

Unique Well Number **206672**

County Anoka
Quad Minneapolis North
Quad Id 120D

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING RECORD
MINNESOTA STATUTES CHAPTER 1031

Entry Date 1991/04/15
Update Date 2014/03/10
Received Date

Well Name FRIDLEY 9

Township	Range	Dir	Section	Subsection	Field Located Elevation	MDH
30	24	W	14	DCCAAB		882.00 ft.

Well Depth 255.00 ft
Depth Completed 255.00 ft
Date Well Completed 1965/12/22

well and contact address FRIDLEY 9
603 61ST AV NE
FRIDLEY MN Changed

Drillhole Angle

Drilling Method

Drilling Fluid

Well Hydrofractured? ☐ YES ☐ NO From ft. to

Use community supply(municipal)

Casing Type Drive Shoe? ☐ YES ☐ NO Hole Diameter (in.)
Diameter 24 Depth 153
30.00 in. from 0.00 to 67.00 ft. lbs/ft
24.00 in. from 0.00 to 153.00 ft. lbs/ft

Description	Color	Hardness	From	To (ft.)
SAND			0	15
SILT & CLAY			15	67
SAND & GRAVEL			67	117
ST. PETER SANDSTONE			117	132
DOLOMITE			132	250
JORDAN SANDROCK		SOFT	250	255

Screen No
Make
Diamter Slot Length Set

Open Hole(ft.) From 153.0 to 255.0
Type

Static Water Level
56.00 ft. land surface Date measured 1965/12/22

Pumping Level (below land surface)
60.00 ft. after hrs. pumping 1200.00 g.p.m.

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

Grouting Information Well grouted? ☐ YES ☐ NO ☐ NOT SPECIFIED

Nearest Known Source of Contamination
feet Direction Type
Well disinfected upon completion? ☐ YES ☐ NO

Pump
☐ Not Installed Date Installed
Manufacture's name JACUZZI
Model number HP 75.00 Volts 220
Length of drop pipe Material Capacity 1100 g.p.m
Type Turbine

Abandoned Wells
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

Well Contractor Cerfication
Keys Well Co. 62012
License Business Name Lic. or Reg No.

Name of Driller Date

Remarks
DEEPENED BY LAYNE MINN. CO. TO 255 FT. IN 1972.

First Bedrock OSTP
Last Strat CJDN
Aquifer Prairie Du Chien-Jordan
Depth to Bedrock 117.00 ft.

Unique Well Number **509089**

County Anoka
Quad Minneapolis North
Quad Id 120D

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING RECORD
MINNESOTA STATUTES CHAPTER 1031

Entry Date 1992/10/01
Update Date 2016/11/15
Received Date

Well Name FRIDLEY MW-1

Township	Range	Dir	Section	Subsection	Field Located Elevation
30	24	W	14	DCCCCD	MDH 862.90 ft.

Well Depth 95.00 ft
Depth Completed 95.00 ft
Date Well Completed 1990/08/25

well and contact address FRIDLEY MW-1
6431 UNIVERSITY AV
FRIDLEY MN 55432 Changed

Drillhole Angle

Drilling Method Non-specified Rotary

Drilling Fluid Bentonite
Well Hydrofractured? YES NO From ft. to

Use monitor well

Casing Type Steel (black or low Drive Shoe? YES NO
Diameter 4 Depth 75
4.00 in. from 0.00 to 75.00 ft. 10.79 lbs/ft
Hole Diameter (in.) 9.00 To 95.0

Description	Color	Hardness	From	To (ft.)
SAND	BROWN	SOFT	0	49
CLAY	BLUE	SOFT	49	61
ROCKS			61	62
SAND	BROWN		62	68
GRAVEL & CLAY	BROWN		68	95

Screen Yes
Make JOHNSON
Diamter Slot 10 Length 10 Set 75 ft. to 85 ft.
Open Hole(ft.) From to
Type

Static Water Level
50.00 ft. land surface Date measured 1990/08/27

Pumping Level (below land surface)
ft. after hrs. pumping g.p.m.

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

Grouting Information Well grouted? ☒ YES ☐ NO ☐ NOT SPECIFIED
Material neat cement From To 75.0 ft. 20.00 Sacks

Nearest Known Source of Contamination
75 feet SW Direction O Type
Well disinfected upon completion? ☐ YES ☐ NO

Pump
☐ Not Installed Date Installed
Manufacture's name
Model number HP Volts
Length of drop pipe Material Capacity g.p.m
Type

Abandoned Wells
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

Remarks
CONTAMINATION SOURCE: STORM SEWER WELL DRILLED FOR B.A. LEISCH + ASSOCIATES ENGINEERS. LOT 4-C 10.

Well Contractor Cerfication
Keys Well Co. 62012
License Business Name Lic. or Reg No.
SAMPSON, C.
Name of Driller Date

First Bedrock
Last Strat
Aquifer Quat. buried artes. aquifer
Depth to Bedrock ft.

MINNESOTA MDH DEPARTMENT OF HEALTH

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

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

Public Water Supply ID:	1020031	PWS Name:	Fridley

Contact Information for Person Completing this Form

Name:	Adam Janzen
Address:	4300 MarketPointe Drive Suite 200
City, State, Zip:	Bloomington, MN, 55435
Phone, Fax, e-mail:	(952) 842-3596 (p), (952) 832-2601 (f), ajanzen@barr.com

Aquifer Properties Determination Methods

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

- ☐ 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

206673					
206672					
209207					

Submitted by: Adam Janzen	Prof. License: 53665	Date: 5/1/2018
Reviewed by: Amal Djerrari	Approved: ◉ Yes ○ No	Approval Date: 5/2/2018

Summary of Aquifer Properties Based on Existing Data

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

Hydraulic Confinement ☑ Confined ☐ Unconfined ☐ Fractured Rock

Aquifer Test Number of test(s) on file used to compile the information tabulated below:
1

Aquifer Properties Summary Table

Representative Values		Unit	Range Minimum	Range Maximum	+/- %
Top Stratigraphic Elev.	642	feet (MSL)	626	653	+1.7/-2.5
Bottom Stratigraphic Elev.	555	feet (MSL)	541	563	+1.4/-2.5
Transmissivity (T)	2689	ft^2/day	1309	4250	+58/-51
Aquifer Thickness (b)	87.3	feet	85	92	+5.4/-2.6
Saturated Thickness* (b)		feet			
Hydraulic Conductivity (k)	30.8	ft/day	15.4	46.2	+50/-50
Primary Porosity (e_p)	0.2	0.00 %			
Secondary Porosity** (e_s)		0.00 %			
Storativity (S)		dimensionless			
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.

Analysis of an aquifer test conducted at Brooklyn Center Well 9 (unique number 110493) estimated a CJDN transmissivity (T) of 2773 ft**2/day. Brooklyn Center Well 9 is screened exclusively in the CJDN. The MDH already has the data for this test. Per the Minnesota Well Record for Brooklyn Center Well 9, the CJDN thickness at the well is 90 feet (27.4 m), resulting in a K value for the CJDN at this location of 30.8 ft/day.

For the model sensitivity analysis, the hydraulic conductivity of the CJDN will each be adjusted +/- 50%. The CJDN range will therefore be 15.4-46.2 ft/day.

The logs for Fridley Wells 3, 4, and 11 were used to determine the range of Jordan thicknesses and contact elevations. The representative values shown are averages of these data.

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

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

Public Water Supply ID:	1020031	PWS Name:	Fridley

Contact Information for Person Completing this Form

Name:	Adam Janzen
Address:	4300 MarketPointe Drive
	Suite 200
City, State, Zip:	Bloomington, MN 55435
Phone, Fax, e-mail:	(952) 842-3596 (p), (952) 832-2601 (f), ajanzen@barr.com

Aquifer Properties Determination Methods

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

- ☐ **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

206657					

Submitted by: Adam Janzen	Prof. License: 53665	Date: 5/1/2018
Reviewed by: Amal Djerrari	Approved: ◉ Yes ○ No	Approval Date: 5/2/2018

Summary of Aquifer Properties Based on Existing Data

Aquifer Name: Tunnel City Group - Wonewoc Sandstone **Aquifer Code:** CTCW

Hydraulic Confinement ☑ **Confined** ☐ **Unconfined** ☐ **Fractured Rock**

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

1

Aquifer Properties Summary Table

Representative Values		Unit	Range		+/- %
			Minimum	Maximum	
Top Stratigraphic Elev.	511	feet (MSL)	511	544	+1.7/-0
Bottom Stratigraphic Elev.	313	feet (MSL)	309	331	+5.8/-1.3
Transmissivity (T)	1348	ft^2/day	904	9330	+592/-33
Aquifer Thickness (b)	198	feet	188	235	+19/-5
Saturated Thickness* (b)		feet			
Hydraulic Conductivity (k)	6.81	ft/day	4.81	39.7	+483/-29
Primary Porosity (e_p)	0.2	0.00 %			
Secondary Porosity** (e_s)		0.00 %			
Storativity (S)		dimensionless			
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 MDH conducted a 24.7-hour pumping test at Blaine Well 7 (unique number 208616) in May 1998. Blaine Well 5 (unique number 208615) was used as an observation well. See attached for details and two sets of MDH analyses (1998 and 2011).

The 1998 analysis arrived at a representative Tunnel City-Wonewoc (TCW) transmissivity of 1,300 ft**2/day (120.8 m**2/day). The data provided from the pumping test at Blaine Well 7 does not allowing the hydraulic conductivities of the Tunnel City Group and Wonewoc to be separated. Therefore, a constant hydraulic conductivity will be applied to both units. According to the Well 7 log, the combined Tunnel City Group and Wonewoc thickness is 191 ft, resulting in a combined hydraulic conductivity of 6.81 ft/day. This value will be used in the base case model.

The model sensitivity analysis will use a lower hydraulic conductivity bound of 4.81 ft/day and an upper hydraulic conductivity bound of 39.7 ft/day. These values were calculated from the 918 ft**2/day (85.3 m**2/day) T value from the 2011 analysis and the 7,580 ft**2/day (704.2 m**2/day) T value from the 1998 analysis.

The logs for Fridley Wells 2, 3, 4, 5, and 11 were used to determine the range of Tunnel City-Wonewoc thicknesses and contact elevations. The representative values shown are from the Well 11 log.

Analysis of the Blaine #7 (208616) Pumping Test
May 28, 1998
Franconia/Ironton-Galesville Aquifer

Introduction

The MDH was requested to assist in the delineation of wellhead protection areas by the City of Blaine, Minnesota, around the public water supply wells serving the community. An important part of the delineation process is to determine aquifer properties at the well site as accurately as possible. This is normally accomplished by performing a pumping test. Because of the need to test most public water supply wells, the MDH agreed to help with the pumping test as a part of technical assistance for communities, and program and staff development.

The pumping test at the Blaine Well #7 was conducted by the MDH, as described below. The results were analyzed using standard nonequilibrium and semisteady-state methods, cited in references. Data plots are included in Appendix 1 and test results are summarized on Table 1. Field data sheets are included in Appendix 2. The analysis shows that the aquifer responds as generally expected from the geologic setting.

Description of the Test

A pressure transducer was placed in Well #7 beginning on May 19, 1998 at 10:30 to obtain background readings. The pumping well was turned off when the transducer was installed providing a long resting period before the start of the test. Well 5 was turned off two days before the start of the test and the data from the pumping well clearly shows the interference between these two wells. No other wells were identified that possibly could cause interference during the test. The test started at 09:00:04.0 on May 28, 1998. Well #7 was pumped at an average rate of 1200 gallons per minute. The flowmeter on the well was used to monitor the discharge. The pumping rate declined during the test from about a maximum of 1300 at the beginning of the test to 1140 gpm at the end. The pump was turned off at 09:40:02.0 on May 29, 1998 to start the recovery period. The recovery period was carried out for 24 hours and the well recovered to pre-pumping levels.

Problems were encountered in the placement of transducers in well numbers 5 and 9. The transducer in Well 5 could not be set deep enough initially and was exposed during part of the pumping period but was re-set for the recovery and good recovery data were obtained for this well. Well 9 was inaccessible for transducer placement and was monitored by hand. The drawdown in farther away wells, 8 and 9, did not stabilize during the pumping period.

Summary of Results

A transmisivity value of 1,300 ft2/day and storage coefficient of 2.0e-5 are chosen as being representative of aquifer properties in the area of the well field for the capture zone analysis. The results are quite consistent between the pumping and recovery periods and are show that the aquifer is quite confined. Little information about leakage can be gained from this analysis because a negative boundary was encountered about 200 minutes into the test. Therefore any influence of leakage on water levels is over shadowed by the effects of variations in permeability.

In addition the farther away wells, 8 and 9, were too far away to clearly show the influence of Well 7 for a 24-hour test. A longer test would be needed to verify the connection with these wells, on the order of

200-hours in duration. A steady state analysis technique used for recovery data gave comparable transmissivity results as the late time recovery from nearby wells and provides an estimate of leakage of 4,850 days. This analysis technique is still being evaluated and Health Department staff are not yet comfortable with its' application for wellhead protection delineation.

Problems with the Analysis

The multiple aquifer construction of Well 5 introduces a level of uncertainty to the interpretation of the results of this test. However, both the pumping and observation wells show similar results and therefore, the test is not unduly affected by the multi-aquifer construction of Well 5.

References:

Jacob, C. E. and Lohman, S. W., (1952) Nonsteady Flow to a Well of Constant Drawdown in an Extensive Aquifer, Trans. American Geophysical Union, Vol. 33, No. 4, August, 1952, pp. 559-69.

Theis, C. V., (1935) The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Ground-Water Storage, Trans. American Geophysical Union, 16th Annual Meeting, April, 1935, pp. 519-24.

Table 1.

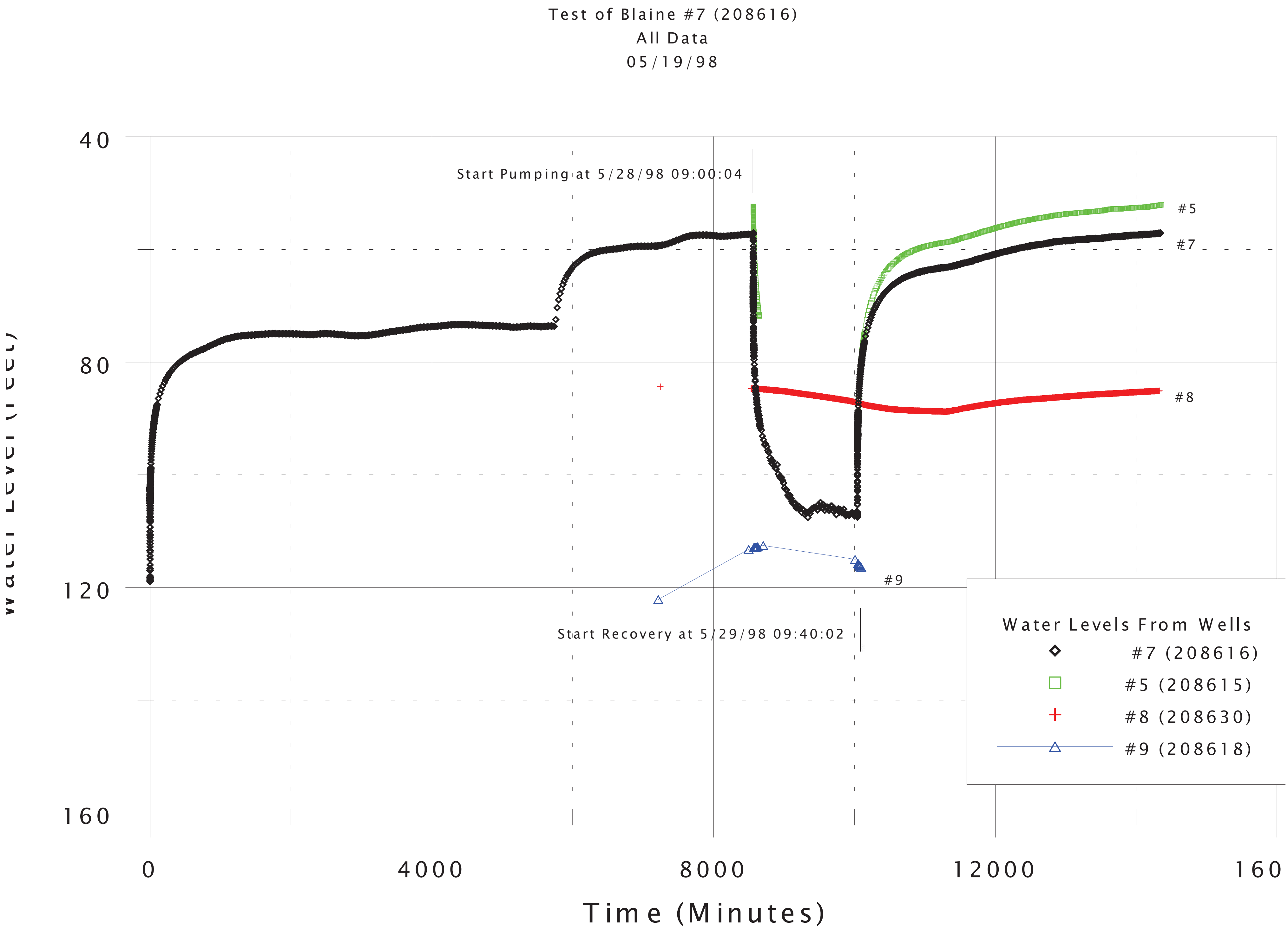
Blaine #7 Pumping Test
May 28, 1998

	Transmissivity T (gpd/ft)	Storage Time Coefficient S	Period Emphasized	Analysis Method
	----------	-----	--------------	--------
Pumping Well #7 (208616)	5,100	NA	Early Pumping	Theis
	2,860	NA	Late Pumping	Jacob
	3,450	NA	Early Recovery	Theis
	1,510	NA	Late Recovery	Jacob t/t'
Observation Well #5 (208615)	13,100	6.1e-6	Early Pumping	Theis
	2,240	1.8e-5	Late Pumping	Jacob
	7,580	5.6e-5	Early Recovery	Theis
	1,180	1.8e-6	Late Recovery	Jacob t/t'

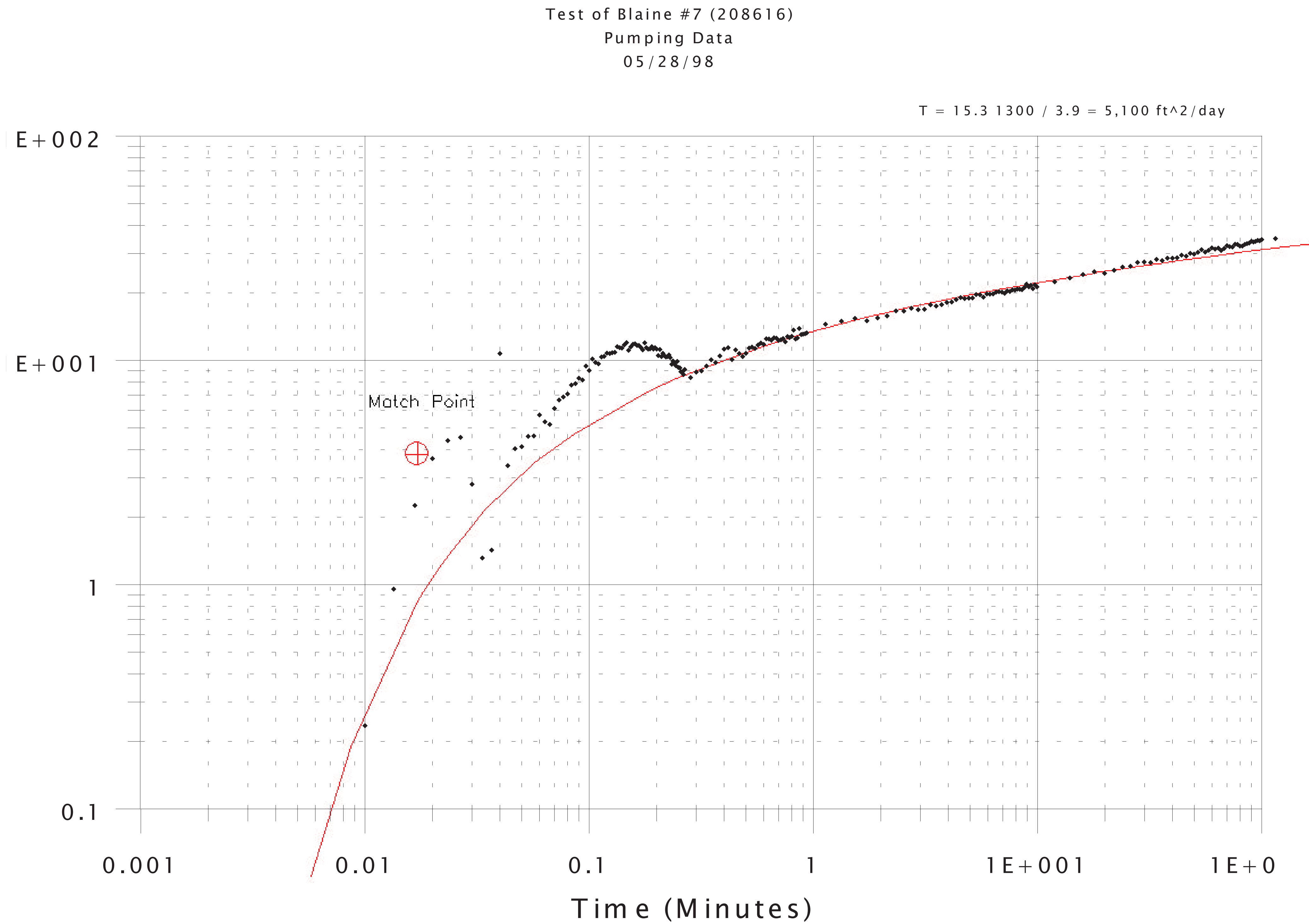
Steady State analysis using recovery data from wells 5 and 8 (208630)

	2010	4,850 days resistance		DeGlee

Representative aquifer values are best shown by the late-time recovery values, giving an average T of 1,300 ft^2/day and a storage coefficient of 2.0e-5



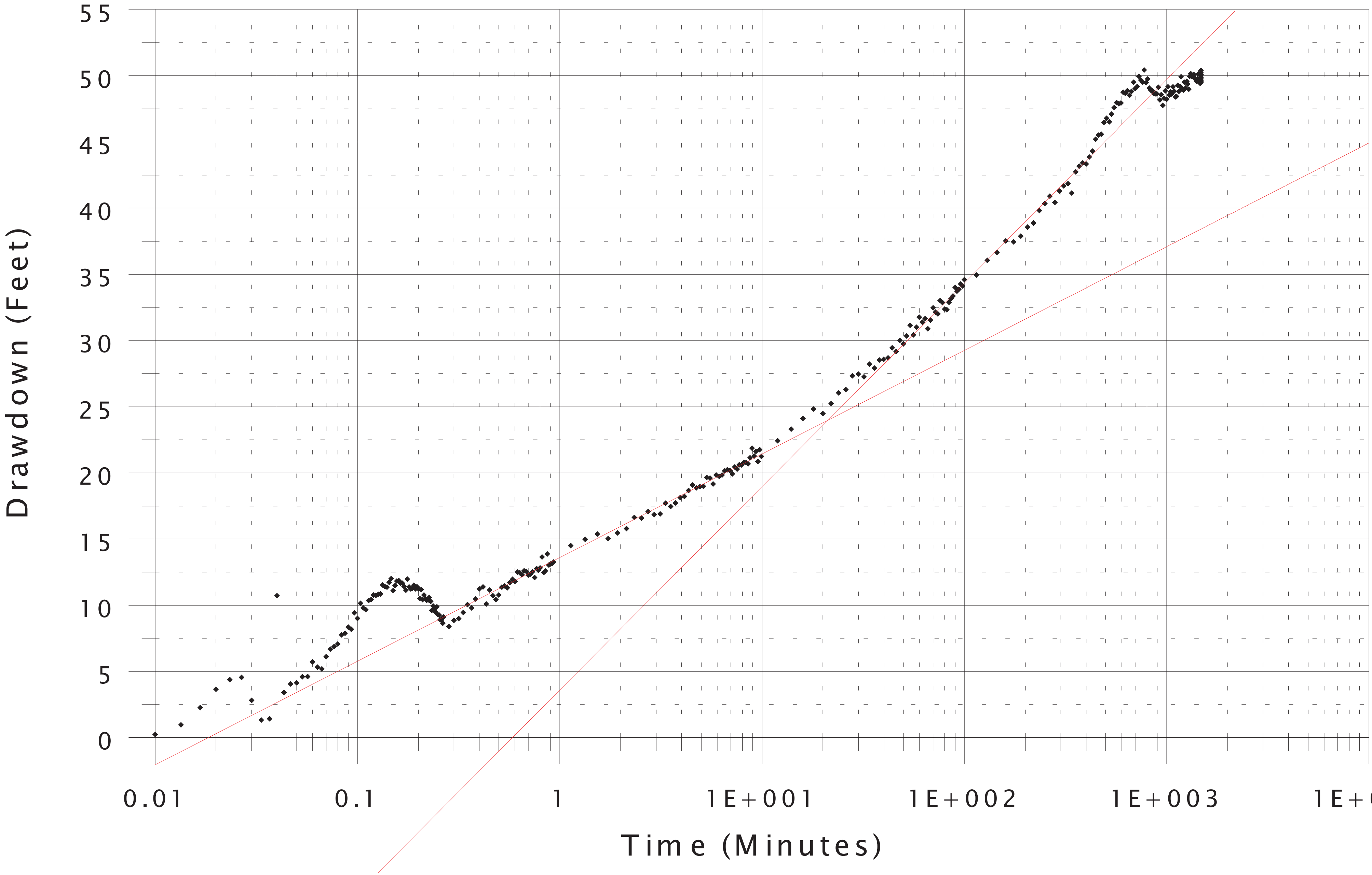
Test of Blaine #7 (208616)
All Data
05/19/98
Start Pumping at 5/28/98 09:00:04
Start Recovery at 5/29/98 09:40:02
#5
#7
#8
#9
40
80
120
160
0
4000
8000
12000
160
Time (Minutes)
Water Levels From Wells
#7 (208616)
#5 (208615)
#8 (208630)
#9 (208618)


Test of Blaine #7 (208616)
Pumping Data
05/28/98
T = 15.3 1300 / 3.9 = 5,100 ft^2/day
E+002
E+001
1
0.1
Match Point
0.001
0.01
0.1
1
1E+001
1E+0
Time (Minutes)

Test of Blaine #7 (208616)
Pumping Data
05/21/98

T! = 35.3 1280 / 7.9 = 5,720 ft^2/day

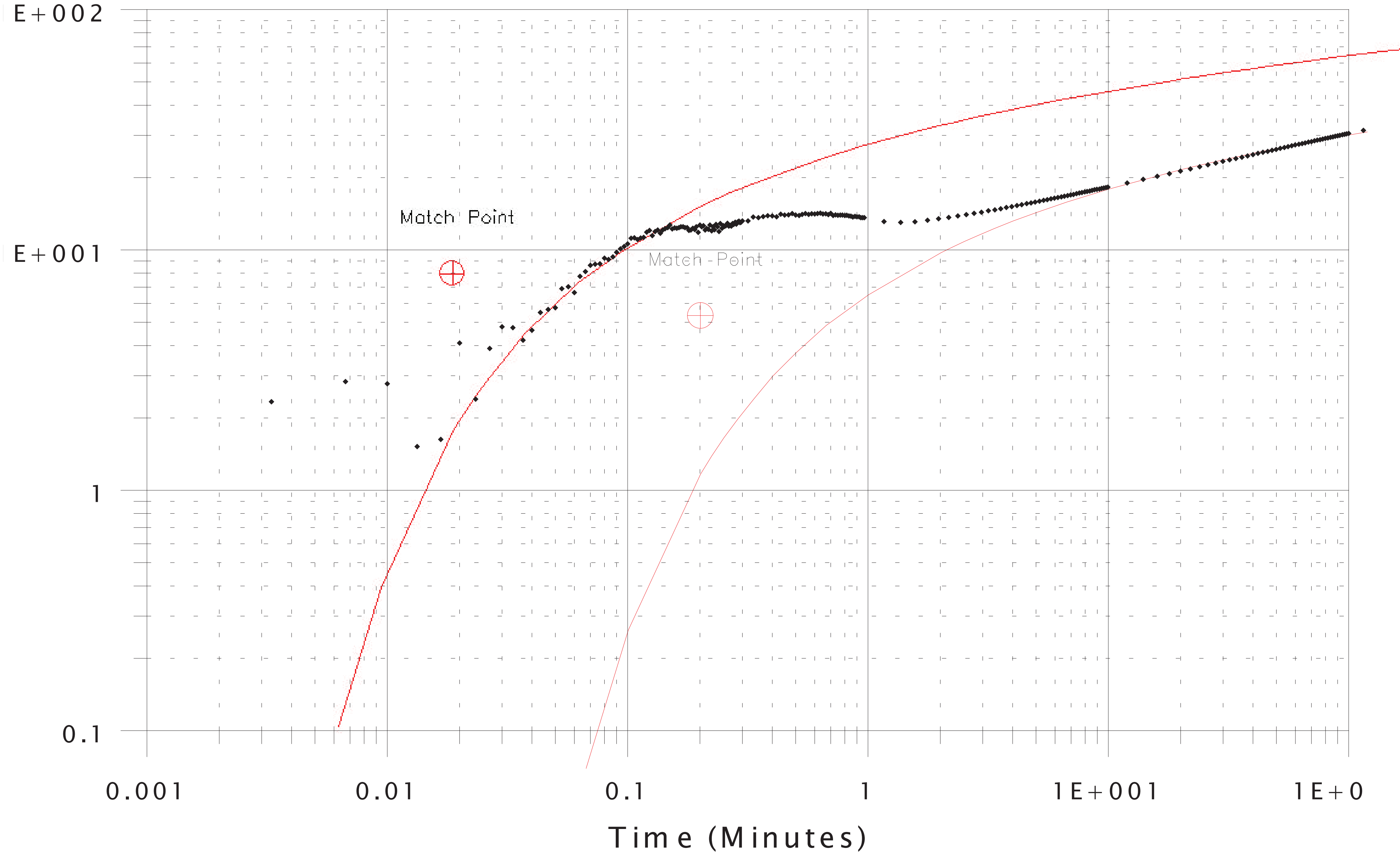
T2 = 35.3 1240 / 15.3 = 2860 ft^2/day

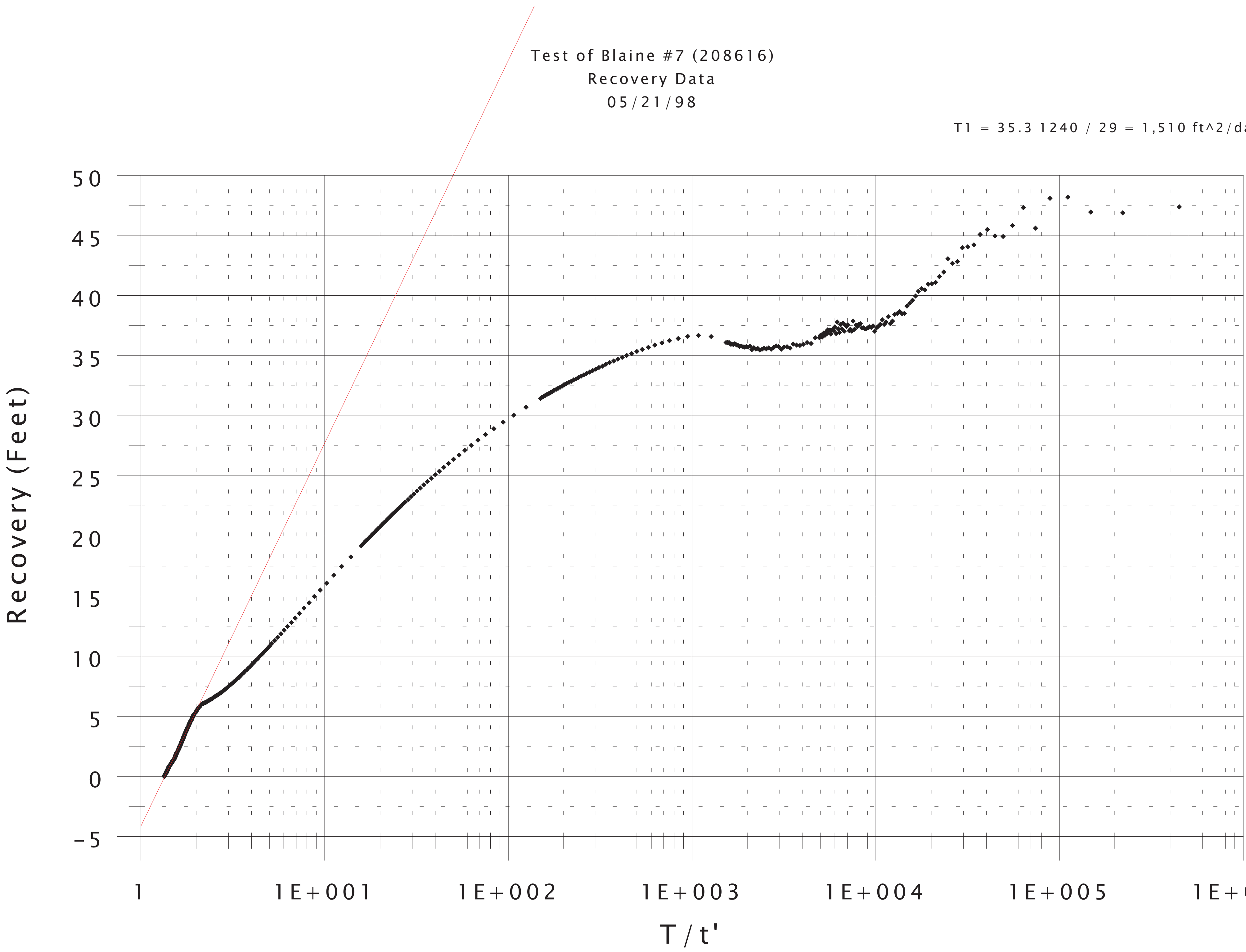


Test of Blaine #7 (208616)
Recovery Data
05/19/98

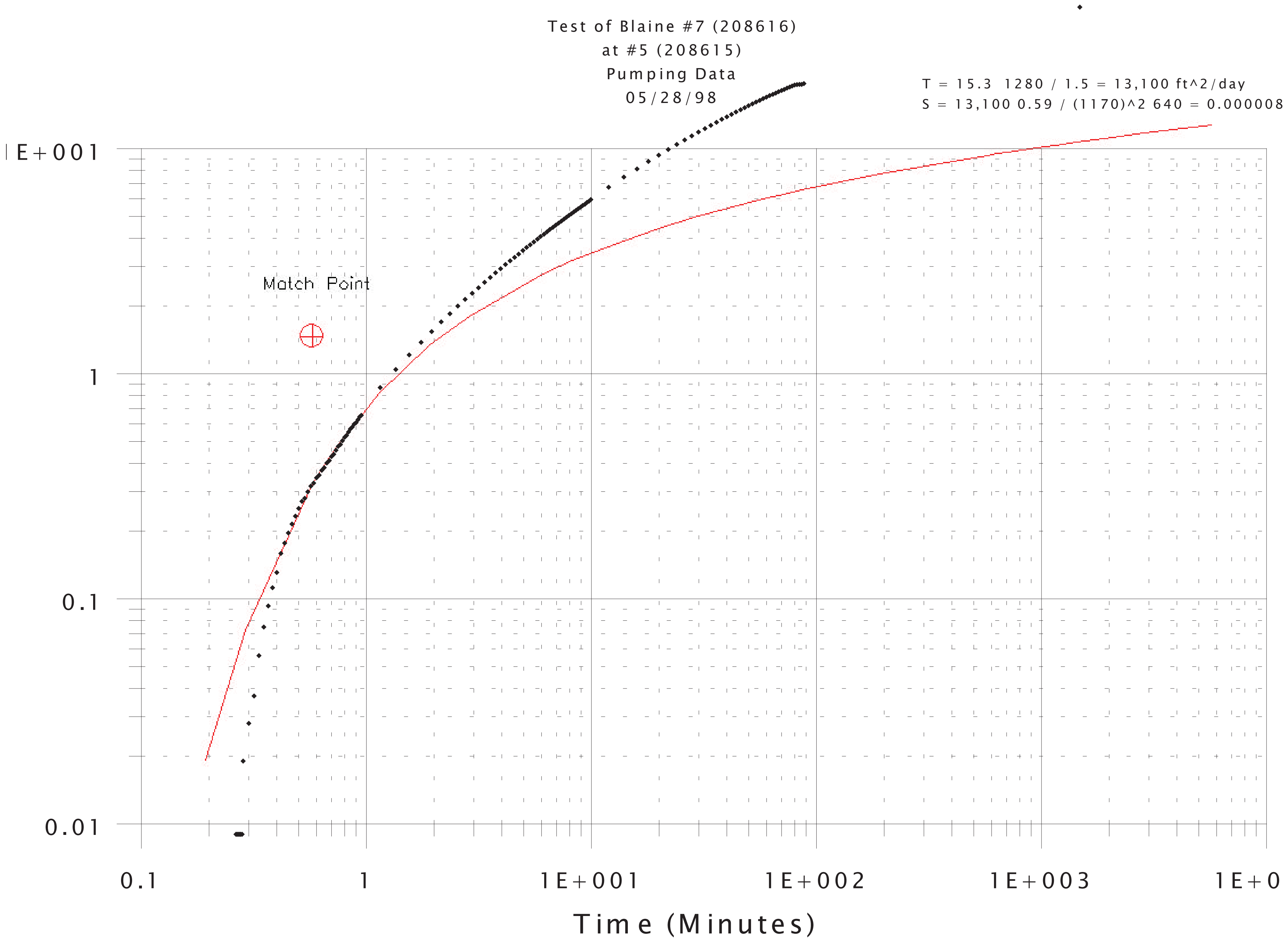
T1 = 15.3 1280 / 8 = 2,450 ft^2/day

T2 = 15.3 1240 / 5.5 = 3,450 ft^2/day





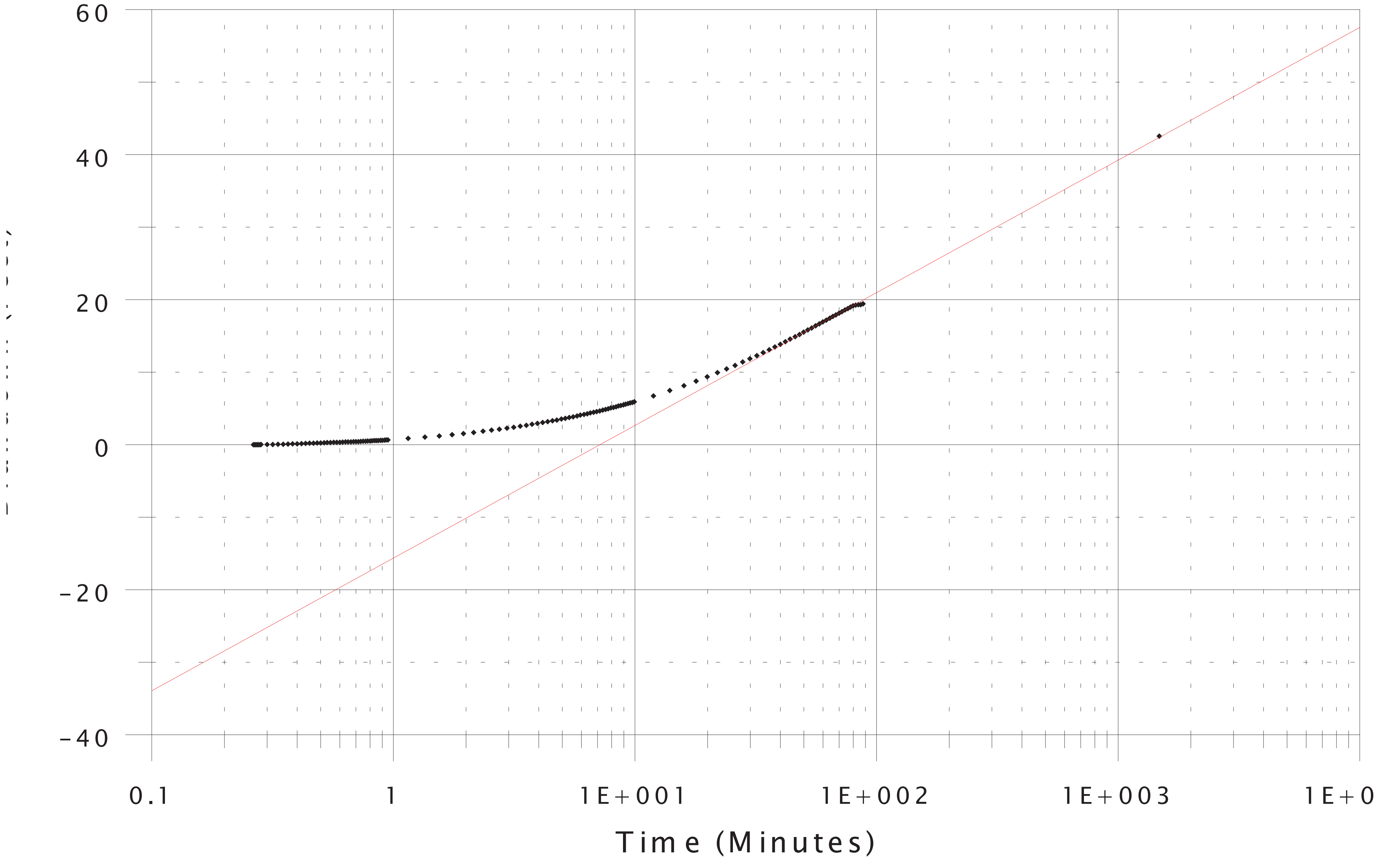
Test of Blaine #7 (208616)
Recovery Data
05/21/98
T1 = 35.3 1240 / 29 = 1,510 ft^2/da
Recovery (Feet)
50
45
40
35
30
25
20
15
10
5
0
-5
1
1E+001
1E+002
1E+003
1E+004
1E+005
T/t'

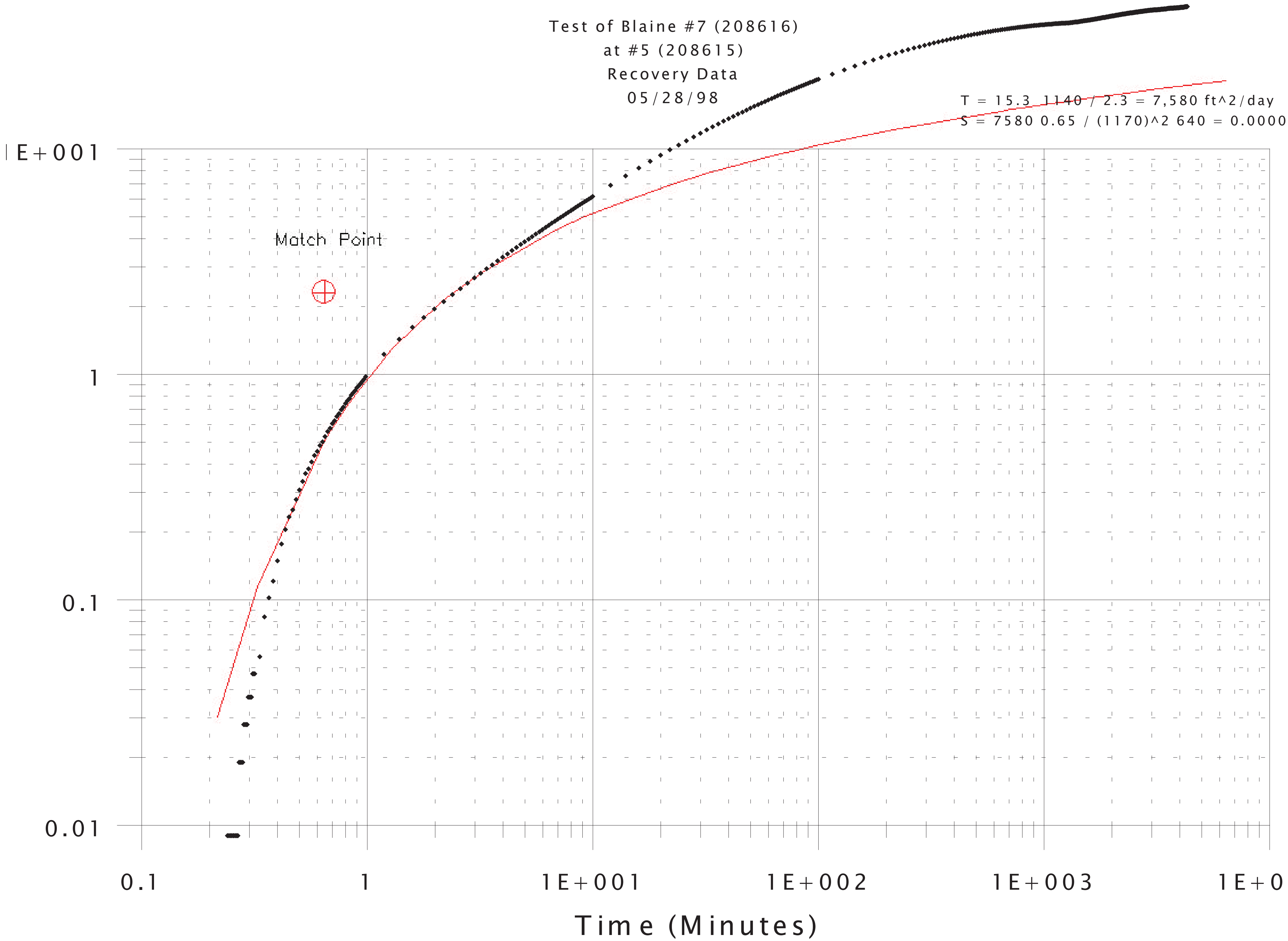


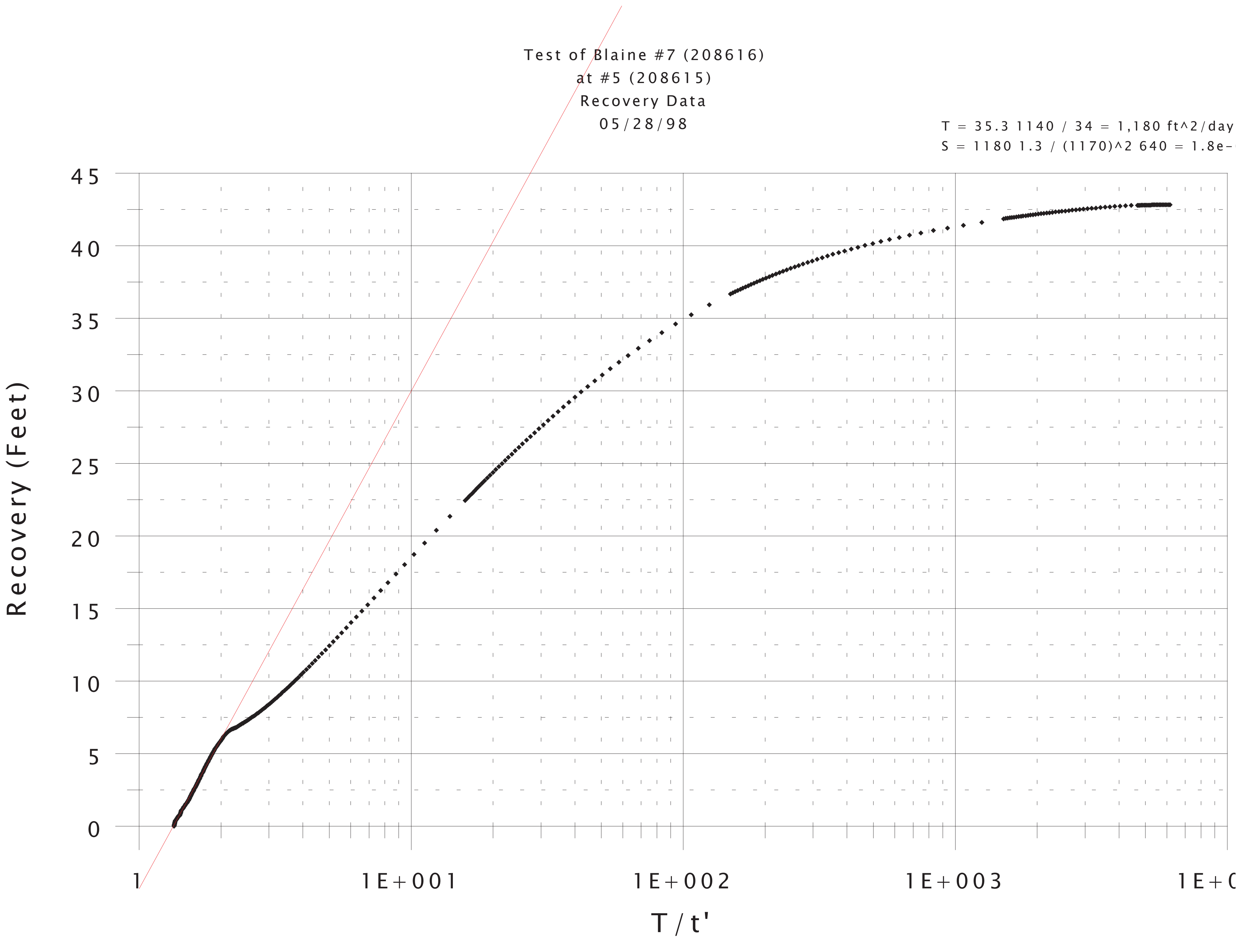
Test of Blaine #7 (208616)
at #5 (208615)
Pumping Data
05/28/98
T = 15.3 1280 / 1.5 = 13,100 ft^2/day
S = 13,100 0.59 / (1170)^2 640 = 0.000008
Match Point
1E+001
1
0.1
0.01
0.1
1
1E+001
1E+002
1E+003
1E+0
Time (Minutes)

Test of Blaine #7 (208616)
at #5 (208615)
Pumping Data
05/28/98

T = 35.3 1140 / 18 = 2,240 ft^2/day
S = 2240 7 / (1170)^2 640 = 0.000018



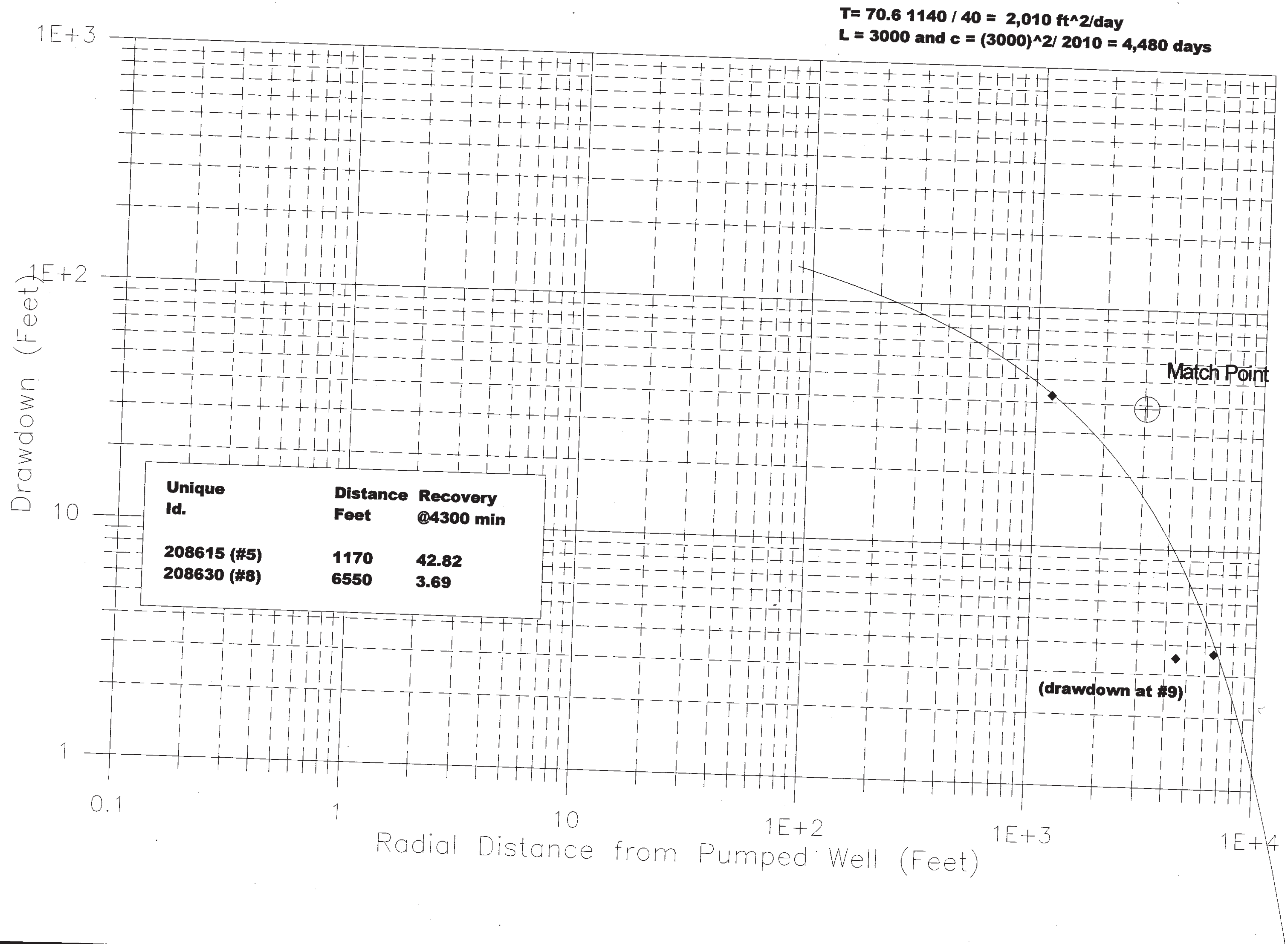

Test of Blaine #7 (208616)
at #5 (208615)
Recovery Data
05/28/98
T = 15.3 1140 / 2.3 = 7,580 ft^2/day
S = 7580 0.65 / (1170)^2 640 = 0.0000
Match Point
1E+001
1
0.1
0.01
0.1
1
1E+001
1E+002
1E+003
1E+0
Time (Minutes)



Test of Blaine #7 (208616)
at #5 (208615)
Recovery Data
05/28/98
T = 35.3 1140 / 34 = 1,180 ft^2/day
S = 1180 1.3 / (1170)^2 640 = 1.8e-
Recovery (Feet)
45
40
35
30
25
20
15
10
5
0
1
1E+001
1E+002
1E+003
1E+0
T/t'

May 28, 1998

Distance Drawdown Plot after 4300 Minutes of Pumping



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

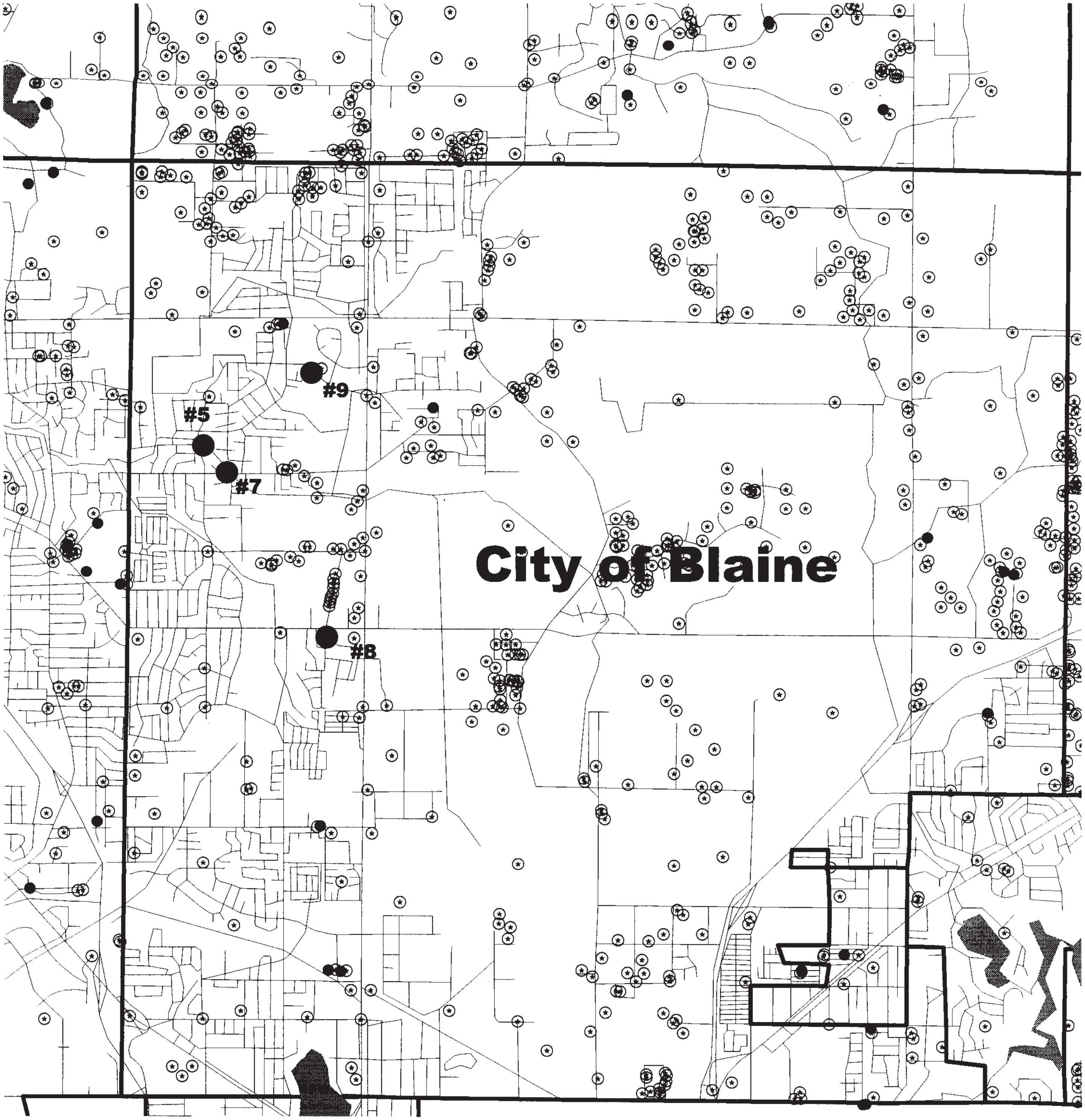
Test No.

Aquifer Test Information

Test Location	Well Owner	Test Conducted By
Blaine #7	City of Blaine	J. Blum (MDH)
Date/Time Test Start: 5/28/98 09:00:04.0	Flow Rate (Units): 1200 gpm	Pump Type: Turbine
Date/Time Recovery Start: 5/29/98 09:40:02.0	Flow Rate Measuring Device: Turbine Flowmeter	Pump Intake Depth
Date/Time Test Finish	Totalizer: End 11,691,800	Pumped Well Inner Casing Diameter
Notes: pre lube 1:06 min	Totalizer: Start 9,922,200	Confined/Unconfined: confined
	Total Pumped (Units): 1,769,600 gallons	Quad Sheet Name/Number

Unique Well Numbers	Location T, R, S, Quarters	Location N, E	Radial Distance	Open Depth	Transducer Setting	Measuring Point Location	Elevation, Datum
Pumped Well #7(208616)		N E					
Observation Wells #5(208615)		N E	1170				
#9(208618)		N E	4470				
#8(208630)		N E	6550				
		N E					
		N E					

Sketch Map of Well Locations



Location of Public Water Supply Wells in the Ironton-Galesville Aquifer, Blaine, MN

IC #140-0523 (5/96)

Aquifer Test Data Form

Test: Blume #7	By: J. Blum	Test Date: 05/28/98	Page ____ of ____

Location (Unique Well No.)	Date Month	Day	Year	Time Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks Totalizer
#7(208616	05	28	98	09	00	04				0	9922200 start test
					05	—				~1320	9,928,600 1280
					10	—				1320	9,935,100 1300
					15	—				1300	9,941,700 1320
					20	—				1300	9,948,100
					25	—				1280	9,954,500
					30	—				1280	9,961,000
					35	—				1280	9,967,400
					40					1300	9,973,800
					45						
					52	—				1280	9,989,000
					55						~~9,955,100~~
				10	–					1280	9,999,100
				11	30					1250	10,110,400
				~~12~~	~~–~~						
				15	–					1210	10,365,000
				21	–					1280	10,813,000
	05	29	98	09	18	—				1150	11,666,900 1160
				09	35	–					11,686,100 1130
				09	40	02	1480				11,697,800 end 1140

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

Notes:

IC #140-0523 (5/96)

Aquifer Test Data Form

Test:	By:	Test Date:	Page ____ of ____

Location (Unique Well No.)	Date Month	Day	Year	Time Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
#9 (208618)	05	28	98	07	55	–		113.22			
#8 (208630)				08	20	–		84.66			XD0= 11.04
#5 (208615)				08	40	–		52.41			XD0= 19.80
#7 (208616)											XDA= 57.25 XD0= 71.24
				09	00	04			start test		9922200 ⏲
#9	05	27	98	10	30	–		122.12			
#5								61.35			
#8								84.37			
#5	05	29	98	09	31	–		94.90			reset probe XD0 4.91
#7	05	29	98	09	40	02					stop pumping XD0 21.94
#9				10	35			116.44			

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

Notes: Prelube 1:06 min
8:58:55 hand/on/pump

Aquifer Test Data Form

Test: Blaine # 7	By: J. Blum	Test Date:	Page ____ of ____

Location (Unique Well No.)	Date Month	Date Day	Date Year	Time Hour	Time Minute	Time Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
#8 208630	06	01	98	09	10	—		85.14			48.67 XDR 10.60 XDo
#7				09	25	—		57.17			57.08 XDR 71.84 XDo
				09	46	—		51.81			52.07 XDR 47.02 XDo

Minnesota Department of Health
Special Services Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

Notes:

IC #140-0523 (5/96)

IC #140-0523 (5/96)

Aquifer Test Data Form

Test:	By:	Test Date:	Page ____ of ____

Location (Unique Well No.)	Date Month	Day	Year	Time Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
#9	05	28	98	09	00			113.22			static (time ~ 7:50AM)
				09	06			112.92			Solinist line left in well between
				09	10			112.92			measurements
				09	15			112.91			Blaine Utilities flow
				09	20			112.89			meter record indicates:
				09	25			112.88			5/26/98 (8:30) 338,798
				09	30			112.87			5/27 (10:00) 339,290
				09	35			112.85			5/28 (9:00) 339,290
				09	40			112.84			
				09	45			112.83			
				09	50			112.81			
				09	55			112.79			
				10	00			112.78			
				10	05			112.76			
				11	23			112.53			
	05	29	98	09	05			114.98			
				09	46			115.70			
				09	50			115.75			
				09	55			115.85			
				10	03			115.94			
				10	10			116.08			
				10	15			116.15			
				10	20			116.22			

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

Notes:

Memo

Date: June 14, 2011 (revised)

To: Blaine WHP Project File (PWSID: 1020006)

From: Justin Blum

Subject: Analysis of the Blaine Well 7 (208616) Pumping Test, May 28, 1998, Ironton-Galesville Aquifer

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The pumping test performed on Blaine Well 7 (208616) was conducted as described below and summarized in Tables 1 and 2. The data were analyzed using standard methods cited in the references. Analysis graphs are presented in Appendix 1 and are summarized in Table 3. Field data sheets and other documentation are included in Appendix 2.

Test Description

Collection of background data:

A pressure transducer was placed in Well 7 beginning on May 19, 1998 at 10:30 to obtain background readings. The pumping well was turned off when the transducer was installed providing a long resting period (nine days) before the start of the test. Well 5 was turned off two days before the start of the test and the background data from the pumping well clearly shows the interference between these two wells.

Other interfering wells/weather conditions/test setup:

No other wells were identified that possibly could cause interference during the test

Pumping rate:

Well 7 was pumped at an average rate of 1200 gallons per minute. The flowmeter on the well was used to monitor the discharge. The pumping rate declined during the test from a maximum at the beginning of the test of about 1300 gpm to 1140 gpm at the end of pumping.

End of data collection:

The recovery period was carried out for 24 hours and the well recovered to pre-pumping levels

Issues encountered during data collection:

Problems were encountered in the placement of transducers in well numbers 5 and 9. The transducer in Well 5 could not be set deep enough initially and was exposed during part of the pumping period but was re-set for the recovery and good recovery data were obtained for this well. Well 9 was inaccessible for transducer placement and was monitored by hand. The drawdown in farther away wells, 8 and 9, did not stabilize during the pumping period.

Problems with the analysis

The multiple aquifer construction of Well 5 introduces a level of uncertainty to the interpretation of the results of this test. Also, the response in well 5 to changing pumping conditions of well 7 was so rapid, 0.5 minute at a distance of 1170 feet, that fracture-flow conditions are strongly indicated. The strong influence of fracture-flow on the drawdown in well 7 is demonstrated by the enhanced efficiency of the well on the distance-drawdown plot. Approximate predicted drawdown at well 7 is 300 feet and observed was about 50 feet.

Because of the influence of fracture-flow, the transient analysis of well 5 data was not based on very early-time data. If later-time transient data are used from Well 5, both well 7 (pumping) and Well 5 (nearest observation well) show similar results and therefore, the test is not unduly affected by the multi-aquifer construction of Well 5 or the communication of the wellbores via fracture(s).

However, a negative boundary was encountered about 250 minutes into the test. Therefore, the influence of leakage on water levels is partly obscured by the effects of variations in permeability. The direction to this boundary from well 7 is not clear, but it is likely to be between well 7 and 9 based on the lack of response in well 9.

The farther away wells, 8 and 9, were too far away to reach steady-state conditions for a 24-hour test of Well 7. The recovery data from well 8 was adjusted to remove regional trends in water levels, which provide an adequate curve match and a high transmissivity value. The steady state analysis of recovery data gave comparable, if low, transmissivity results.

Selected References

Cooper, H.H. and Jacob, C.E. (1946) A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well-filed History, Trans. American Geophysical Union, V. 27, pp. 526 – 534.

Theis, C. V., (1935) The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Ground-Water Storage, Trans. American Geophysical Union, 16th Annual Meeting, April, 1935, pp. 519-24.

deGlee Method [English] in:
Kruseman and De Ridder, (1991) Analysis and Evaluation of Pumping Test Data (2nd Edition), Publication 47, International Institute for Land Reclamation and Improvement, P.O. Box 45, 6700 AA Wageningen, The Netherlands, pp. 76-78.

Walton, W.C., (1960) Leaky Artesian Aquifer Conditions In Illinois, Illinois State Water Survey, Bulletin 39, pp. 27.

Agarwal, R.G. 1980. A new method to account for producing time effects when drawdown type curves are used to analyze pressure buildup and other test data. SPE Paper 9289, presented at the 55th SPE Annual Technical Conference and Exhibition, Dallas, Texas, September 21–24, 1980.

Jenkins, D. and Prentice, J. (1982) Theory for Aquifer Test Analysis in Fractured Rocks Under Linear (Nonradial) Flow Conditions, Ground Water, Vol. 20, No. 1, p. 12-21.

Sen, Z. (1986) Aquifer Test Analysis in Fractured Rocks with Linear Flow Pattern, Ground Water, Vol. 24, No. 1, p. 72-78.

Table 1. Aquifer Test Information

Test Location	Blaine 7 (208616)
Well Owner	City of Blaine
Test Conducted By	J. Blum (MDH)
Aquifer	Ironton-Galesville
Confined / Unconfined	Confined
Date/Time Monitoring Start	May 19, 1998 10:30
Date/Time Pump off Before Test	48 hours
Date/Time Test Start	May 28, 1998 09:00:04.0
Date/Time Recovery Start	May 29, 1998 09:40:02.0
Date/Time Test Finish	May 30, 1998
Flow Rate	1300 to 1140 gpm, average 1200 gpm
WL Data Collection Method	Transducer, manual
Number of Observation Wells	3

Table 2. Wells Monitored During the Test

Well Name	Unique Well No.	Radial Distance (feet)	Static Water Levels (feet below measuring point)			Aquifer
			Start	Mid-test	End	
Pumped Well: 7	208616	1	57.11	106.73	57.08	
Ob Wells: 5	208615	1170	52.36	94.92	52.08	
8	208630	6550	84.68	87.10	85.09	
9	208618	4470				

Test Type:

☒ **Constant Rate** ☐ **Variable Rate** ☐ **Recovery** ☐ **Step Drawdown**

☐ **Other (Describe)** ________________

☐ **Data scanned** ☐ **Data entered into database**

Table 3. Analysis Results

Unique Well No.	Transmissivity ft²/day	Storage Coefficient	Analysis Method	Remarks
Pumped Well: 7 (208616)	5680	NA	Theis	
	3140		Cooper Jacob	
Ob Wells: 5 (208615)	3160	3.6e-5	Theis	
	2600	2.0e-5	Cooper Jacob	
8 (208630)	12500	7.7e-5	Theis	Adjusted to remove regional water level trend
Steady-state Distance Drawdown Analysis		**L (feet)**	**C (days)**	
	918	3000	9800	de Glee

Representative Aquifer Characteristics:

Transient Analysis

Transmissivity : 3000 (ft^2/day)
Storage Coefficient : 3.0e-5

Steady-state Analysis

Transmissivity : 918 (ft^2/day)
Leakage Factor : 3000 feet
Hydraulic Resistance : 9800 days

Boundaries:

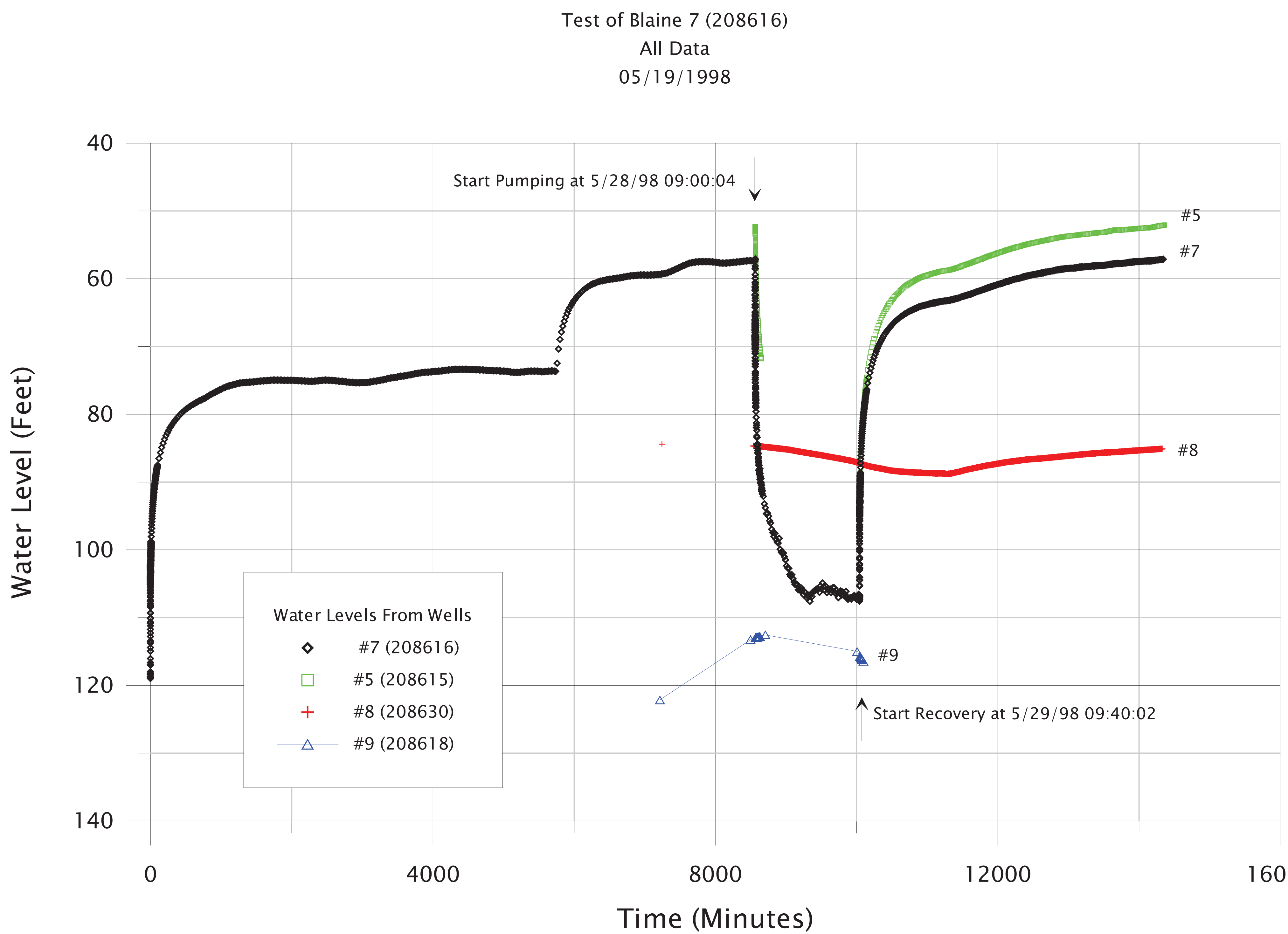
A negative boundary was encountered within 250 minutes of pumping start. It appears that the boundary is between wells 7 and 9 because of the lack of drawdown in well 9.

Conceptual model:

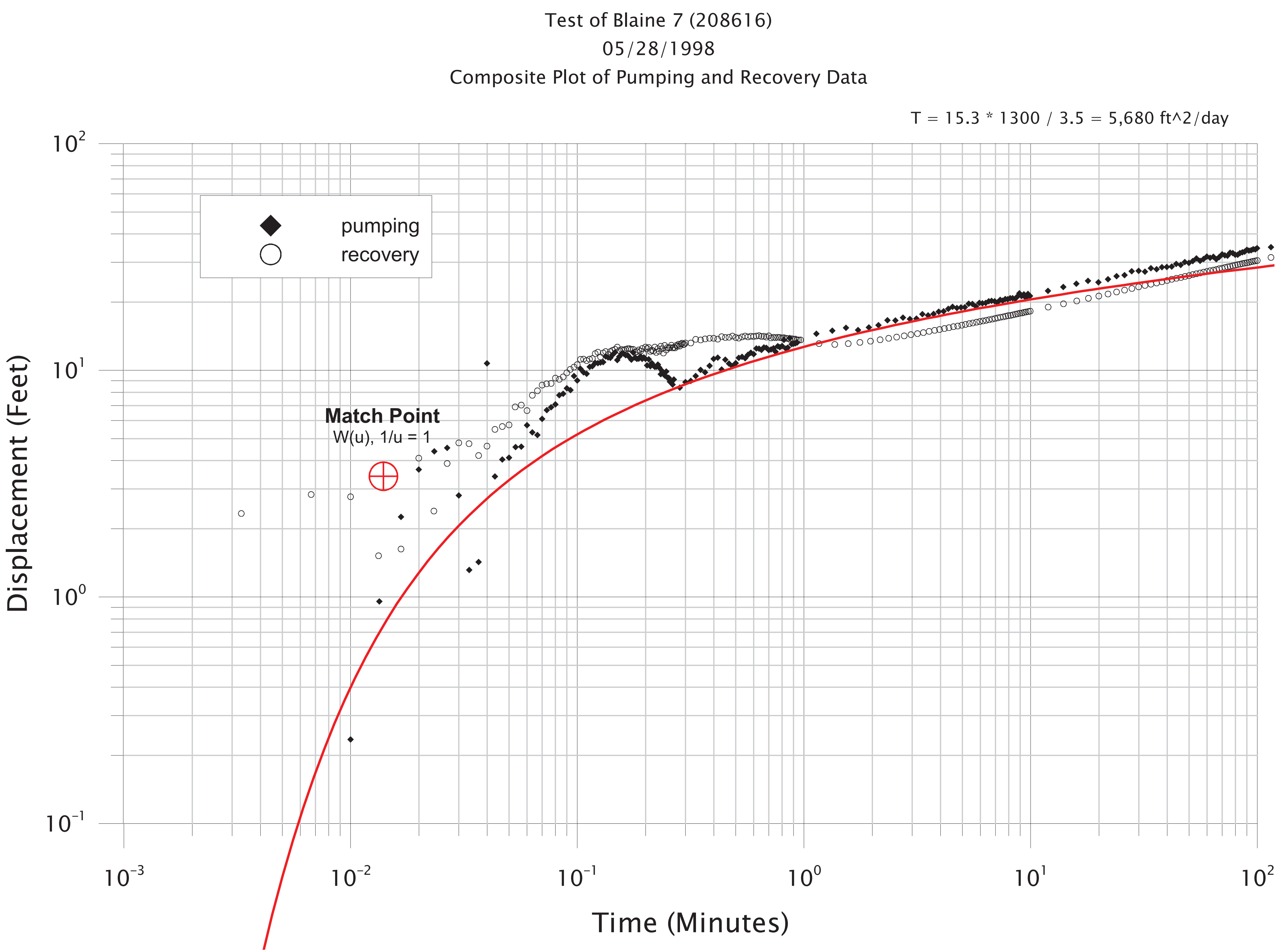
The results are quite consistent between the pumping and recovery periods and show that the aquifer is highly confined.

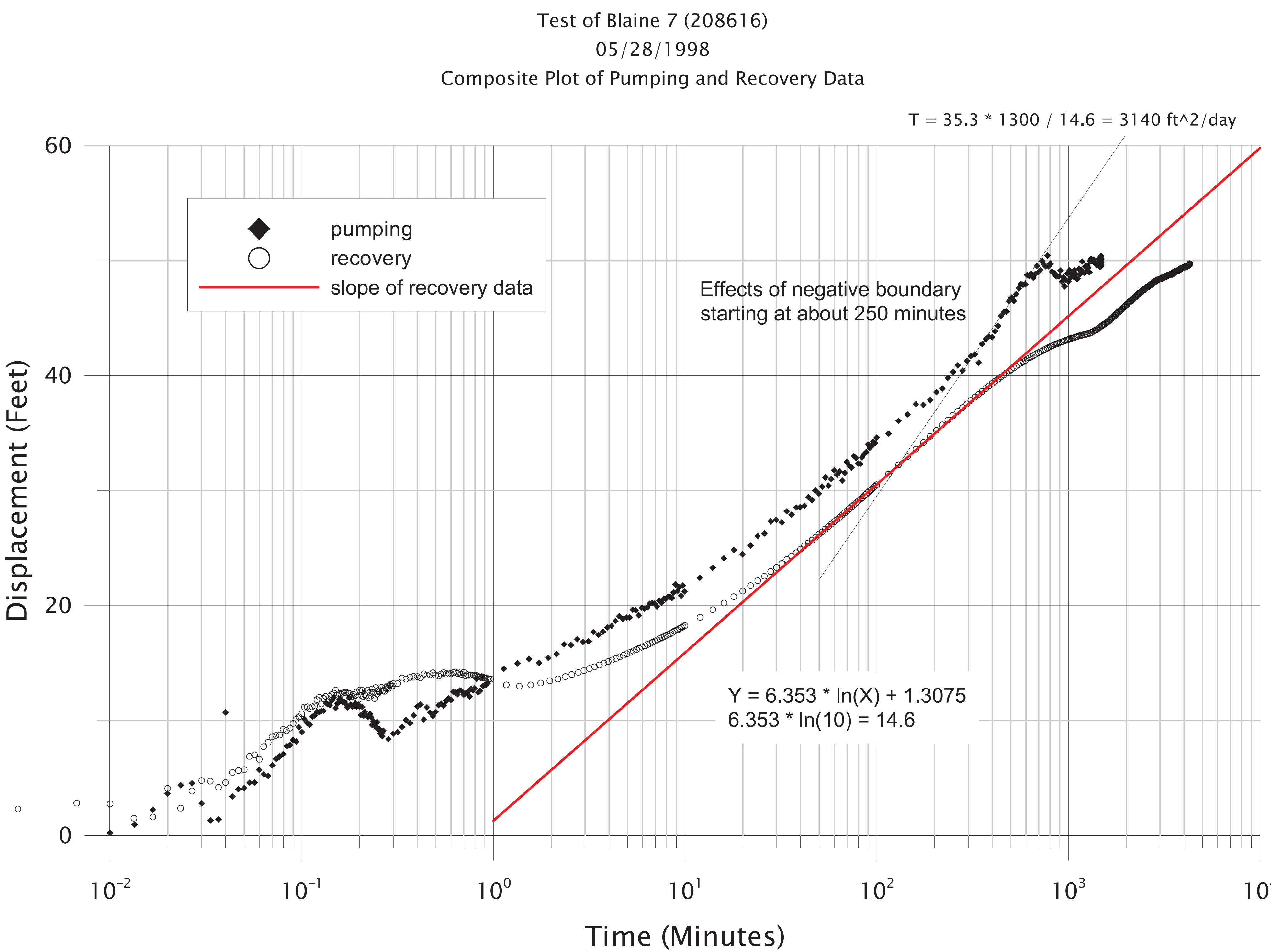
Appendix 1

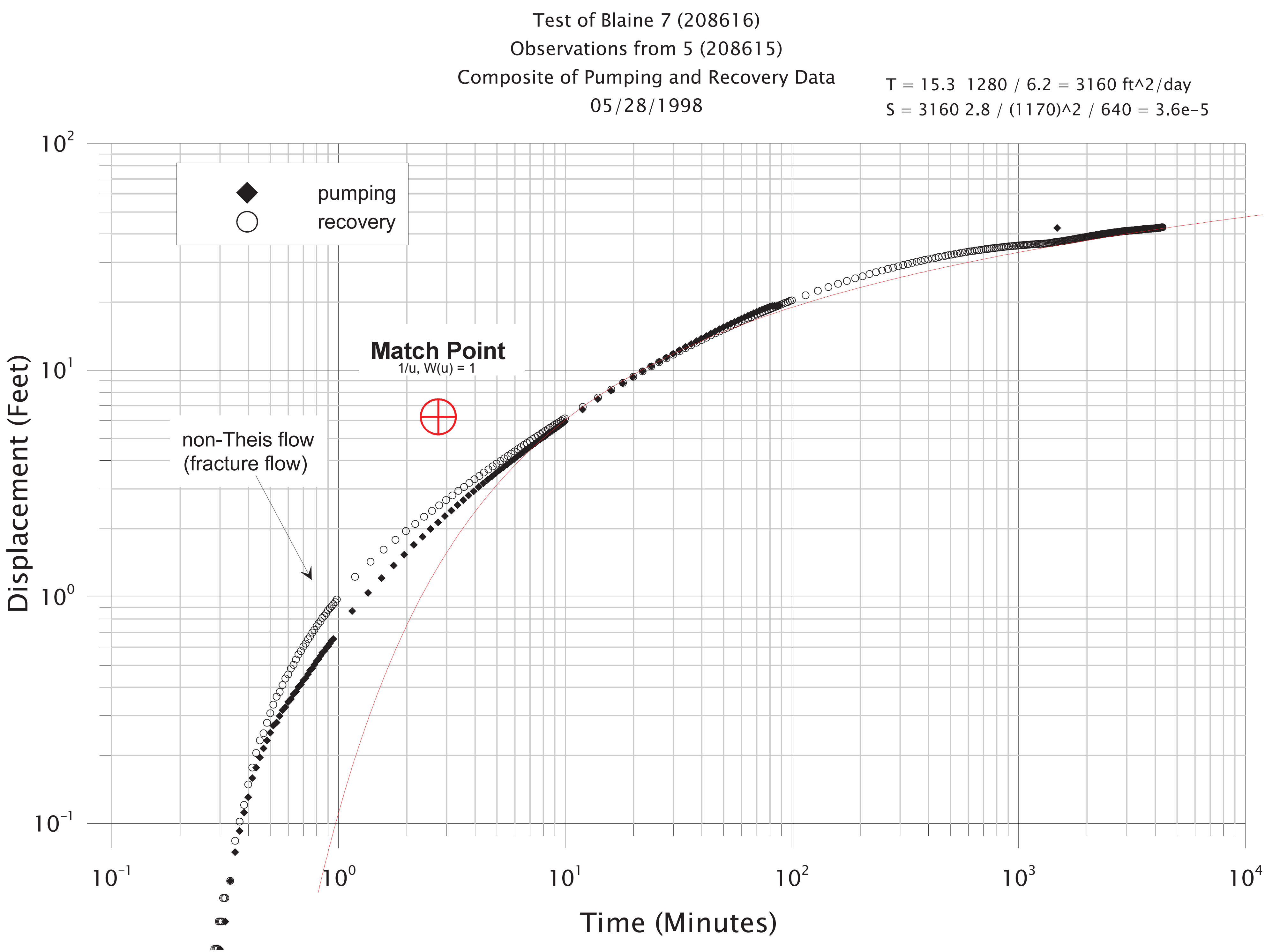
Graphical Analysis



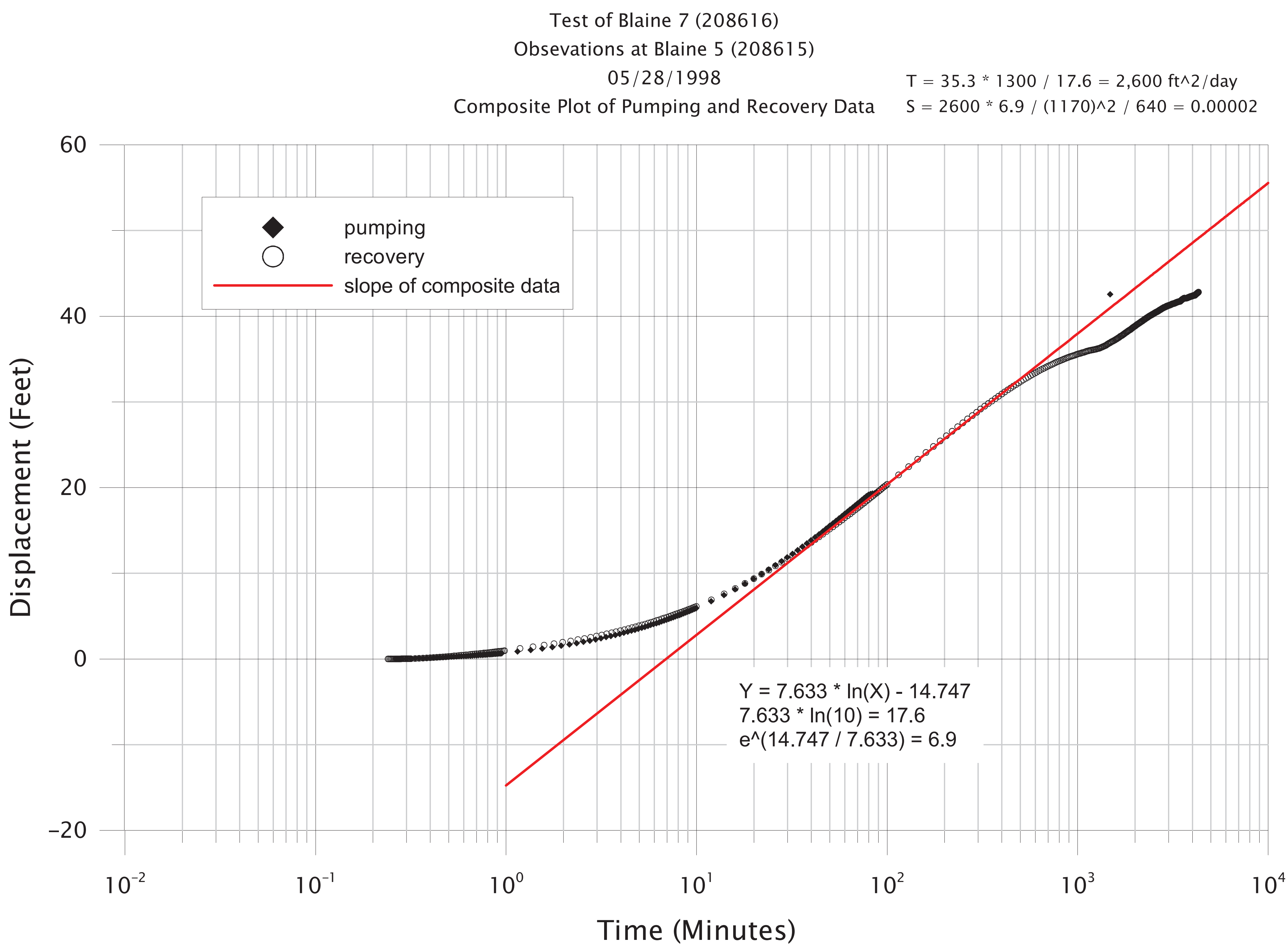
Test of Blaine 7 (208616)
All Data
05/19/1998
Water Level (Feet)
Time (Minutes)
40
60
80
100
120
140
0
4000
8000
12000
160
Start Pumping at 5/28/98 09:00:04
Start Recovery at 5/29/98 09:40:02
#5
#7
#8
#9
Water Levels From Wells
#7 (208616)
#5 (208615)
#8 (208630)
#9 (208618)


Test of Blaine 7 (208616)
05/28/1998
Composite Plot of Pumping and Recovery Data
T = 15.3 * 1300 / 3.5 = 5,680 ft^2/day
pumping
recovery
Match Point
W(u), 1/u = 1
Displacement (Feet)
Time (Minutes)

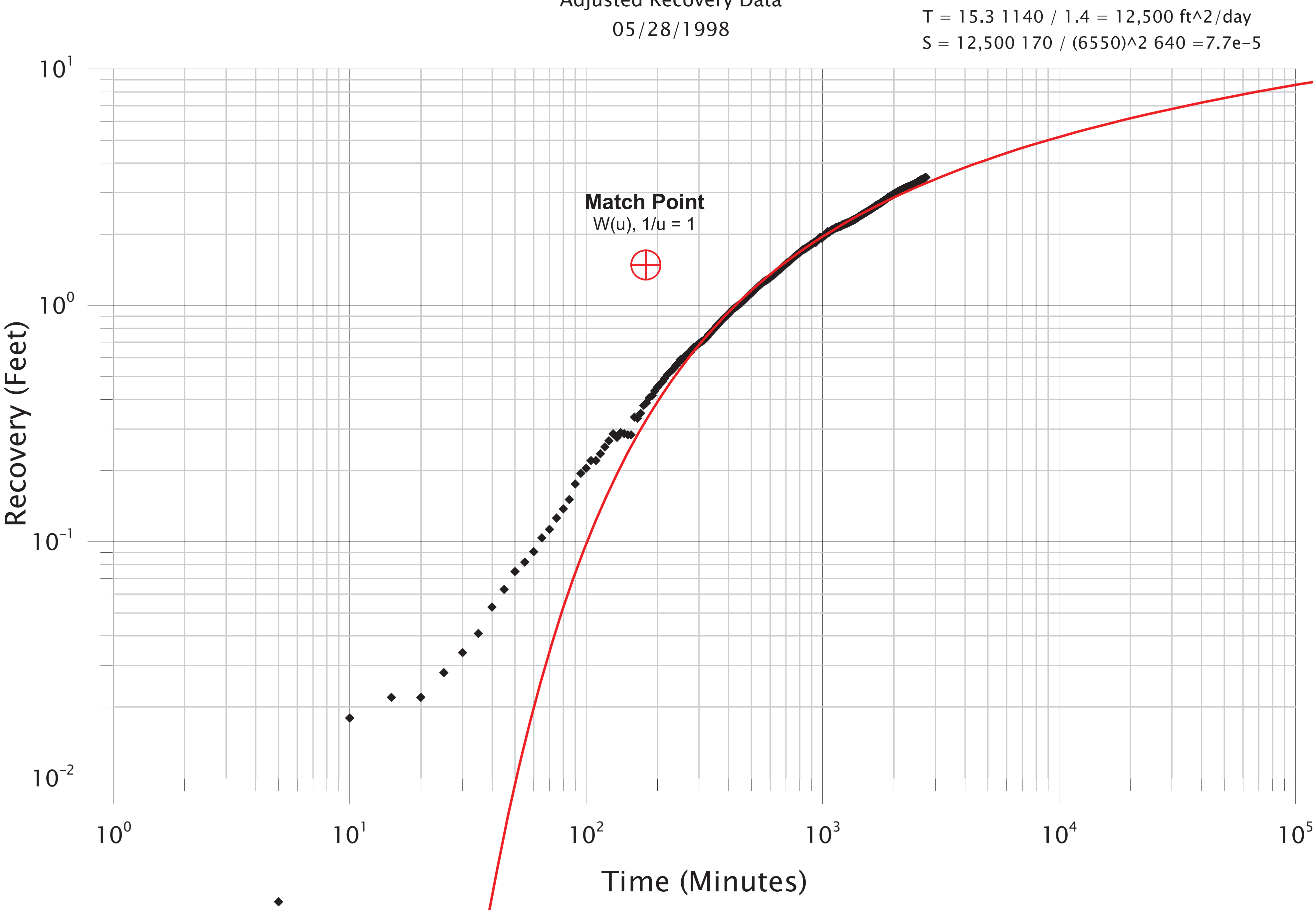

Test of Blaine 7 (208616)
05/28/1998
Composite Plot of Pumping and Recovery Data
T = 35.3 * 1300 / 14.6 = 3140 ft^2/day
pumping
recovery
slope of recovery data
Effects of negative boundary starting at about 250 minutes
Y = 6.353 * ln(X) + 1.3075
6.353 * ln(10) = 14.6
Displacement (Feet)
60
40
20
0
10^-2
10^-1
10^0
10^1
10^2
10^3
10^4
Time (Minutes)



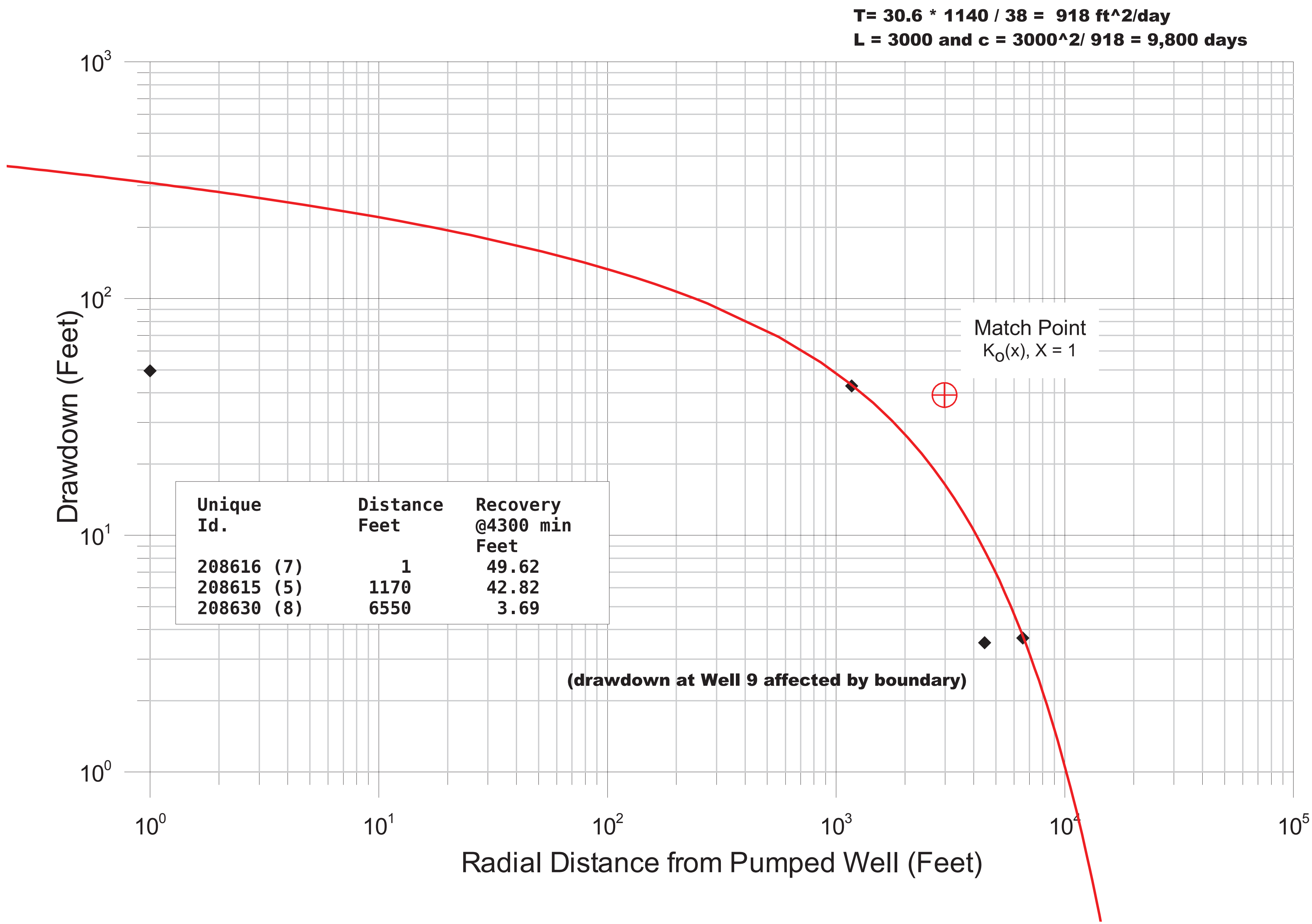
Test of Blaine 7 (208616)
Observations from 5 (208615)
Composite of Pumping and Recovery Data
05/28/1998
T = 15.3 1280 / 6.2 = 3160 ft^2/day
S = 3160 2.8 / (1170)^2 / 640 = 3.6e-5
pumping
recovery
Match Point
1/u, W(u) = 1
non-Theis flow
(fracture flow)
Displacement (Feet)
Time (Minutes)
10^2
10^1
10^0
10^-1
10^-1
10^0
10^1
10^2
10^3
10^4


Test of Blaine 7 (208616)
Obsevations at Blaine 5 (208615)
05/28/1998
Composite Plot of Pumping and Recovery Data
T = 35.3 * 1300 / 17.6 = 2,600 ft^2/day
S = 2600 * 6.9 / (1170)^2 / 640 = 0.00002
pumping
recovery
slope of composite data
Y = 7.633 * ln(X) - 14.747
7.633 * ln(10) = 17.6
e^(14.747 / 7.633) = 6.9
Displacement (Feet)
60
40
20
0
−20
Time (Minutes)
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}

Test of Blaine 7 (208616)
at 8 (208630)
Adjusted Recovery Data
05/28/1998



Test of Blaine 7 (208616)
May 28, 1998
Distance Drawdown Plot after 4300 Minutes of Pumping



Appendix 2

Documentation

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

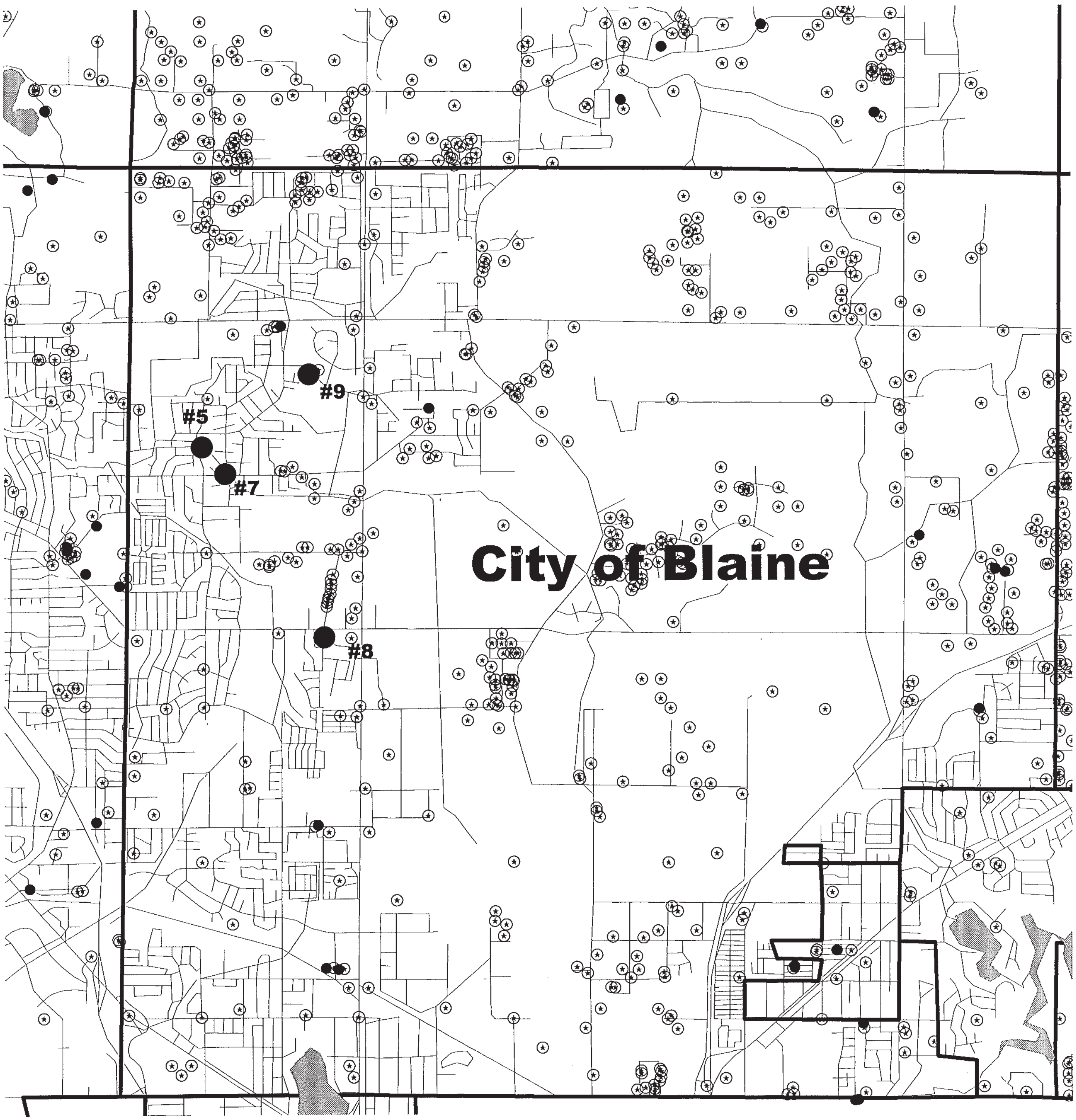
Test No.

Aquifer Test Information

Test Location Blaine #7	Well Owner City of Blaine	Test Conducted By J. Blum (MDH)
Date/Time Test Start 5/28/98 09:00:04.0	Flow Rate (Units) 1200 gpm	Pump Type Turbine
Date/Time Recovery Start 5/29/98 09:40:02.0	Flow Rate Measuring Device Turbine Flowmeter	Pump Intake Depth
Date/Time Test Finish	Totalizer: End 11,691,800	Pumped Well Inner Casing Diameter
Notes pre lube 1:06 min	Totalizer: Start 9,922,200	Confined/Unconfined confined
	Total Pumped (Units) 1,769,600 gallons	Quad Sheet Name/Number

Unique Well Numbers	Location T, R, S, Quarters	Location N, E	Radial Distance	Open Depth	Transducer Setting	Measuring Point Location	Elevation, Datum
Pumped Well #7 (208616)		N E					
Observation Wells #5 (208615)		N E	1170				
#9 (208618)		N E	4470				
#8 (208630)		N E	6550				
		N E					
		N E					

Sketch Map of Well Locations



Location of Public Water Supply Wells in the Ironton-Galesville Aquifer, Blaine, MN

IC #140-0523 (5/96)

Aquifer Test Data Form

Test: Blume #7	By: J. Blum	Test Date: 05/28/98	Page ____ of ____

Location (Unique Well No.)	Date Month	Day	Year	Time Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks Totalizer
#7(208616	05	28	98	09	00	04				0	9922200 start test
					05	—				~1320	9,928,600 1280
					10	—				1320	9,935,100 1300
					15	—				1300	9,941,700 1320
					20	—				1300	9,948,100
					25	—				1280	9,954,500
					30	—				1280	9,961,000
					35	—				1280	9,967,400
					40					1300	9,973,800
					45					1280	9,989,000
					52	—					~~9,955,100~~
					55					1280	9,999,100
				10	—					1250	10,110,400
				11	30						
				~~12~~	~~—~~					1210	10,365,000
				15	—					1280	10,813,000
				21	—					1150	11,666,500 1160
	05	29	98	09	18	—					11,686,100 1130
				09	35	—					11,691,800 end 1140
				09	40	02	1480				

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

Notes:

IC #140-0523 (5/96)

Aquifer Test Data Form

Test:	By:	Test Date:	Page ____ of ____

Location (Unique Well No.)	Date Month	Day	Year	Time Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
#9 (208618)	05	28	98	07	55	–		113.22			
#8 (208630)				08	20	–		84.66			XD₀= 11.04
#5 (208615)				08	40	–		52.41			XD₀= 19.80
#7 (208616)											XDR= 57.25 XD₀= 71.24
				09	00	04			start test		9922208
#9	05	27	98	10	30	–		122.12			
#5								61.55			
#8								84.37			
#5	05	29	98	09	31	–		94.90			reset probe XD₀ 4.91
#7	05	29	98	09	40	02					stop pumping XD₀ 21.94
#9				10	35			116.44			

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

Notes: Prelube 1:06 min
8:58:55 hand/on/pump

Aquifer Test Data Form

Test: Blaine #7				By: J. Blann				Test Date:		Page ____ of ____	
Location (Unique Well No.)	Date Month	Day	Year	Time Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
#8 208630	06	01	98	09	10	—		85.14			48.67 XDR 10.60 XDo
#7				09	25	—		57.17			57.08 XDR 71.84 XDo
				09	48	—		51.81			52.07 XDR 47.02 XDo

Minnesota Department of Health
Special Services Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

Notes:

IC #140-0523 (5/96)

IC #140-0523 (5/96)

Aquifer Test Data Form

Test:	By:	Test Date:	Page ____ of ____

Location (Unique Well No.)	Date Month	Date Day	Date Year	Time Hour	Time Minute	Time Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
#9	05	28	98	09	00			113.22			static (time ~ 7:50 AM)
				09	06			112.92			Solinist line left in well between
				09	10			112.92			measurements
				09	15			112.91			Blaine Utilities flow
				09	20			112.89			meter record indicates:
				09	25			112.88			5/26/98 (8:30) 338,798
				09	30			112.87			5/27 (10:00) 339,290
				09	35			112.85			5/28 (9:00) 339,290
				09	40			112.84			
				09	45			112.83			
				09	50			112.81			
				09	55			112.79			
				10	00			112.78			
				10	05			112.76			
				11	23			112.53			
	05	29	98	09	05			114.98			
				09	46			115.70			
				09	50			115.75			
				09	55			115.85			
				10	03			115.94			
				10	10			116.08			
				10	15			116.15			
				10	20			116.22			

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

Notes:

MINNESOTA MDH DEPARTMENT OF HEALTH

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

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

Public Water Supply ID:	1020031	PWS Name:	Fridley

Contact Information for Person Completing this Form

Name:	Adam Janzen
Address:	4300 MarketPointe Drive
	Suite 200
City, State, Zip:	Bloomington, MN 55435
Phone, Fax, e-mail:	(952) 842-3596 (p), (952) 832-2601 (f), ajanzen@barr.com

Aquifer Properties Determination Methods

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

- ☐ 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

206674	206657				
206670					
201158					
206675					

Submitted by: Adam Janzen	Prof. License: 53665	Date: 5/1/2018
Reviewed by: Amal Djerrari	Approved: ◉ Yes ○ No	Approval Date: 5/2/2018

Summary of Aquifer Properties Based on Existing Data

Aquifer Name: Mt. Simon Sandstone	**Aquifer Code:** CMTS

Hydraulic Confinement ☑ **Confined** ☐ **Unconfined** ☐ **Fractured Rock**

Aquifer Test Number of test(s) on file used to compile the information tabulated below:
5

Aquifer Properties Summary Table

Representative Values		Unit	Range		+/- %
			Minimum	Maximum	
Top Stratigraphic Elev.	227.5	feet (MSL)	225	243	+6.8/-1.1
Bottom Stratigraphic Elev.	21	feet (MSL)	15	53	+152/-29
Transmissivity (T)	5048	ft^2/day	2242	10605	+110/-56
Aquifer Thickness (b)	206.5	feet	190	210	+1.7/-8
Saturated Thickness* (b)		feet			
Hydraulic Conductivity (k)	24.4	ft/day	11.8	50.5	+107/-52
Primary Porosity (e_p)	0.2	0.00 %			
Secondary Porosity** (e_s)		0.00 %			
Storativity (S)		dimensionless			
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.

Production tests were conducted on Fridley Well 2 (206674) and Fridley Well 3 (206670). Three production tests were conducted on Fridley Well 2. Of these three tests, two were found to be acceptable for analysis. Five production tests were performed on Fridley Well 3. Of these five tests, three were found to be acceptable for analysis (see attached sheet provided by MDH).

Below is a summary of the results from the two tests for Fridley Well 2 (206674):

Flow Rate (gpm)	T(ft**2/day)
1018	2389
1319	2855

Below is a summary of the results from the three tests for Fridley Well 3 (206670):

Flow Rate (gpm)	T(ft**2/day)
935	8890
1016	9671
1212	10602

The representative hydraulic conductivity of the Mt. Simon of 24.4 ft/day was calculated from the geometric mean of the average transmissivities from Well 2 and Well 3 (5048 ft**2/day) and the average Mt. Simon thickness of 206.5 feet at Wells 2 and 3. For the model sensitivity analysis, the upper hydraulic conductivity of the CMTS will be set to the maximum result from the production tests (50.5 ft/day) and the lower hydraulic conductivity of the CMTS will be set to the minimum result from the production tests (11.8 ft/day).

The logs for Fridley Wells 2, 3, 4, and 5 were used to determine the range of Mt. Simon thicknesses and contact elevations. The representative values are arithmetic means of the values at Wells 2 and 3.

DRAFT / Beta Version 1

Worksheet for Estimating Transmissivity and Hydraulic Conductivity from Specific Capacity Test Data

Explanation and notes attached.

		Field Data										*Estimated Parameters*			*Calculated Results*							
			Depth to Water				Aquifer			Screened Interval						Saturated		Partial				
		inches	feet	gpm	hours	feet		feet	feet	feet	feet	-	sec^2/ft^5	feet	feet	feet	feet	-	gpm/ft	sq ft/sec	sq ft/day	ft/day
Location	Unique ID	Well Diam.	Initial	Mean Pumping Rate	Test Duration	Final	Aquifer	Depth to Top	Depth to Bottom	Depth to Top	Depth to Bottom	Storage Coeff. (S)	Well loss Coeff. (C)	Aquifer Thickness (b)	Measured Drawdown (sm)						Transmissivity (T)	Conductivity (K)
FRIDLEY 11	206657	24.00	52.0	1000	16	144.0	CJMS	325	669	325	669	0.001	0	344	92.00	344.0	0.0E+00	0.00	10.87	2.9E-02	2521.9	7.3
FRIDLEY 3	206670	10.00	150.0	1600.0	4.0	248.0	CMTS	660	870	784	836	0.001	0	210	98.00	52.0	0.0E+00	13.57	16.33	1.3E-01	11037.4	52.6
FRIDLEY 3	206670	10.00	150.0	800.0	2.5	226.0	CMTS	660	870	784	836	0.001	0	210	76.00	52.0	0.0E+00	13.57	10.53	8.1E-02	6966.3	33.2
FRIDLEY 3	206670	10.00	150.0	935.0	2.5	220.0	CMTS	660	870	784	836	0.001	0	210	70.00	52.0	0.0E+00	13.57	13.36	1.0E-01	8889.5	42.3
FRIDLEY 3	206670	10.00	150.0	1016.0	4.5	221.0	CMTS	660	870	784	836	0.001	0	210	71.00	52.0	0.0E+00	13.57	14.31	1.1E-01	9670.9	46.1
FRIDLEY 3	206670	10.00	150.0	1212.0	2.0	226.0	CMTS	660	870	784	836	0.001	0	210	76.00	52.0	0.0E+00	13.57	15.95	1.2E-01	10601.9	50.5
FRIDLEY 2	206674	16.00	130.0	400.0	8.5	236.0	CMTS	635	838	675	838	0.001	0	203	106.00	163.0	0.0E+00	0.91	3.77	1.1E-02	934.1	4.6
FRIDLEY 2	206674	16.00	130.0	1018.0	10.5	243.0	CMTS	635	838	675	838	0.001	0	203	113.00	163.0	0.0E+00	0.91	9.01	2.8E-02	2388.6	11.8
FRIDLEY 2	206674	16.00	130.0	1319.0	3.5	246.0	OPDC	635	838	675	838	0.001	0	203	116.00	163.0	0.0E+00	0.91	11.37	3.3E-02	2854.5	14.1
																			FRIDLEY 3 MEAN		9720.8	46.3
																			FRIDLEY 2 MEAN		2621.6	12.9
																				GEOMEAN	5048.2	24.4

Appendix C

Groundwater Model Details

Table C1
Hydraulic Conductivity Summary
Fridley WHPP Amendment

Aquifer	Base Model Transmissivity (ft^2/day)	Unit Thickness (ft)	Base Model Kx (ft/day)	Base Model Kz (ft/day)	Upper Bound Kx (ft/day)	Upper Bound Kz (ft/day)	Lower Bound Kx (ft/day)	Lower Bound Kz (ft/day)
Quaternary	64000	161	398	39.8	596	59.6	199	19.9
Prairie du Chien Group	149000	135	1104	16.7	1252	19.0	205	3.11
Jordan Sandstone	2689	87.3	30.8	3.08	46.2	4.62	15.4	1.54
Tunnel City Group	953	140	6.81	0.068	39.7	0.397	4.81	0.048
Wonewoc Sandstone	395	58	6.81	0.68	39.7	3.97	4.81	0.48
Mt. Simon Sandstone	5048	207	24.4	2.44	50.5	5.05	11.8	1.18

Aquifer	Base Model Transmissivity (m^2/day)	Unit Thickness (m)	Base Model Kx (m/day)	Base Model Kz (m/day)	Upper Bound Kx (m/day)	Upper Bound Kz (m/day)	Lower Bound Kx (m/day)	Lower Bound Kz (m/day)
Quaternary	5946	49	121	12.1	182	18.2	60.6	6.06
Prairie du Chien Group	13843	41	336	5.10	382	5.78	62.5	0.95
Jordan Sandstone	250	27	9.39	0.94	14.1	1.41	4.69	0.47
Tunnel City Group	89	43	2.08	0.021	12.1	0.121	1.47	0.015
Wonewoc Sandstone	37	18	2.08	0.21	12.1	1.21	1.47	0.15
Mt. Simon Sandstone	469	63	7.45	0.75	15.4	1.54	3.60	0.36

Table C2
High-Capacity Pumping Updates
Fridley WHPP Amendment

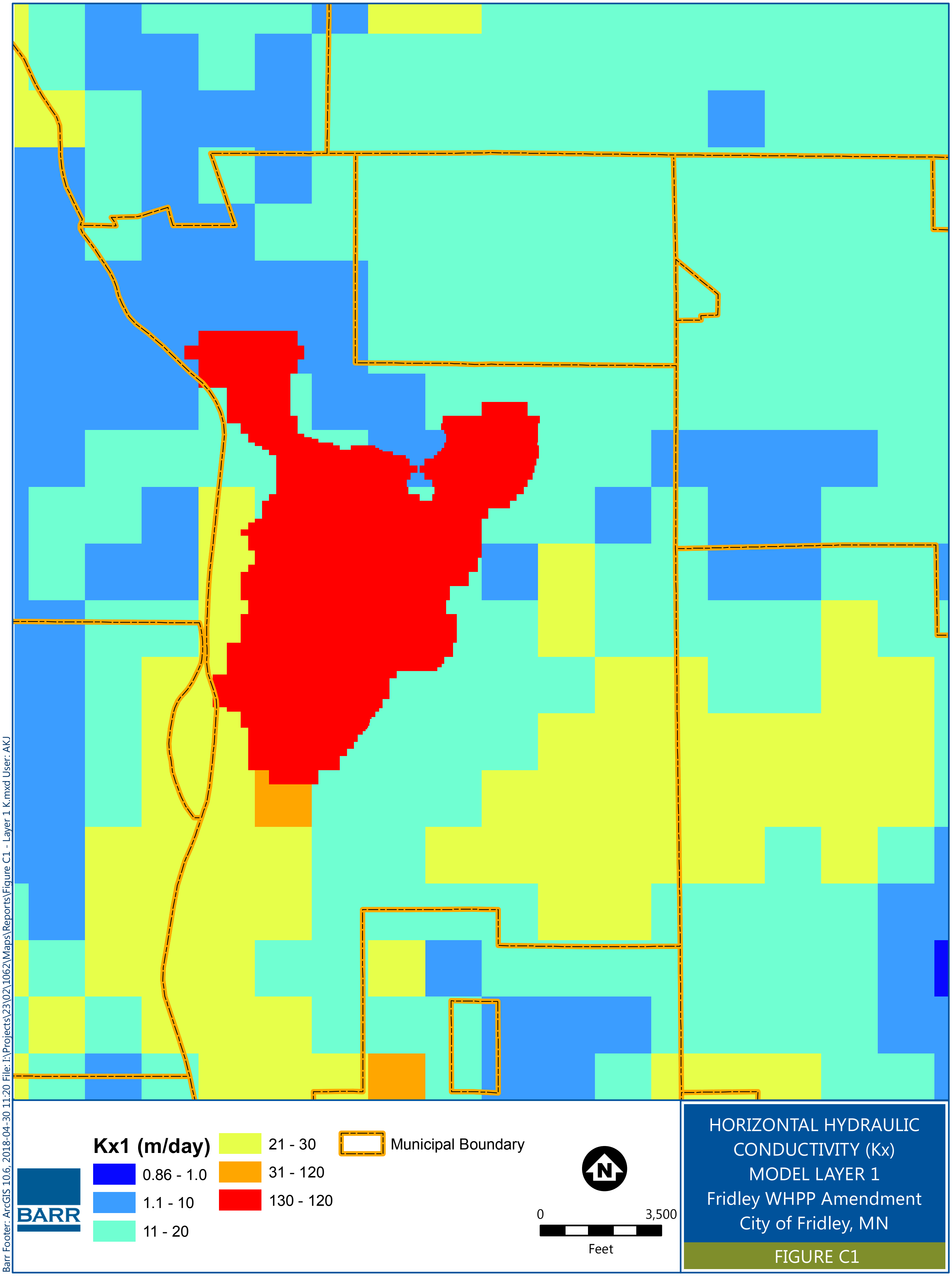
Unique Number	Permittee	DNR Permit Number	2012-2016 Average Annual Volume of Water Pumped (MG)	Existing MM3 Rate (m^3/day)	Updated Rate (m^3/day)
110485	New Brighton, City Of	1970-0157	69.82	96.47	724.13
110488	BNSF Railway	1986-6292	0.99	50.82	10.23
110493	Brooklyn Center, City of	1976-6396	71.74	1348.13	744.12
127269	Brooklyn Center, City of	1976-6396	1.38	38.04	14.34
151587	Blaine, City of	1976-6227	20.43	403.89	211.86
180920	Spring Lake Park, City Of	1972-0123	27.68	698.88	287.14
184900	Brooklyn Park, City of - Public Works Dept	1976-6046	0.00	202.25	0.00
200252	Marshall Concrete Products	1965-1355	1.46	27.94	15.18
200524	St Anthony, City Of	1960-0907	153.87	1716.30	1595.91
200588	Xcel Energy	1978-6037	0.00	144.46	0.00
203026	Brooklyn Park, City of - Public Works Dept	1976-6046	0.00	25.41	0.00
203257	Brooklyn Center, City of	1976-6396	123.56	2193.27	1281.58
203258	Brooklyn Center, City of	1976-6396	183.85	2930.36	1906.79
203259	Brooklyn Center, City of	1976-6396	28.98	1818.75	300.56
203260	Brooklyn Center, City of	1976-6396	1.05	17.62	10.93
203321	Brooklyn Center, City of	1976-6396	408.11	2816.93	4232.84
203424	Brookdale Mall HH, LLC	1975-6259	0.00	10.91	0.00
203577	Minneapolis Parks & Rec Board	1978-6334	0.78	46.10	8.13
206638	Spring Lake Park, City Of	1972-0123	62.35	708.57	646.65
206659	Brand-Broadway Assoc	1963-1021	6.56	0.00	67.99
206660	Brand-Broadway Assoc	1963-1021	37.41	395.57	388.01
206679	Ind School District 14	1991-6160	3.62	51.65	37.54
206680	Stylmark INC	1960-0717	0.51	7.63	5.27
206683	Ind School District 14	1968-1184	4.65	71.22	48.24
206716	Mounds View, City Of	1976-6253	103.44	78.86	1072.81
206717	Mounds View, City Of	1976-6253	154.75	1502.18	1604.99
206720	Mounds View, City Of	1976-6253	19.60	759.46	203.32
206721	Mounds View, City Of	1976-6253	21.13	1117.06	219.13
206722	Mounds View, City Of	1976-6253	139.44	1793.40	1446.28
206761	New Brighton, City Of	1969-1220	3.56	48.55	36.93
206792	New Brighton, City Of	1970-0157	85.73	3579.83	889.12
206793	New Brighton, City Of	1970-0157	152.16	1487.93	1578.13
206795	New Brighton, City Of	1970-0157	31.67	80.00	328.44
206796	New Brighton, City Of	1970-0157	151.02	1083.82	1566.34
206797	New Brighton, City Of	1970-0157	103.06	873.34	1068.88
208645	Blaine, City of	1976-6227	338.63	2474.02	3512.13
208646	Blaine, City of	1976-6227	394.07	2406.03	4087.16
223294	Spring Lake Park, City Of	1972-0123	59.13	684.12	613.27
255337	Cemstone Products Company	1986-6056	0.00	25.91	0.00
255921	GAF Corporation	1985-6009	39.26	641.57	407.18
255950	Hard Chrome Inc	2003-3153	14.51	187.57	150.53
415905	Brooklyn Park, City Of - Edinburgh Golf Course	1985-6270	15.32	126.28	158.93
415906	Brooklyn Park, City Of - Edinburgh Golf Course	1985-6270	30.65	458.35	317.85
431653	BAE Systems	1987-6280	2.67	89.62	27.66

Table C2
High-Capacity Pumping Updates
Fridley WHPP Amendment

Unique Number	Permittee	DNR Permit Number	2012-2016 Average Annual Volume of Water Pumped (MG)	Existing MM3 Rate (m^3/day)	Updated Rate (m^3/day)
431654	BAE Systems	1987-6280	19.74	169.04	204.72
431655	BAE Systems	1987-6280	18.37	201.95	190.54
431656	BAE Systems	1987-6280	12.60	114.85	130.67
439723	Bell Lumber And Pole Co	1986-6104	0.00	0.35	0.00
468118	Brooklyn Center, City of	1976-6396	232.05	1331.12	2406.77
478398	Metropolitan Council	1992-6089	0.00	14.14	0.00
480297	Metropolitan Council	1992-6089	0.00	14.18	0.00
482891	Minneapolis Parks & Rec Board	1993-6159	15.05	243.38	156.05
509083	New Brighton, City Of	1970-0157	37.39	125.52	387.76
520931	New Brighton, City Of	1970-0157	0.00	37.51	0.00
538076	Kurt Manufacturing	1996-6184	14.30	155.16	148.33
538124	Medtronic Inc	2004-3110	11.75	56.64	121.83
554216	New Brighton, City Of	1970-0157	58.20	2501.92	603.67
559393	BNSF Railway	1986-6292	1.10	56.09	11.41
559394	BNSF Railway	1986-6292	0.40	30.56	4.15
561185	US Navy	1992-6127	46.71	570.29	484.50
561186	US Navy	1992-6127	15.14	377.35	157.00
563006	Spring Lake Park, City Of	1972-0123	99.19	972.60	1028.81
582628	New Brighton, City Of	1970-0157	269.12	4478.14	2791.21
592308	MN Pollution Control Agency - St Paul	1999-6094	0.46	13.17	4.77
611095	US Navy	1992-6127	11.81	146.56	122.50
611096	US Navy	1992-6127	6.22	94.32	64.47
611097	US Navy	1992-6127	19.69	482.54	204.25
611098	US Navy	1992-6127	4.86	55.60	50.39
616482	MN Pollution Control Agency - St Paul	1999-6094	0.00	5.86	0.00
616483	MN Pollution Control Agency - St Paul	1999-6094	0.41	5.27	4.23
616485	MN Pollution Control Agency - St Paul	1999-6094	2.18	21.22	22.60
616486	MN Pollution Control Agency - St Paul	1999-6094	3.66	51.50	37.96
616507	MN Pollution Control Agency - St Paul	1999-6094	0.00	8.31	0.00
616512	MN Pollution Control Agency - St Paul	1999-6094	0.99	34.49	10.23
623328	MN Pollution Control Agency - St Paul	1999-6094	0.37	13.54	3.85
623340	MN Pollution Control Agency - St Paul	1999-6094	3.02	49.48	31.28
628907	MN Pollution Control Agency - St Paul	1999-6094	0.05	1.91	0.52
628911	MN Pollution Control Agency - St Paul	1999-6094	0.05	3.42	0.47
628999	MN Pollution Control Agency - St Paul	1999-6094	0.79	20.82	8.21
645009	Brooklyn Center, City of	2004-3239	103.70	657.17	1075.58
660019	Hard Chrome Inc	2003-3005	0.04	4.55	0.38
660020	Hard Chrome Inc	2003-3005	0.11	2.93	1.14
660021	Hard Chrome Inc	2003-3005	0.12	4.25	1.21
683303	MN Pollution Control Agency - St Paul	1999-6094	0.78	20.53	8.10
717750	Ashland Petroleum Company	2007-0285	2.67	9.41	27.68
717754	Ashland Petroleum Company	2007-0285	0.96	7.56	10.00
735054	Xcel Energy	1978-6037	37.61	240.57	390.13

Table C2
High-Capacity Pumping Updates
Fridley WHPP Amendment

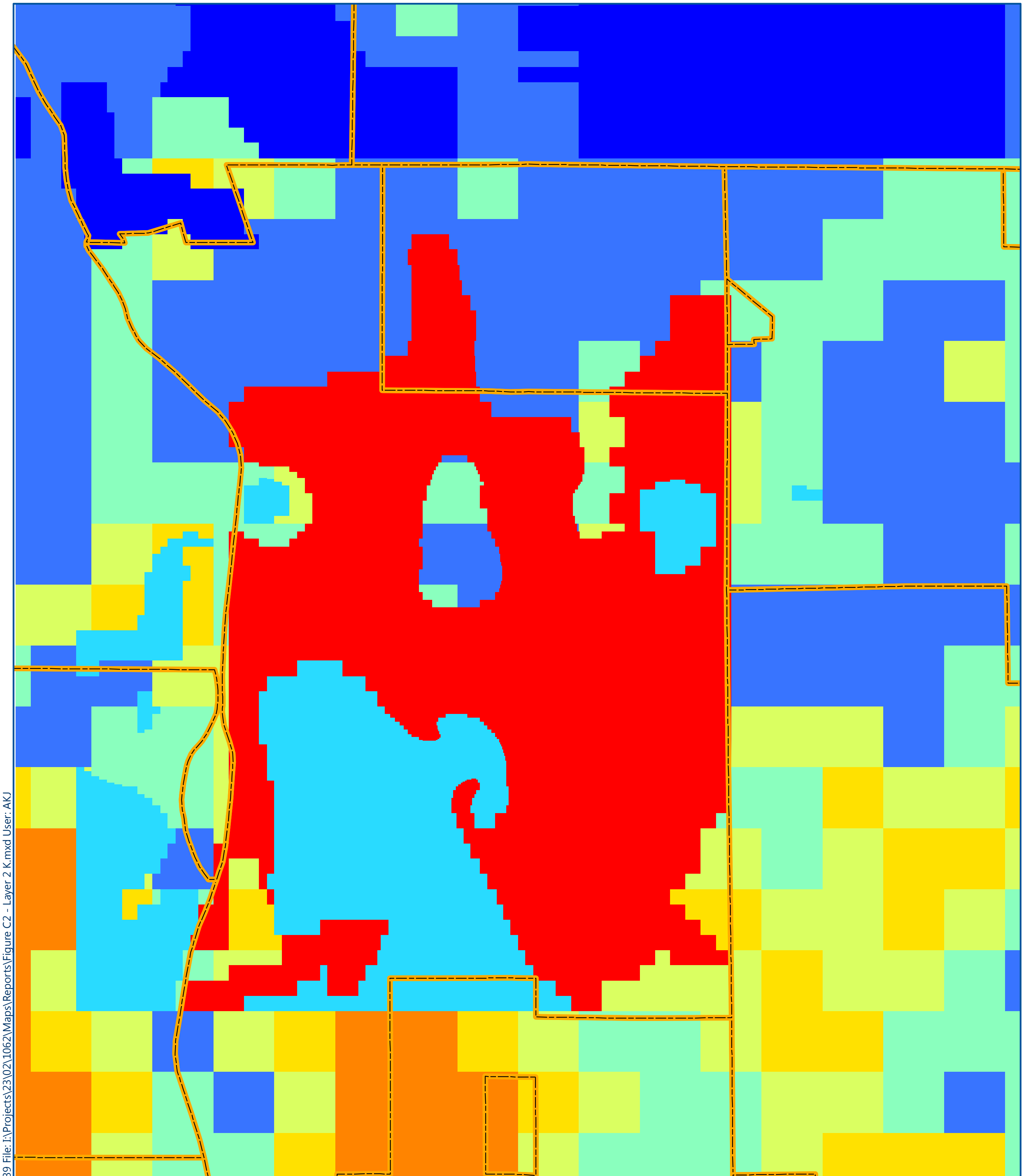
Unique Number	Permittee	DNR Permit Number	2012-2016 Average Annual Volume of Water Pumped (MG)	Existing MM3 Rate (m^3/day)	Updated Rate (m^3/day)
737627	Soo Line Railroad Company dba Canadian Pacific	2007-0727	6.76	28.95	70.15
737634	Soo Line Railroad Company dba Canadian Pacific	2007-0211	9.21	51.02	95.50
737636	Soo Line Railroad Company dba Canadian Pacific	2007-0727	1.86	8.17	19.34
751349	Soo Line Railroad Company dba Canadian Pacific	2007-0727	4.52	17.10	46.91
751350	Soo Line Railroad Company dba Canadian Pacific	2007-0727	0.83	5.26	8.59
755058	Soo Line Railroad Company dba Canadian Pacific	2007-0727	1.00	3.98	10.35
755059	Soo Line Railroad Company dba Canadian Pacific	2007-0211	9.09	40.27	94.26
756598	Ashland Petroleum Company	2007-0285	0.00	0.05	0.00



BARR

HORIZONTAL HYDRAULIC CONDUCTIVITY (Kx)
MODEL LAYER 1
Fridley WHPP Amendment
City of Fridley, MN

FIGURE C1



Kx2 (m/day)

0.6 - 1.0	20.1 - 30.0
1.1 - 11.7	30.1 - 50.0
11.8	50.1 - 121.0
11.9 - 20.0	121.0

Municipal Boundary

N

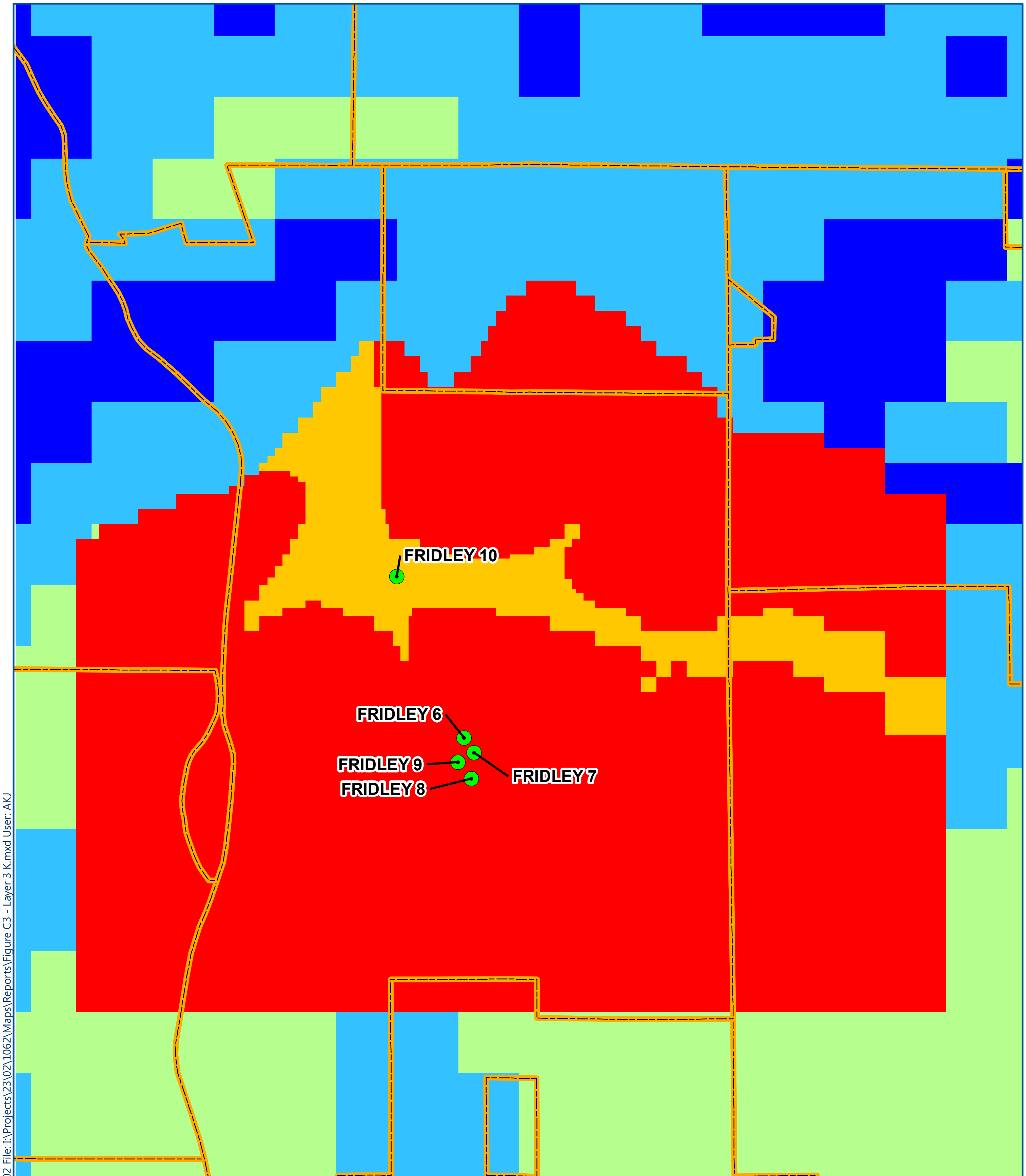
0 3,500

Feet

BARR

HORIZONTAL HYDRAULIC CONDUCTIVITY (Kx)
MODEL LAYER 2
Fridley WHPP Amendment
City of Fridley, MN

FIGURE C2



Fridley Municipal Well Open to Prairie du Chien or Quaternary

Municipal Boundary

Kx3 (m/day)

- 1.00 - 10.00
- 10.01 - 50.00
- 50.01 - 120.99
- 121.00
- 336.00

N

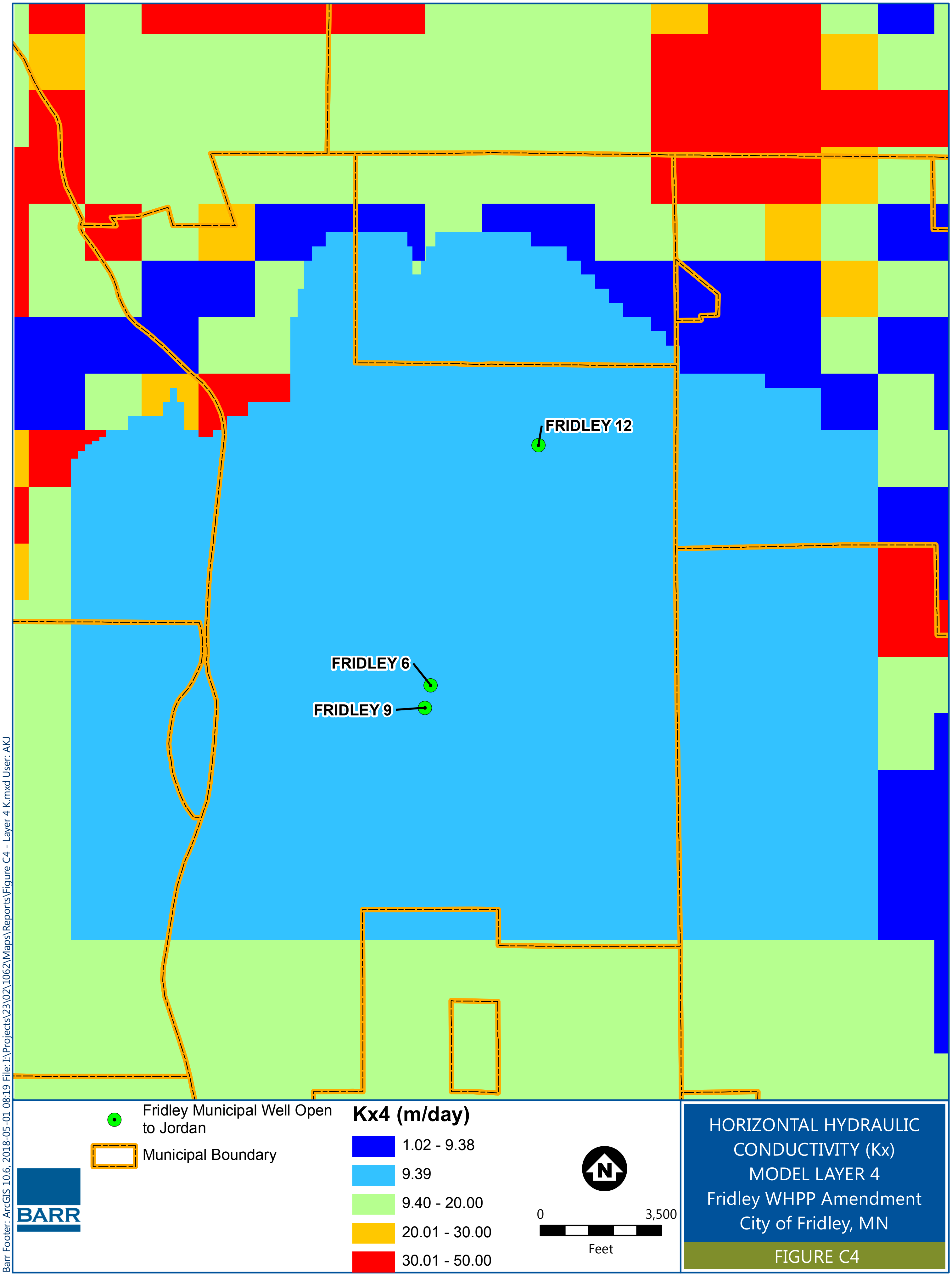
0 3,500

Feet

BARR

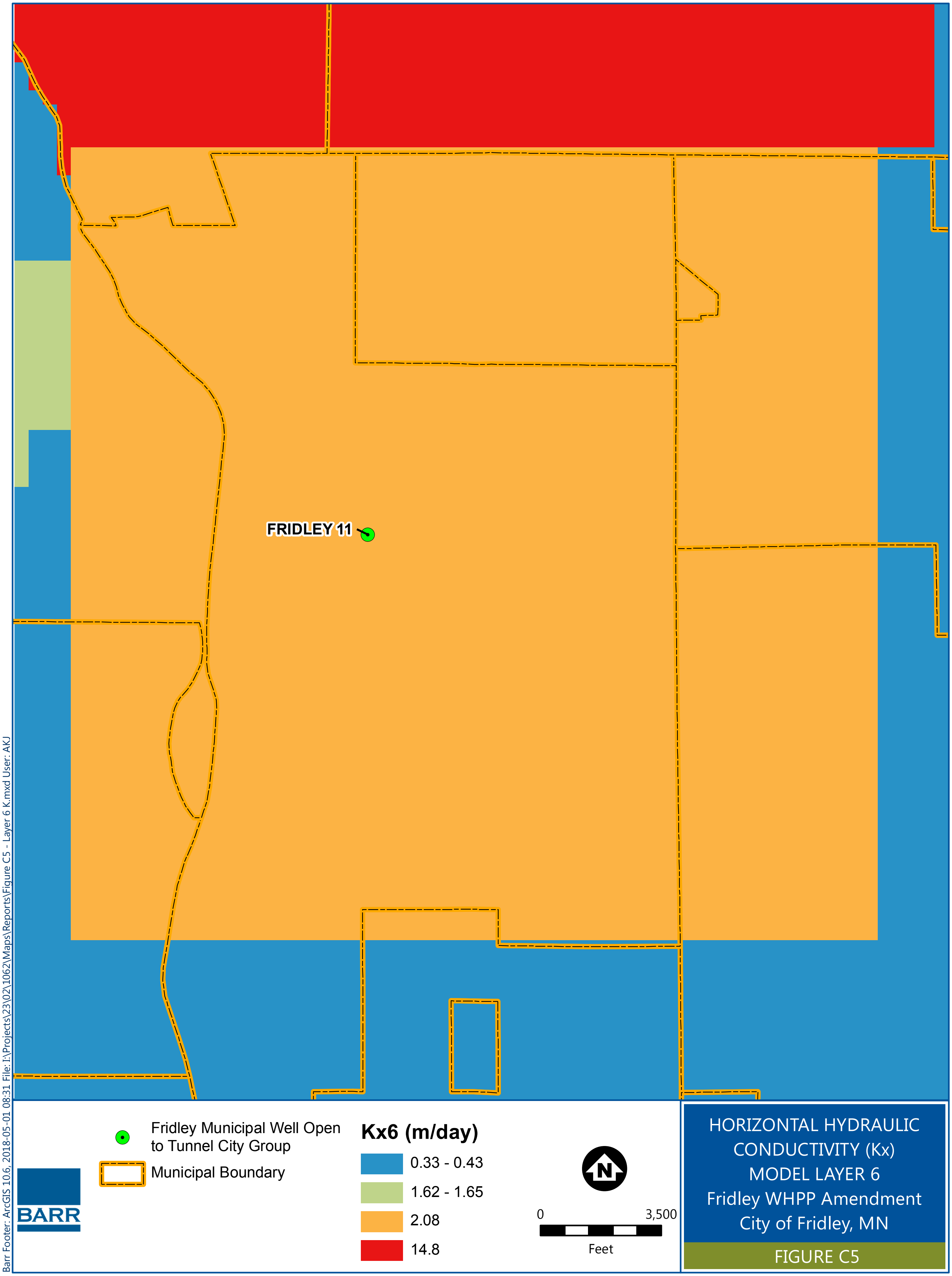
HORIZONTAL HYDRAULIC CONDUCTIVITY (Kx)
MODEL LAYER 3
Fridley WHPP Amendment
City of Fridley, MN

FIGURE C3



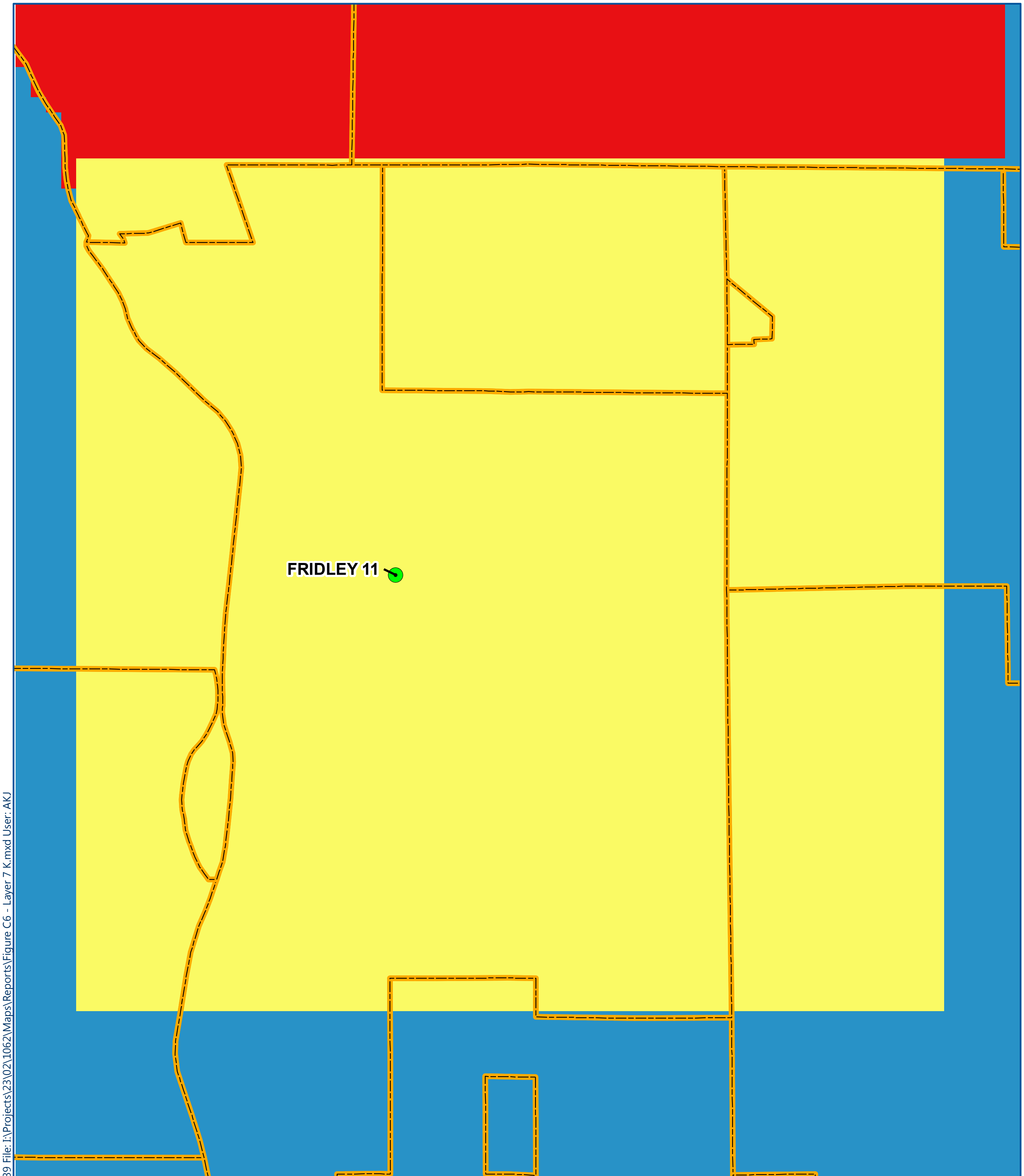
HORIZONTAL HYDRAULIC CONDUCTIVITY (Kx)
MODEL LAYER 4
Fridley WHPP Amendment
City of Fridley, MN

FIGURE C4



HORIZONTAL HYDRAULIC CONDUCTIVITY (Kx)
MODEL LAYER 6
Fridley WHPP Amendment
City of Fridley, MN

FIGURE C5



Fridley Municipal Well Open to Wonewoc Sandstone

Municipal Boundary

Kx7 (m/day)

0.35 - 0.57

2.08

11.1

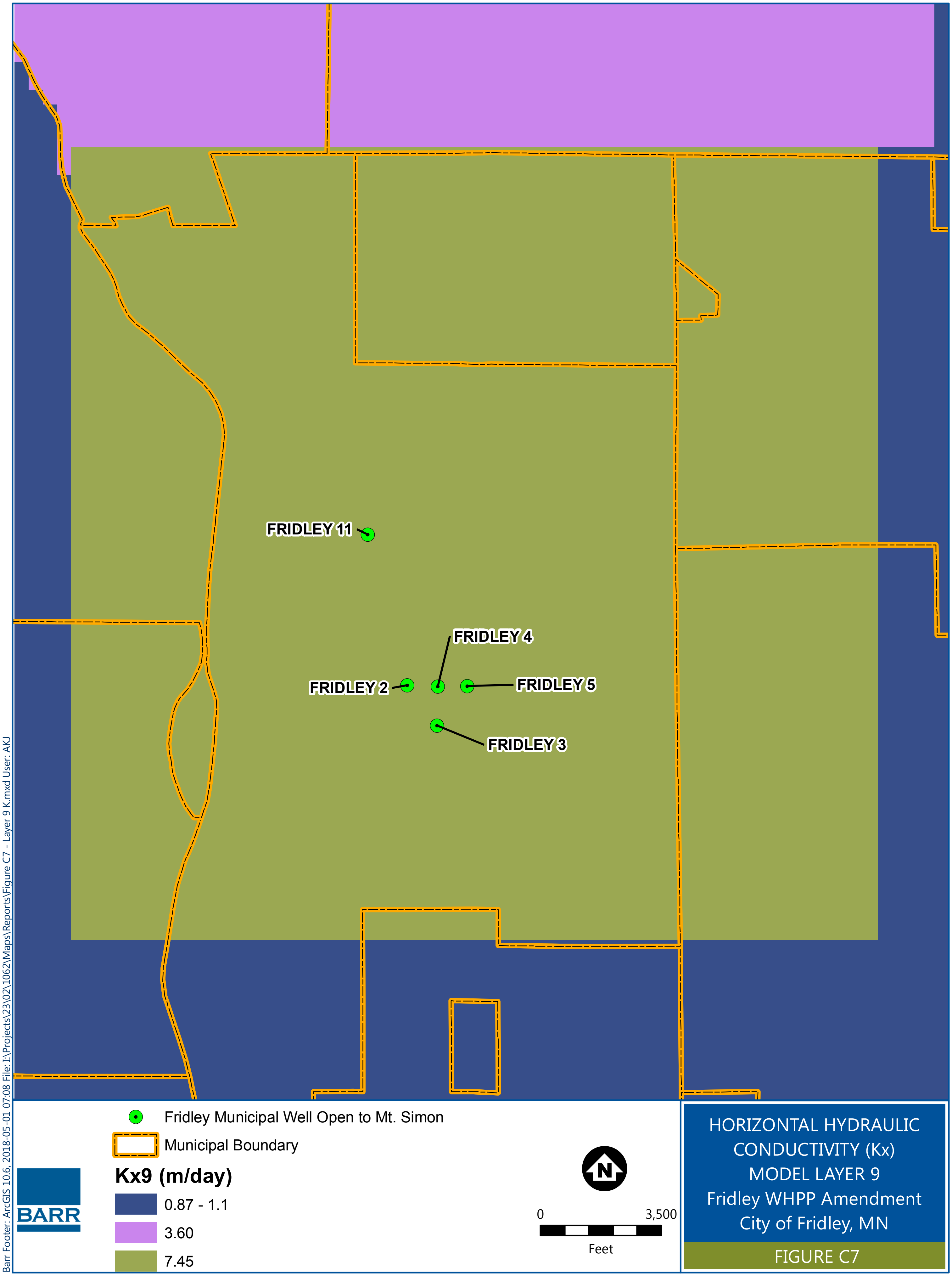
0 3,500

Feet

BARR

HORIZONTAL HYDRAULIC CONDUCTIVITY (Kx)
MODEL LAYER 7
Fridley WHPP Amendment
City of Fridley, MN

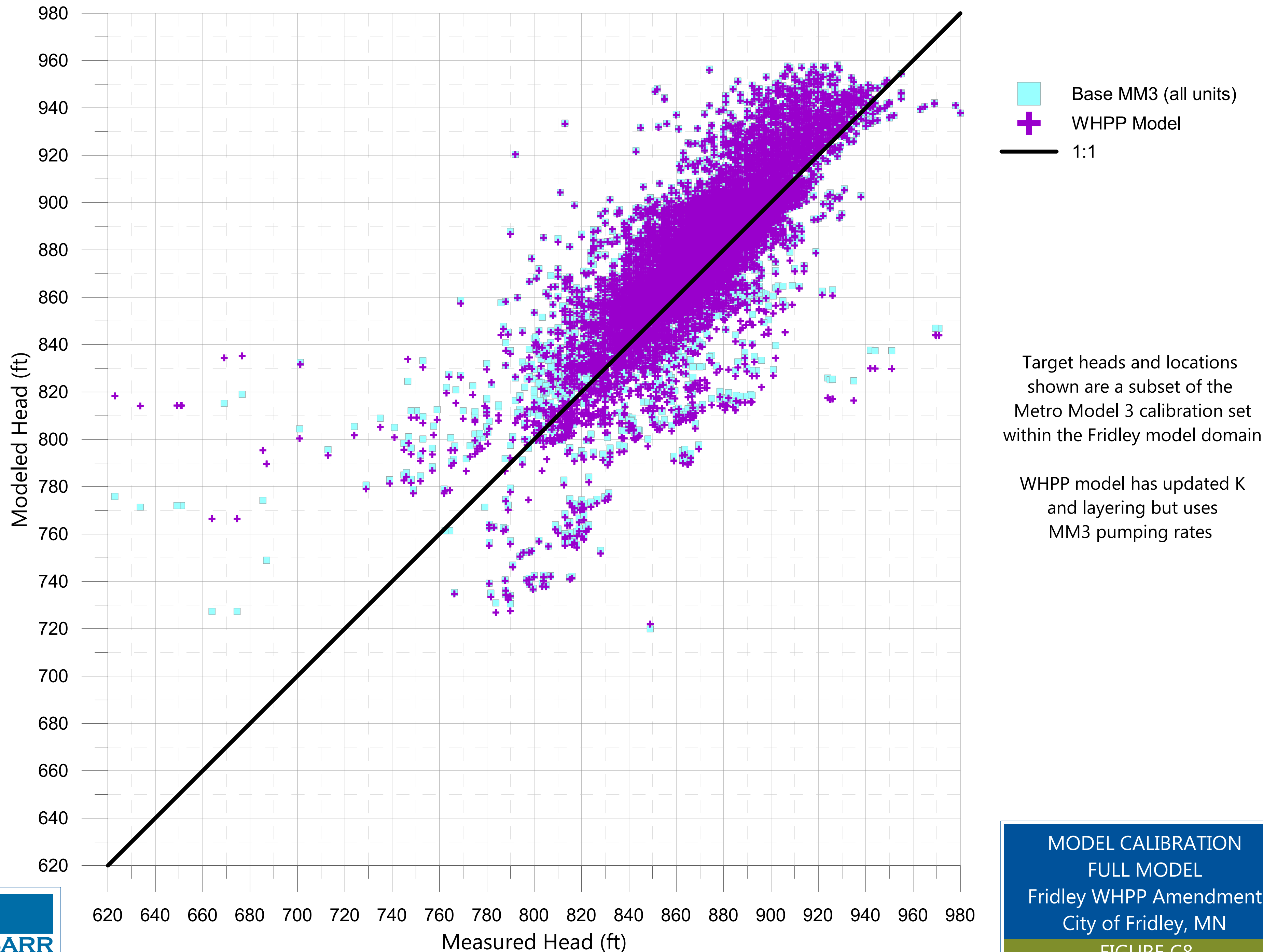
FIGURE C6



HORIZONTAL HYDRAULIC CONDUCTIVITY (Kx) MODEL LAYER 9
Fridley WHPP Amendment
City of Fridley, MN

FIGURE C7

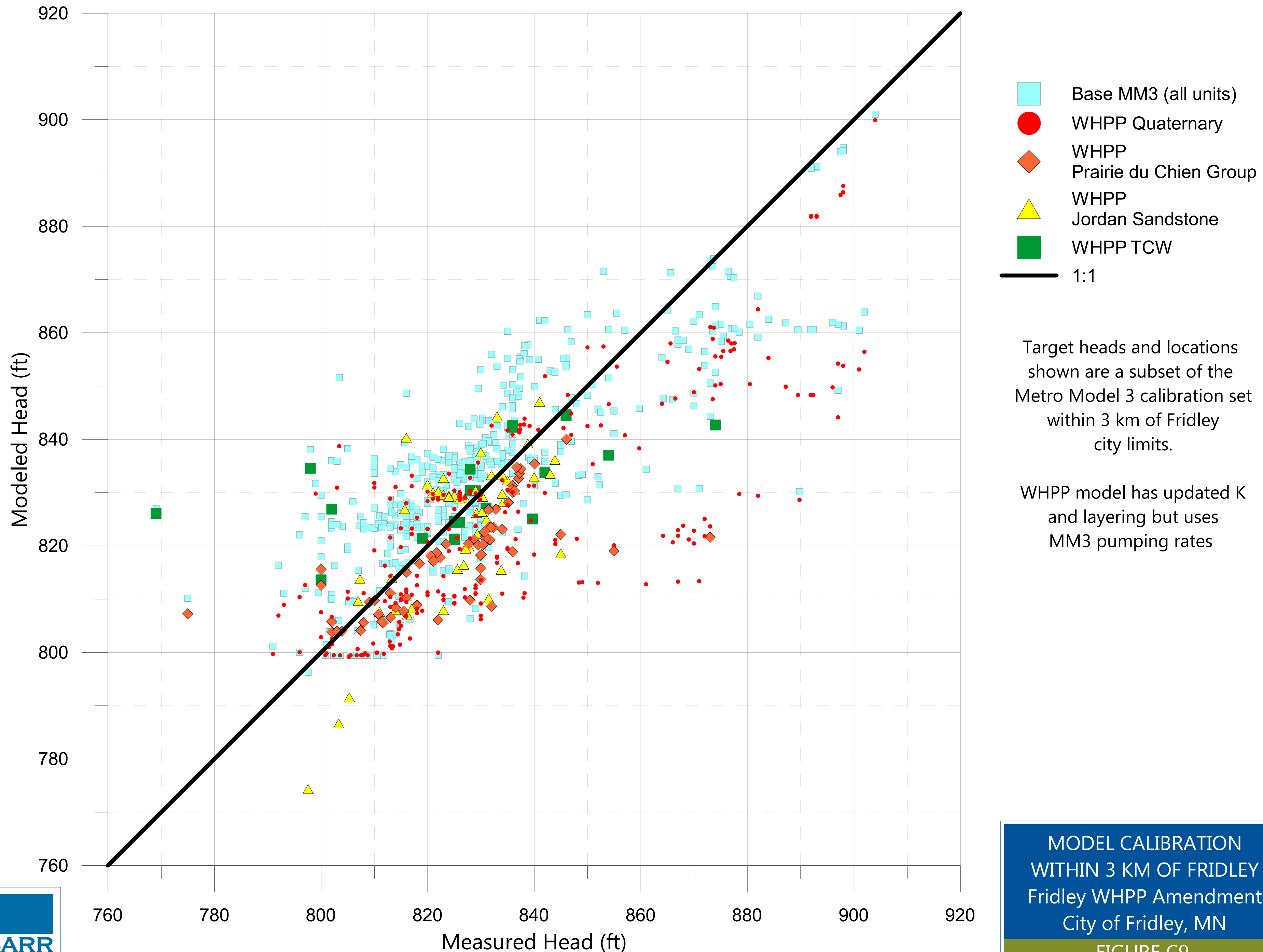
BARR



BARR

MODEL CALIBRATION
FULL MODEL
Fridley WHPP Amendment
City of Fridley, MN

FIGURE C8



Target heads and locations shown are a subset of the Metro Model 3 calibration set within 3 km of Fridley city limits.

WHPP model has updated K and layering but uses MM3 pumping rates

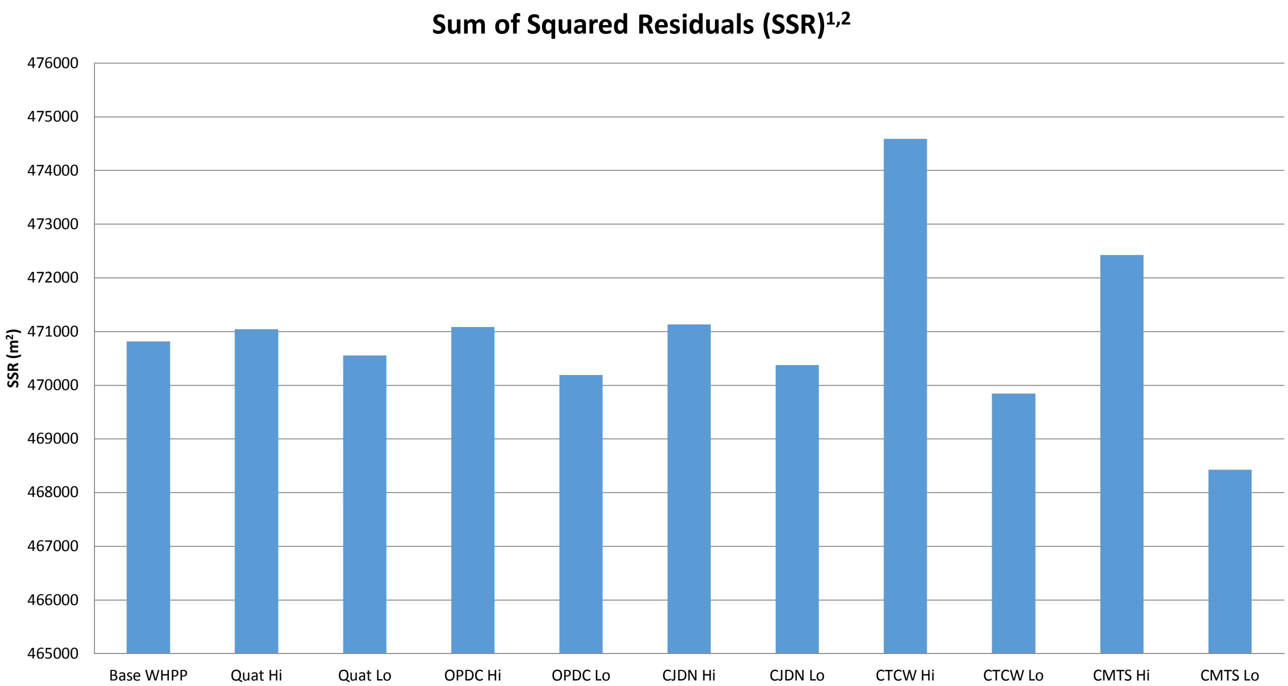
BARR

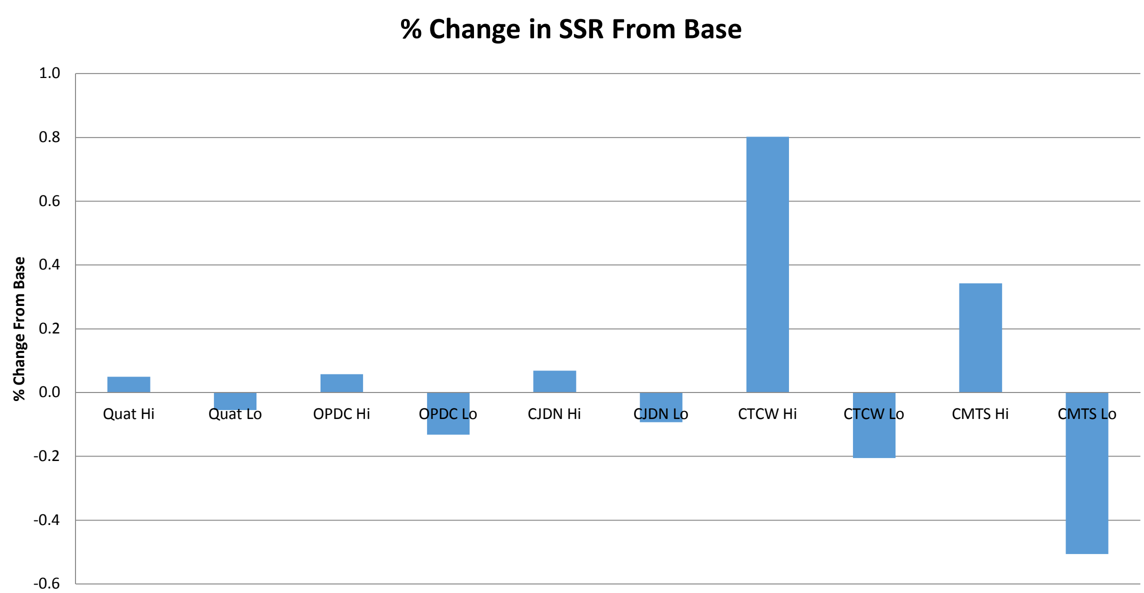
MODEL CALIBRATION
WITHIN 3 KM OF FRIDLEY
Fridley WHPP Amendment
City of Fridley, MN

FIGURE C9

P:\Mpls\23 MN\02\23021062 Fridley WHPP Amendment\WorkFiles\Report\Appendices\Appendix C - Groundwater Model Details\support\Figure C9 - Calibration Comparison_3km.grf

Figure C10
Sensitivity Analysis Results
Fridley WHPP Amendment





Appendix D

Fracture Flow Delineation

OPDC Thicknesses

Well	OPDC Thickness from Log (ft)	Thickness to Use in Delineations (ft)	Thickness to Use in Delineations (m)
Fridley 6	108	123.75	37.7
Fridley 7	134		
Fridley 8	135		
Fridley 9	118		
Fridley 12	72	72	21.9

Combined Wells 6, 7, 8, and 9 Center of Pumping

Well	UTM X	UTM Y	Pumping Rate (m^3/day)
6	479923	4992127	1610
7	480005	4992003	356
8	479984	4991790	2973
9	479875	4991927	1559
Combined	479943.8853	4991918.036	6498

OPDC Contribution to Well 12

Total Well 12 Pumping Rate	3055	m^3/day
Flow from L3 to L4 in Well 12 capture zone	1578.9	m^3/day
Flow from L4 to L3 in Well 12 capture zone	45.559	m^3/day
Net Contribution from OPDC	1533.341	m^3/day
Percentage from OPDC	50.2%	

> 10%, fracture flow delineation required

Combined Wells 6, 7, 8, and 9: 1-Year

Calculation for Fixed Radius with No Upgradient Extension

See method 1 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

Input Variables	
Well Pumping Rate m^3/day	6498
Pumping Period (years)	1
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	37.7

Calculated Fixed Radius (m)	Volume (m^3)
598	42,353,036

$$R = \sqrt{\frac{Q}{nL\pi}}$$

Where:

Q = Well Discharge (L^3)=(Well pumping rate)(pumping time period)

n = effective porosity

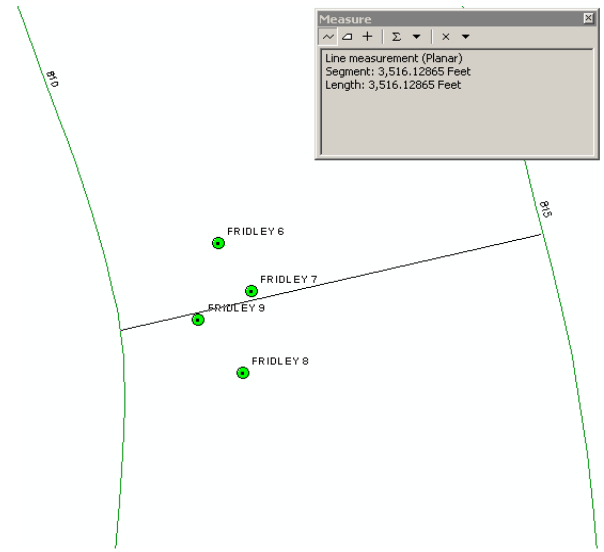
L = thickness of saturated portion of aquifer (L)   note: lesser of open borehole or 200 ft

Combined Wells 6, 7, 8, and 9: 5-Year

Calculation for Ratio of Well Discharge to the Discharge Vector (Q/Qs)

See: Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

If well is open to both a porous media aquifer and a fractured or solution-weathered bedrock aquifer then delineation Technique 3 should be used



Input variables	
Well Discharge, Q (m^3/day)	6498
Well Discharge, Q (gpm)	1192
Aquifer Thickness, H (ft)	124
Aquifer Hydraulic Conductivity K (m/day)	336.00
Hydraulic Gradient, I (ft/ft)	0.0014

Calculated Q/Qs (m)

360

Equation listed in Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

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

Calculation for Fixed Radius with No Upgradient Extension

See method 1 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

Input Variables	
Well Pumping Rate m^3/day	6498
Pumping Period (years)	5
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	37.7

Calculated 5-yr Fixed Radius (m)

1337

Volume (m^3)

211,765,179

$$R = \sqrt{\frac{Q}{nL\pi}}$$

Where:

Q = Well Discharge (L^3/T)=(Well pumping rate)(pumping time period)

n = effective porosity

L = thickness of saturated portion of aquifer (L)   note: lesser of open borehole or 200 ft

Well 12: 1-Year

Calculation for Fixed Radius with No Upgradient Extension

See method 1 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

Input Variables			Calculated Fixed Radius (m)	Volume (m^3)
Well Pumping Rate m^3/day	1533		381	9,994,098
Pumping Period (years)	1			
Effective porosity, n	0.056			
Thickness of saturated portion of aquifer, L (m)	21.9			

$$R = \sqrt{\frac{Q}{nL\pi}}$$

Where:

Q = Well Discharge (L^3)=(Well pumping rate)(pumping time period)

n = effective porosity

L = thickness of saturated portion of aquifer (L)   note: lesser of open borehole or 200 ft

Well 12: 5-Year

Calculation for Ratio of Well Discharge to the Discharge Vector (Q/Qs)

See: Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

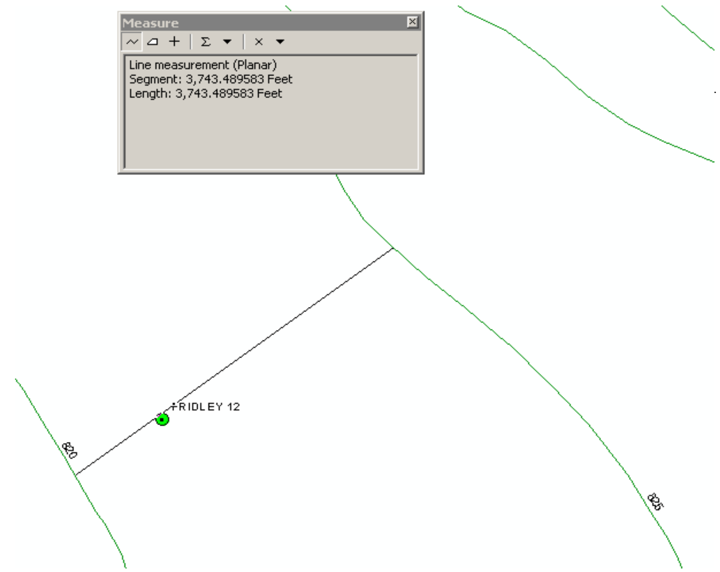
If well is open to both a porous media aquifer and a fractured or solution-weathered bedrock aquifer then delineation Technique 3 should be used

Input variables

Well Discharge, Q (m^3/day)	1533
Well Discharge, Q (gpm)	281
Aquifer Thickness, H (ft)	72
Aquifer Hydraulic Conductivity K (m/day)	336.00
Hydraulic Gradient, I (ft/ft)	0.0013

Calculated Q/Qs (m)

156



Equation listed in Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

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

Calculation for Fixed Radius with No Upgradient Extension

See method 1 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

Input Variables

Well Pumping Rate m^3/day	1533
Pumping Period (years)	5
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	21.9

Calculated 5-yr Fixed Radius (m)

851

Volume (m^3)

49,970,488

$$R = \sqrt{\frac{Q}{nL\pi}}$$

Where:

Q = Well Discharge (L^3/T)=(Well pumping rate)(pumping time period)

n = effective porosity

L = thickness of saturated portion of aquifer (L)   note: lesser of open borehole or 200 ft

Appendix E

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:	1020031	TIER:	2
SYSTEM NAME:	Fridley	WHP RANK:	
WELL NAME:	Well #1	UNIQUE WELL #:	00206685

COUNTY: Anoka TOWNSHIP NUMBER: 30 RANGE: 24 W SECTION: 23 QUARTERS: DCAA

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Tunnel City-Mt.Simon	
DNR Geologic Sensitivity Rating	:	Low	20
L Score	:	0	
Geologic Data From	:	Well Record	
Year Constructed	:	1956	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	389	5
Well Depth	:	925	
Casing grouted into borehole?		Yes	0
Cement grout between casings?		Yes	0
All casings extend to land surface?		Yes	0
Gravel - packed casings?		No	0
Wood or masonry casing?		No	0
Holes or cracks in casing?		No	0
Isolation distance violations?			0
Pumping Rate	:	700	10
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	<1 01/01/1976	0
Maximum tritium detected	:	Unknown	0
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		35
Wellhead Protection Vulnerability Rating	:		NOT VULNERABLE
Vulnerability Overridden	:		

COMMENTS

Low vulnerability rating is based on the presence of the basal St. Peter Sandstone.
Well construction details regarding grout between casings phoned in by John Flora at city of Fridley on 1/26/99.

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:	1020031	TIER:	2
SYSTEM NAME:	Fridley	WHP RANK:	
WELL NAME:	Well #2	UNIQUE WELL #:	00206674

COUNTY: Anoka   TOWNSHIP NUMBER: 30   RANGE: 24 W   SECTION: 14   QUARTERS: DCBB

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Mt. Simon	
DNR Geologic Sensitivity Rating	:	Very low	10
L Score	:	11	
Geologic Data From	:	Well Record	
Year Constructed	:	1960	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	675	0
Well Depth	:	842	
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	:	700	10
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	.3 01/01/1976	0
Maximum tritium detected	:	Unknown	0
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		20
Wellhead Protection Vulnerability Rating	:		NOT VULNERABLE
Vulnerability Overridden	:		

COMMENTS

Very low rating is based on an L-11 score of the combined thicknesses of the St. Lawrence and Eau Claire confining layers.

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: 1020031 TIER: 2
SYSTEM NAME: Fridley WHP RANK:
WELL NAME: Well #3 UNIQUE WELL #: 00206670

COUNTY: Anoka TOWNSHIP NUMBER: 30 RANGE: 24 W SECTION: 14 QUARTERS: DCDD

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Mt. Simon	
DNR Geologic Sensitivity Rating	:	Very low	10
L Score	:	11	
Geologic Data From	:	Well Record	
Year Constructed	:	1961	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	752	0
Well Depth	:	870	
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	:	750	10
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	<.4	0
Maximum tritium detected	:	Unknown	0
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		20
Wellhead Protection Vulnerability Rating	:		NOT VULNERABLE
Vulnerability Overridden	:		

COMMENTS

Very low vulnerability is based on a composite L-11 score from the combined thicknesses of the St. Lawrence and Eau Claire confining layers.

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: 1020031
SYSTEM NAME: Fridley
WELL NAME: Well #4

TIER: 2
WHP RANK:
UNIQUE WELL #: 00201158

COUNTY: Anoka TOWNSHIP NUMBER: 30 RANGE: 24 W SECTION: 14 QUARTERS: DCAA

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Mt. Simon	
DNR Geologic Sensitivity Rating	:	Very low	0
L Score	:	17	
Geologic Data From	:	Well Record	
Year Constructed	:	1961	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	663	0
Well Depth	:	831	
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	:	650	10
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	.1 06/05/1987	0
Maximum tritium detected	:	Unknown	0
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	A	-20
Wellhead Protection Score	:		-10
Wellhead Protection Vulnerability Rating	:		NOT 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:	1020031	TIER:	2
SYSTEM NAME:	Fridley	WHP RANK:	
WELL NAME:	Well #5	UNIQUE WELL #:	00206675

COUNTY: Anoka TOWNSHIP NUMBER: 30 RANGE: 24 W SECTION: 14 QUARTERS: DDBA

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Mt. Simon	
DNR Geologic Sensitivity Rating	:	Very low	0
L Score	:	12	
Geologic Data From	:	Well Record	
Year Constructed	:	1961	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	656	0
Well Depth	:	845	
Casing grouted into borehole?		Yes	0
Cement grout between casings?		Unknown	5
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	:	.3 01/01/1976	0
Maximum tritium detected	:	Unknown	0
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		15
Wellhead Protection Vulnerability Rating	:		NOT 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:	1020031	TIER:	2
SYSTEM NAME:	Fridley	WHP RANK:	
WELL NAME:	Well #6	UNIQUE WELL #:	00206673

COUNTY: Anoka TOWNSHIP NUMBER: 30 RANGE: 24 W SECTION: 14 QUARTERS: DCAB

CRITERIA		DESCRIPTION		POINTS
Aquifer Name(s)	:	Prairie Du Chien-Jordan		
DNR Geologic Sensitivity Rating	:	Medium		25
L Score	:	0		
Geologic Data From	:	Well Record		
Year Constructed	:	1972		
Construction Method	:	Cable Tool/Bored		0
Casing Depth	:	153		10
Well Depth	:	255		
Casing grouted into borehole?		Yes		0
Cement grout between casings?		Not applicable		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	:	1350		20
Pathogen Detected?				0
Surface Water Characteristics?				0
Maximum nitrate detected	:	.1 01/01/1976		0
Maximum tritium detected	:	Unknown		0
Non-THMS VOCs detected?		1,1,2-Trichloroethane	08/12/1989	VULNERABLE
Pesticides detected?				0
Carbon 14 age	:	Unknown		0
Wellhead Protection Score	:			55
Wellhead Protection Vulnerability Rating	:			VULNERABLE
Vulnerability Overridden	:			

COMMENTS

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

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

PWSID: 1020031
SYSTEM NAME: Fridley
WELL NAME: Well #7

TIER: 2
WHP RANK:
UNIQUE WELL #: 00206678

COUNTY: Anoka | TOWNSHIP NUMBER: 30 | RANGE: 24 W | SECTION: 14 | QUARTERS: DCAD

CRITERIA		DESCRIPTION		POINTS
Aquifer Name(s)	:	Prairie Du Chien Group		
DNR Geologic Sensitivity Rating	:	Low		20
L Score	:	3		
Geologic Data From	:	Well Record		
Year Constructed	:	1970		
Construction Method	:	Cable Tool/Bored		0
Casing Depth	:	138		10
Well Depth	:	262		
Casing grouted into borehole?		Unknown		0
Cement grout between casings?		Unknown		5
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	:	700		10
Pathogen Detected?				0
Surface Water Characteristics?				0
Maximum nitrate detected	:	.2 01/01/1976		0
Maximum tritium detected	:	Unknown		0
Non-THMS VOCs detected?		1,1,2-Trichloroethane	08/12/1989	VULNERABLE
Pesticides detected?				0
Carbon 14 age	:	Unknown		0
Wellhead Protection Score	:			45
Wellhead Protection Vulnerability Rating	:			VULNERABLE
Vulnerability Overridden	:			

COMMENTS

Well originally drilled in 1966. Deepened to bedrock in 1970.

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

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

PWSID: 1020031
SYSTEM NAME: Fridley
WELL NAME: Well #8

TIER: 2
WHP RANK:
UNIQUE WELL #: 00206669

COUNTY: Anoka | TOWNSHIP NUMBER: 30 | RANGE: 24 W | SECTION: 14 | QUARTERS: DCDD

CRITERIA		DESCRIPTION		POINTS
Aquifer Name(s)	:	Prairie Du Chien Group		
DNR Geologic Sensitivity Rating	:	High		VULNERABLE
L Score	:	0		
Geologic Data From	:	Well Record		
Year Constructed	:	1969		
Construction Method	:	Cable Tool/Bored		0
Casing Depth	:	138		10
Well Depth	:	265		
Casing grouted into borehole?		Unknown		0
Cement grout between casings?		Unknown		5
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	:	1400		20
Pathogen Detected?				0
Surface Water Characteristics?				0
Maximum nitrate detected	:	.2 08/12/1989		0
Maximum tritium detected	:	Unknown		0
Non-THMS VOCs detected?		1,1,2-Trichloroethane	08/12/1989	VULNERABLE
Pesticides detected?				0
Carbon 14 age	:	Unknown		0
Wellhead Protection Score	:			35
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: 1020031 | TIER: 2
SYSTEM NAME: Fridley | WHP RANK:
WELL NAME: Well #9 | UNIQUE WELL #: 00206672

COUNTY: Anoka | TOWNSHIP NUMBER: 30 | RANGE: 24 W | SECTION: 14 | QUARTERS: DCBD

CRITERIA		DESCRIPTION		POINTS
Aquifer Name(s)	:	Prairie Du Chien-Jordan		
DNR Geologic Sensitivity Rating	:	Low		20
L Score	:	0		
Geologic Data From	:	Well Record		
Year Constructed	:	1972		
Construction Method	:	Cable Tool/Bored		0
Casing Depth	:	145		10
Well Depth	:	262		
Casing grouted into borehole?		Unknown		0
Cement grout between casings?		Unknown		5
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	:	1350		20
Pathogen Detected?				0
Surface Water Characteristics?				0
Maximum nitrate detected	:	.2 01/01/1976		0
Maximum tritium detected	:	Unknown		0
Non-THMS VOCs detected?		1,1,2-Trichloroethane	08/12/1989	VULNERABLE
Pesticides detected?				0
Carbon 14 age	:	Unknown		0
Wellhead Protection Score	:			55
Wellhead Protection Vulnerability Rating	:			VULNERABLE
Vulnerability Overridden	:			

COMMENTS

Low rating is based on the presence of the basal St. Peter confining layer.

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P.O. Box 64975 St. Paul MN 55164 - 0975

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

PWSID: 1020031
SYSTEM NAME: Fridley
WELL NAME: Well #10

TIER: 2
WHP RANK:
UNIQUE WELL #: 00206658

COUNTY: Anoka   TOWNSHIP NUMBER: 30   RANGE: 24 W   SECTION: 11   QUARTERS: CDCC

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Quaternary Buried Artesian Aquifer	
DNR Geologic Sensitivity Rating	:	Low	20
L Score	:	2	
Geologic Data From	:	Well Record	
Year Constructed	:	1969	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	128	10
Well Depth	:	199	
Casing grouted into borehole?		Yes	0
Cement grout between casings?		Yes	0
All casings extend to land surface?		Yes	0
Gravel - packed casings?		No	0
Wood or masonry casing?		No	0
Holes or cracks in casing?		No	0
Isolation distance violations?			0
Pumping Rate	:	700	10
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	<.4	0
Maximum tritium detected	:	6.5 11/04/1999	VULNERABLE
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		40
Wellhead Protection Vulnerability Rating	:		VULNERABLE
Vulnerability Overridden	:		

COMMENTS

Well construction details regarding presence of grout between casings and absence of holes or cracks in casing, in addition to absence of isolation distance violations phoned in by John Flora of city of Fridley on 1/26/99.

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: 1020031 TIER: 2
SYSTEM NAME: Fridley WHP RANK:
WELL NAME: Well #11 UNIQUE WELL #: 00206657

COUNTY: Anoka TOWNSHIP NUMBER: 30 RANGE: 24 W SECTION: 11 QUARTERS: CDCC

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan-Mt.Simon	
DNR Geologic Sensitivity Rating	:	Low	20
L Score	:	1	
Geologic Data From	:	Data Inferred From Nearby Wells	
Year Constructed	:	1970	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	325	5
Well Depth	:	669	
Casing grouted into borehole?		Yes	0
Cement grout between casings?		Unknown	5
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	:	750	10
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	<.4	0
Maximum tritium detected	:	1.1 04/23/1997	VULNERABLE
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		40
Wellhead Protection Vulnerability Rating	:		VULNERABLE
Vulnerability Overridden	:		

COMMENTS

Low vulnerability rating is based on the geologic log of well #10 (206658).

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: 1020031
SYSTEM NAME: Fridley
WELL NAME: Well #12

TIER: 2
WHP RANK:
UNIQUE WELL #: 00209207

COUNTY: Anoka | TOWNSHIP NUMBER: 30 | RANGE: 24 W | SECTION: 12 | QUARTERS: BDCC

CRITERIA		DESCRIPTION		POINTS
Aquifer Name(s)	:	Jordan		
DNR Geologic Sensitivity Rating	:	Very low		15
L Score	:	5		
Geologic Data From	:	Public Water File		
Year Constructed	:	1970		
Construction Method	:	Cable Tool/Bored		0
Casing Depth	:	234		5
Well Depth	:	276		
Casing grouted into borehole?		Yes		0
Cement grout between casings?		Yes		0
All casings extend to land surface?		Yes		0
Gravel - packed casings?		No		0
Wood or masonry casing?		No		0
Holes or cracks in casing?		No		0
Isolation distance violations?				0
Pumping Rate	:	1200		20
Pathogen Detected?				0
Surface Water Characteristics?				0
Maximum nitrate detected	:	.38 05/20/2014		0
Maximum tritium detected	:	Unknown		0
Non-THMS VOCs detected?		Xylenes	01/26/1999	VULNERABLE
Pesticides detected?				0
Carbon 14 age	:	Unknown		0
Wellhead Protection Score	:			40
Wellhead Protection Vulnerability Rating	:			VULNERABLE
Vulnerability Overridden	:			

COMMENTS

Well construction details regarding drilling method, presence of grout around borehole and between casings, and absence of holes or cracks in casing and isolation distance violations phoned in by John Flora of the city of Fridley on 1/26/99. Vulnerable status based on tritium result from nearby well 206657 (Fridley Well No. 11).

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: 1020031
SYSTEM NAME: Fridley
WELL NAME: Well #13

TIER: 2
WHP RANK:
UNIQUE WELL #: 00206696

COUNTY: Anoka | TOWNSHIP NUMBER: 30 | RANGE: 24 W | SECTION: 27 | QUARTERS: BADC

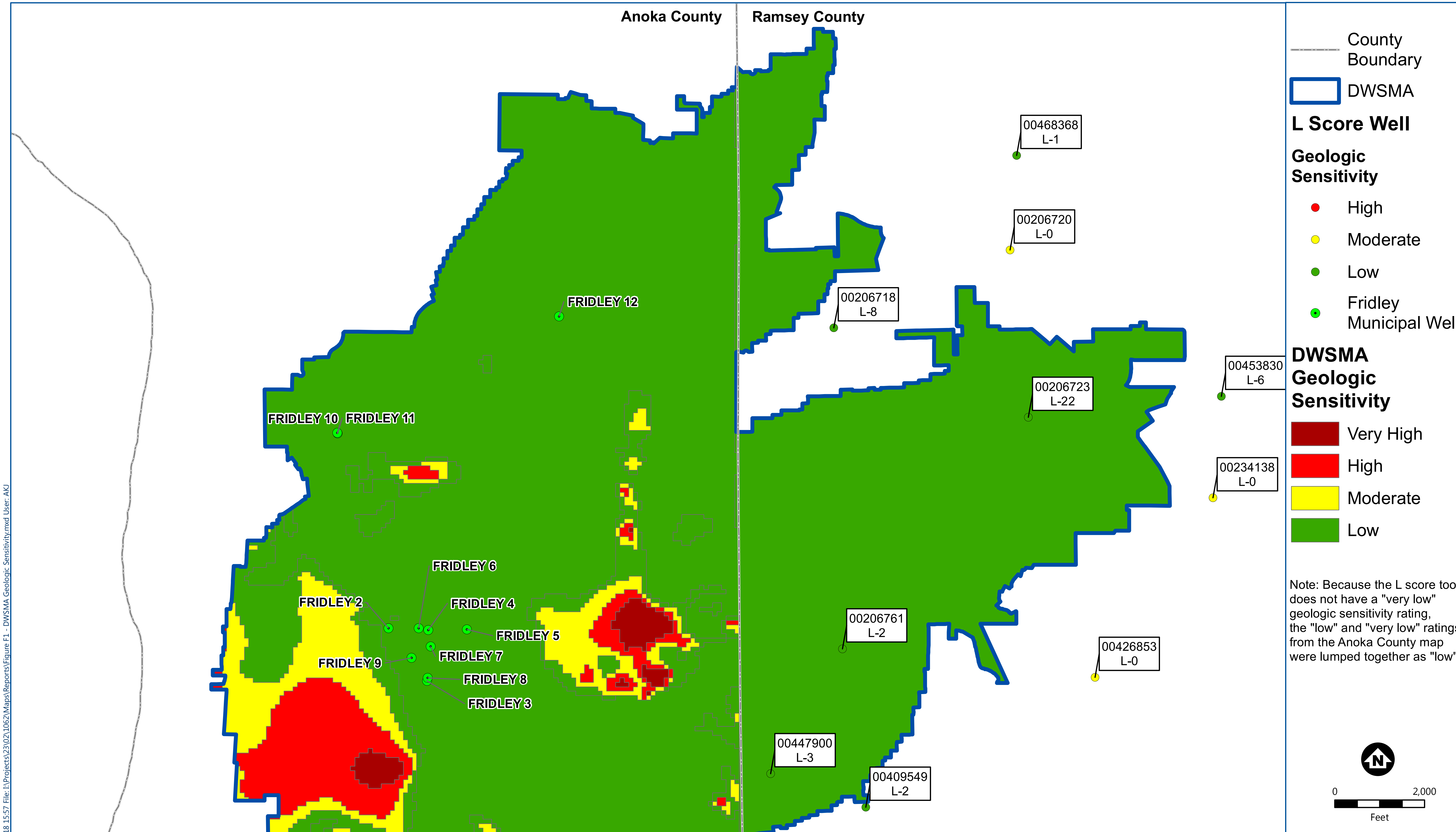
CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Prairie Du Chien-Jordan	
DNR Geologic Sensitivity Rating	:	High	0
L Score	:	0	
Geologic Data From	:	Well Record	
Year Constructed	:	1970	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	191	10
Well Depth	:	332	
Casing grouted into borehole?		Yes	0
Cement grout between casings?		Yes	0
All casings extend to land surface?		Yes	0
Gravel - packed casings?		No	0
Wood or masonry casing?		No	0
Holes or cracks in casing?		No	0
Isolation distance violations?			0
Pumping Rate	:	825	10
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	<.4	0
Maximum tritium detected	:	5.9 01/01/1999	VULNERABLE
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		20
Wellhead Protection Vulnerability Rating	:		VULNERABLE
Vulnerability Overridden	:		

COMMENTS

Well construction details regarding presence of grout between casings and absence of holes or cracks in casing and isolation distance violations phoned in by John Flora of the city of Fridley on 1/26/99.

Appendix F

Aquifer Vulnerability Supporting Information



DWSMA GEOLOGIC SENSITIVITY
Fridley WHPP Amendment
City of Fridley, MN

FIGURE F1

BARR

Appendix G

Groundwater Model Files and GIS Shapefiles