SUMMARY OF RELEVANT HISTORICAL DATA PERTAINING TO GROUNDWATER AND SURFACE WATER INTERACTIONS WITHIN AN UNNAMED TRIBUTARY OF HONEY CREEK AND A PORTION OF HONEY CREEK

SCIO TOWNSHIP, WASHTENAW COUNTY, MICHIGAN

PREPARED
FOR

GELMAN SCIENCES, INC.

March 2019
Project No.806500

FLEIS&VANDENBRINK
DESIGN. BUILD. OPERATE.

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LIST OF FIGURES, TABLES AND APPENDICIES

LIST OF ABBREVIATIONS/ACRONYMS

amsl	Above Mean Sea Level
bgl	Below Ground Level
bgs	Below Ground Surface
cfs	Cubic Feet Per Second
cfm	Cubic Feet Per Minute
ft	Feet
F&V	Fleis & VandenBrink
GSI	Groundwater Surface Water Interface
HC	Honey Creek
HCT	Honey Creek Tributary (or Unnamed Tributary)
MDEQ	Michigan Department of Environmental Quality
NPDES	National Pollution Discharge Elimination System
NREPA	Natural Resources and Environmental Protection Act
ppb	Parts Per Billion (also shown as ug/L)
RRD	Remediation and Redevelopment Division of the MDEQ
USEPA	United States Environmental Protection Agency
USGS	U.S. Geological Survey

1.0 INTRODUCTION

The Gelman Sciences Inc (Gelman) site in Scio Township of Washtenaw County is located along an unnamed tributary of Honey Creek (HC). For the purposes of this report and to be consistent with historical references, this tributary will be referred to as the Honey Creek Tributary (HCT). The HCT flows from the Gelman site area into Little Lake, and it continues to where it merges with HC. HC then flows east-northeast to the Huron River. The former Gelman property area, the HCT and HC are shown on Figure 1.

1,4-Dioxane-containing groundwater related to the Gelman site may discharge into portions of the HCT and HC. In addition, Gelman has a National Pollutant Discharge Elimination System (NPDES) permit to discharge treated groundwater into the HCT. The current permit allows for discharge of up to 1,300 gallons per minute (gpm); the average daily discharge volume during 2017 was approximately 476 gpm and approximately 482 gpm in 2018. The permit limit for 1,4-dioxane is 7 ug/L (monthly average); the average monthly concentration discharged in 2017 was 5.4 ug/L and 5.6 ug/L in 2018

This document presents a conceptual understanding for hydrological interactions between groundwater and surface water within the HCT/HC drainage system and summarizes historical data for the HCT/HC system as it relates to the hydrogeology of the HCT/HC. It also addresses the potential for 1,4-dioxane related to the Gelman site in surface water to impact Barton Pond, a drinking water source for the City of Ann Arbor (City).

2.0 HYDROLOGIC SETTING

Honey Creek is a small tributary to the Huron River, which drains approximately 20 square miles west of the City. HC, when including intermittent upper reaches, is approximately nine (9) miles long and has a total elevation change of approximately 160 feet. There are two principal branches of HC: an east branch and a west branch. These branches converge just north of I-94 (Section 22, Scio Twp.). The watershed areas for the HCT and the HC are shown on Figure 2.

The HCT drains approximately eight (8) square miles of land surface. The HCT originates in the First and Second Sister Lakes region and flows west-northwest approximately 9,975 feet to its convergence with the U of M Lake Drain. From this point, it flows an additional 2,515 feet to its confluence with the HC. The elevation drop in the HCT through this region is approximately 60 feet, resulting in a hydraulic gradient of approximately 0.005.

For this project, relevant portions of the HCT and HC are divided into five (5) reaches, which are shown on Figure 3 as Reaches A, B, C, D and E. Also shown on this figure are monitoring wells in the vicinity of the Reaches.

Flow in HC and its tributaries has been evaluated by the Michigan Department of Environmental Quality (MDEQ), Gelman, the United States Geological Survey (USGS) and others (Mendelson et al). For the flow calculations included in this report, we primarily relied on stream flow measurements that were collected by the USGS on September 10, 2003. This data set was chosen because it had the lowest flows and was believed to be most representative of base flow. The USGS flow measurement locations are shown on Figure 4. The data, along with the entire USGS report that included the data, are provided in Appendix 1. Please note that at the time these data were collected, Gelman would have been discharging approximately 1,126 gpm of treated water into the HCT/HC via their NPDES discharge. This flow has been reduced over time and is currently approximately 476 gpm.

3.0 SUBSURFACE CONDITIONS

3.1 Hydrogeology (General Setting)

The HCT/HC are underlain by glacial deposits ranging in thickness from 150 to 180 feet. Descriptions of these deposits are presented in several historical reports for the Gelman site, the most relevant being the PLS report titled *Hydrogeological Investigation of the Little Lake Area System and Portions of the Honey Creek Corridor, March 4, 2015*.

Surface water levels in the HCT have been periodically collected, with the most comprehensive set of measurements collected by Gelman in 1999. Groundwater elevation data are routinely collected by Gelman. Time-series plots comparing groundwater and surface water elevation data are presented as Appendix 2. Wells used in this analysis are shown on Figure 5.

The surface water elevations of the HCT are shown relative to the most recent potentiometric surface elevation map for the uppermost regional aquifer on Figure 5. For example, near the Marshy Area, the HCT is at an elevation of approximately 903 ft above mean sea level (amsl). The upper regional aquifer in this area (associated with historical high levels of 1,4-dioxane in the former Redskin Well and MW-2) has a hydraulic head of approximately 887 feet amsl, which is approximately 18 feet below the level of the HCT. Hydrological interactions in this area are discussed later in this report (5.1 Reach A - Marshy Area to Aprill Drive).

Interaction between the HCT and HC and the uppermost regional aquifers only occurs where the HCT is low enough in elevation to intersect with the aquifer. This condition occurs in areas downgradient of Little Lake and west of the Gelman property, primarily within Reaches C, D and E where 1,4-dioxane concentrations in the groundwater are significantly lower and have been decreasing over time. The majority of the 1,4-dioxane associated with the Gelman site is contained in the deeper aquifers that do not interact with the HCT. The deeper aquifers in the area of the Gelman property where high concentrations of 1,4-dioxane have been observed have potentiometric surfaces that are well below the HCT and therefore are not discussed in this report.

The hydrologic relationship between the HTC/HC and groundwater containing 1,4-dioxane is discussed further in Section 5.

4.0 1,4 DIOXANE TRENDS IN SURFACE AND GROUNDWATER

4.1 Surface Water 1,4-Dioxane Trends

Gelman and others have collected surface water samples from the HCT and HC for analysis of 1,4-dioxane, starting as early as 1986. These data are provided in a table in Appendix 3 and the samples locations are shown on Figure 6.

The presence of 1,4-dioxane in surface water in the HCT/HC may be associated with four (4) primary processes: 1) the venting (discharge) of groundwater containing 1,4-dioxane, 2) surface water runoff containing 1,4-dioxane, 3) discharge of treated groundwater by Gelman and 4) 1,4-dioxane in the HCT/HC attributable to other non-Gelman sources.

1,4-Dioxane trends in the HCT/HC have been downward over time. The highest observed 1,4-dioxane levels in surface water were observed in the earliest samples (270 ug/L, HCT-2, 10/25/1989). 1,4-Dioxane concentrations measured in surface water in September 2018 are all less than 5.2 ug/L, with the highest concentration (5.2 ug/L) measured at the Gelman outfall. It is important to note that the early surface water sampling data preceded Gelman’s NPDES discharge of treated groundwater, which represents a source of dilution water.

Surface water samples have been collected near the confluence of the HC and Huron River since 1987. Concentrations of 1,4-dioxane in these samples has ranged between non-detect (<1 ug/L) and 7 ug/L. The most recent sample from HC near the confluence of the Huron River was collected by MDEQ on September 18, 2018 and analyzed for 1,4-dioxane. This sample was taken at a time of year typically associated with near baseflow conditions. The 1,4-dioxane concentration in the sample was non-detect (<1 ug/L).

4.2 Groundwater 1,4-Dioxane Trends

Gelman has routinely collected groundwater samples from monitoring wells along the HCT/HC since the mid-1980s. Trend graphs for representative wells in each reach are provided in Appendix 4. Please refer to Figure 3 for well locations. If the data were not conducive to developing trend graphs, data tables are provided in lieu of graphs.

1,4-Dioxane concentrations in groundwater in all the reaches have declined since monitoring was initiated. The relevancy of groundwater trends in each reach is discussed below.

5.0 REACH DESCRIPTIONS

Four (4) reaches of the HCT and one (1) reach of HC are described below. Flow information for each reach has been evaluated using the USGS 2003 flow measurements provided in Table 1.

5.1 Reach A - Marshy Area to Aprill Drive

The Marshy Area refers to a wetland on the north side of the property owned by Gelman. The northern border of the Marshy Area is the HCT. Numerous investigations have been conducted and multiple monitoring wells have been installed to monitor groundwater conditions in the Marshy Area. Additionally, a groundwater extraction well, PW-1, has been operated in the Marshy Area since 1994. Operation of this extraction well along with natural processes have substantially reduced 1,4-dioxane levels in Marshy Area groundwater.

The subsurface in the Marshy Area consists of peat underlain by marl and other fine- to coarse-grained deposits. Because of its high porosity and low permeability, the peat and other fine-grained deposits contain 1,4-dioxane in groundwater associated with a historical release to the Marshy Area.

The HCT is stagnant or has intermittent flows where it borders the Marshy Area. Gelman's NPDES Outfall 0001 is present in Reach A, downgradient of the Marshy Area. The discharge of treated groundwater increases surface water elevations within the HCT upstream of the Gelman NPDES discharge into the Marshy Area, which elevates the hydraulic head in the HCT. Comparisons of water levels in the HCT and groundwater elevations in the Marshy Area indicate that the tributary is primarily an influent stream (contributes surface water to the zone of saturation) in the Marshy Area.

The flux of groundwater from the Marshy Area to the HCT is little to none due to the low permeability of the peat and consistently downward vertical hydraulic gradients measured in this area. However, USGS flow measurements collected during a low-flow period in 2003 suggest that during very dry periods, groundwater can discharge to surface water in the Marshy Area at a rate of approximately 30 gpm (calculations provided in Table 1), which represents a worst-case scenario.

Historically, 1,4-dioxane levels in groundwater sampled from the Marshy Area have been as high as 202,000 ug/L. Gelman has been operating an extraction well (PW-1) in the Marshy Area since 1994. Operation of this extraction well along with natural processes have substantially reduced 1,4-dioxane levels in Marshy Area groundwater. Recent 1,4-dioxane concentrations in groundwater sampled from Gelman monitoring wells in the Marshy Area are less than 6,000 ug/L. Operation of the extraction well has also helped to reduce the already limited flux of groundwater from the Marshy Area to the HCT.

West of the Marshy Area in this reach, shallow water-bearing zones do not appear to discharge to the HCT, based on comparison of groundwater and surface water elevation data (Appendix 2). An example of a monitoring well completed in the shallow water-bearing zone/aquifer is MW-11s. Hydraulic heads at MW-11s are lower than those in the HCT, as shown below, indicating that groundwater does not discharge to surface water in this area. In addition, shallow groundwater elevations are higher than those in deeper groundwater zones, indicating that hydraulic gradients are conducive to downward vertical groundwater migration, not upward migration and discharge to surface water (see table below). The shallowest water-bearing zones in this reach overlie more substantial aquifers that are primarily associated with the transport of 1,4-dioxane.

Screen Interval (feet below ground)		Groundwater Elevation (feet amsl)
MW-11s	14-16	898.33
MW-11i	39-41	885.99
MW-11d	87-90	878.74

- Water level data collected 9/20/17.
- HCT Elevation in this area approximately = approximately 902.5 ft amsl

Because of this downward hydraulic potential, the lateral movement of groundwater is competing with a downward flow potential. This strong downward flow potential minimizes the lateral flow of groundwater in the shallow water bearing zones toward the HCT.

Some minor venting of groundwater into the HCT on the Gelman site along the north/south portion of the HCT and the northern border of the Marshy Area is possible. 1,4-Dioxane concentrations in wells in this area indicate 1,4-dioxane concentrations in this area exceed 280 ug/L. It is also possible that transient 1,4-dioxane surface water in the Marshy Area could discharge into the HCT. If the GSI criteria for the Gelman site were to change from 2,800 ug/L to 280 ug/L, additional investigations may be necessary in Reach A to understand GSI compliance.

5.2 Reach B – Aprill Drive to Exit of Little Lake

Reach B includes a portion of the HCT that flows into Little Lake, all of which is "perched" above the regional aquifer, as shown on Figure 5 and on time-series plots included in Appendix 2. Little Lake has an elevation of approximately 895.5 feet amsl, and the underlying aquifer has an elevation of approximately 883 feet amsl (Figure 5). A test boring drilled on the northwest side of Little Lake as part of the shallow groundwater investigation (RL-25) demonstrated that there are unsaturated soils adjacent to the lake to a depth of 20 feet below ground level (the boring was drilled to an elevation of 891.74 feet amsl), further supporting the interpretation that Little Lake (and some areas downstream of Little Lake) is a losing water body.

USGS flow measurements collected during a low-flow period in 2003 suggest that during very dry periods, groundwater can discharge to surface water within portions of Reach B at a rate of approximately 130 gpm (calculations provided in Table 1), which likely represents a worst-case scenario.

Time-series plots showing 1,4-dioxane concentrations in groundwater wells located near Reach B are presented in Appendix 4. Review of these data demonstrates that it is unlikely that any 1,4-dioxane-impacted groundwater into Reach B would vent to the HCT at concentrations in excess of 280 ug/L, the current Part 201 GSI criterion. This is not an area where Gelman anticipates the need for further evaluation of a potential GSI pathway.

5.3 Reach C – Exit of Little Lake to Park Road

As shown on Figure 5, surface water elevations are significantly higher than groundwater elevations in the eastern part of Reach C, but a reversal in the relative elevations occurs in the western portion of this reach. Springs are present on the property owned by the Huron Valley Swim Club, which suggests that groundwater may discharge to surface water within this reach of the HCT. Flow measurements representative of the base flow (groundwater-derived) conditions were collected along the portion of the HCT where springs have been noted during a very dry period in the Fall of 1988 (flow measurements collected by Gelman consultants). Flow data indicate approximately 15 gpm (HTI-3, 9/1/98) of groundwater was discharged into the HCT within this reach. However, USGS flow measurements collected during a low-flow period in 2003 suggested a loss of surface water flow of approximately 256 gpm within this reach (calculations provide in Table 1). Thus, despite the change in vertical hydraulic gradients from east to west along this reach and the presence of springs, little groundwater discharges to surface water within Reach C.

There are no shallow monitoring wells located in close proximity to Reach C, but interpolation of 1,4-dioxane concentrations from wells located around this reach suggests that it is unlikely that any discharges of 1,4-dioxane-impacted groundwater into Reach C would vent into the creek at concentrations in excess of 280 ug/L, the current Part 201 GSI criterion. This is not an area where Gelman anticipates the need for further evaluation of a potential GSI pathway.

5.4 Reach D – Park Road to HC

Reach D is characterized by artesian conditions, as demonstrated on Figure 5 and in time-series plots included in Appendix 2. This reach also included the Artesian Well Area. The Artesian Well Area is located on the north bank of the HCT (see attached figures). In the 1980s, there were three individual flowing artesian wells in this area. Two of the wells were used by contractors for dewatering during the installation of a sanitary sewer on the south side of Jackson Road. The other well was a landscape feature owned by a private land owner. Eventually, these wells were abandoned by others, but the boreholes were not plugged. The former boreholes continue to discharge groundwater along the HCT bank with little remnants of the former well locations.

USGS flow measurements collected during a low-flow period in 2003 suggest the groundwater contribution to surface water in this reach is approximately 195 gpm (calculations provided in Table 1). This is the first reach of the HCT where it appears likely that groundwater consistently discharges to surface water.

The distribution and concentrations of 1,4-dioxane in groundwater in this area have been very well investigated as part of the Gelman Little Lake investigations (*Hydrogeological Investigation of the Little Lake Area System and Portions of the Honey Creek Corridor, March 4, 2015*). 1,4-Dioxane is present in groundwater in a plume extending from approximately Little Lake to HC. Years of groundwater monitoring (beginning in the mid-1980s) has demonstrated this plume has an overall decaying trend. Time-series plots showing 1,4-dioxane concentrations in groundwater wells located near Reach D are presented in Appendix 4. Review of these data demonstrates that it is not possible for discharges of 1,4-dioxane-impacted groundwater into Reach D to vent into the creek would vent into the creek at concentrations in excess of 280 ug/L, the current Part 201 GSI criterion. This is not an area where Gelman anticipates further evaluation of a potential GSI pathway.

5.5 Reach E – Honey Creek to Dexter Road

Access to HC in this area is very difficult due to wetlands and the lack of roads. As such, no borings or wells have been installed along HC to collect empirical data. USGS flow measurements collected during a low-flow period in 2003 suggest the groundwater contribution in this reach is approximately 300 gpm (calculations provided in Table 1).

Time-series plots showing 1,4-dioxane concentrations in groundwater wells located near Reach E are presented in Appendix 2. Review of these data demonstrates that it is very unlikely that any discharges of 1,4-dioxane-impacted groundwater into Reach E would vent into the creek at concentrations in excess of 280 ug/L, the current Part 201 GSI criterion. This is not an area where Gelman anticipates further evaluation of a potential GSI pathway.

6.0 GSI AND PROTECTION OF SURFACE WATER-BASED DRINKING WATER SOURCES

Under base flow conditions, HC discharges approximately 5.85 cfs of water into Barton Pond (USGS flow data – Appendix 1). Historical flow data for the Huron River for gauges at Dexter and Ann Arbor are provided in Appendix 5. Significant dilution occurs when the Honey Creek flows mix with the flow in the Huron River.

1,4-Dioxane is not being detected at the confluence of the HC and the Huron River. Surface water samples have been collected near the confluence since 1987. Concentrations of 1,4-dioxane in these samples has ranged between non-detect (<1 ug/L) and 7 ug/L. The most recent sample from HC near the confluence of the Huron River was collected by MDEQ on September 18, 2018 and analyzed for 1,4-dioxane. This sample was taken at a time of year typically associated with near baseflow conditions. Nevertheless, the 1,4-dioxane concentration in the sample was non-detect (<1 ug/L).

The City's drinking water intake is routinely monitored for 1,4-dioxane. Gelman obtained data from the City for the period April 13, 1992 to November 8, 2016. These data are provided in Appendix 6. According to the City, the samples are collected at the intake sampling location. In November of 2014, the City began using USEPA method 522 which allows for a Method Detection Limit (MDL) of 0.07 ug/L (vs. 1 ug/L). No 1,4-dioxane was detected in the City intake water during this 24-year monitoring period.

The City continues to routinely collect samples from their intake and analyze them for 1,4-dioxane. The concentrations of 1,4-dioxane have remained below the 0.07 ug/L MDL. The City sampled the intake and treated water on February 6, 2019 and analyzed both samples for 1,4-dioxane. The lab used in the analysis reported results below the MDL of 0.070 ug/L. The lab apparently estimated concentrations 1,4-dioxane in water sampled from the City intake to be 0.061 ug/L, and 0.03 ug/L in the treated drinking water.

No relationship has been established between 1,4-dioxane in the HCT/HC and the trace levels of 1,4-dioxane apparently detected in water sampled from the City intake and treated water. No “upset conditions” with regard to Gelman’s permitted discharge or other circumstances associated with the Gelman site that might have increased the amount of 1,4-dioxane in the HC prior to the reported Barton Pond detection are known to have occurred.

The continued absence of 1,4-dioxane at concentrations above detectable levels in water sampled from the drinking water intake is evidence that the small amount of 1,4-dioxane mass entering the HCT/HC from the Gelman site is not impacting the Ann Arbor drinking water that is derived from the Huron River.

1,4-Dioxane concentration trends in both groundwater and the HCT/HC have declined substantially since monitoring began in the mid-1980s as a result of the substantial remedial efforts by Gelman. Given these trends and considering there have been no historical detections of 1,4-dioxane above MDLs (1 ug/L and 0.070 ug/L) in samples from Barton Pond since monitoring began in 1992 (when 1,4-dioxane concentrations in groundwater and surface water were much higher) it is even more unlikely that 1,4-dioxane from the Gelman site would be detected in the City’s intake in the future.

7.0 OTHER RESOURCES RELATED TO THE HC/HCT

Mendelson, M.A., and P. Monks. 1994. Modeling stormwater flows for Honey Creek, Michigan. M.S. Thesis, University of Michigan.

Huron River Watershed Council, Bacteria Reduction Implementation Plan for the Honey Creek Watershed, 2014-2024, Version 3.0, May 2014

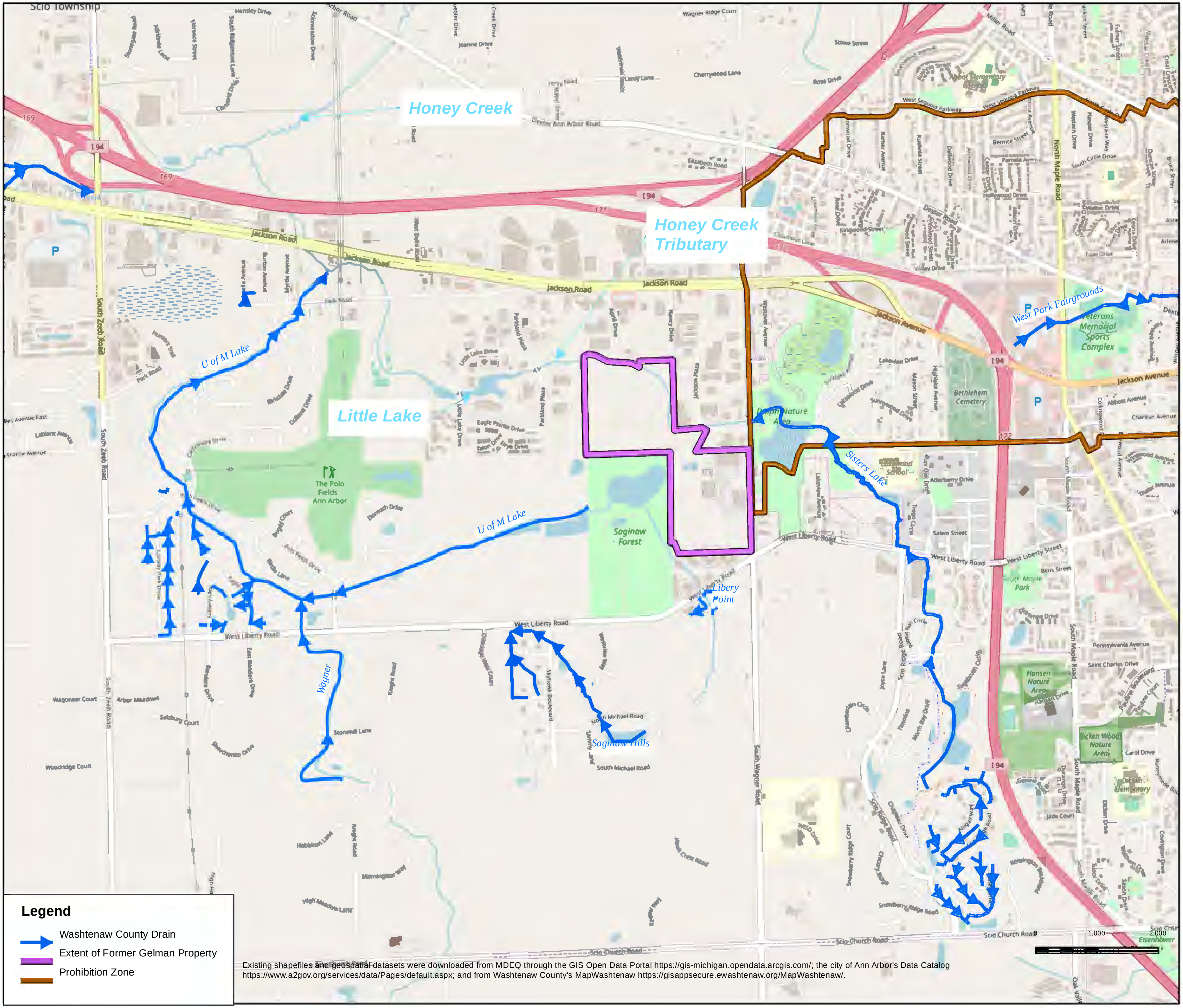
Huron River Watershed Council, Watershed Management Plan for the Huron River in Ann Arbor – Ypsilanti Metropolitan Area, Revised October 2011 https://www.hrwc.org/resources/ (searchable database - search for Honey Creek)

Michigan Department of Environmental Quality - Water Bureau, April 2009 Total Maximum Daily Load for E. coli for Honey Creek, Washtenaw County

Michigan Department of Environmental Quality – Gelman Site of Contamination Information Page, https://www.michigan.gov/deq/0,4561,7-135-3311_4109_9846-71595--,00.html

Wiley, M.J., and J.S. Diana. 1989. An evaluation of the ecological impact of long-term chronic exposure of the biota of Honey Creek to 1,4-Dioxane, report to: Braithwaite Consultants Inc., Ann Arbor MI. 80 pp.

FIGURES



Existing shapefiles and geospatial datasets were downloaded from MDEQ through the GIS Open Data Portal https://gis-michigan.opendata.arcgis.com/; the city of Ann Arbor's Data Catalog https://www.a2gov.org/services/data/Pages/default.aspx; and from Washtenaw County's MapWashtenaw https://gisappsecure.ewashtenaw.org/MapWashtenaw/.

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SURACE WATER FEATURES

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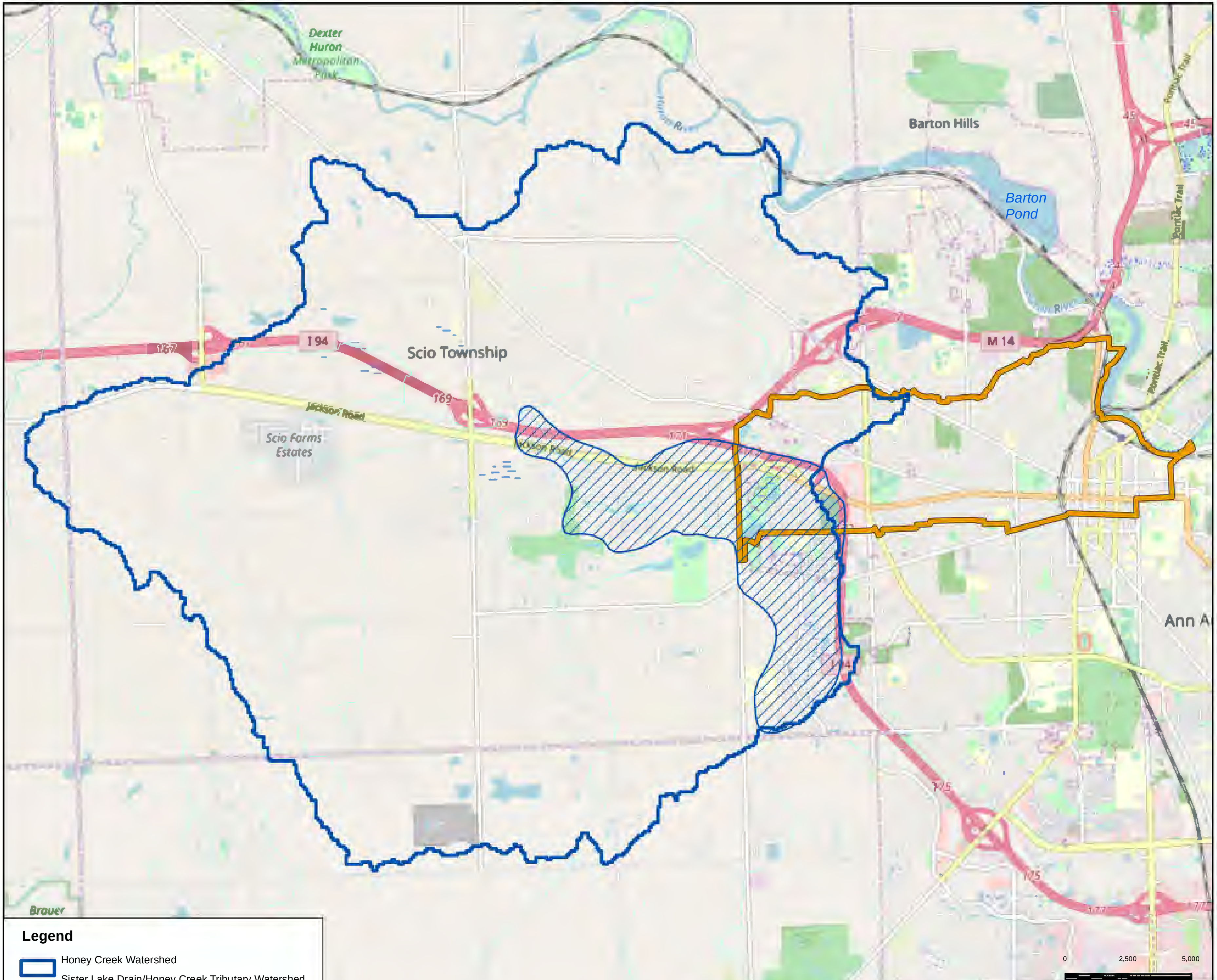
FIG 1



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WATERSHEDS OF SISTER LAKE DRAIN/HONEY CREEK TRIBUTARY & HONEY CREEK

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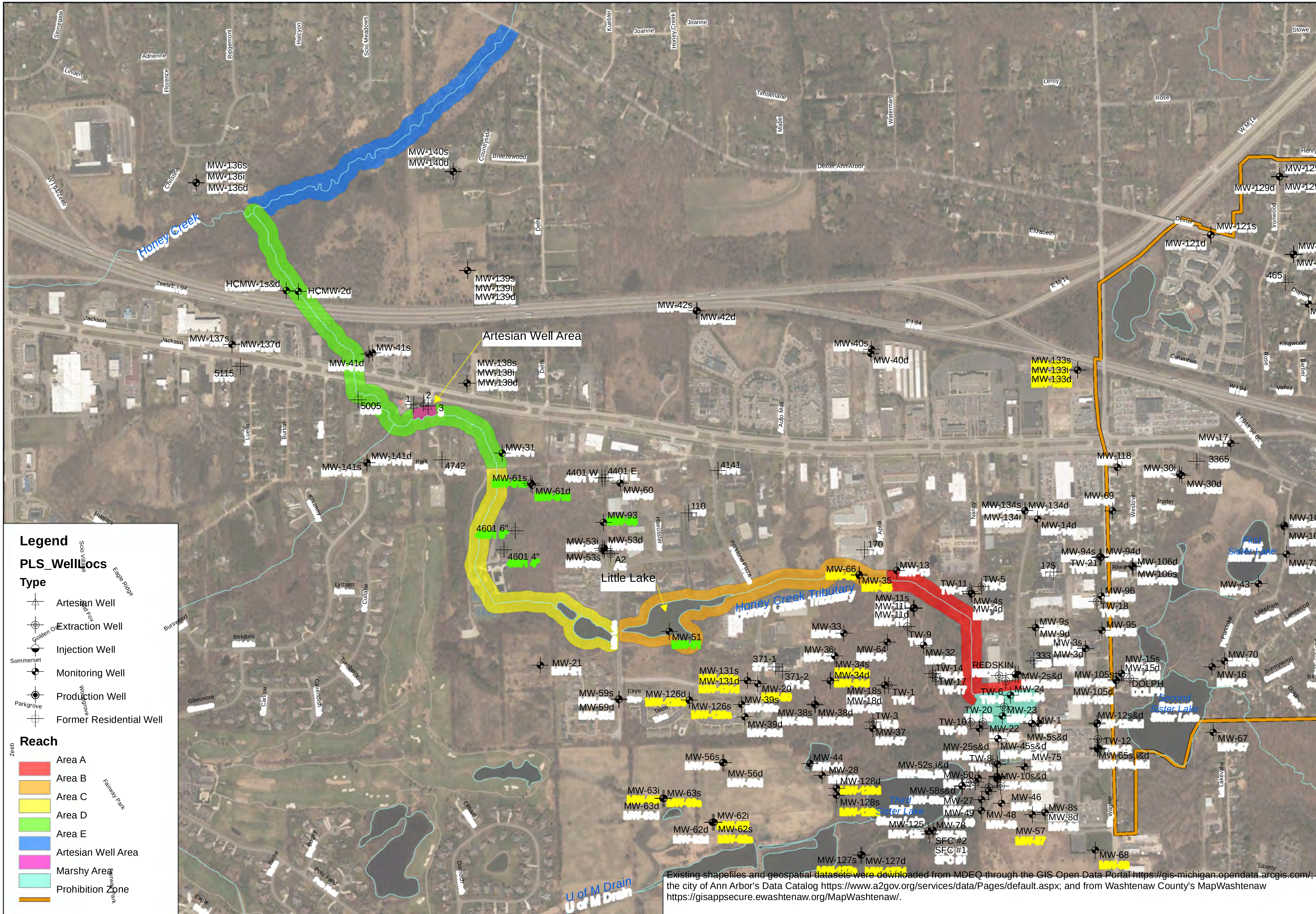
FIG 2



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WELL LOCATIONS WITHIN VICINITY OF REACH AREAS

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FIG 3

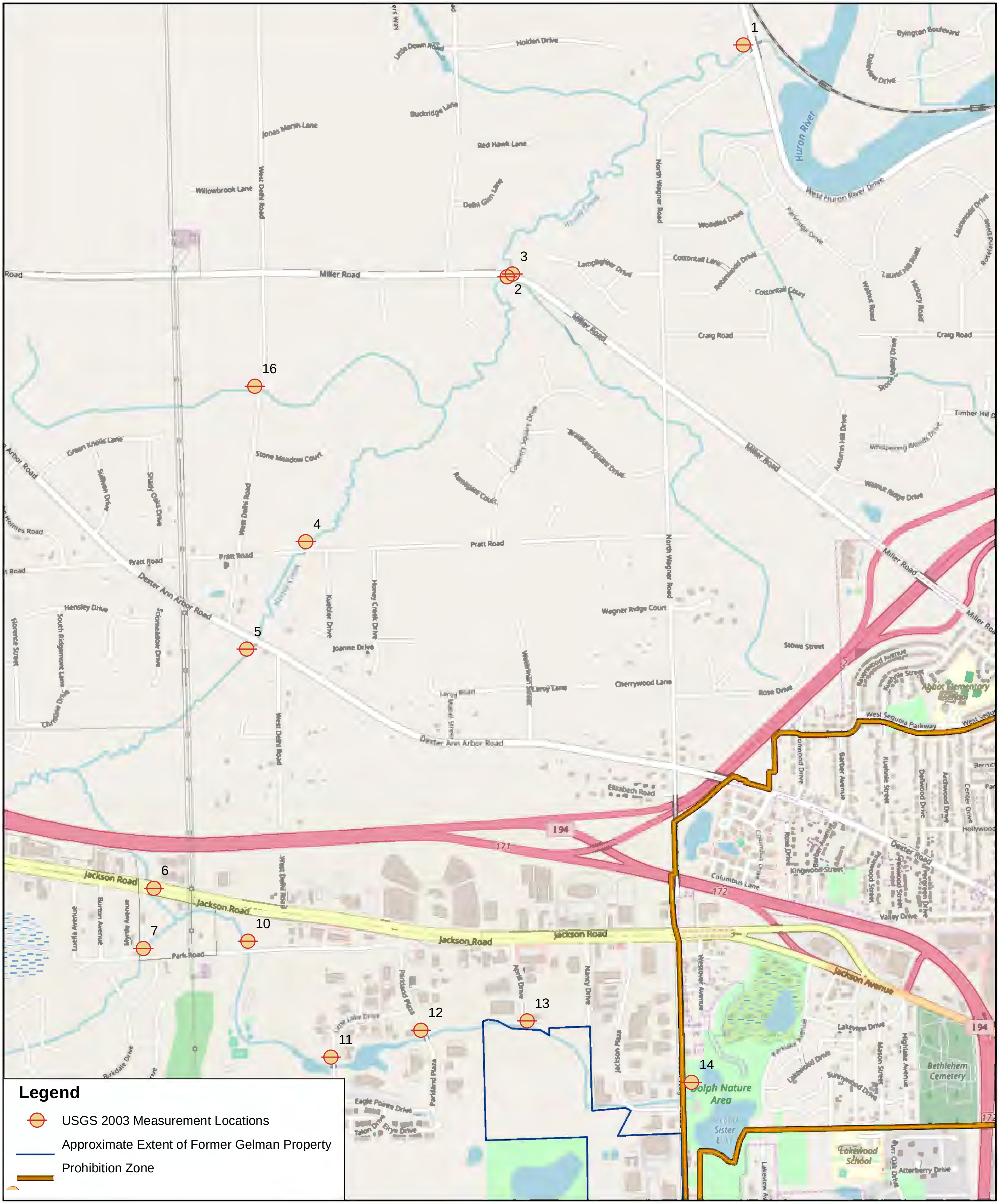

FIG 4

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USGS 2003 Measurement Locations

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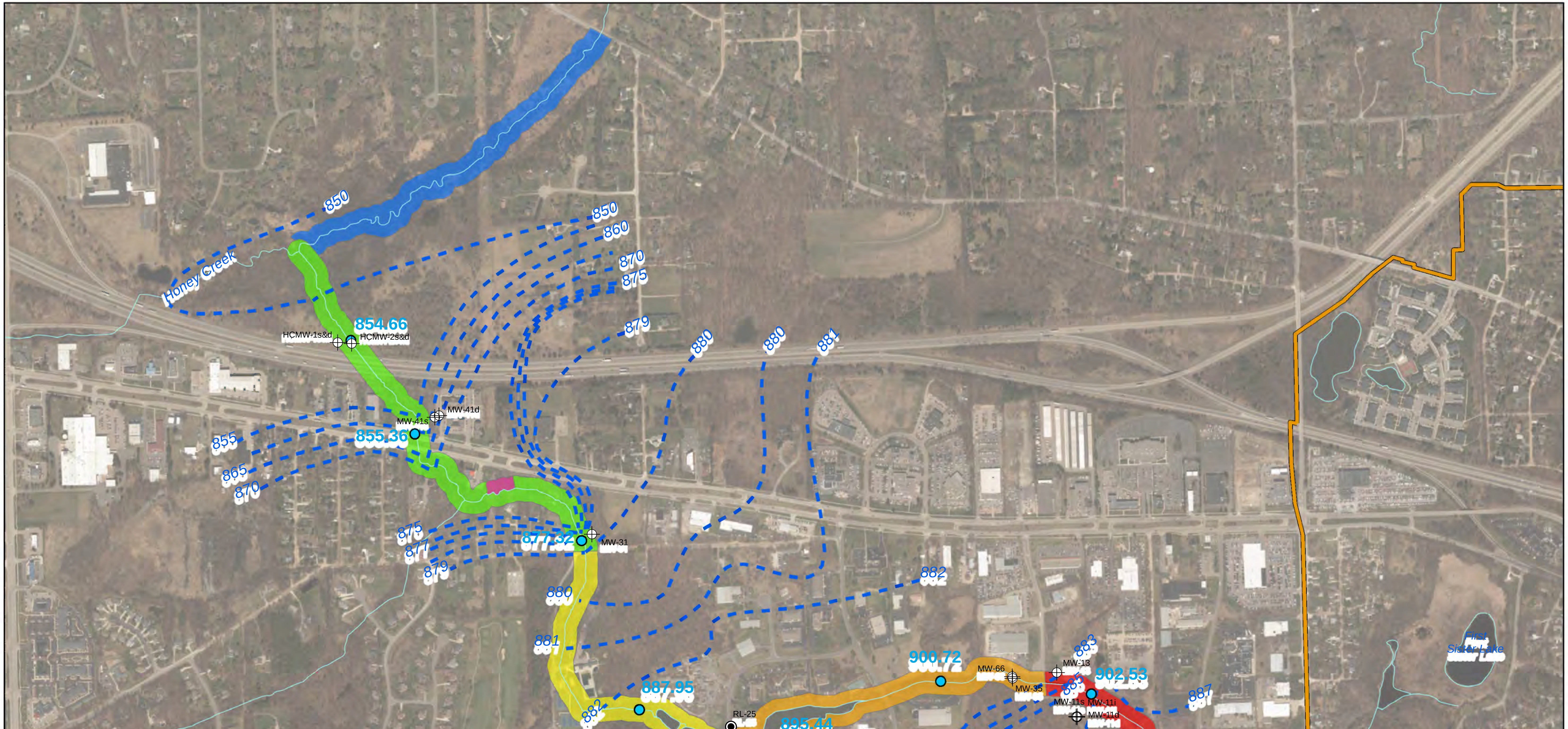

Legend

- Potentiometric Surface Contour September 20, 2017
- Selected Monitoring Well
- Selected Extraction Well
- Selected Soil Boring

Reach

- Area A
- Area B
- Area C
- Area D
- Area E
- Artesian Well Area
- Marshy Area
- Prohibition Zone

Aug. 1999 Surface Water Measurement Location

Existing shapefiles and geospatial datasets were downloaded from MDEQ through the GIS Open Data Portal https://gis-michigan.opendata.arcgis.com/; the city of Ann Arbor's Data Catalog https://www.a2gov.org/services/data/Pages/default.aspx; and from Washtenaw County's MapWashtenaw https://gisappsecure.ewashtenaw.org/MapWashtenaw/.

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POTENTIOMETRIC SURFACE UPPER REGIONAL AQUIER AND SURFACE WATER ELEVATIONS

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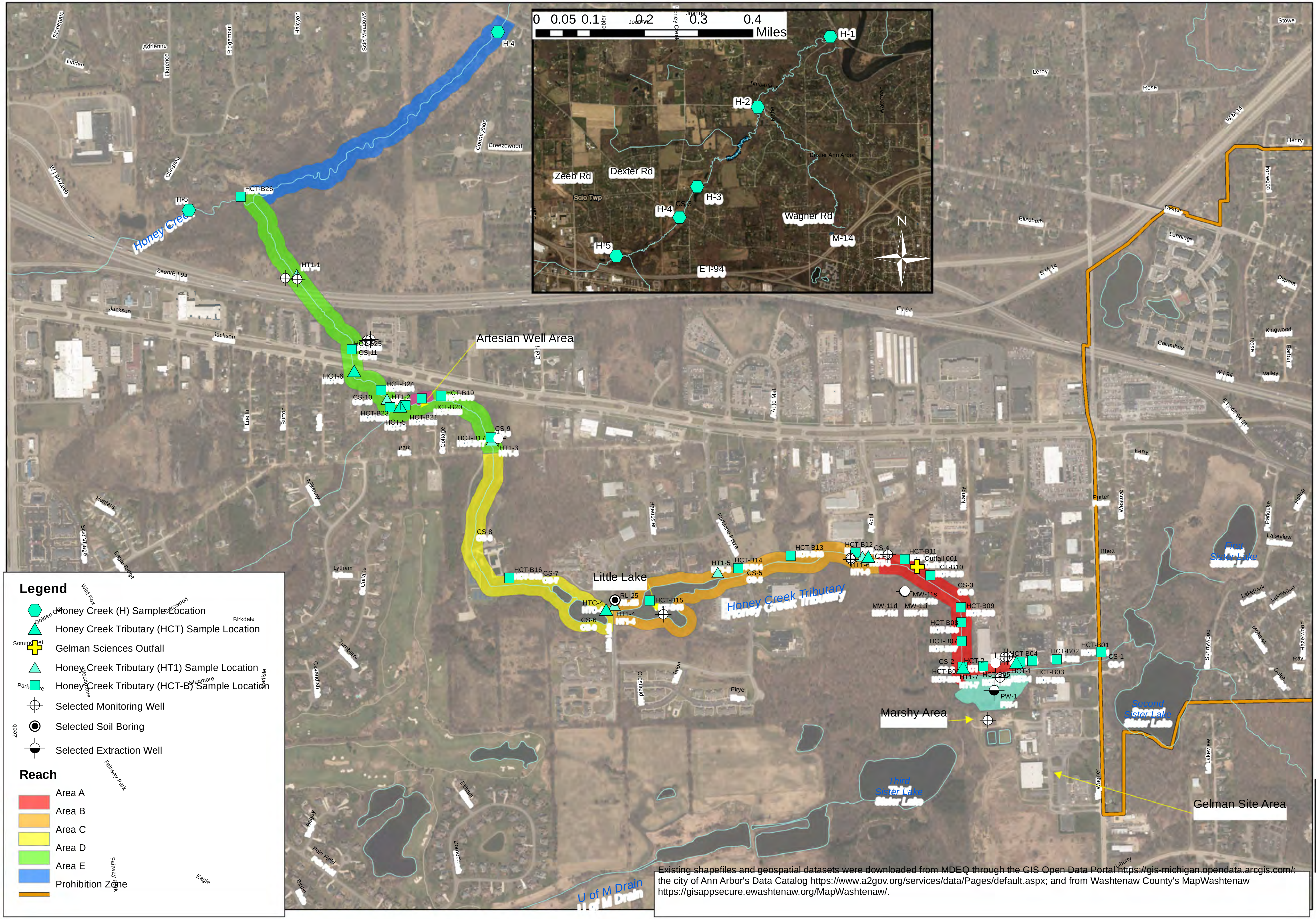
FIG 5



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SURFACE WATER SAMPLING LOCATIONS

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FIG 6

TABLES

Table 1 - Flow Data Summary
806500 - Gelman Sciences Inc.
Summary of Relevant Historical Data Pertaining to Groundwater and Surface Water interactions Within and Unnamed Tributary of Honey Creek and a Portion Honey Creek
February, 2019

Reach	Description of Reach	USGS Flow Measurement Stations Upstream and Downstream	Flow Upstream (cfs)	Contribution from Other Flow Sources (cfs)[1]	Adjusted Upstream Flow (cfs)	Flow Downstream (cfs)	Contribution from Other Flow Sources (cfs)[1]	Adjusted Downstream Flow (cfs)
Area A	Marshy Area to Aprill Drive	14 to 13	0.18	0	0.18	2.76	2.51[a]	0.25
Area B	Aprill Drive to Exit of Little Lake	13 to 11	2.76	2.51[a]	0.25	3.05	2.51[a]	0.54
Area C	Exit Little Lake to Park Road	11 to 10	3.05	2.51[a]	0.54	2.48	2.51[a]	-0.03
Area D	Park Road to the Confluence with Honey Creek	10 to 6	2.48	2.51[a]	-0.03	3.1	2.695[a,b,c]	0.405
Area E	Honey Creek to Dexter Road	6 to 5	3.1	2.695[a,b,c]	0.405	5.49	4.415[a,b,c,d,e]	1.075

HCT Reach	Description of HCT Reach	Estimated Groundwater Contribution in Reach (cfs)	Estimated Groundwater Contribution in Reach (gpm)	Estimated Groundwater Contribution in Reach (gpd)
Area A	Marshy Area to Aprill Drive	0.07	31	45197
Area B	Aprill Drive to Exit of Little Lake	0.29	130	187245
Area C	Exit Little Lake to Park Road	-0.57	-256	-368033
Area D	Park Road to the Confluence with Honey Creek	0.435	195	280867
Area E	Honey Creek to Dexter Road	0.67	300	432600
Artesian Well Area		0.145	65	93622
Totals		**1.04**	**466**	**671498**

	Minimum Recorded Daily Mean Flow (USGS)	Maximum Recorded Daily Mean Flow (USGS)	Mean of Daily Mean Flow (USGS)	Adjusted Low Flow Measurement (USGS)[1]
Honey Creek Flow at Huron River Discharge (cfs)				3.34[a]
Historic Huron Flow at Dexter, 1946 to 1977 (cfs)	41	3090	346	
Historic Huron Flow at Ann Arbor, 1914 to 2019 (cfs)	4	5840	470	

Notes:
Artesian Well Area Estimated flow from historic measurements= 65 gpm or 0.145 cfs
Gelman NPDES Discharge on September 10, 2003 1126 gpm or 2.51 cfs
All USGS flow measurements collected September 10, 2003
[1]Contribution from other flow sources determined based on the following flow measurements as indicated:
[a]Gelman NPDES Discharge on September 10, 2003 (2.51 cfs)
[b]Artesian Wells (0.145 cfs)
[c]U of M Drain at Station #7, USGS flow measurement September 10, 2003 (0.04 cfs)
[d]Honey Creek at Station #15, USGS flow measurement September 10, 2003 (1.69 cfs)
[e]Unnamed Tributary of Honey Creek at Station #18, USGS flow measurement September 10, 2003 (<0.03 cfs)

APPENDIX 1

Appendix 1 – USGS Flow Measurements

Table 3. Streamflow measurements with magnitude and percent difference between sites in Washtenaw County, Mich.
[--, no data; % percentage]

	June 18, 2003			August 20, 2003			September 10, 2003		
	Streamflow	[1]Difference		Streamflow	[1]Difference		Streamflow	[1]Difference	
Site	ft³/s	ft³/s	[2]%	ft³/s	ft³/s	[2]%	ft³/s	ft³/s	[2]%
1	[3]7.29	-0.09	-0.3	7.27	-0.49	-6.5	5.85	.00	0.0
2	7.33	.71	10	7.72	0.71	9.6	5.83	.23	4.0
3	.05	υ	υ	.04	υ	υ	<.02	υ	υ
4	[3]6.57	-.77	-11	7.01	-0.11	-1.6	5.60	.11	2.0
5	[3]7.34	2.37	38	7.12	1.88	30	5.49	.70	14
6	[3]3.42	.43	13	--	--	--	3.10	.58	21
7	0.19	.12	46	.06	.06	200	.04	.04	200
8	0.07	.00	.0	.00	.00	.0	.00	-.02	-200
9	0.07	υ	υ	.00	υ	υ	<.02	υ	υ
10	2.80	.34	13	3.12	-1.22	-33	2.48	-.57	-21
11	[3]2.46	.07	2.9	4.34	.69	17	3.05	.26	8.9
12	2.39	.09	3.8	3.65	.63	19	2.79	.03	1.1
13	[3]2.30	[4]τ	[4]τ	3.02	[4]τ	[4]τ	2.76	[4]τ	[4]τ
14	0.11	υ	υ	.79	υ	υ	.18	υ	υ
15	1.55	υ	υ	2.06	υ	υ	1.69	υ	υ
16	0.05	υ	υ	.00	υ	υ	.00	υ	υ
17	0.00	υ	υ	.00	υ	υ	.00	υ	υ
18	--	--	--	<.1	υ	υ	<.03	υ	υ

Source – Healy, Denis F., 2005, Ground-Water/Surface-Water Relations along Honey Creek, Washtenaw County, Michigan 2003: U.S. Geological Survey Open-File Report 2004-1387, 17p

The following 50% and 95% exceedance flows have been calculated by the MDEQ for the HCT downstream of the U of M Drain, SW ¼ of the SE ¼ of Section 22, T2S, R5E, Scio Township, Washtenaw County. The Drainage area at this location is estimated to be 6.2 square miles.

	Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sept.**
50%	0.6	1.1	1.4	1	1.2	3.7	3.5	1.8	1	0.6	0.5	0.5
95%	0.3	0.4	0.4	0.4	0.4	0.9	1.3	0.6	0.4	0.3	0.3	0.3

Ground-Water/Surface-Water Relations along Honey Creek, Washtenaw County, Michigan, 2003

By Denis F. Healy

Prepared in Cooperation with the city of Ann Arbor, Michigan

Open-File Report 2004-1387

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
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Conversion Factors, Horizontal Datum, and Abbreviations

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
	Concentration	
grains per gallon (grains/gal)	0.01712	micorgrams per liter (µg/L)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C=(°F-32)/1.8

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius µS/cm at 25 °C). Concentrations of chemical constituents in water are given in micrograms per liter (µg/L).

Ground-Water/Surface-Water Relations along Honey Creek, Washtenaw County, Michigan, 2003

By Denis F. Healy

ABSTRACT

The U.S. Geological Survey (USGS), in cooperation with the city of Ann Arbor, Mich., investigated the ground-water/surface-water relations along the lower reaches of Honey Creek, Washtenaw County, Mich., and an unnamed tributary to Honey Creek (the discharge tributary) from June through October 2003. Streamflow in these reaches was artificially high during a naturally low-flow period due to an anthropogenic discharge. Ground-water/surface-water relations were examined by seepage runs (series of streamflow measurements for the computation of streams gains or losses) and measurements of the difference in head between the stream surface and shallow aquifer. Specific conductance and water-temperature measurements were used as ancillary data to help identify gaining and losing reaches. Three seepage runs and four runs in which hydraulic-head differences between the stream and shallow aquifer were measured (piezometer runs) were made during periods of base flow.

Streamflow measurements were made at 18 sites for the seepage runs. Instream piezometers were installed at 16 sites and bank piezometers were installed at 2 sites. Two deeper instream piezometers were installed at site 13 on September 4, 2003 to collect additional data on the ground-water/surface-water relations at that site.

The seepage runs indicate that the main stem of Honey Creek and the discharge tributary in the study area are overall gaining reaches. The seepage runs also indicate that smaller reaches of Honey Creek and the discharge tributary may be losing reaches and that this relation may change over time with changing hydraulic conditions. The piezometer-run measurements support the seepage-run results on the main stem, whereas piezometer-run measurements both support and conflict with seepage-run measurements on the discharge tributary. Seepage runs give an average for the reach, whereas piezometer head-difference measurements are for a specific area around the piezometer. Data that may appear to be conflicting actually may be showing that within a gaining reach there are localized areas that lose streamflow.

The overall gain in streamflow along with specific measurements of head differences, specific conductance, and water temperature indicate that ground water is discharging to Honey Creek and the discharge tributary. Although reaches and areas that lose streamflow have been identified, data collected during this study cannot confirm or disprove that the loss is to the regional ground-water system.

INTRODUCTION

The city of Ann Arbor, Mich., and the surrounding region rely heavily on ground water for municipal, domestic, and other water supplies. Currently about 20 percent of the city's municipal source water is ground water; however, Ann Arbor anticipates increased use of ground-water resources and plans to develop a regional ground-water-flow model suitable for guiding locations of new water supplies and for protecting these supplies.

Ground-water-flow models simulate the flow of ground water through physical, electric analog, or mathematical representations of the geologic, hydrologic, and anthropogenic environment of the area being studied. Models can vary in scope from local to regional and are used by water scientist and managers to understand the ground-water system and to predict changes in water flow and availability due to changes in the system and/or magnitude and changes in the concentrations of constituents in the ground water and the flow paths that the constituents follow.

Conceptual models describe the important features of the environment to be simulated and identify the processes taking place within that environment. They are used as frameworks on which to build the ground-water flow models. In the glaciated Midwest, a necessary prerequisite to developing a conceptual model of regional ground-water flow is an understanding of the relationship of ground water and surface water.

In the Great Lakes Region, regional ground-water flows occur in both glacial deposits and bedrock aquifers depending on the hydraulic properties of the aquifer and confining units, and the topographic relief (Grannemann and others, 2000). In the study area, the local ground-water-flow system is recharged by or discharges to surface water bodies, including lakes, ponds, and small streams. The regional system discharges to the Huron River.

At a local scale, the ground-water/surface-water relations in stream channels are of two types, one in which water is exchanged with the local or regional ground-water system and the other in which water is exchanged between the stream and the hyporheic zone defined by subsurface flow paths that begin in the stream and return to the stream (Harvey and Bencala, 1993; Wroblicky and others, 1998). The hyporheic zone can be viewed as the subset of localized finer-scale interactions between the channel and ground water that occur within the larger-scale patterns of loss and gain of channel water (Harvey and Wagner, 2000).

During the summer and fall of 2003, the U.S. Geological Survey (USGS), in cooperation with the city of Ann Arbor, identified gaining and losing reaches in Honey Creek, a small stream tributary to Huron River, to characterize the ground-water/surface-water relations as a prerequisite for a regional ground-water flow model of the Ann Arbor area.

Purpose and scope

The purpose of this report is to describe the ground-water/surface-water relations of Honey Creek and its tributaries. Streamflow, differences in hydraulic head between the stream and shallow aquifer, specific conductance, and water-temperature measurements are used as multiple lines of evidence to determine losing or gaining reaches.

Field-data collection for this study was from June through October 2003. During this time, three sets of stream gain-loss measurements were made at 18 sites at base flow. From these measurements, the loss or gain in streamflow for 10 reaches between tributary sites 13 and 6, and Honey Creek sites 5 and 1 were calculated. Also during this time, four surveys were conducted during which hydraulic head, specific conductance, and water-temperature differences between the stream and shallow aquifer were measured using 18 instream piezometers and two bank piezometers at 16 sites.

Study area

Honey Creek drains a small 23.2-mi^2 basin mainly just west of Ann Arbor in Scio Township, Washtenaw County, in southeast Michigan (fig. 1). Honey Creek flows into the Huron River upstream of Ann Arbor and its tributaries are small and many are intermittent. Part of or all of four Honey Creek tributaries included in the study have been incorporated into the Washtenaw County drain system (fig. 1). The Honey Creek basin is underlain by Mississippian age Coldwater Shale which is overlain by stratified glacial deposits that range in thickness from about 200-270 ft. Land use/ land cover in the basin is approximately 15 percent urban; 33 percent agriculture; 25 percent upland forest; 17 percent open land; and 10 percent lowlands, wetlands, and water (Michigan Department of Natural Resources, 2001). During the study, residential housing was constructed near sites 11 and 12 and sites 8 and 9 (fig. 1). Commercial and residential development was active along Honey Creek upstream from site 15 (fig. 1).

During the period of this study, treated water was discharged into the unnamed tributary of Honey Creek that is downstream of Sister's Lake Drain (fig. 1). Streamflow measurements showed that the magnitude of this discharge was near or greater than the streamflow contribution to Honey Creek from the part of the basin upstream of the study area. The discharge outfall is upstream of site 13 and the unnamed tributary is henceforth referred to as the "discharge tributary" (fig. 1).

The upstream site in this study was at Zeeb Road upstream from the confluence of the discharge tributary with Honey Creek (site 15 in fig. 1). This reach of the creek runs through the major road intersection of Zeeb Road with Jackson Road and Interstate 94 and has been extensively engineered with culverts and riprap (fig. 2). Downstream from Interstate 94, the Honey Creek streambed appeared to be in a natural condition with the channel disturbed only near road intersections (fig. 3). Land use along these reaches is suburban and low-density housing with some agriculture. The creek bottom ranges from hard sand and gravel to soft fine-organic sediments.

The Honey Creek tributaries were also disturbed near road intersections and along some reaches where they ran along commercial development and residential housing. There is an impoundment on the discharge tributary between sites 12 and 11, henceforth referred to as the "little lake" (fig. 1). A smaller settling pond is just downstream from site 11.

METHODS OF INVESTIGATION

Seepage runs

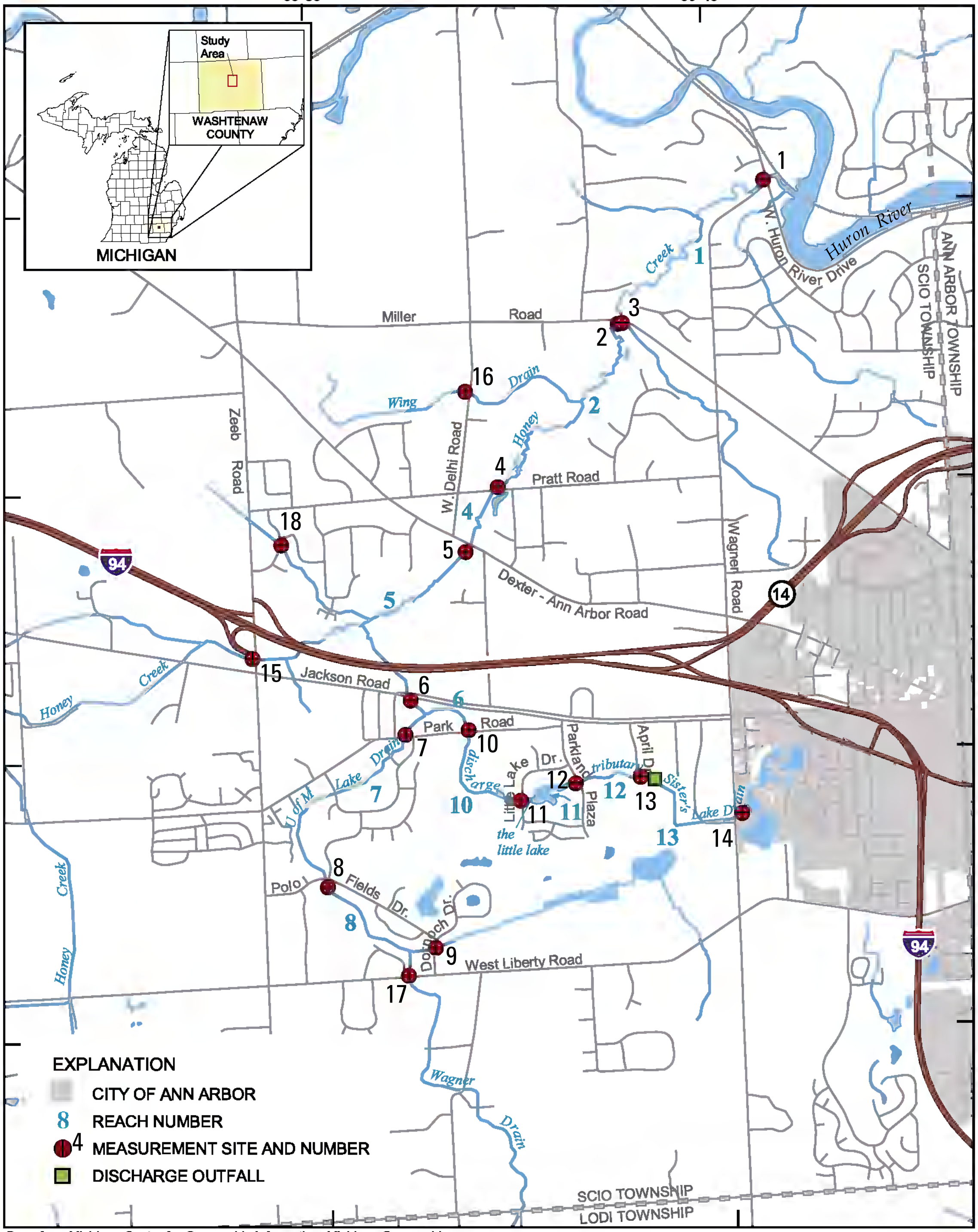
The difference in streamflow between an upstream and downstream site is

$$\Delta Q = Q_S + Q_A + Q_G,$$

where ΔQ is the difference in streamflow, Q_S is the sum of surface-water inflows and outflows, Q_A is the sum of atmospheric inflows and outflows, and Q_G is the sum of ground-water inflows and outflows. Sets of measurements over short periods to determine ΔQ at multiple sites along a stream are commonly called seepage runs.

Along the study reach, the surface-water inflows consisted of small tributaries and drains and the treatment discharge between sites 13 and 14 (fig. 1). Streamflows in the tributaries and drains were measured upstream from their confluence with the main study reach. Site 1 is the only surface-water outflow for the study reach.

Atmospheric deposition and evapotranspiration are the main pathways for atmospheric inflows and outflows. The



Base from Michigan Center for Geographic Information: Michigan Geographic Framework, Version 3b - Washtenaw County, 1:24,000, 2003
Michigan Georef from Oblique Mercator Projection
Standard Parallels 42°16', 42°19'
Central Meridian 83°49'

Figure 1. The Honey Creek study area, Washtenaw County, Michigan.

Figure 2. Culvert, riprap, and drain downstream from the intersection of Zeeb Road and Honey Creek (site 15), Washtenaw County, Mich., July 29, 2003.

seepage runs were made during good weather when there was no wet atmospheric input into the watershed. From potential evapotranspiration values published on the World Wide Web by Michigan Automated Weather Network (Michigan State University, 2003), estimated instream evapotranspiration in the time between upstream and downstream measurements was estimated as two or more orders of magnitude less than the streamflow in Honey Creek, and therefore was considered negligible for gain-loss computations.

Streamflow measurements were made during periods of base flow to avoid transient flows from bank storage or time-lagged infiltration from storms. Base-flow conditions were identified by examining hydrographs for the nearby streamflow-gaging stations USGS 04173500, Mill Creek near Dexter, Mich., and USGS 04174518, Malletts Creek at Ann Arbor, Mich. (U.S. Geological Survey, 2003). The hydrologic response of the suburban Honey Creek basin was assumed to be intermediate between that of the urban Malletts Creek basin and the more agricultural Mill Creek basin.

During seepage runs, streamflow measurements were made at 17 or 18 sites (fig. 1, table 1). Depending on flow conditions and measurement cross sections, measurements were made with a Price AA meter, Price pygmy meter, acoustic Doppler velocimeter (ADV), or portable Parshall flume. Standard USGS methods, as described in detail in Rantz and others (1982) and the ADV operations manual (SonTek, 2003) were used to make measurements and compute the streamflows.

Seepage runs were made on June 18, August 20, and September 10, 2003. Attempts at seepage runs were made on July 16 and July 29 when the pump and treat system was shut down for maintenance, but field observations showed that the lower flows were not in equilibrium with bank storage and with instream storage in the ponds and wetlands along the stream.

To determine whether a reach was gaining or losing, the percentage difference between the sum of the upstream measurements and the downstream measurement was computed by dividing the difference between the measurements by their average then multiplying by 100. Previous studies have shown that the standard deviation of consecutive measurements is approximately 2.2 percent (Rantz and others, 1982). To account for this possible measurement error, a percentage difference at which there was a 95 percent probability that the measured streamflows were different was computed. For the 2.2-percent standard deviation, this 95 percent probability percentage difference was 4.3 percent. To be more conservative, this figure was rounded up to 5 percent for this study. Any computed percentage difference between the upstream and downstream measurements greater than 5 percent was considered a real gain or loss and for the purposes of this report, hereafter called a significant gain or loss.

When streamflow is low, small differences in the measurements may produce large percentage differences. To compensate for this, it was decided that the average streamflow of the upstream and downstream sites had to exceed 0.5 ft^3/s before the greater than 5-percent gain or loss would be considered significant.

Because the treatment discharge was much larger than the streamflow at site 14, fluctuations in this discharge could have masked any loss or gain in this reach. For this

Figure 3. Bridge at site 4, Honey Creek at Pratt Rd near Ann Arbor, Mich., on September 10, 2003.

Table 1. Honey Creek study sites, Washtenaw County, Mich.
[°, degrees; ′, minutes; ″, seconds; --, piezometer not installed at site]

Site number	USGS identi-fication number	[1]USGS site name	Latitude	Longitude	Depth to center of well screen from stream-bed (feet)
1	04174310	Honey Creek at Huron River Drive	42° 19′ 04.7″	-83° 47′ 44.2″	3.07
2	04174300	Honey Creek at Miller Rd near Foster, Mich.	42°18′ 33.6″	-83° 48′ 28.5″	2.86
3	04174299	Honey Creek trib at Miller Rd	42° 18′ 34.0″	-83° 48′ 27.5″	2.55
4	041742955	Honey Creek at Pratt Rd	42° 17′ 58.4″	-83° 49′ 05.3″	2.85
5	04174295	Honey Creek at Dexter-Ann Arbor Rd near Scio, Mich.	42° 17′ 44.3″	-83° 49′ 15.7″	3.38
6	04174293	Honey Creek trib at Jackson Rd	42° 17′ 11.3″	-83° 49′ 33.4″	2.65
7	041742914	U of M Lake Drain at Park Rd	42° 17′ 04.4″	-83° 49′ 34.6″	2.95
8	041742912	U of M Lake Drain at Polo Fields Dr	42° 16′ 31.6″	-83° 49′ 59.2″	2.73
9	041742907	U of M Lake Drain at Dornoch Dr	42° 16′ 16.7″	-83° 49′ 27.6″	4.36
10	041742926	Honey Creek trib at Park Rd – instream piezometer	42° 17′ 04.9″	-83° 49′ 16.3″	5.31
		[2]bank piezometer			5.19
11	041742924	Honey Creek trib at Little Lake Rd	42° 16′ 49.2″	-83° 49′ 01.2″	2.67
12	041742922	Honey Creek trib at Parkland Plaza Rd	42° 16′ 52.5″	-83° 48′ 44.6″	3.63
13	04174292	Honey Creek trib at April Rd – shallow piezometer	42° 16′ 53.5″	-83° 48′ 25.3″	3.28
		[3]mid-level piezometer			5.75
		[3]deep piezometer			8.31
		[3]bank piezometer			4.39
14	041742916	Sister's Lake Drain at Dolph Park	42° 16′ 45.2″	-83° 47′ 55.6″	4.65
15	04174288	Honey Creek at Zeeb Rd	42° 17′ 21.5″	-83° 50′ 20.8″	3.08
16	041742965	Wing Drain at West Delhi Rd	42° 18′ 19.8″	-83° 49′ 13.7″	2.60
17	04174291	Wagner Drain at Liberty Rd	42° 16′ 11.0″	-83° 49′ 35.5″	--
18	04174294	Honey Creek trib at Stonegate Rd	42° 17′ 47.0″	-83° 50′ 10.8″	--

[1] All site names in their official form conclude with "near Ann Arbor, Mich.", unless otherwise noted.
[2] The depth of the center of the well screen below the streambed is calculated from the streambed elevation at the instream piezometer.
[3] The depth of the center of the well screen below the streambed is calculated from the streambed elevation at the shallow instream piezometer.

reason, no estimate was made as to whether the reach between sites 14 and 13 was losing or gaining.

The equations used to compute the change in streamflow in the reach upstream from specific sites are presented in table 2. For the remainder of this report, reaches will be referred to by the site number of the site at the downstream end of the reach; for example, reach 1 is bounded by site 1 downstream and sites 2 and 3 upstream (table 2).

Piezometer measurements

The piezometers used for this study were small-diameter wells with 0.5 ft well-screen openings backed by 80 gauze (approximately 0.007 inch opening) wire mesh. The piezometers were made from 11/4-in.-diameter well drive points and steel pipe. Water levels in the piezometers and the stream surface level were measured with a steel or electric tape measure from a designated reference point on the top of the piezometer. At sites 10 and 13, the two sites where there were multiple

Table 2. Equations used to compute streamflow differences in study reaches in Washtenaw County, Mich.
[Q number, measured streamflow at site (number)]

Reach upstream from site	Reach designation	Equation
1	1	$Q_1 - Q_2 - Q_3$
2	2	$Q_2 - Q_{16} - Q_4$
4	4	$Q_4 - Q_5$
5	5	$Q_5 - Q_6 - Q_{15} - Q_{18}$
		$Q_5 - Q_7 - Q_{10} - Q_{15} - Q_{18}$ (August 20, 2003)
6	6	$Q_6 - Q_7 - Q_{10}$
7	7	$Q_7 - Q_8$
8	8	$Q_8 - Q_9 - Q_{17}$
10	10	$Q_{10} - Q_{11}$
11	11	$Q_{11} - Q_{12}$
12	12	$Q_{12} - Q_{13}$

piezometers, the difference in the elevations of the top of piezometers were surveyed, and all water-level measurements were referenced to the top of shallow-depth instream piezometer.

Piezometers were installed at sites 1 through 16 by manually forcing the piezometer into the streambed to the point of resistance, which was the level where a relatively large increase in force was required to drive the piezometer deeper. The depth of the center of the well screen below the streambed for each piezometer is given in table 1. For sites 10 and 13, this depth was referenced to the streambed at the shallow-depth instream piezometer.

Piezometer data were collected on July 25, August 20, September 10, and October 10, 2003. Additional piezometer data were collected on July 10 and during attempted seepage runs on July 16 and July 29. On these dates the pump and treat system was shut down and the flow system was not in equilibrium with bank and instream storage. Piezometer data were collected during the seepage run of June 18; however, quality-control concerns about the methods and equipment used during this run make the validity of these data questionable. These data are not used or presented in this report. The piezometer at site 16 was measured only on June 18; this piezometer was pulled on September 4 to be installed at another site.

Two additional instream piezometers were installed at site 13 on September 4 to collect more data on the ground-water/surface-water relations at that site. Additional piezometer data were collected for site 13 on September 8, 17, and 30.

Hydraulic head

The difference in water levels measured in a stream and in a piezometer in or near the stream will indicate the ground-water-flow potential (Freeze and Cherry, 1979). The water level relative to an arbitrary datum is referred to as the hydraulic head (referred to herein as “head”) at that point. The head reflects the energy of the water due to elevation and pressure. The reference point for each site was arbitrarily set at an elevation of 20 ft. The head for each water level was calculated as 20 ft minus the tape measurement. For sites 10 and 13, the heads presented in this report were adjusted to the reference points of the shallow instream piezometers. Head measurements at one site have no relation to head measurements at other sites because the reference points at the different sites were not surveyed to the same datum.

The ground-water-flow potential or head difference was computed by subtracting the head measured at the stream surface from the head of the shallow aquifer measured in the piezometer. A positive difference (shallow aquifer head higher than the stream head) indicates a pressure gradient towards the stream; a negative difference (shallow aquifer head lower than the stream head) indicates a pressure gradient away from the stream. Tape reading accuracy was ± 0.01 ft. Stream-surface levels were estimated during many measurements because of the surface oscillations that are caused by nonlaminar flow. Many of the piezometers were at slight angles. Because of these uncertainties, a conservative ± 0.05 ft was used for this project to determine whether the measured head difference indicated a positive (head difference ≥ 0.05 ft), negative (head difference ≤ -0.05 ft), or neutral (-0.05 ft< head difference < 0.05 ft) flow potential.

Specific conductance and water temperature

Conductance is a measure of the ability of a solution to conduct electricity and is reported in microsiemens per centimeter (µS/cm). Pure water has low conductance. As ion concentrations increase, conductance of the solution increases; therefore, the conductance measurement provides an indication of ion concentration (Hem, 1985). Because conductance is temperature-dependent, a reference measurement, specific conductance, is used to compare the conductance of solutions at different temperatures. Specific conductance is the conductance corrected to 25 °C.

For this study, specific conductance and water temperature were measured in the piezometer and in the stream near the piezometer at each site according to procedures detailed in Wilde and Radtke (1998). At sites 10 and 13, measurements were made in each piezometer and in the stream. A combination probe was lowered to the bottom of the piezometer and raised a few inches from the bottom so the probe was in the open-screen section of the piezometer. The probe was allowed to stabilize for both temperature and conductance before the readings were recorded. The accuracy of the specific conductance measurements was ± 2 percent. The accuracy of the water temperature measurements was 0.5 °C, and they were rounded to the nearest 0.5 °C.

Data from these measurements cannot be used directly to show the movement of the ground water; instead, the data were used to support or not support the interpretation of the head potential. Because the specific conductance of the treatment discharge was much higher than the ground-water specific conductance, the measurement from the piezometer and the stream were compared for magnitude of difference. A large difference suggested no interaction between the ground water and surface water or that ground water was flowing toward and discharging to the stream. A decrease in the difference suggested interaction between the ground water and surface water: the less the difference, the stronger the interaction. The decrease in the difference, however, may also be due to increased conductance in the ground water.

Water-temperature data were used as ancillary data to assist in the interpretation of the head measurements. The difference between the water temperature measured in the piezometer and in the stream at each site was compared in a similar manner as the specific conductance data. Temperature relations between the ground water and surface water, however, are more complex than that for specific conductance. During the late summer and early fall, there may be large diurnal fluctuations in stream-water temperature. The magnitude of water temperatures measured in the piezometer and stream may be close in the morning and very different in the afternoon. If the area around the piezometer is a losing reach, then the diurnal fluctuation may also be observed in the ground-water temperature measurements, but the peak may be muted and time lagged.

The ground-water temperatures were also examined for continuity over the period of the study. Measured temperatures showing little or no change during the study would indicate little or no interaction between the ground water and stream. Continuity of water temperature, however, is not proof that ground water is flowing towards the stream. For example, there may be no interaction if the stream and ground water are flowing along parallel streamlines.

GROUND-WATER/SURFACE-WATER RELATIONS

Seepage runs give data on a regional scale in that they give an average for an entire reach (Dumouchelle, 2001). Head measurements indicate ground-water-flow potential near the piezometer. The data from the different methods will be presented individually.

Seepage runs

Streamflow measurements for the 18 sites and the magnitude and percentage difference in the reaches above the sites (as determined from the equations in table 2) for the seepage runs on June 18, August 20, and September 10 are presented in table 3. Streamflow measurements made on July 16 and July 29 are presented in appendix Table 1-1.

In table 3, both the magnitude and percentage difference of the change can be observed. Over the three seepage runs, losing reaches were found a total of seven times in reaches 1, 4, 8, and 10. Four of the seven losing reaches met the criteria to be considered a significant losing reach: reach 1 on August 20, reach 4 on June 18, and reach 10 on August 20 and September 10. Over the three seepage runs, gaining reaches were found a total of 19 times in reaches 2, 4, 5, 6, 7, 10, 11, and 12. Of the 19 gaining reaches, 11 met the criteria to be considered a significant gaining reach: reach 2 on June 18 and August 20; reach 5 on June 18, August 20, and September 10; reach 6 on June 18 and September 10; reach 10 on June 18; reach 11 on August 20 and September 10; and reach 12 on August 20. Reach 10 was the only reach to show both a significant loss (August 20) and a significant gain (June 18). The significant losing and gaining reaches for each seepage run are shown on figure 4.

In addition to the individual reaches discussed above, the following reaches were examined for loss or gain: 1) between sites 13 and 10 on the discharge tributary and 2) between sites 3, 5, and 16 and site 1 on the main stem. The percentage difference for both reaches was computed by use of the streamflows presented in table 3. The magnitude of the streamflow

Table 3. Streamflow measurements with magnitude and percent difference between sites in Washtenaw County, Mich.
[--, no data; % percentage]

	June 18, 2003			August 20, 2003			September 10, 2003		
	Streamflow	[1]Difference		Streamflow	[1]Difference		Streamflow	[1]Difference	
Site	ft^3/s	ft^3/s	[2]%	ft^3/s	ft^3/s	[2]%	ft^3/s	ft^3/s	[2]%
1	[3]7.29	-0.09	-0.3	7.27	-0.49	-6.5	5.85	.00	0.0
2	7.33	.71	10	7.72	0.71	9.6	5.83	.23	4.0
3	.05	υ	υ	.04	υ	υ	<.02	υ	υ
4	[3]6.57	-.77	-11	7.01	-0.11	-1.6	5.60	.11	2.0
5	[3]7.34	2.37	38	7.12	1.88	30	5.49	.70	14
6	[3]3.42	.43	13	--	--	--	3.10	.58	21
7	0.19	.12	46	.06	.06	200	.04	.04	200
8	0.07	.00	.0	.00	.00	.0	.00	-.02	-200
9	0.07	υ	υ	.00	υ	υ	<.02	υ	υ
10	2.80	.34	13	3.12	-1.22	-33	2.48	-.57	-21
11	[3]2.46	.07	2.9	4.34	.69	17	3.05	.26	8.9
12	2.39	.09	3.8	3.65	.63	19	2.79	.03	1.1
13	[3]2.30	[4]τ	[4]τ	3.02	[4]τ	[4]τ	2.76	[4]τ	[4]τ
14	0.11	υ	υ	.79	υ	υ	.18	υ	υ
15	1.55	υ	υ	2.06	υ	υ	1.69	υ	υ
16	0.05	υ	υ	.00	υ	υ	.00	υ	υ
17	0.00	υ	υ	.00	υ	υ	.00	υ	υ
18	--	--	--	<.1	υ	υ	<.03	υ	υ

[1] Difference is measured with respect to the upstream-site streamflow as determined from equations in table 2. Negative difference denotes a loss of streamflow; positive difference denotes a gain in streamflow.

[2] The percentage difference is the difference between the upstream and downstream measurements as determined from equations in talbe 2, divided by the average of the upstream and downstream measurements and multiplied by 100.

[3] Value is an average of two or more individual streamflow measurements.

[4] No estimate for this reach is computed because the treatment discharge was much larger than the streamflow at site 14, and fluctuations in this discharge could mask any loss or gain in this reach

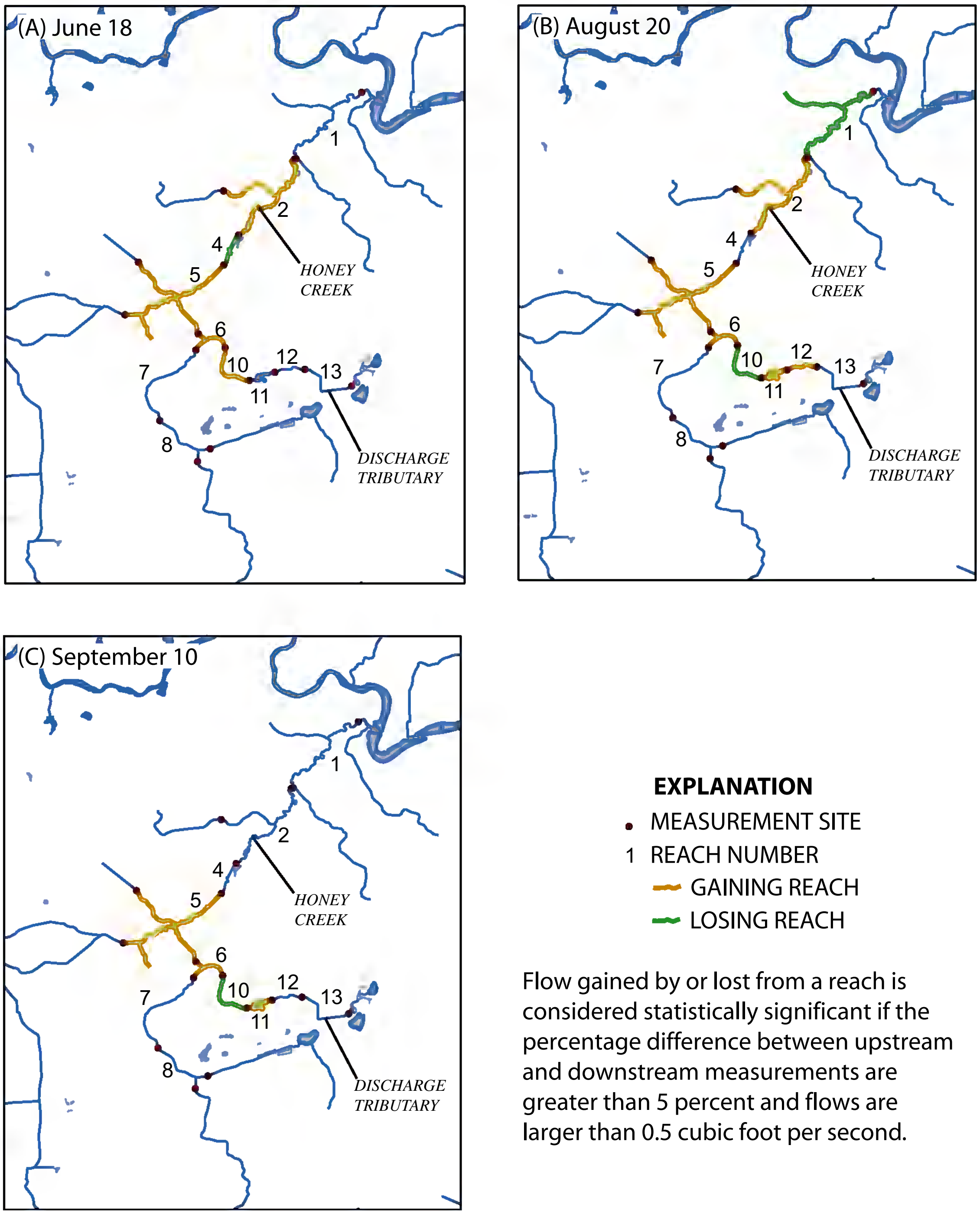


Figure 4. Reaches of Honey Creek with statistically significant streamflow gain or loss as measured during seepage runs (A) June 18, (B) August 20, and (C) September 10, 2003, Honey Creek, Washtenaw County, Mich. (See fig. 1 for locations of measurement sites.)

difference and the percentage difference for the reach between sites 13 and 10 on the discharge tributary on June 18 were 0.50 ft^3/s and 20 percent, on August 20 were 0.10 ft^3/s and 3.2 percent, and on September 10 were –0.28 ft^3/s and -10.7 percent. For the three runs, one showed a significant gain; the second, no significant difference; and the third, a significant loss. The magnitude of the streamflow difference and percentage difference between sites 3, 5, and 16 and site 1 on June 18 were -0.15 ft^3/s and -2.0 percent, on August 20 were 0.11 ft^3/s and 1.5 percent, and on September 10 were 0.34 ft^3/s and 6.0 percent. For the three runs, two showed no significant difference and the third, a significant gain.

Piezometer measurements

The head, specific-conductance, and water-temperature data measured at each piezometer and corresponding stream location, and the magnitude of the head difference between the stream and shallow aquifer are listed in table 4. The head, specific-conductance, and water-temperature data and the magnitude of the head difference measured at the four piezometers at site 13 in September and October are listed in table 5. The head, specific conductance, and water temperature data measured on July 10, July 16, and July 29 are presented in appendix Table 1-2.

Head difference

Head difference is the difference between the heads measured in the stream and shallow aquifer and is measured with respect to the stream level. A positive head difference indicates flow potential towards the stream; a negative head difference indicates flow potential away from the stream.

Head differences at the Honey Creek main stem sites 1, 2, 4, 5, and 15 and tributary sites 7 and 14 showed a positive or neutral flow potential for all measurements. Head differences at the discharge tributary sites 10, 11, 12, and 13, including the bank piezometers at sites 10 and 13, showed a negative or neutral flow potential for all measurements. Head differences at tributary site 3 and discharge tributary site 6 showed negative flow potentials on July 25, positive flow potentials on August 20 and September 10, and neutral flow potentials on October 10. Head differences at tributary site 9 showed negative flow potential on August 20, positive flow potential on July 25 and October 10, and a neutral flow potential on September 10. The U of M Lake Drain at site 8 was dry three of the four measurement dates. On October 10, head difference measured at site 8 showed a negative flow potential.

Head-difference measurements at site 4 seem more strongly positive than what would be expected because reach 4 was a significantly losing reach on June 18 and showed no significant change on August 20 and September 10. This strong positive flow potential may be due to shallow ground-water flow from a small pond on the east bank of Honey Creek just upstream from site 4, or the site may be in an area where the hyporheic zone is discharging to the stream, or a combination of the two factors may be the cause. In any case, it is a good example of how local area head-difference measurements differ from reach-averaged seepage-run results.

The head differences of –0.52 ft at the discharge tributary site 6 on July 26 and of –0.46 ft at the U of M Lake Drain site 8 on October 10 may be due to anthropogenic influences. The site 6 head difference may be the result of a misread tape, but this cannot be verified; therefore, the head difference is reported in table 4 as it was recorded on the field notes. The streamflow observed at site 8 on October 10 appeared much larger than the observed streamflow at either site 7 or site 9, the sites downstream and upstream from site 8 on the U of M Lake Drain. It is likely that the anomalously high streamflow observed at site 8 was due to a short-duration discharge from a well or fire hydrant to reach 8 or the Wagner Drain.

The magnitudes of the four significantly negative head differences measured at site 11 were the largest measured during the study. Only site 7 had a significantly positive head difference of the same magnitude. Site 11 is between the little lake and the settling pond on the discharge tributary, and the strong negative head difference may be an artifact of the piezometer location. The water levels in the little lake and the settling pond had an elevation difference of at least 3 ft. The discharge tributary leaves the little lake through a culvert under Little Lake Road and discharges back to the streambed about 20 ft upstream from the piezometer location. The culvert keeps the stream at about the same elevation as the little lake at its discharge point, but ground-water levels develop a natural gradient between the little lake and the settling pond. At site 11, water is flowing from the stream to the hyporheic zone.

Five measurements of head, specific conductance, and water-temperature were made at discharge tributary site 13 after the installation of the mid-level and deep piezometers (table 5). Two of the measurements were part of piezometer measurement runs on September 10 and October 10. The other three runs were made only to measure this piezometer nest. Head differences for the shallow piezometer showed a small positive flow potential on September 8 (0.05 ft) and neutral flow potentials on the other four measurement days. Head differences for the mid-level, deep, and bank piezometers showed negative potential on all measurement days.

Overall head-potential measurements at site 13 during September and October showed a strong negative potential away from the discharge tributary (table 5). Between the mid-level and deep piezometers, the negative head potential exceeded more than 4.4 ft on all five measurement runs. From the resistance met during the driving of the piezometers, there appears to be a cohesive layer beneath this reach of the discharge tributary channel. This layer may be isolating this section of the discharge tributary from the deeper ground-water system. The strong negative potential may mean that the deep piezometer penetrated a sand layer with a higher hydraulic conductivity than shallower layers or that there is drawdown in this area from nearby pumping wells. However, the reason for

Table 4. Head, specific-conductance, and water-temperature measurements from sites 1 – 15 with head difference the between stream and the shallow aquifer, 2003, Washtenaw County, Mich.

[--, no data]

Site	Date	Head (feet)			Specific conductance (microsiemens per centimeter)		Water temperature (degrees Celsius)	
		Stream	Shallow aquifer	[1]Difference	Stream	Shallow aquifer	Stream	Shallow aquifer
1	25-Jul	--	--	--	--	--	--	--
	20-Aug	17.10	17.15	0.05	1,222	320	20.5	16.5
	10-Sep	17.03	17.09	.06	1,330	422	17.5	15.5
	10-Oct	17.06	17.02	-.04	1,441	402	14.5	12.5
2	25-Jul	19.50	19.50	.00	1,447	818	22.0	14.5
	20-Aug	19.57	19.70	.13	1,222	995	21.0	15.0
	10-Sep	19.52	19.63	.11	1,330	812	18.5	14.5
	10-Oct	19.49	19.62	.13	1,450	1,003	15.0	13.0
3	25-Jul	19.00	18.92	-.08	1,085	671	21.5	15.5
	20-Aug	19.01	19.09	.08	1,145	1,442	22.0	16.0
	10-Sep	18.99	19.06	.07	1,127	1,237	18.5	15.5
	10-Oct	19.08	19.12	.04	1,229	1,214	14.0	12.0
4	25-Jul	--	--	--	--	--	--	--
	20-Aug	19.11	19.74	.63	1,224	809	20.5	17.0
	10-Sep	19.09	19.62	.53	1,343	981	18.5	16.0
	10-Oct	19.07	19.75	.68	1,512	1,003	15.5	13.0
5	25-Jul	18.45	18.80	.35	1,480	1,366	22.0	10.5
	20-Aug	18.69	19.05	.36	1,226	1,142	20.5	10.5
	10-Sep	18.59	18.93	.34	1,350	1,458	18.5	10.5
	10-Oct	18.51	18.91	.40	1,531	1,445	16.0	10.5
6	25-Jul	17.64	17.12	-.52	1,772	690	22.0	18.0
	20-Aug	17.66	17.71	.05	1,395	578	22.0	19.5
	10-Sep	17.60	17.67	.07	1,649	487	20.0	18.0
	10-Oct	17.64	17.61	-.03	1,739	361	15.5	14.0
7	25-Jul	17.86	18.46	.60	830	809	15.5	15.0
	20-Aug	17.91	18.72	.81	788	813	17.0	16.0
	10-Sep	17.90	18.68	.78	828	828	15.0	16.0
	10-Oct	17.94	18.59	.65	898	784	14.0	13.5
8	25-Jul	--	--	--	--	566	--	17.0
	20-Aug	--	17.18	--	--	629	--	18.5
	10-Sep	--	17.05	--	--	552	--	18.0
	10-Oct	17.28	16.92	-.46	497	632	14.5	14.5
9	25-Jul	18.20	18.34	.14	1,185	334	18.5	13.5
	20-Aug	18.99	18.84	-.15	849	333	17.5	14.0
	10-Sep	18.94	18.97	.03	782	268	16.0	14.0
	10-Oct	18.98	19.06	.08	863	240	11.0	12.0
10 stream	25-Jul	19.24	19.07	-.17	1,804	794	22.0	17.5
	20-Aug	19.22	19.17	-.05	1,420	717	21.5	18.5
	10-Sep	19.25	19.03	-.22	1,679	722	19.5	16.5
	10-Oct	19.14	19.04	-.10	1,785	656	15.0	14.5
10 bank	25-Jul	19.24	19.06	-.18	1,804	750	22.0	15.0
	20-Aug	19.22	19.20	-.02	1,420	654	21.5	16.0
	10-Sep	19.25	19.07	-.18	1,679	695	19.5	16.0
	10-Oct	19.14	18.98	-.16	1,785	767	15.0	14.5
11	25-Jul	18.19	17.27	-.92	1,806	1,737	20.0	20.5
	20-Aug	18.43	17.56	-.87	1,466	1,345	20.5	21.0
	10-Sep	18.22	17.41	-.81	1,717	1,240	18.5	19.0
	10-Oct	18.23	17.37	-.86	1,807	1,462	15.0	14.0
12	25-Jul	19.16	19.00	-.16	1,920	1,577	16.0	16.0
	20-Aug	19.17	19.05	-.12	1,605	1,325	16.5	17.5
	10-Sep	19.09	19.03	-.06	1,801	1,612	15.0	16.5
	10-Oct	19.17	19.04	-.13	1,789	1,041	14.0	14.0
13 stream	25-Jul	18.46	18.46	.00	1,916	1,703	16.0	15.0
	20-Aug	18.61	18.54	-.07	1,598	1,877	17.0	16.0
	10-Sep	18.50	18.54	.04	1,798	1,931	15.0	15.5
	10-Oct	18.48	18.45	-.03	1,794	1,872	14.0	14.0
13 bank	25-Jul	18.46	18.31	-.15	1,916	1,595	16.0	15.5
	20-Aug	18.61	18.39	-.22	1,598	1,593	17.0	16.5
	10-Sep	18.50	18.39	-.11	1,798	1,592	15.0	16.0
	10-Oct	18.48	18.30	-.18	1,794	1,496	14.0	13.5
14	25-Jul	19.16	19.21	.05	980	938	22.0	18.5
	20-Aug	19.38	19.60	.22	737	955	22.0	19.5
	10-Sep	19.29	19.42	.13	768	969	19.0	19.0
	10-Oct	19.33	19.47	.14	765	981	14.5	15.0
15	25-Jul	18.65	19.17	.52	1,034	685	22.5	17.5
	20-Aug	18.70	18.98	.28	967	314	17.0	14.5
	10-Sep	18.71	18.70	-.01	1,010	807	15.5	14.5
	10-Oct	18.59	18.55	-.04	1,085	593	15.5	13.0

[1] The difference in head is measured with respect to the stream level. A negative head difference indicates flow potential away from the stream; a positive head difference indicates flow potential towards the stream.

Table 5. Head, specific conductance, and water-temperature measurements at site 13 with head difference between the stream and shallow aquifer during September and October 2003, Washtenaw County, Mich.
[--, no data]

Piezometer	Date	Head (feet)			Specific Conductance (microsiemens per centimeter)		Water temperature (degrees Celsius)	
		Stream	Piezometer	[1]Difference	Stream	Piezometer	Stream	Piezometer
Shallow	8-Sep	18.49	18.54	0.05	1,600	1,745	16.0	16.0
	10-Sep	18.50	18.54	.04	1,798	1,931	15.0	15.5
	17-Sep	18.46	18.49	.03	--	--	--	--
	30-Sep	18.55	18.54	-.01	--	--	--	--
	10-Oct	18.48	18.45	-.03	1,794	1,872	14.0	14.0
Mid-level	8-Sep	18.49	18.38	-.11	1,600	1,570	16.0	15.0
	10-Sep	18.50	18.27	-.23	1,798	1,894	15.0	15.5
	17-Sep	18.46	18.29	-.17	--	--	--	--
	30-Sep	18.55	18.10	-.45	--	--	--	--
	10-Oct	18.48	17.80	-.68	1,794	1,900	14.0	14.0
Deep	8-Sep	18.49	13.13	-5.36	1,600	1,092	16.0	14.0
	10-Sep	18.50	12.93	-5.57	1,798	1,299	15.0	14.0
	17-Sep	18.46	13.24	-5.22	--	--	--	--
	30-Sep	18.55	13.57	-4.98	--	--	--	--
	10-Oct	18.48	13.39	-5.09	1,794	508	14.0	13.5
Bank	8-Sep	18.49	18.38	-.11	1,600	1,315	16.0	16.0
	10-Sep	18.50	18.39	-.11	1,798	1,592	15.0	16.0
	17-Sep	18.46	18.32	-.14	--	--	--	--
	30-Sep	18.55	--	--	--	--	--	--
	10-Oct	18.48	18.30	-.18	1,794	1,496	14.0	13.5

[1] The difference in head is measured with respect to the stream level. A negative head difference indicates flow potential away from the stream; a positive head difference indicates flow potential towards the stream.

this large head potential is unknown.

Specific conductance and water temperature

If continuous specific conductance and water-temperature data had been collected, the continuity of the data would enable inferences to be made about the relation between the ground water and the stream water. The discrete samples collected do not show these relations but can be used as ancillary data to help in the interpretation of the head data.

Specific conductance values in the shallow aquifer at sites 1, 6, and 10 were 703 to 1,378 µS/cm less than the comparable specific conductance values in the stream at these sites (table 4). The relatively large magnitude of the difference in specific conductance implies little or no outflow of stream water to the shallow aquifer at these sites.

Specific conductance values in the shallow aquifer at sites 2 and 4 were 227 to 629 µS/cm less than the comparable specific conductance values in the stream at these sites (table 4). This difference is smaller in magnitude than the differences measured at sites 1, 6, and 10 and may indicate more interaction between the stream and the shallow aquifer.

Specific conductance values in the shallow aquifer at sites 5, 11, 12, and 13 showed differences from the comparable stream measurements that ranged from -279 to 748 µS/cm (table 4). The magnitude of the specific conductance values in the shallow aquifer (1,041-1,931 µS/cm) at these sites indicates that there may be a high degree of interaction between the stream and the shallow aquifer. However, it is possible that the ground water at these sites had a specific conductance near that of the stream and that ground-water flow was towards the stream.

The difference between ground-water temperature measured in the piezometers and the corresponding stream-water temperature varied from -11.5 to 1.5 °C. However, because of the diurnal fluctuation in stream-water temperature and possibly in ground-water temperature at some sites, the magnitude of this difference by itself does not give any information about the interaction between ground water and stream water.

The ground-water temperature measured at site 4 was 10.5 °C for all four measurements (table 4). These were the four lowest temperature measurements made during the study. Although not conclusive in itself, the consistency of these measurements indicates that there was no ground-water/surface-water interaction at the piezometer depth.

Additional data were collected at site 13 after the installation of the mid-level and deep piezometers. These data showed decreasing specific conductance and water temperature with depth on September 8 and 10 (table 5). On October 10, specific conductance increased from the shallow to the mid-level piezometer; the increase was slight and within the measurement error of the instrument. Specific conductance decreased by 1,392 µS/cm from the mid-level to the deep piezometer, indicating that the bottom of the zone receiving stream infiltration was above the piezometer depth.

At site 13, ground-water measurements on September 8 showed a negative temperature gradient from the shallow to the deep piezometer (table 5). On September 10 and October 10, ground-water temperatures in the shallow and mid-level piezometers were the same, then decreased to the deep piezometer.

COMPARISON OF RESULTS OF SEEPAGE RUNS AND PIEZOMETER MEASUREMENTS

Two primary methods, seepage runs and head difference between the stream and shallow aquifer were used to examine the ground-water/surface-water relations along Honey Creek and the discharge tributary. Seepage runs give average loss or gain for a reach but cannot describe the heterogeneity of the loss or gain over that reach. The head measurements give site-specific data that cannot be extrapolated to other areas in the reach. For the most part on the main stem, the two methods gave confirming results, whereas on the discharge tributary, the two methods gave both confirming and varying results.

The seepage runs show that the main stem of Honey Creek downstream from site 15 was an overall gaining stream. For the three runs, the increase from the combined streamflow of sites 3, 6 (7 and 10 on August 20), 15, 16, and 18 to the streamflow at site 1 was 36 percent on June 18, 31 percent on August 20, and 19 percent on September 10.

Smaller reaches within this larger reach showed variability in the relation between the stream and shallow aquifer. The statistically significant differences in streamflow indicate that reach 5 was a gaining reach on all three runs, reach 2 was a gaining reach on two of the three runs, and reaches 1 and 4 were each a losing reach on one of the runs (fig. 4).

Head differences between the stream and shallow aquifer at sites on the main stem of Honey Creek were mostly significantly positive; no significant negative head difference was measured at any of the main stem sites. These measurements support the seepage-run result that the main stem was overall a gaining stream. The consistency of the piezometer water-temperature measurements at site 5 supports the head-difference indication at that site that ground water was flowing towards the creek. The specific-conductance measurements at site 1 indicate little or no interaction between the stream and shallow aquifer at the depth the measurements were made.

Results of the seepage runs on the discharge tributary were mixed. The discharge tributary between sites 13 and 10 had a significant gain in streamflow of 20 percent on June 18, an insignificant change in streamflow of 3.2 percent on August 20, and a significant loss in streamflow of -11 percent on September 10. Site 6 was not measured during the August 20 seepage run. The discharge tributary between sites 13 and 6 had significant gains in streamflow of 39 percent on June 18 and 12 percent on September 10. Reach 10 was the only reach on the discharge tributary to have significant losses, a loss of -33 percent on August 20 and a loss of -21 percent on September 10 (fig. 4, table 3), whereas this reach had a significant gain of 13 percent during the June 18 seepage run. These measurements demonstrate the temporal variability of ground-water/surface-water relations by showing that under different hydrologic conditions, a reach may be losing or gaining. It was noted, however, that during the June 18 seepage run, the streamflow measurement for site 10 was made upstream from Park Road, whereas during the August 20 and September 10 seepage runs, the streamflow measurements for site 10 were made downstream from Park Road. It is, therefore, possible that the measurements showed a substantial loss of streamflow to the hyporheic zone because of the restriction at the Park Road culvert.

The head differences between the stream and shallow aquifer at sites along the discharge tributary vary in their support of the seepage-run results. The head differences measured at site 6 on August 20 and September 10 were significantly positive, supporting the seepage-run results of a gaining reach. The head differences measured at site 10 for the instream piezometers were significantly negative, supporting the seepage-run results of a losing reach. The head difference measured at the bank piezometer was nonsignificant on August 20 and significantly negative on September 10. Head-difference measurements at site 12 and at both piezometers at site 13 were significantly negative on August 20, in contrast to the seepage-run result that reach 12 was a gaining reach.

The ancillary specific-conductance and water-temperature measurements from sites on the discharge tributary also showed mixed agreement with the seepage-run results. Specific-conductance measurements at sites 6 and 10 indicated little mixing of stream water and ground water at the piezometer depth. This supports the seepage-run results for reach 6 but conflicts with the losing-reach results for reach 10. Specific-conductance measurements at sites 12 and 13 on August 20 indicated mixed water that was predominantly surface water at the piezometer depth. This seems to conflict with the seepage-run result that reach 12 was gaining; however, reach 12 may have been gaining water that had entered the hyporheic zone upstream from site 13.

The overall gain in streamflow along with local measurements of head differences, specific conductance, and water temperature indicated that ground water was discharging to Honey Creek and the discharge tributary. Although reaches and areas that lose streamflow have been identified, it cannot be determined as a result of this study whether the loss is to the regional ground-water system.

SUMMARY AND CONCLUSIONS

The USGS, in cooperation with the city of Ann Arbor, Mich., investigated the ground-water/surface-water relations along Honey Creek during summer and fall 2003. Honey Creek drains a small 23.2-mi^2 basin in Washtenaw County in southeast Michigan. The basin is covered by stratified glacial deposits that range in thickness from approximately 200 ft to 270 ft. Land use/ land cover in the basin is approximately 15 percent urban; 33 percent agriculture; 25 percent upland forest; 17 percent open land; and 10 percent lowlands, wetlands, and water.

Two methods, seepage runs and measurements of the hydraulic-head difference between the stream and shallow aquifer, were used to examine the ground-water/surface-water relations along Honey Creek. Specific-conductance and water-temperature measurements were used as ancillary data to assist in the interpretation of the head measurements. Three seepage runs and four piezometer-measurement runs were made June through October 2003.

Because the seepage runs were made during periods of base flow and no wet atmospheric input, the difference between the sum of upstream streamflow measurements and the downstream streamflow measurement will give the quantity of the ground-water loss or gain. Seepage runs give average loss or gain for a reach but cannot indicate whether loss or gain is uniform over that reach. During seepage runs, streamflow measurements were made at 17 or 18 sites. Standard USGS methods, as described in detail in Rantz and others (1982) were used to make and compute the measurements.

Instream piezometers were installed at sites 1 through 16, bank piezometers were installed at sites 10 and 13, and two deeper instream piezometers were also installed at site 13. The measurements of head, specific conductance, and water temperature made at the piezometer sites are site specific and cannot be extrapolated to other areas in the reach. Head differences were computed by subtracting the stream-surface head from the shallow aquifer head measured in the piezometer. A positive head potential (shallow aquifer head greater than the stream-surface head) indicated flow towards the stream; negative head potential (shallow aquifer head less than stream-surface head) indicated flow away from the stream.

The seepage runs indicated that the main stem of Honey Creek below site 15 and the discharge tributary below site 13 were overall gaining reaches. The seepage runs also indicated that smaller reaches of Honey Creek and the discharge tributary may be losing reaches and that this relation may change over time with changing hydraulic conditions. The piezometer runs support the seepage-run results on the main stem, whereas the piezometer runs both support and conflict with seepage-run measurements on the discharge tributary. Seepage runs give an average for the reach, whereas piezometer head-potential measurements are for a specific area. Data that may appear to be conflicting actually may be showing that within a gaining reach there are localized areas that lose streamflow. Although reaches and areas that lose streamflow have been identified, it cannot be determined as a result of this study whether the loss is to the regional ground-water system.

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Appendix 1. Seepage-run and piezometer-run measurements

Table 1-1. Streamflow measurements for the July 16 and July 29, 2003, seepage runs, Honey Creek, Washtenaw County, Mich.

[ft^3/s, cubic feet per second; --, no data]

Site	July 16 ft^3/s	July 29 ft^3/s
1	--	--
2	--	6.66
3	--	.02
4	--	5.65
5	3.51	6.36
6	1.11	--
7	.03	.02
8	--	.00
9	--	.00
10	.98	--
11	.43	2.63
12	.11	.52
13	.08	.69
14	.08	.04
15	.97	2.67
16	.05	.00
17	.00	.00
18	--	.01

Table 1-2. Head, specific conductance, and water-temperature measurements from the July 10, July 16, and July 29, 2003, piezometer runs, Honey Creek, Washtenaw County, Mich.

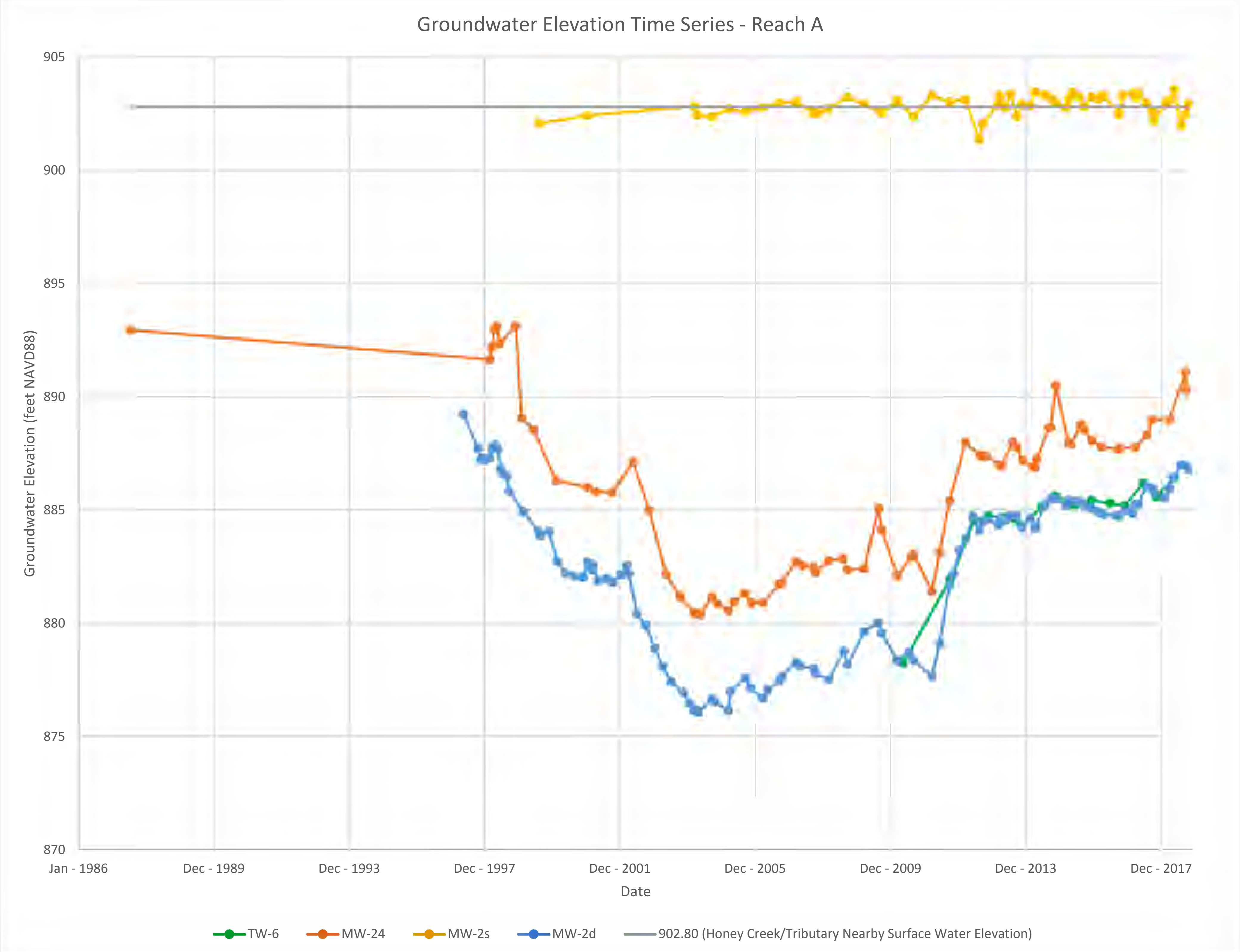
[--, no data]

Site	Date	Head (feet)		Specific conductance (microsiemens per centimeter)		Water temperature (degrees Celsius)	
		Stream	Piezometer	Stream	Piezometer	Stream	Piezometer
1	10-Jul	--	--	--	--	--	--
	16-Jul	--	--	--	--	--	--
	29-Jul	--	--	--	--	--	--
2	10-Jul	--	--	--	--	--	--
	16-Jul	--	--	--	--	--	--
	29-Jul	--	--	--	--	--	--
3	10-Jul	--	--	--	--	--	--
	16-Jul	--	--	--	--	--	--
	29-Jul	--	--	--	--	--	--
4	10-Jul	--	--	--	--	--	--
	16-Jul	--	--	--	--	--	--
	29-Jul	--	--	--	--	--	--
5	10-Jul	--	--	--	--	--	--
	16-Jul	18.35	18.80	1,348	1,438	19.0	10.0
	29-Jul	--	--	--	--	--	--
6	10-Jul	--	--	--	--	--	--
	16-Jul	17.44	16.97	1,760	734	19.5	18.5
	29-Jul	--	--	--	--	--	--
7	10-Jul	17.96	18.19	830	809	18.0	15.0
	16-Jul	17.89	18.36	834	812	15.0	14.0
	29-Jul	--	--	--	--	--	--
8	10-Jul	--	--	--	--	--	--
	16-Jul	--	--	--	--	--	--
	29-Jul	--	--	--	--	--	--
9	10-Jul	18.95	17.56	935	390	23.0	12.5
	16-Jul	--	--	--	--	--	--
	29-Jul	--	--	--	--	--	--
10 stream	10-Jul	19.20	19.15	1,670	878	23.5	14.5
	16-Jul	19.03	19.03	1,875	876	21.0	15.0
	29-Jul	--	--	--	--	--	--
10 bank	10-Jul	--	--	--	--	--	--
	16-Jul	19.03	18.95	1,875	818	21.0	15.5
	29-Jul	--	--	--	--	--	--
11	10-Jul	18.07	17.31	1,769	1,604	21.0	21.5
	16-Jul	17.86	16.99	1,876	1,693	20.5	20.5

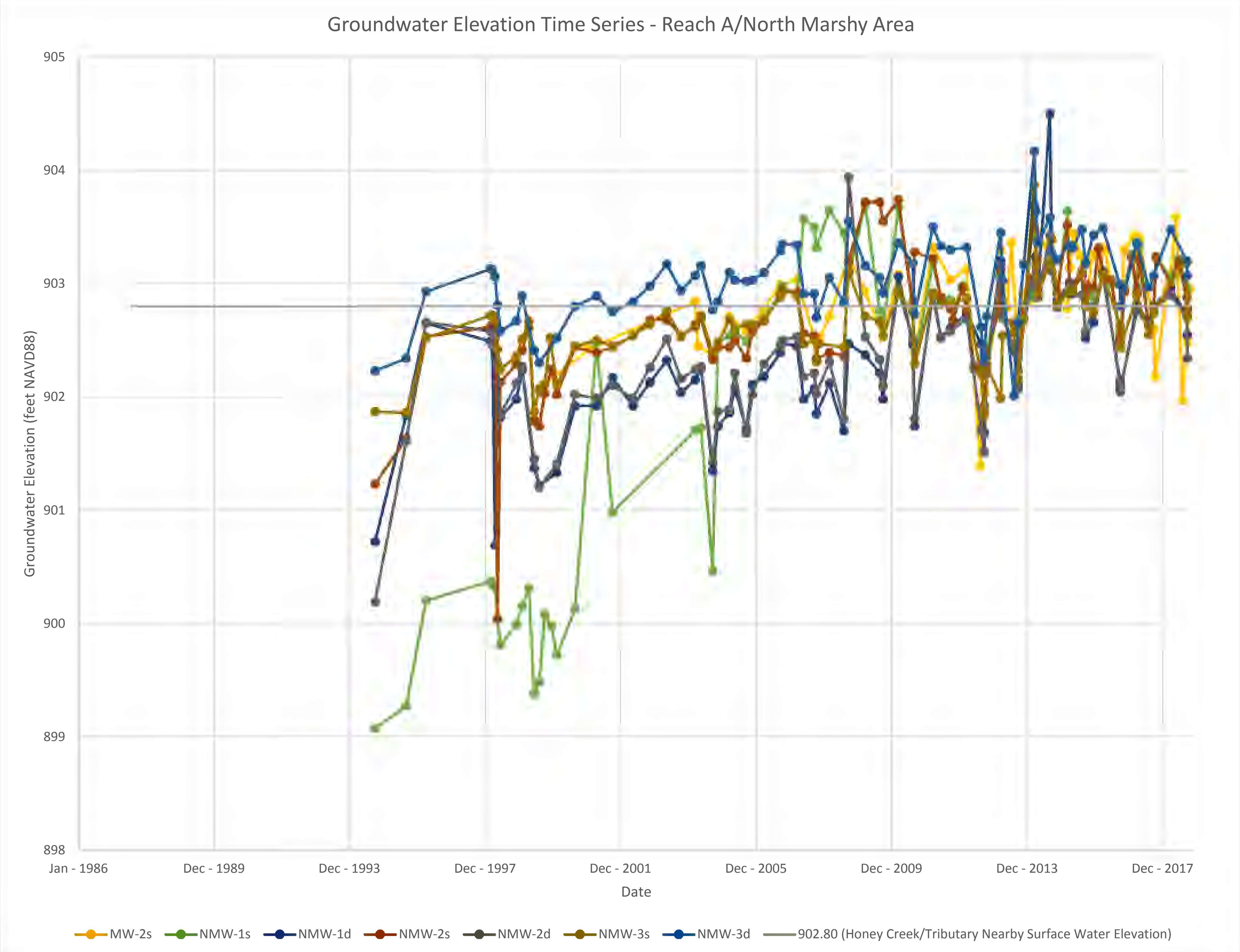
Table 1-2. Head, specific conductance, and water-temperature measurements from the July 10, July 16, and July 29, 2003, piezometer runs, Honey Creek, Washtenaw County, Mich.--Continued

Site	Date	Head (feet)		Specific conductance (microsiemens per centimeter)		Water temperature (degrees Celsius)	
		Stream	Piezometer	Stream	Piezometer	Stream	Piezometer
	29-Jul	--	--	--	--	--	--
12	10-Jul	18.91	18.98	1,082	1,525	21.0	21.5
	16-Jul	18.64	18.76	1,166	1,548	17.0	16.0
	29-Jul	--	--	--	--	--	--
13 stream	10-Jul	18.20	18.21	1,025	2,035	24.0	14.5
	16-Jul	18.00	17.06	1,048	2,020	17.0	15.0
	29-Jul	18.14	18.15	1,139	2,036	17.5	15.0
13 bank	10-Jul	18.20	18.14	1,025	1,622	24.0	16.0
	16-Jul	18.00	--	1,048	1,617	17.0	15.0
	29-Jul	18.14	18.08	1,139	1,564	17.5	16.0
14	10-Jul	--	--	--	--	--	--
	16-Jul	19.11	19.22	1,047	958	19.0	18.0
	29-Jul	19.11	19.11	924	929	18.5	18.5
15	10-Jul	--	--	--	--	--	--
	16-Jul	18.69	19.20	1,022	661	20.5	17.5
	29-Jul	--	--	--	--	--	--

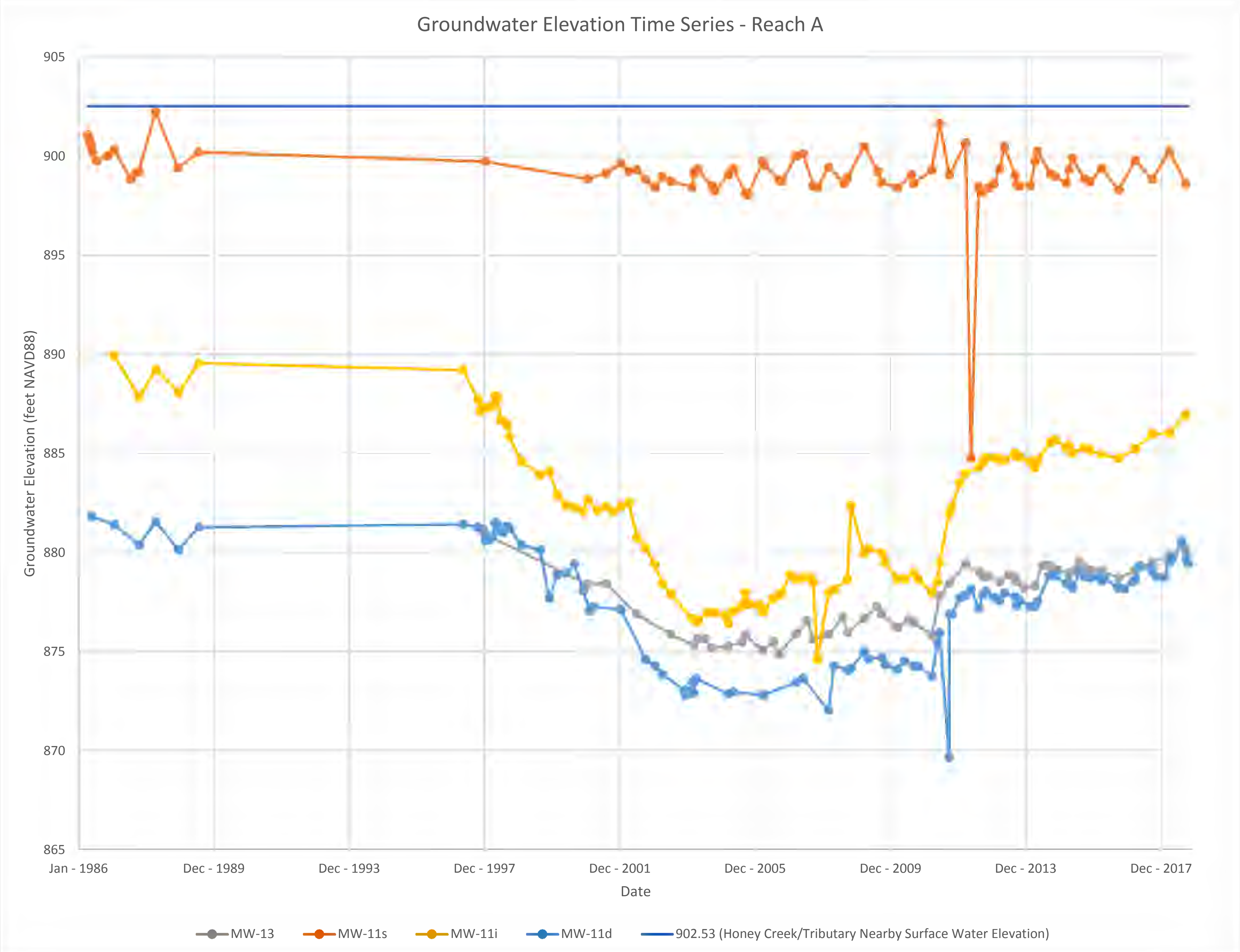
APPENDIX 2



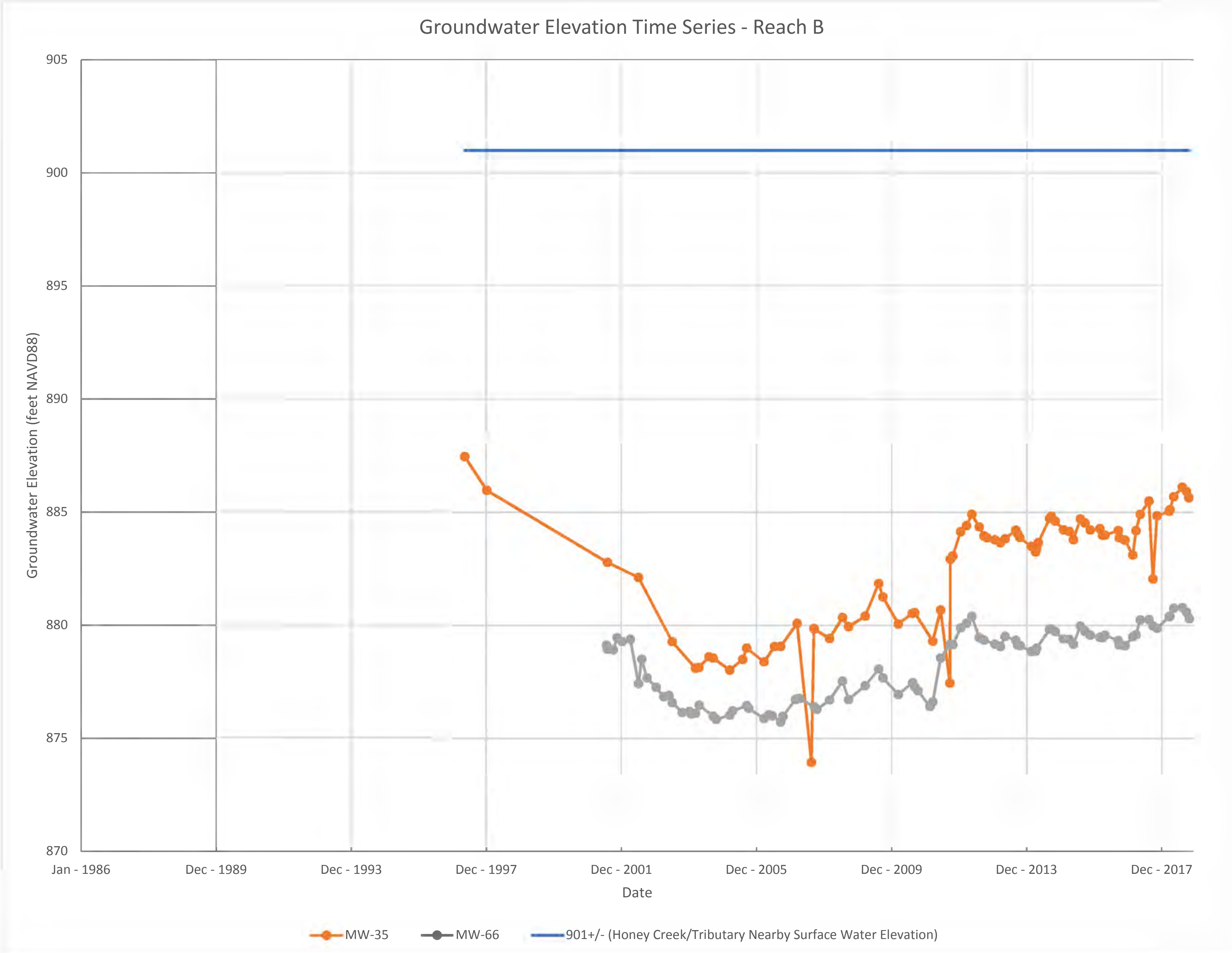
Groundwater Elevation Time Series - Reach A
905
900
895
890
885
880
875
870
Groundwater Elevation (feet NAVD88)
Jan - 1986
Dec - 1989
Dec - 1993
Dec - 1997
Dec - 2001
Dec - 2005
Dec - 2009
Dec - 2013
Dec - 2017
Date
TW-6
MW-24
MW-2s
MW-2d
902.80 (Honey Creek/Tributary Nearby Surface Water Elevation)

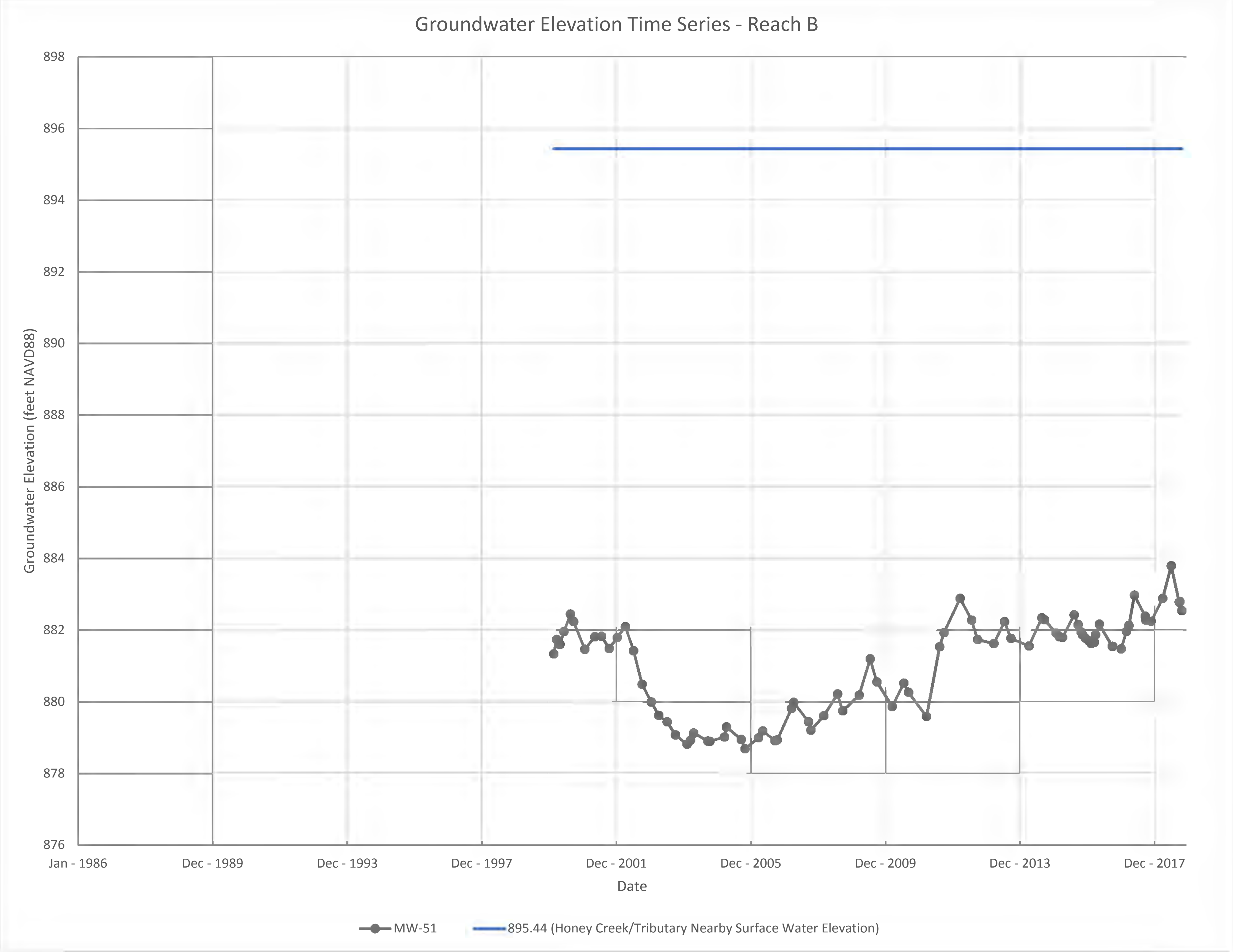


Groundwater Elevation Time Series - Reach A/North Marshy Area
905
904
903
902
901
900
899
898
Groundwater Elevation (feet NAVD88)
Jan - 1986
Dec - 1989
Dec - 1993
Dec - 1997
Dec - 2001
Dec - 2005
Dec - 2009
Dec - 2013
Dec - 2017
Date
MW-2s
NMW-1s
NMW-1d
NMW-2s
NMW-2d
NMW-3s
NMW-3d
902.80 (Honey Creek/Tributary Nearby Surface Water Elevation)

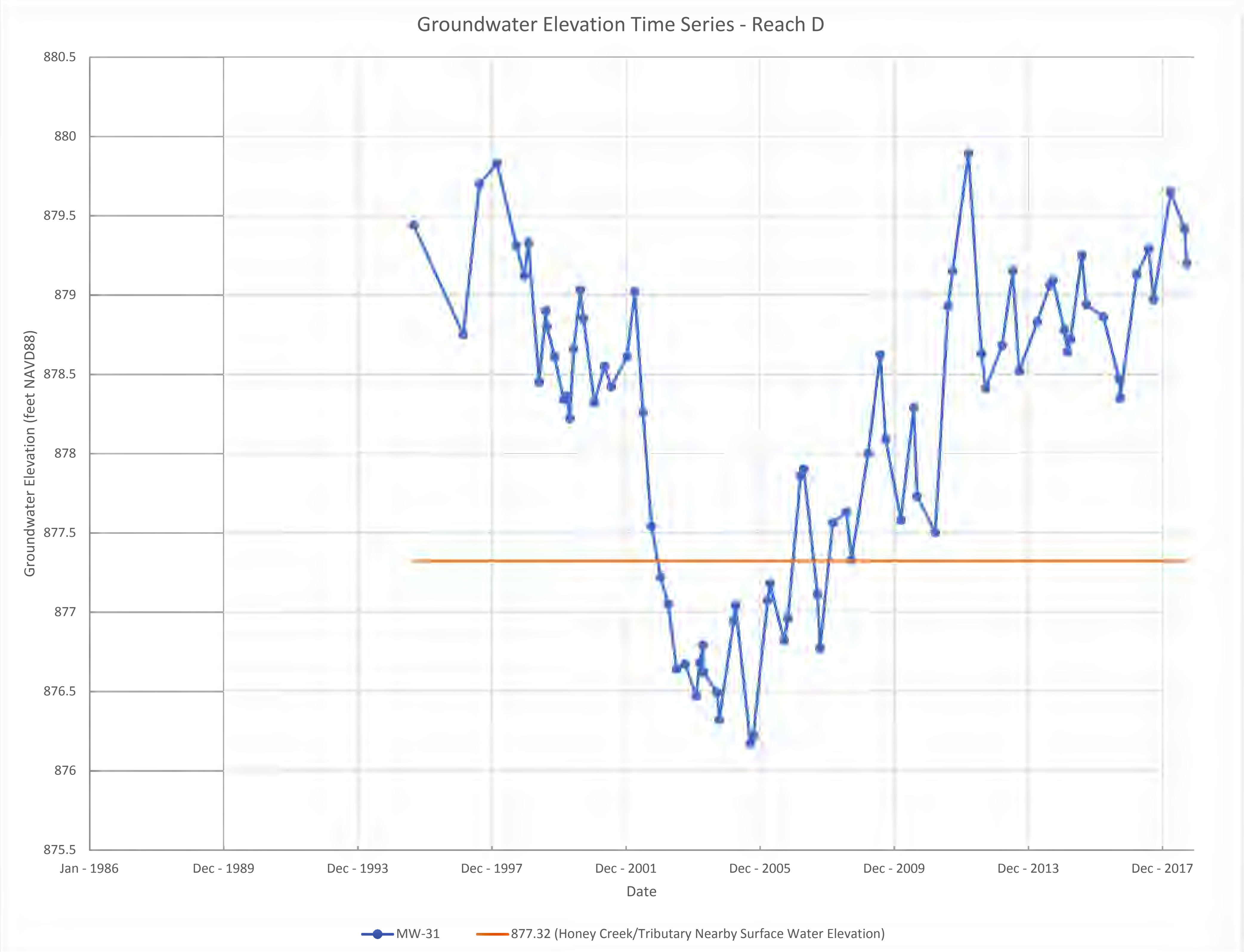


Groundwater Elevation Time Series - Reach A
905
900
895
890
885
880
875
870
865
Groundwater Elevation (feet NAVD88)
Jan - 1986
Dec - 1989
Dec - 1993
Dec - 1997
Dec - 2001
Dec - 2005
Dec - 2009
Dec - 2013
Dec - 2017
Date
MW-13
MW-11s
MW-11i
MW-11d
902.53 (Honey Creek/Tributary Nearby Surface Water Elevation)

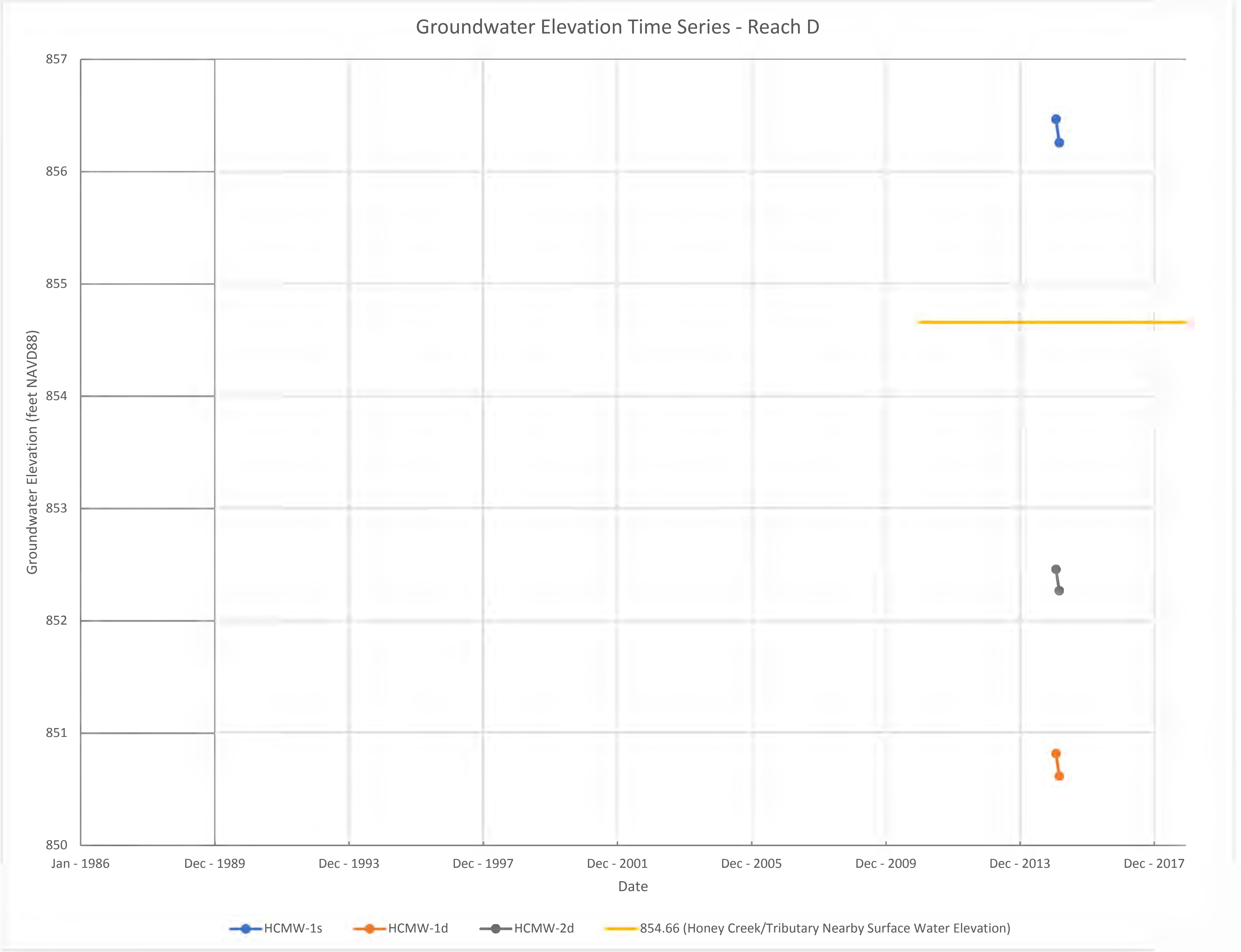

Groundwater Elevation Time Series - Reach B
905
900
895
890
885
880
875
870
Groundwater Elevation (feet NAVD88)
Jan - 1986
Dec - 1989
Dec - 1993
Dec - 1997
Dec - 2001
Dec - 2005
Dec - 2009
Dec - 2013
Dec - 2017
Date
MW-35
MW-66
901+/- (Honey Creek/Tributary Nearby Surface Water Elevation)



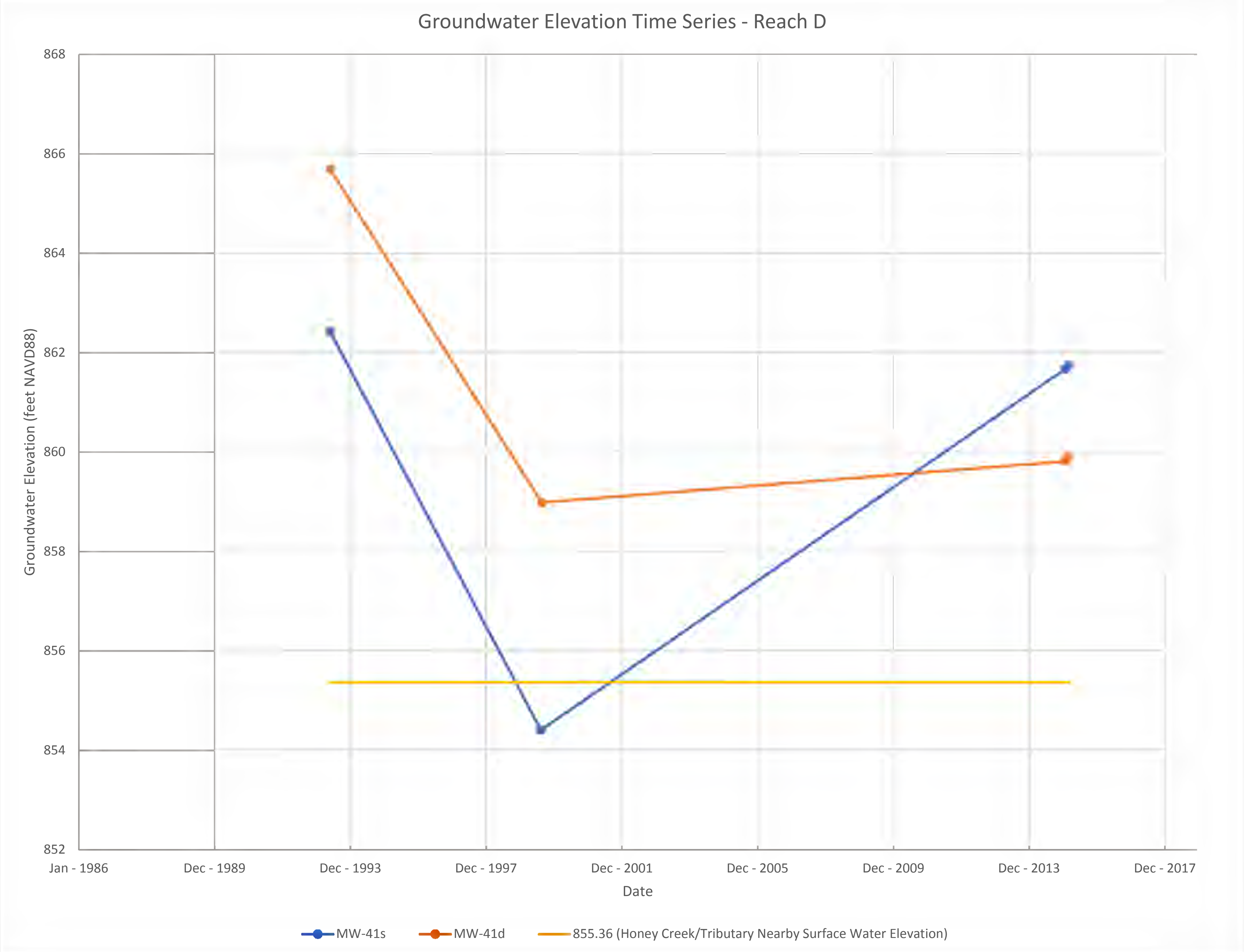
Groundwater Elevation Time Series - Reach B
898
896
894
892
890
888
886
884
882
880
878
876
Groundwater Elevation (feet NAVD88)
Jan - 1986
Dec - 1989
Dec - 1993
Dec - 1997
Dec - 2001
Dec - 2005
Dec - 2009
Dec - 2013
Dec - 2017
Date
MW-51
895.44 (Honey Creek/Tributary Nearby Surface Water Elevation)



Groundwater Elevation Time Series - Reach D
880.5
880
879.5
879
878.5
878
877.5
877
876.5
876
875.5
Groundwater Elevation (feet NAVD88)
Jan - 1986
Dec - 1989
Dec - 1993
Dec - 1997
Dec - 2001
Dec - 2005
Dec - 2009
Dec - 2013
Dec - 2017
Date
MW-31
877.32 (Honey Creek/Tributary Nearby Surface Water Elevation)



Groundwater Elevation Time Series - Reach D
857
856
855
854
853
852
851
850
Groundwater Elevation (feet NAVD88)
Jan - 1986
Dec - 1989
Dec - 1993
Dec - 1997
Dec - 2001
Dec - 2005
Dec - 2009
Dec - 2013
Dec - 2017
Date
HCMW-1s
HCMW-1d
HCMW-2d
854.66 (Honey Creek/Tributary Nearby Surface Water Elevation)



Groundwater Elevation Time Series - Reach D
868
866
864
862
860
858
856
854
852
Groundwater Elevation (feet NAVD88)
Jan - 1986
Dec - 1989
Dec - 1993
Dec - 1997
Dec - 2001
Dec - 2005
Dec - 2009
Dec - 2013
Dec - 2017
Date
MW-41s
MW-41d
855.36 (Honey Creek/Tributary Nearby Surface Water Elevation)

APPENDIX 3

Sample Identification	Date	Result	Units	Laboratory	Comments
HCT	5/12/1992	<1	µg/L	GSI	Jackson Plaza and Wagner Road Crossing
HCT-B01/HCT 2-1	2/25/1987	<10	µg/L	GSI	Dolph Park
HCT-B02/HCT 2-2	2/25/1987	<10	µg/L	GSI	South of 425 Jackson Plaza
HCT-B03/HCT 2-3	4/11/1986	<1,000	µg/L	GSI	East of Jackson Plaza culvert
	2/25/1987	<10	µg/L	GSI	
HCT-B04/HCT 2-4	2/25/1987	22	µg/L	GSI	West of Jackson Plaza culvert
HCT-1	4/14/1988	45	µg/L	GSI	Purge pipe crossing
	5/13/1988	246	µg/L	GSI	
	6/16/1988	3	µg/L	GSI	
	8/25/1988	54	µg/L	ATS	
	9/25/1988	90	µg/L	ATS	
	1/21/1989	35	µg/L	GSI	
	1/21/1989	39	µg/L	GSI	
	2/27/1989	110	µg/L	GSI	
	3/20/1989	10	µg/L	GSI	
	4/24/1989	31	µg/L	GSI	
	5/23/1989	130	µg/L	GSI	
	7/10/1989	27	µg/L	GSI	
	8/24/1989	17	µg/L	GSI	
	9/19/1989	2	µg/L	GSI	
	10/25/1989	83	µg/L	GSI	
	11/30/1989	20	µg/L	GSI	
	12/26/1989	35	µg/L	GSI	
	1/30/1990	18	µg/L	GSI	
	3/14/1990	6	µg/L	GSI	
	3/28/1990	33	µg/L	GSI	
	5/22/1990	13	µg/L	GSI	
	6/7/1990	48	µg/L	GSI	
	8/6/1990	12	µg/L	GSI	
	11/27/1990	50	µg/L	GSI	
	4/10/1991	20	µg/L	GSI	
	8/23/1991	6	µg/L	GSI	
	5/12/1992	7	µg/L	GSI	
	7/23/1992	13	µg/L	GSI	
	11/12/1992	3	µg/L	GSI	
	3/3/1993	23	µg/L	GSI	
	5/26/1993	22	µg/L	GSI	
	7/22/1993	3	µg/L	GSI	
	8/19/1993	20	µg/L	GSI	
	12/16/1993	4	µg/L	GSI	
	6/18/1994	3	µg/L	Matrix	
HCT-Marshy	9/18/2018	<1	µg/L	MDEQ	Honey Creek Tributary - Marshy Area
HCT-B05/HCT 2-5	2/25/1987	78	µg/L	GSI	South of 300 Jackson Plaza
HT1-7	8/19/1988	22	µg/L	ATS	Corner SW of Redskin Industries Bldg
	9/15/1988	35	µg/L	ATS	
	10/14/1988	280	µg/L	ATS	
	11/10/1988	<1	µg/L	ATS	
	11/10/1988	1	µg/L	ATS	
	12/11/1988	35	µg/L	ATS	
	1/6/1989	33	µg/L	ATS	
HCT-2/ HCT-B06/HCT 2-6	1/27/1986	<1,000	µg/L	GSI	Corner SW of Redskin Industries Bldg
	1/27/1986	<1,000	µg/L	GSI	
	4/11/1986	<1,000	µg/L	GSI	
	2/25/1987	293	µg/L	GSI	
	4/14/1988	79	µg/L	GSI	
	5/13/1988	180	µg/L	GSI	
	8/25/1988	48	µg/L	GSI	
	9/25/1988	110	µg/L	ATS	
	1/21/1989	48	µg/L	GSI	
	1/21/1989	96	µg/L	GSI	
	3/20/1989	12	µg/L	GSI	
	4/24/1989	42	µg/L	GSI	
	5/23/1989	220	µg/L	GSI	
	7/10/1989	23	µg/L	GSI	
	8/24/1989	26	µg/L	GSI	
	9/20/1989	3	µg/L	GSI	
	10/25/1989	270	µg/L	GSI	
	11/30/1989	47	µg/L	GSI	
	12/26/1989	31	µg/L	GSI	
	3/14/1990	5	µg/L	GSI	
	3/28/1990	57	µg/L	GSI	

Sample Identification	Date	Result	Units	Laboratory	Comments
HCT-2/ HCT-B06/HCT 2-6	5/22/1990	15	µg/L	GSI	Corner SW of Redskin Industries Bldg
	6/18/1990	44	µg/L	GSI	
	8/6/1990	24	µg/L	GSI	
	11/27/1990	80	µg/L	GSI	
	4/10/1991	81	µg/L	GSI	
	8/23/1991	48	µg/L	GSI	
	5/12/1992	12	µg/L	GSI	
	7/23/1992	63	µg/L	GSI	
	11/12/1992	3	µg/L	GSI	
	3/3/1993	68	µg/L	GSI	
	5/26/1993	23	µg/L	GSI	
	7/22/1993	11	µg/L	GSI	
	8/19/1993	26	µg/L	GSI	
	12/16/1993	44	µg/L	GSI	
	6/18/1994	34	µg/L	Matrix	
HCT-B07/HCT 2-7	2/25/1987	217	µg/L	GSI	300' North of southwest corner of Jackson Plaza
HCT-B08/HCT 2-8	2/25/1987	187	µg/L	GSI	430' North of southwest corner of Jackson Plaza
HCT-B09/HCT 2-9	2/25/1987	159	µg/L	GSI	550' North of southwest corner of Jackson Plaza
HCT-B10/HCT 2-10	2/25/1987	112	µg/L	GSI	South of Nancy Drive
HCT-Outfall 001	11/7/2017	1.6	µg/L	MDEQ	Honey Creek Tributary Outfall
	12/6/2017	1.1	µg/L	MDEQ	
	9/18/2018	4.9	µg/L	MDEQ	
HCT-Outfall UP	9/18/2018	5.2	µg/L	MDEQ	Honey Creek Tributary Outfall UP
HCT-1.1	1/30/1990	18	µg/L	GSI	Honey Creek Tributary at discharge point
	2/1/1990	28	µg/L	GSI	
HCT-B11/HCT 2-11	2/25/1987	104	µg/L	GSI	Between Nancy & Aprill Drives
HCT-2.1	1/30/1990	40	µg/L	GSI	Honey Creek downstream of discharge, before Little Lake
	2/1/1990	50	µg/L	GSI	
HCT-3	4/14/1988	61	µg/L	GSI	South of Aprill Drive
	5/13/1988	38	µg/L	GSI	
	6/16/1988	<2	µg/L	GSI	
	8/25/1988	13	µg/L	ATS	
	9/25/1988	14	µg/L	ATS	
	1/21/1989	78	µg/L	GSI	
	1/21/1989	54	µg/L	GSI	
	2/27/1989	58	µg/L	GSI	
	3/21/1989	22	µg/L	GSI	
	4/24/1989	37	µg/L	GSI	
	5/23/1989	40	µg/L	GSI	
	7/10/1989	9	µg/L	GSI	
	8/24/1989	5	µg/L	GSI	
	9/19/1989	7	µg/L	GSI	
	10/24/1989	59	µg/L	GSI	
	11/30/1989	83	µg/L	GSI	
	12/26/1989	16	µg/L	GSI	
	3/14/1990	14	µg/L	GSI	
	3/28/1990	53	µg/L	GSI	
	5/22/1990	20	µg/L	GSI	
	6/12/1990	26	µg/L	GSI	
	8/6/1990	6	µg/L	GSI	
	11/27/1990	31	µg/L	GSI	
	4/10/1991	68	µg/L	GSI	
	8/23/1991	2	µg/L	GSI	
	5/12/1992	14	µg/L	GSI	
	7/23/1992	7	µg/L	GSI	
	11/12/1992	5	µg/L	GSI	
	3/3/1993	13	µg/L	GSI	
	5/26/1993	4	µg/L	GSI	
	7/22/1993	2	µg/L	GSI	
	8/19/1993	27	µg/L	GSI	
	12/16/1993	26	µg/L	GSI	
	6/18/1994	5	µg/L	Matrix	
HT1-6	8/19/1988	6	µg/L	ATS	South of Aprill Drive
	9/15/1988	1	µg/L	ATS	
	10/14/1988	25	µg/L	ATS	
	11/10/1988	1	µg/L	ATS	
	12/11/1988	38	µg/L	ATS	
	1/6/1989	25	µg/L	ATS	
HCT-B12/HCT 2-12	2/6/1986	<1,000	µg/L	GSI	South of Aprill Drive
	2/25/1987	59	µg/L	GSI	
HCT-B13/HCT 2-13	2/25/1987	33	µg/L	GSI	Between Aprill Drive & Parkland Plaza

Sample Identification	Date	Result	Units	Laboratory	Comments
HCT-B14/HCT 2-14	2/6/1986	<1,000	µg/L	GSI	Parkland Plaza culvert
HCT-B14/HCT 2-14	2/25/1987	33	µg/L	GSI	Parkland Plaza culvert
HCT-3.01	5/12/1992	15	µg/L	GSI	Honey Creek Tributary before Little Lakes at Parkland Plaza
HT1-5	8/19/1988	6	µg/L	ATS	East end of Little Lake
HT1-5	9/15/1988	1	µg/L	ATS	East end of Little Lake
HT1-5	10/14/1988	24	µg/L	ATS	East end of Little Lake
HT1-5	10/14/1988	22	µg/L	ATS	East end of Little Lake
HT1-5	11/10/1988	1	µg/L	ATS	East end of Little Lake
HT1-5	12/11/1988	26	µg/L	ATS	East end of Little Lake
HT1-5	1/6/1989	19	µg/L	ATS	East end of Little Lake
Little Lake	11/7/2017	1.6	µg/L	MDEQ	At Little Lake
Little Lake	12/6/2017	3.6	µg/L	MDEQ	At Little Lake
Little Lake	9/18/2018	4.1	µg/L	MDEQ	At Little Lake
HCT-B15/HCT 2-15	2/25/1987	20	µg/L	GSI	At Little Lake
HT1-4	8/19/1988	<1	µg/L	ATS	West end of Little Lake
HT1-4	9/15/1988	<1	µg/L	ATS	West end of Little Lake
HT1-4	10/14/1988	2	µg/L	ATS	West end of Little Lake
HT1-4	11/10/1988	<1	µg/L	ATS	West end of Little Lake
HT1-4	12/11/1988	12	µg/L	ATS	West end of Little Lake
HT1-4	1/6/1989	9	µg/L	ATS	West end of Little Lake
HCT-4	4/14/1988	38	µg/L	GSI	West of Little Lake, at two-track
HCT-4	5/13/1988	31	µg/L	GSI	West of Little Lake, at two-track
HCT-4	8/25/1988	<1	µg/L	ATS	West of Little Lake, at two-track
HCT-4	9/25/1988	1	µg/L	ATS	West of Little Lake, at two-track
HCT-4	1/21/1989	12	µg/L	GSI	West of Little Lake, at two-track
HCT-4	1/21/1989	13	µg/L	GSI	West of Little Lake, at two-track
HCT-4	2/27/1989	32	µg/L	GSI	West of Little Lake, at two-track
HCT-4	3/21/1989	19	µg/L	GSI	West of Little Lake, at two-track
HCT-4	4/24/1989	24	µg/L	GSI	West of Little Lake, at two-track
HCT-4	5/23/1989	14	µg/L	GSI	West of Little Lake, at two-track
HCT-4	7/10/1989	12	µg/L	GSI	West of Little Lake, at two-track
HCT-4	8/24/1989	2	µg/L	GSI	West of Little Lake, at two-track
HCT-4	9/19/1989	4	µg/L	GSI	West of Little Lake, at two-track
HCT-4	1/30/1990	25	µg/L	GSI	West of Little Lake, at two-track
HCT-4	3/14/1990	9	µg/L	GSI	West of Little Lake, at two-track
HCT-4	3/28/1990	20	µg/L	GSI	West of Little Lake, at two-track
HCT-4	5/22/1990	15	µg/L	GSI	West of Little Lake, at two-track
HCT-4	6/12/1990	19	µg/L	GSI	West of Little Lake, at two-track
HCT-4	8/6/1990	2	µg/L	GSI	West of Little Lake, at two-track
HCT-4	11/27/1990	11	µg/L	GSI	West of Little Lake, at two-track
HCT-4	4/10/1991	26	µg/L	GSI	West of Little Lake, at two-track
HCT-4	8/23/1991	<2	µg/L	GSI	West of Little Lake, at two-track
HCT-4	5/12/1992	8	µg/L	GSI	West of Little Lake, at two-track
HCT-4	7/23/1992	4	µg/L	GSI	West of Little Lake, at two-track
HCT-4	11/12/1992	8	µg/L	GSI	West of Little Lake, at two-track
HCT-4	3/3/1993	15	µg/L	GSI	West of Little Lake, at two-track
HCT-4	5/26/1993	5	µg/L	GSI	West of Little Lake, at two-track
HCT-4	7/22/1993	2	µg/L	GSI	West of Little Lake, at two-track
HCT-4	8/19/1993	2	µg/L	GSI	West of Little Lake, at two-track
HCT-4	12/16/1993	10	µg/L	GSI	West of Little Lake, at two-track
HCT-4	6/18/1994	2	µg/L	Matrix	West of Little Lake, at two-track
HCT-3.1	1/30/1990	25	µg/L	GSI	Honey Creek Tributary after Little Lakes
HCT-3.1	2/1/1990	22	µg/L	GSI	Honey Creek Tributary after Little Lakes
HCT-B16/HCT 2-16	2/25/1987	39	µg/L	GSI	Southeast of Huron Valley Swim Club
HCT-Park	11/7/2017	2.0	µg/L	MDEQ	Honey Creek Tributary - Park Rd
HCT-Park	12/6/2017	3.4	µg/L	MDEQ	Honey Creek Tributary - Park Rd
HCT-Park	9/18/2018	3.8	µg/L	MDEQ	Honey Creek Tributary - Park Rd
HT1-3	8/19/1988	17	µg/L	ATS	Park Road
HT1-3	9/15/1988	35	µg/L	ATS	Park Road
HT1-3	10/14/1988	28	µg/L	ATS	Park Road
HT1-3	11/9/1988	7	µg/L	ATS	Park Road
HT1-3	12/11/1988	19	µg/L	ATS	Park Road
HT1-3	1/6/1989	16	µg/L	ATS	Park Road
HT1-3	1/6/1989	13	µg/L	ATS	Park Road
HCT-B17/HCT 2-17	2/6/1986	<1,000	µg/L	GSI	Park Road culvert
HCT-B17/HCT 2-17	2/25/1987	40	µg/L	GSI	Park Road culvert
HC-1	12/11/1987	52	µg/L	ATS	North of Park Road
HCT-B19/HCT 2-19	2/25/1987	15	µg/L	GSI	South of 4665 Jackson Road
HCT-B20/HCT 2-20	2/25/1987	23	µg/L	GSI	Southwest of ART-2
HCT-B21/HCT 2-21	2/25/1987	<10	µg/L	GSI	Southwest of ART-1

Sample Identification	Date	Result	Units	Laboratory	Comments
HCT-5	4/14/1988	32	µg/L	GSI	Between artesian wells and confl. of HCT with HC proper
	5/13/1988	29	µg/L	GSI	
	6/16/1988	26	µg/L	GSI	
	8/25/1988	15	µg/L	ATS	
	9/25/1988	13	µg/L	ATS	
	1/21/1989	25	µg/L	GSI	
	1/21/1989	28	µg/L	GSI	
	2/27/1989	27	µg/L	GSI	
	3/21/1989	19	µg/L	GSI	
	4/24/1989	24	µg/L	GSI	
	5/23/1989	24	µg/L	GSI	
	7/10/1989	25	µg/L	GSI	
	8/24/1989	21	µg/L	GSI	
	9/19/1989	10	µg/L	GSI	
	11/30/1989	24	µg/L	GSI	
	12/26/1989	25	µg/L	GSI	
	3/14/1990	12	µg/L	GSI	
	3/28/1990	30	µg/L	GSI	
	5/22/1990	25	µg/L	GSI	
	6/12/1990	31	µg/L	GSI	
	8/6/1990	24	µg/L	GSI	
	11/27/1990	29	µg/L	GSI	
	4/17/1991	31	µg/L	GSI	
	8/23/1991	25	µg/L	GSI	
	5/12/1992	17	µg/L	GSI	
	7/23/1992	23	µg/L	GSI	
	11/12/1992	7	µg/L	GSI	
	3/3/1993	20	µg/L	GSI	
	5/26/1993	20	µg/L	GSI	
	7/22/1993	35	µg/L	GSI	
	12/16/1993	20	µg/L	GSI	
	6/18/1994	19	µg/L	Matrix	
HCT-B22/HCT 2-22	2/25/1987	19	µg/L	GSI	At confl. with Third Sister Lake Tributary
HCT-B23/HCT 2-23	2/25/1987	<10	µg/L	GSI	50' south of confl. With Third Sister Lake Tributary
HT1-2	8/19/1988	13	µg/L	ATS	Northwest of confluence with Thirds Sister Lake Tributary
	9/15/188	18	µg/L	ATS	
	10/14/1988	17	µg/L	ATS	
	11/10/1988	3	µg/L	ATS	
	12/11/1988	14	µg/L	ATS	
	1/6/1989	12	µg/L	ATS	
HCT-B24/HCT 2-24	2/25/1987	16	µg/L	GSI	50' northwest of confl. With Third Sister Lake Tributary
HCT-6/ HCT-B25/HCT 2-25	2/25/1987	<10	µg/L	GSI	Culvert north of Jackson Road
	4/14/1988	12	µg/L	GSI	
	6/16/1988	30	µg/L	GSI	
	8/25/1988	14	µg/L	ATS	
	9/25/1988	10	µg/L	ATS	
	1/21/1989	17	µg/L	GSI	
	1/21/1989	18	µg/L	GSI	
	2/28/1989	21	µg/L	GSI	
	3/21/1989	17	µg/L	GSI	
	4/24/1989	18	µg/L	GSI	
	5/24/1989	18	µg/L	GSI	
	7/10/1989	24	µg/L	GSI	
	8/24/1989	27	µg/L	GSI	
	9/19/1989	5	µg/L	GSI	
	10/24/1989	18	µg/L	GSI	
	11/30/1989	16	µg/L	GSI	
	12/26/1989	19	µg/L	GSI	
	3/14/1990	8	µg/L	GSI	
	3/28/1990	22	µg/L	GSI	
	5/22/1990	14	µg/L	GSI	
	6/12/1990	24	µg/L	GSI	
	8/9/1990	22	µg/L	GSI	
	11/27/1990	15	µg/L	GSI	
	4/17/1991	19	µg/L	GSI	
	8/23/1991	20	µg/L	GSI	
	5/12/1992	11	µg/L	GSI	
	7/23/1992	12	µg/L	GSI	
	11/12/1992	8	µg/L	GSI	
	3/3/1993	10	µg/L	GSI	
	8/19/1993	<1	µg/L	GSI	
	7/22/1993	22	µg/L	GSI	
	12/16/1993	12	µg/L	GSI	
	6/18/1994	18	µg/L	Matrix	

Sample Identification	Date	Result	Units	Laboratory	Comments
HCT-Jackson	11/7/2017	1.9	µg/L	MDEQ	Honey Creek Tributary - Jackson Rd
	12/6/2017	2.6	µg/L	MDEQ	
	9/18/2018	3.9	µg/L	MDEQ	
HT1-1	8/18/1988	9	µg/L	ATS	North of Zeeb/I-94
	9/15/1988	13	µg/L	ATS	
	10/14/1988	14	µg/L	ATS	
	11/10/1988	1	µg/L	ATS	
	12/11/1988	10	µg/L	ATS	
	1/5/1989	7	µg/L	ATS	
HC-2	12/11/1987	36	µg/L	ATS	North of Zeeb/I-94
HCT-4.1	1/30/1990	12	µg/L	GSI	Honey Creek Tributary before confl. with Honey Creek proper
	2/1/1990	10	µg/L	GSI	
HCT-5.5	1/30/1990	<1	µg/L	GSI	Confluence point: Honey Creek Trib. With Honey Creek proper
	2/1/1990	<1	µg/L	GSI	
H-5/HC-A6	8/18/1988	<1	µg/L	ATS	Honey Creek before confluence with Honey Creek Trib.
	9/15/1988	<1	µg/L	ATS	
	10/14/1988	<1	µg/L	ATS	
	11/10/1988	<1	µg/L	ATS	
	12/11/1988	<1	µg/L	ATS	
	1/5/1989	<1	µg/L	ATS	
HCT-B26	2/25/1987	<10	µg/L	GSI	Dexter Road culvert
H-4/HC-A7	8/18/1988	<1	µg/L	ATS	Southwest of Dexter Road
	9/15/1988	1	µg/L	ATS	
	10/14/1988	1	µg/L	ATS	
	11/11/1988	<1	µg/L	ATS	
	12/10/1988	1	µg/L	ATS	
	1/5/1989	1	µg/L	ATS	
HC-Dexter	11/7/2017	1.2	µg/L	MDEQ	Honey Creek - Dexter Rd
	12/6/2017	<1.0	µg/L	MDEQ	
	9/18/2018	2.1	µg/L	MDEQ	
HCT-6.2	5/12/1992	2	µg/L	GSI	Honey Creek proper after Dexter-Ann Arbor Rd crossing
HCT-6.3	5/12/1992	2	µg/L	GSI	Honey Creek proper at Miller Rd crossing
H-3/HC-4	12/11/1987	8	µg/L	ATS	North of Platt Road
	8/18/1988	<1	µg/L	ATS	
	9/16/1988	1	µg/L	ATS	
	10/14/1988	1	µg/L	ATS	
	11/10/1988	<1	µg/L	ATS	
	12/10/1988	1	µg/L	ATS	
	1/5/1989	1	µg/L	ATS	
H-2/HC-5	12/11/1987	7	µg/L	ATS	South of Miller Road
	8/18/1988	2	µg/L	ATS	
	9/16/1988	1	µg/L	ATS	
	10/14/1988	1	µg/L	ATS	
	11/11/1988	<1	µg/L	ATS	
	12/10/1988	1	µg/L	ATS	
	1/5/1989	1	µg/L	ATS	
HCT-5.1	1/30/1990	<2	µg/L	GSI	Honey Creek proper before confluence point
	2/1/1990	<1	µg/L	GSI	
HR001	6/19/1991	<1	µg/L	GSI	North of railroad, before Honey Creek confluence point
	7/9/1992	<1	µg/L	GSI	
HR002	6/19/1991	3	µg/L	GSI	Honey Creek between Huron River Dr bridge and Huron River
	7/9/1992	2	µg/L	GSI	
HCT-7	1/30/1990	2	µg/L	GSI	Honey Creek property outfall to Huron River at Huron Rv Dr
	2/1/1990	1	µg/L	GSI	
	5/12/1992	1	µg/L	GSI	
H-1/HC-6	12/11/1987	7	µg/L	ATS	Honey Creek at Huron River Confluence
	8/18/1988	<1	µg/L	ATS	
	9/16/1988	1	µg/L	ATS	
	10/14/1988	1	µg/L	ATS	
	11/11/1988	<1	µg/L	ATS	
	12/10/1988	1	µg/L	ATS	
	1/5/1989	1	µg/L	ATS	
HC/HR	7/24/2017	<1.0	µg/L	MDEQ	Honey Creek-Huron River Confluence
	9/18/2018	<1	µg/L	MDEQ	
HCT-6.1	1/30/1990	2	µg/L	GSI	Honey Creek proper after confluence point
	2/1/1990	2	µg/L	GSI	
HR003	6/19/1991	<1	µg/L	GSI	Railroad crossing after the Honey Creek confluence point
	7/9/1992	<1	µg/L	GSI	

Notes:

ATS = Ann Arbor Technical Services, Inc.

GSI = Gelman Sciences, Inc.

MDEQ = Michigan Department of Environmental Quality Environmental Laboratory

APPENDIX 4

REACH A

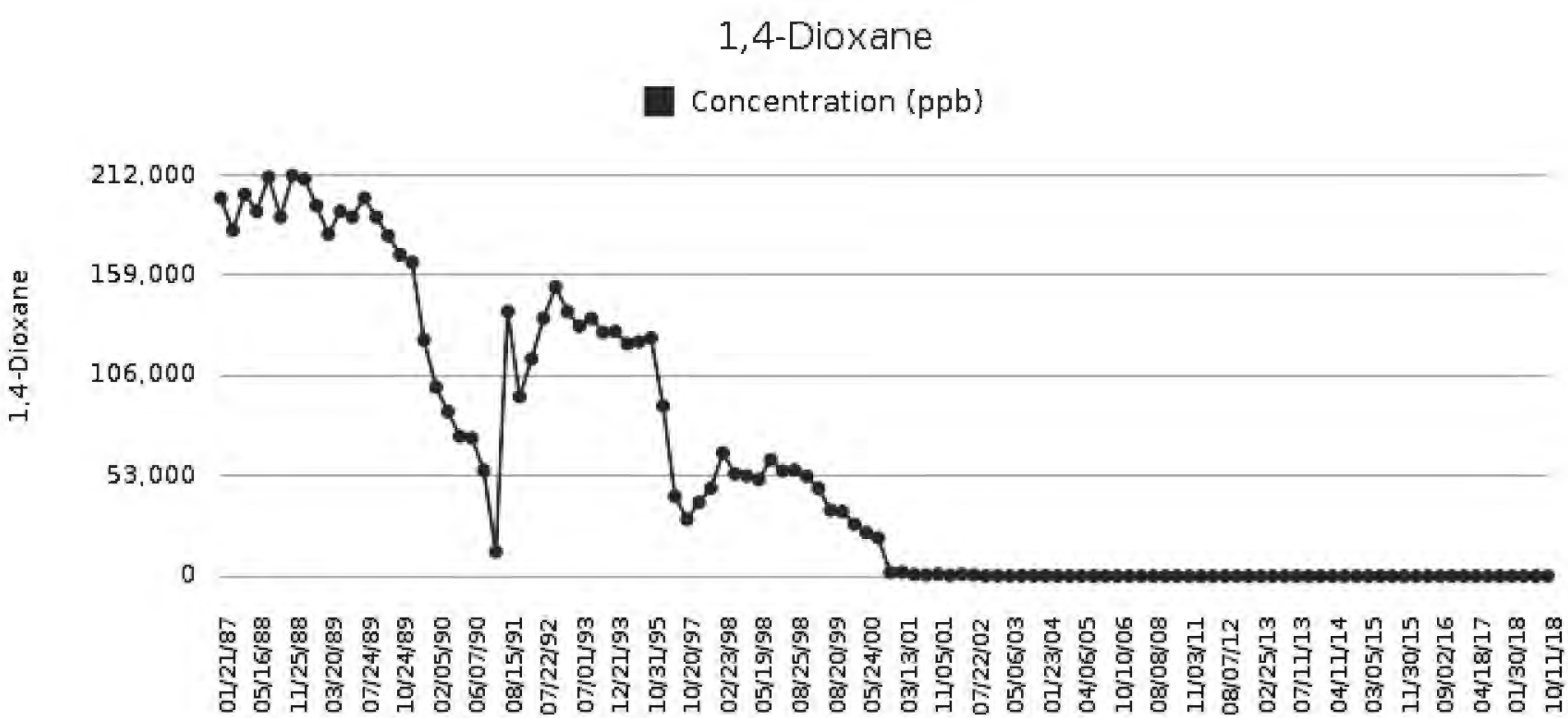
Gelman Sciences, Inc. d/b/a
Pall Life Sciences
642 South Wagner Road
Ann Arbor, MI 48103-9019 US
www.pall.com

Analytical Data Graph

Printed: 11/29/2018

Well Name: MW-2d

Aquifer:	C3	Date Installed:	03/06/1986	Boring Depth:	53.50 Feet bgl	Screen 1:	53.50 to 50.50 Feet
Map Location:	N-16	Well Driller:		Ground Elevation:	909.43 Feet	Screen Length:	3.00
X Coordinate:	13275977.00	Well Type:	Monitoring Wells	TOC Elevation:	911.34 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	284351.00	Sampling Interval:	Quarterly	TOC to screen bottom:	56.00 Feet		
Comments:							



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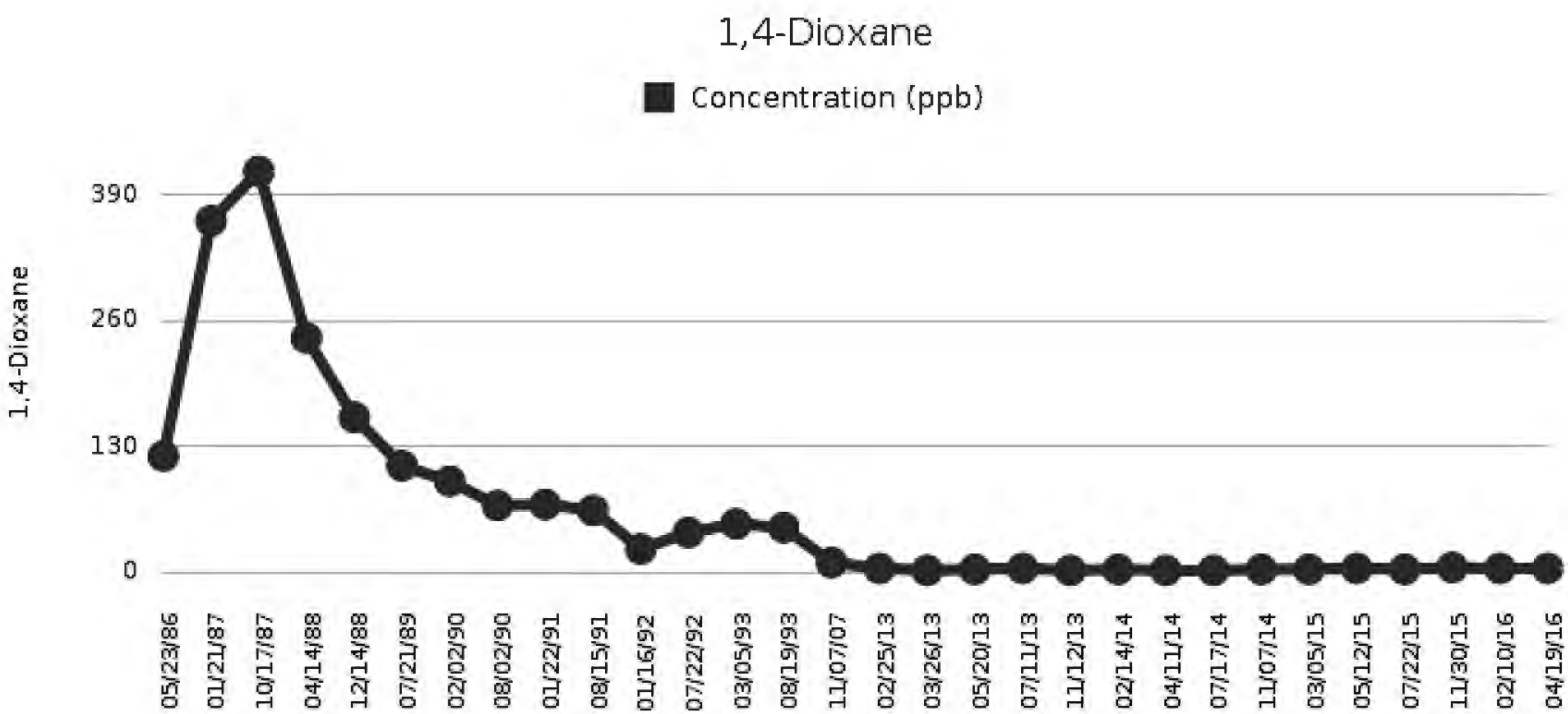
Printed: 11/29/2018

Well Name: MW-2s

Aquifer:	SH	Date Installed:	03/06/1986	Boring Depth:	10.00 Feet bgl	Screen 1:	9.89 to 7.87 Feet
Map Location:	N-16	Well Driller:		Ground Elevation:	908.98 Feet	Screen Length:	2.00
X Coordinate:	13276005.00	Well Type:	Monitoring Wells	TOC Elevation:	911.11 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	284353.00	Sampling Interval:	Quarterly	TOC to screen bottom:	12.52 Feet		
Comments:							



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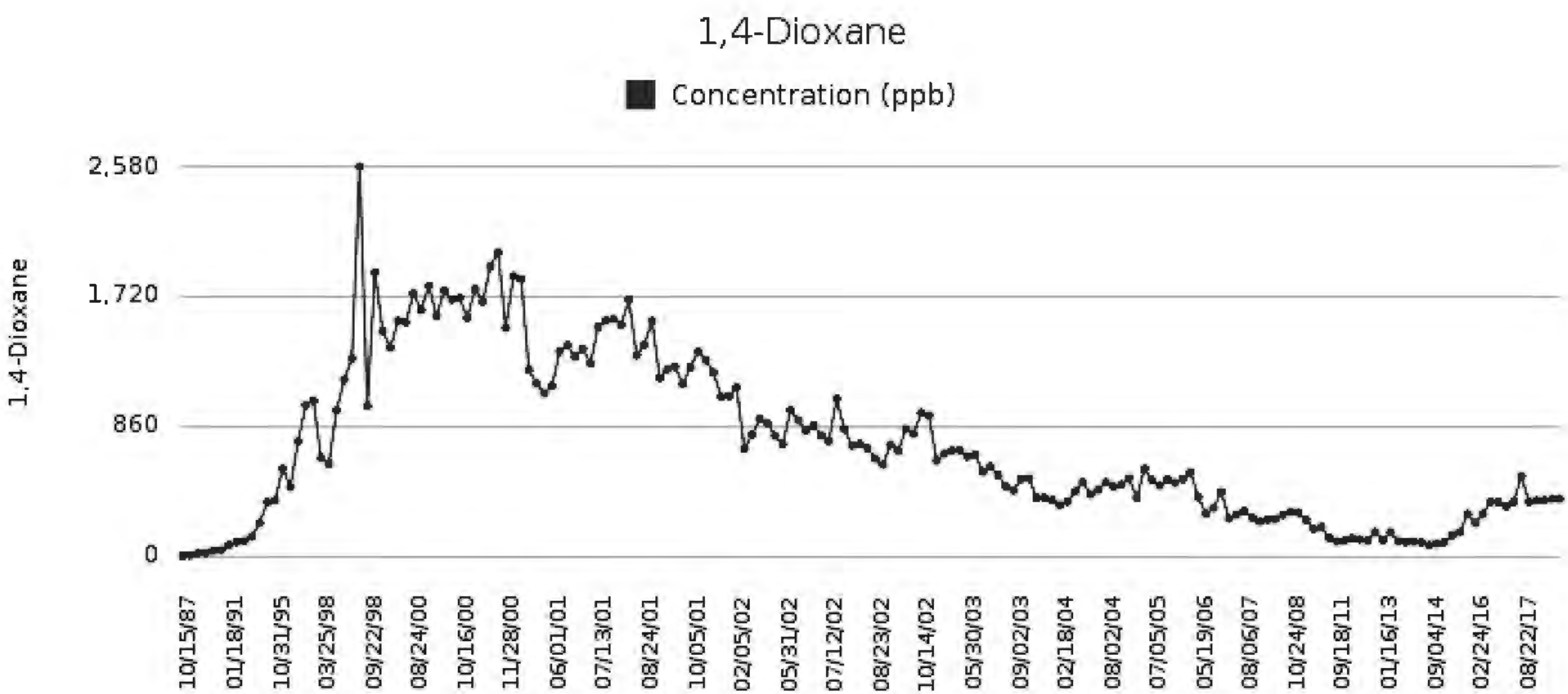
Well Name: MW-11d

Aquifer:	D2	Date Installed:	04/03/1986	Boring Depth:	90.00 Feet bgl	Screen 1:	90.00 to 87.00 Feet
Map Location:	M-14	Well Driller:		Ground Elevation:	910.65 Feet	Screen Length:	3.00
X Coordinate:	13274908.95	Well Type:	Monitoring Wells	TOC Elevation:	913.02 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	285046.96	Sampling Interval:	Quarterly	TOC to screen bottom:	93.00 Feet		
Comments:							



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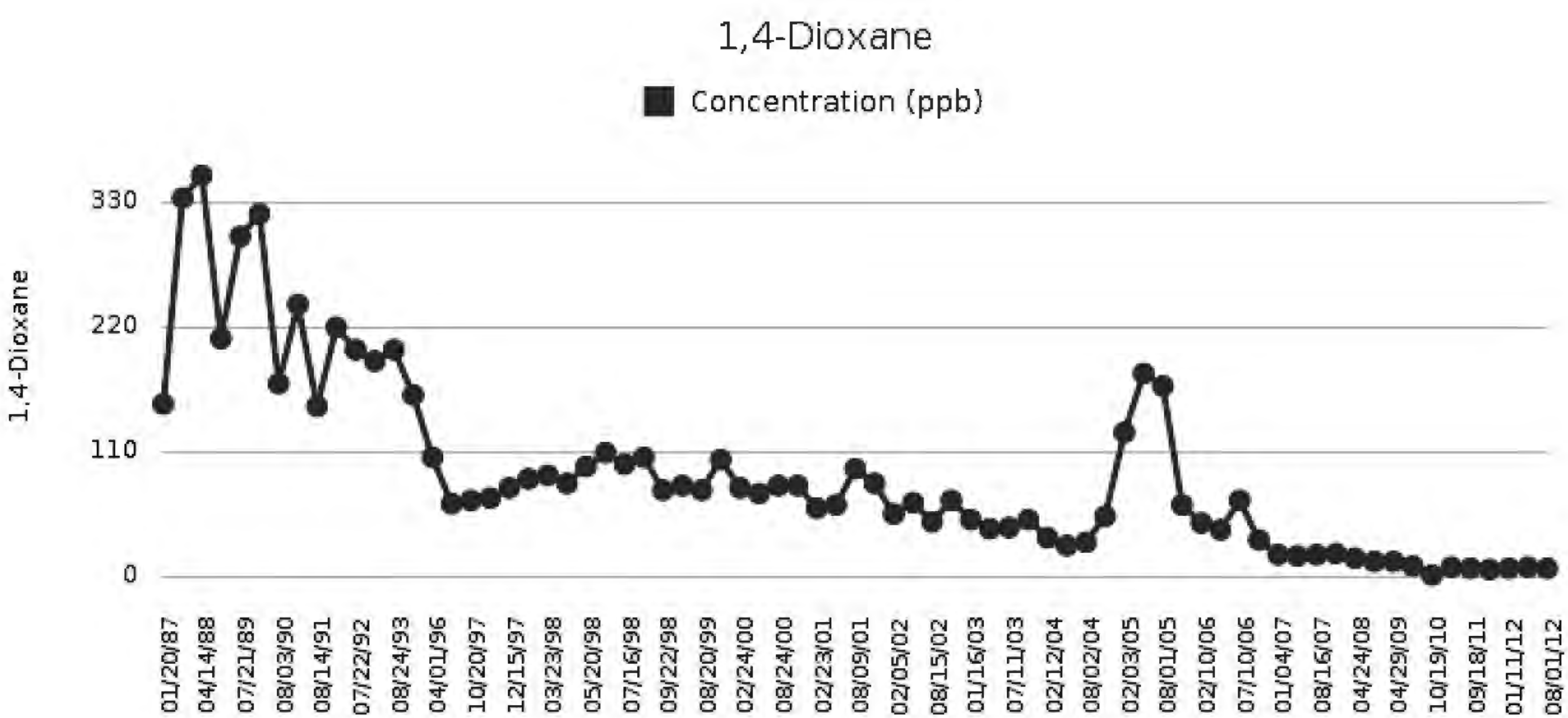
Analytical Data Graph

Printed: 11/29/2018

Well Name: MW-11i

Aquifer:	C3	Date Installed:	10/13/1986	Boring Depth:	50.00 Feet bgl	Screen 1:	41.00 to 39.00 Feet
Map Location:	M-14	Well Driller:		Ground Elevation:	910.59 Feet	Screen Length:	2.00
X Coordinate:	13274903.69	Well Type:	Monitoring Wells	TOC Elevation:	913.01 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	285096.42	Sampling Interval:	None	TOC to screen bottom:	44.00 Feet		
Comments:							



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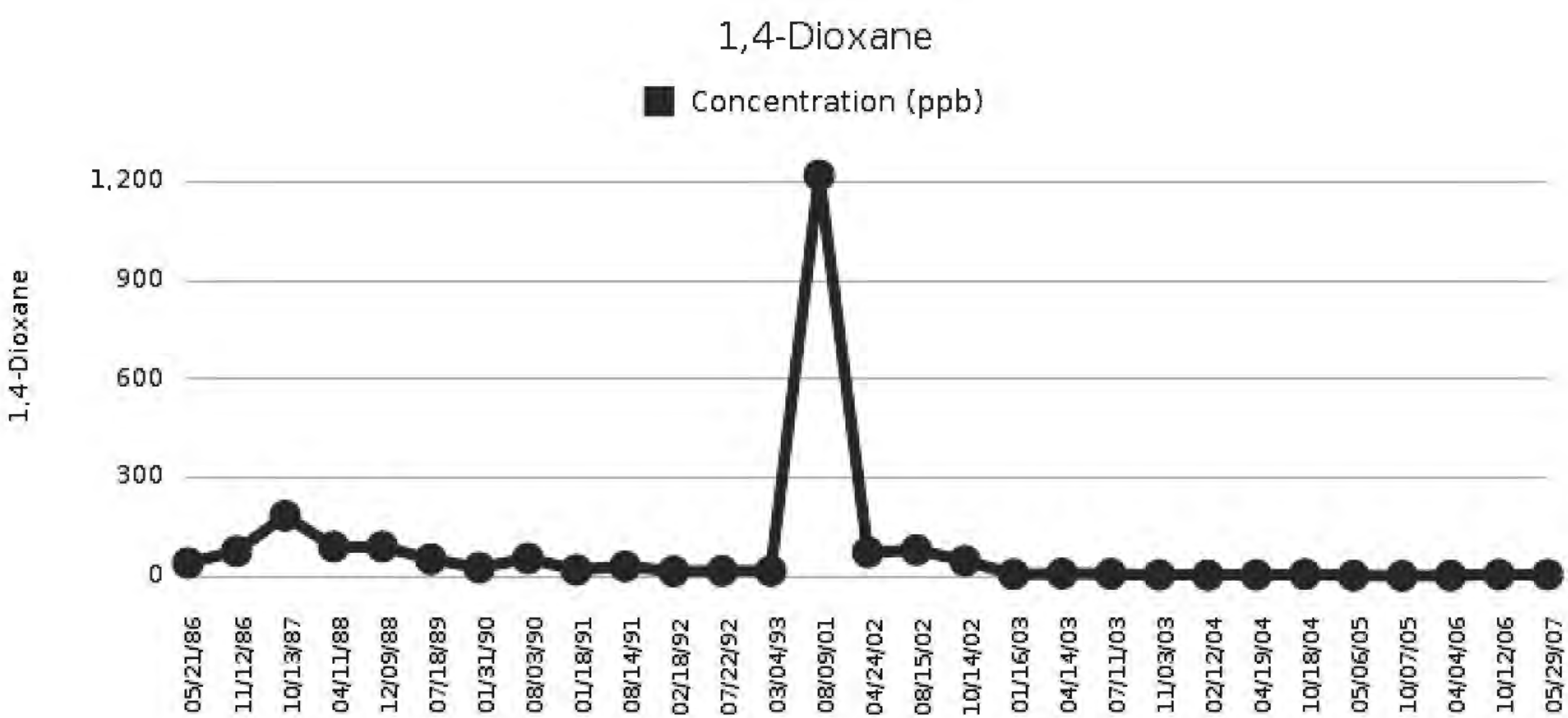
Well Name: MW-11s

Aquifer:	SH	Date Installed:	04/03/1986	Boring Depth:	16.14 Feet bgl	Screen 1:	16.14 to 14.14 Feet
Map Location:	M-14	Well Driller:		Ground Elevation:	910.79 Feet	Screen Length:	2.00
X Coordinate:	13274885.71	Well Type:	Monitoring Wells	TOC Elevation:	913.05 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	285069.22	Sampling Interval:	None	TOC to screen bottom:	19.00 Feet		
Comments:							



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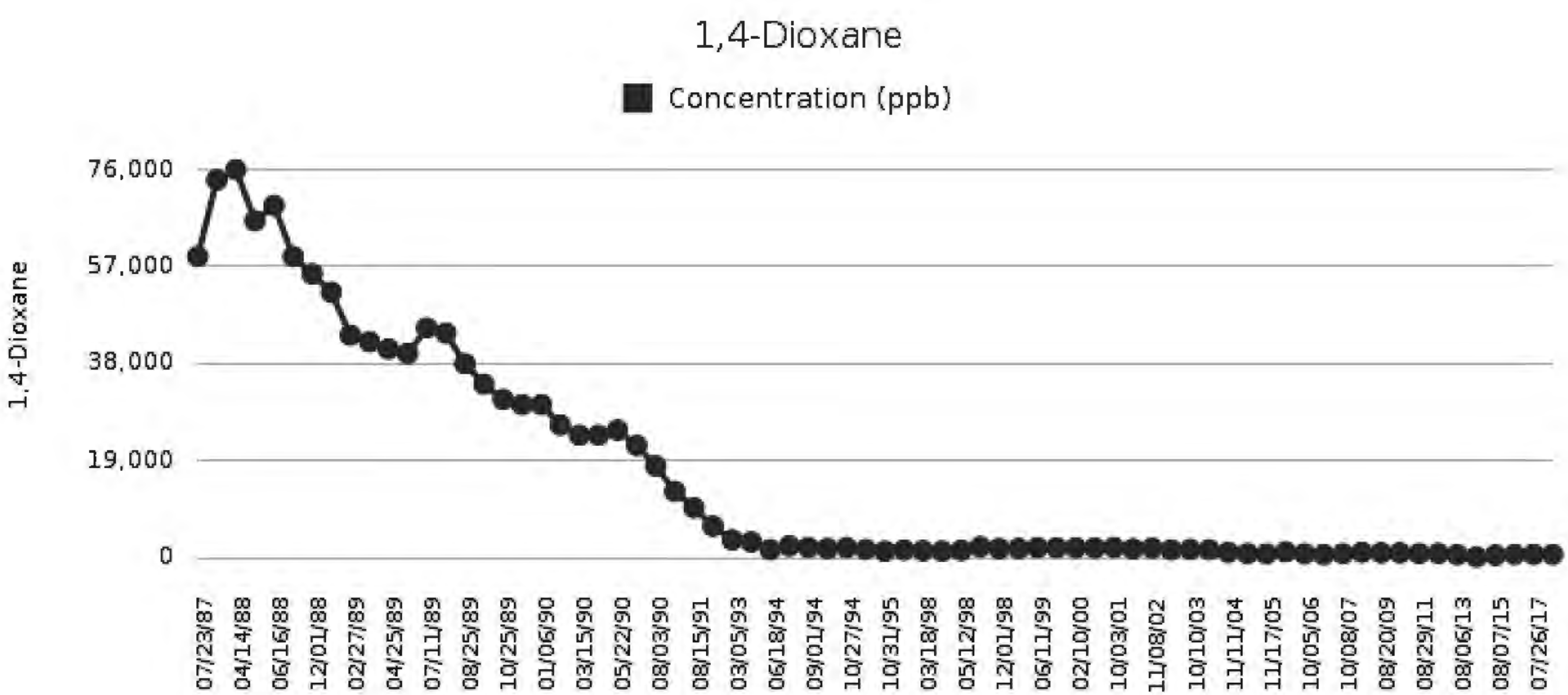
Analytical Data Graph

Printed: 12/04/2018

Well Name: MW-24

Aquifer:	C3	Date Installed:	07/22/1987	Boring Depth:	26.00 Feet bgl	Screen 1:	25.00 to 23.00 Feet
Map Location:	N-16	Well Driller:	Keck	Ground Elevation:	902.85 Feet	Screen Length:	2.00
X Coordinate:	13275929.00	Well Type:	Monitoring Wells	TOC Elevation:	904.37 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	284151.00	Sampling Interval:	Annual	TOC to screen bottom:	27.00 Feet		
Comments:							



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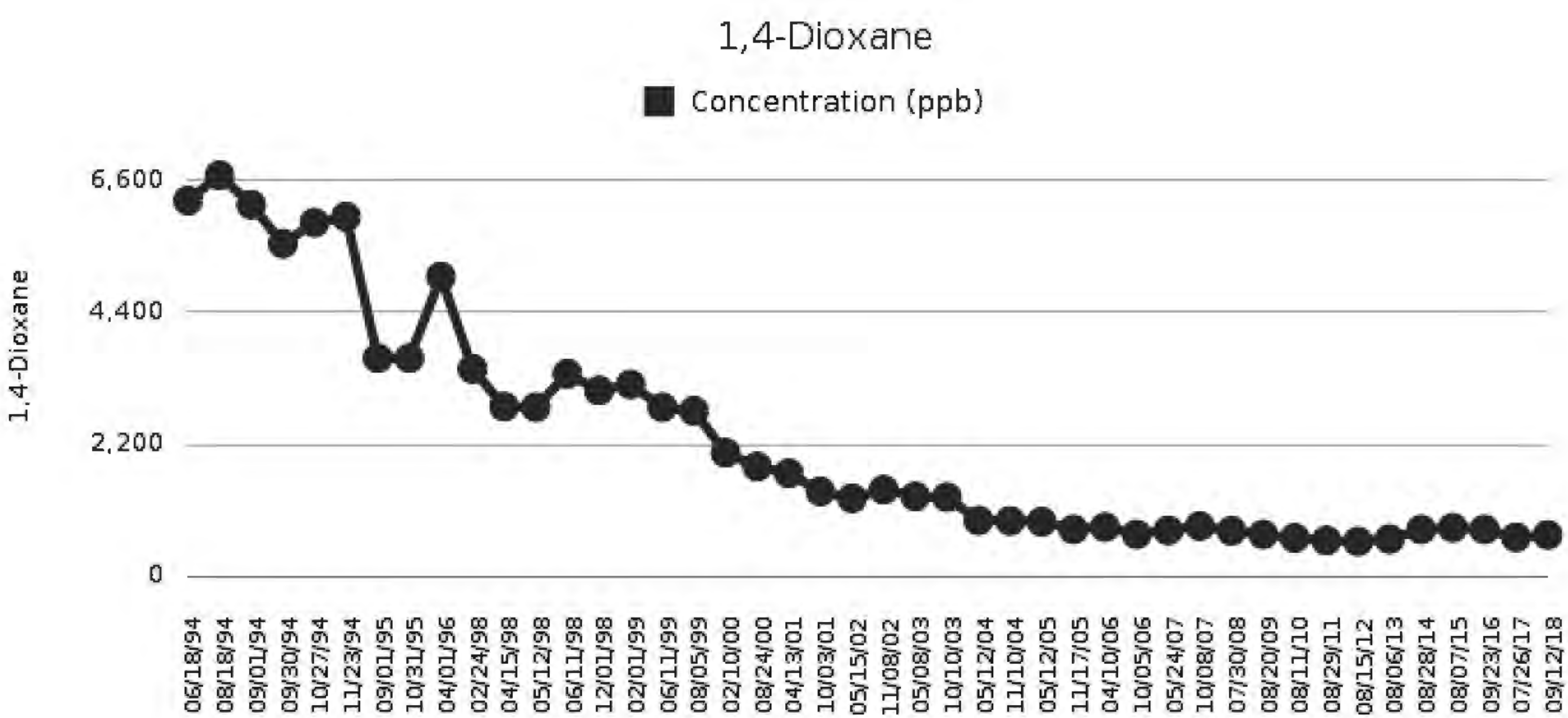
Analytical Data Graph

Printed: 11/29/2018

Well Name: NMW-1d

Aquifer:	Marshy	Date Installed:	03/16/1994	Boring Depth:	13.50 Feet bgl	Screen 1:	13.50 to 10.50 Feet
Map Location:	N-16	Well Driller:	Alpha Geoscience	Ground Elevation:	Unknown Feet	Screen Length:	3.00
X Coordinate:	13275861.93	Well Type:	Monitoring Wells	TOC Elevation:	905.87 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	284227.85	Sampling Interval:	Annual	TOC to screen bottom:	16.50 Feet		
Comments:							



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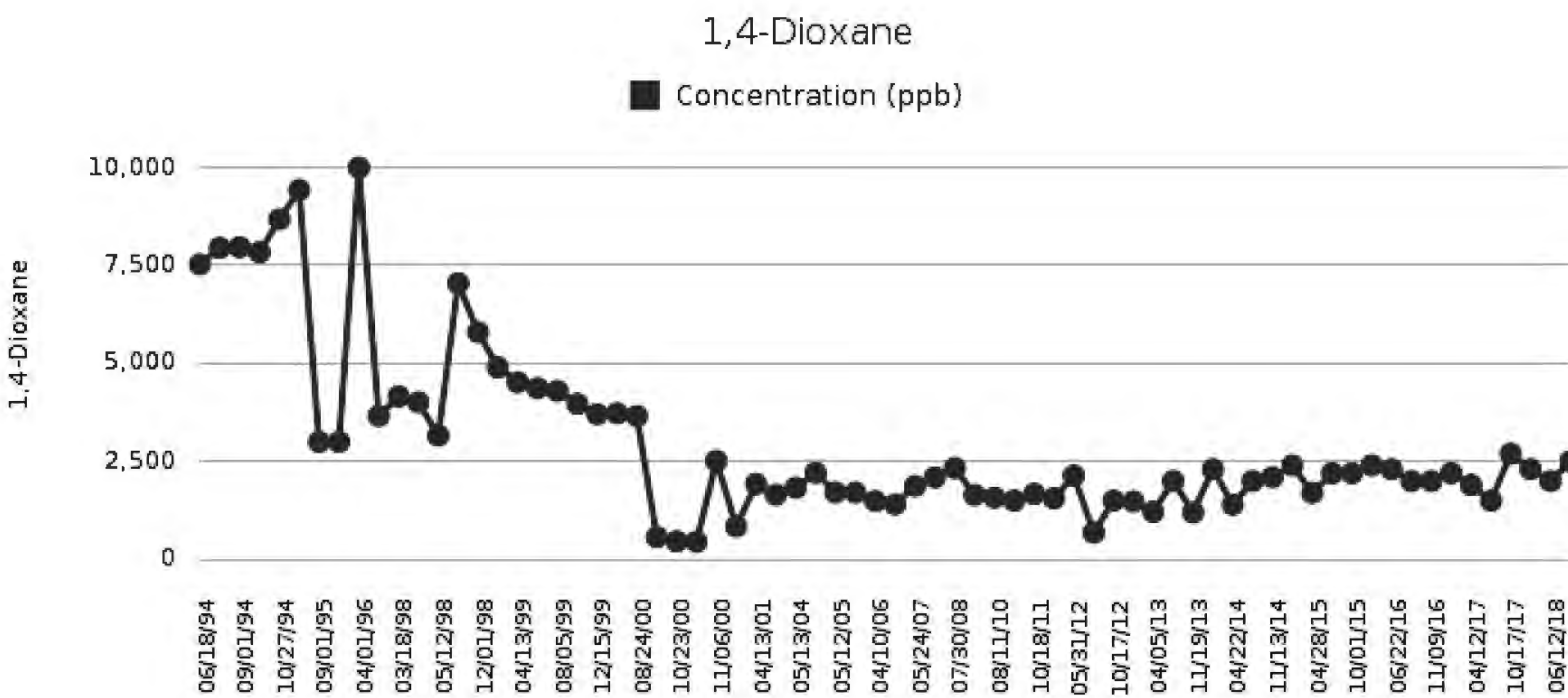
Well Name: NMW-1s

Aquifer:	Marshy	Date Installed:	03/16/1994	Boring Depth:	7.00 Feet bgl	Screen 1:	7.00 to 4.00 Feet
Map Location:	N-16	Well Driller:	Alpha Geoscience	Ground Elevation:	Unknown Feet	Screen Length:	3.00
X Coordinate:	13275861.93	Well Type:	Monitoring Wells	TOC Elevation:	903.88 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	284227.85	Sampling Interval:	Quarterly	TOC to screen bottom:	10.00 Feet		
Comments:	05-10-02, top of pipe cut off. 09/22/04 re-surveyed, Old TOC 906.73, Db updated with new.						



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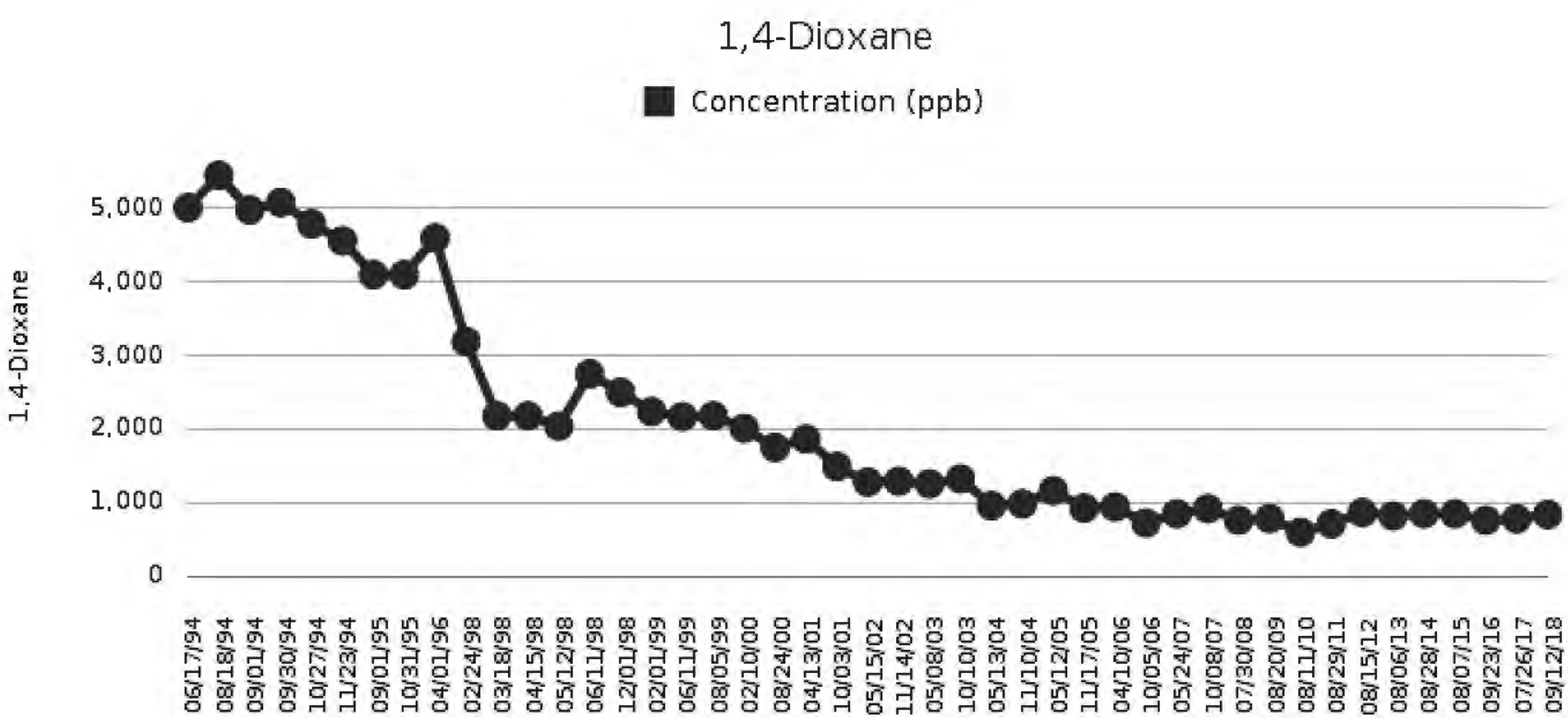
Printed: 11/29/2018

Well Name: NMW-2d

Aquifer:	Marshy	Date Installed:	03/16/1994	Boring Depth:	13.00 Feet bgl	Screen 1:	13.00 to 10.00 Feet
Map Location:	N-15	Well Driller:	Alpha Geoscience	Ground Elevation:	Unknown Feet	Screen Length:	3.00
X Coordinate:	13275727.98	Well Type:	Monitoring Wells	TOC Elevation:	906.20 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	284217.37	Sampling Interval:	Annual	TOC to screen bottom:	16.00 Feet		
Comments:							



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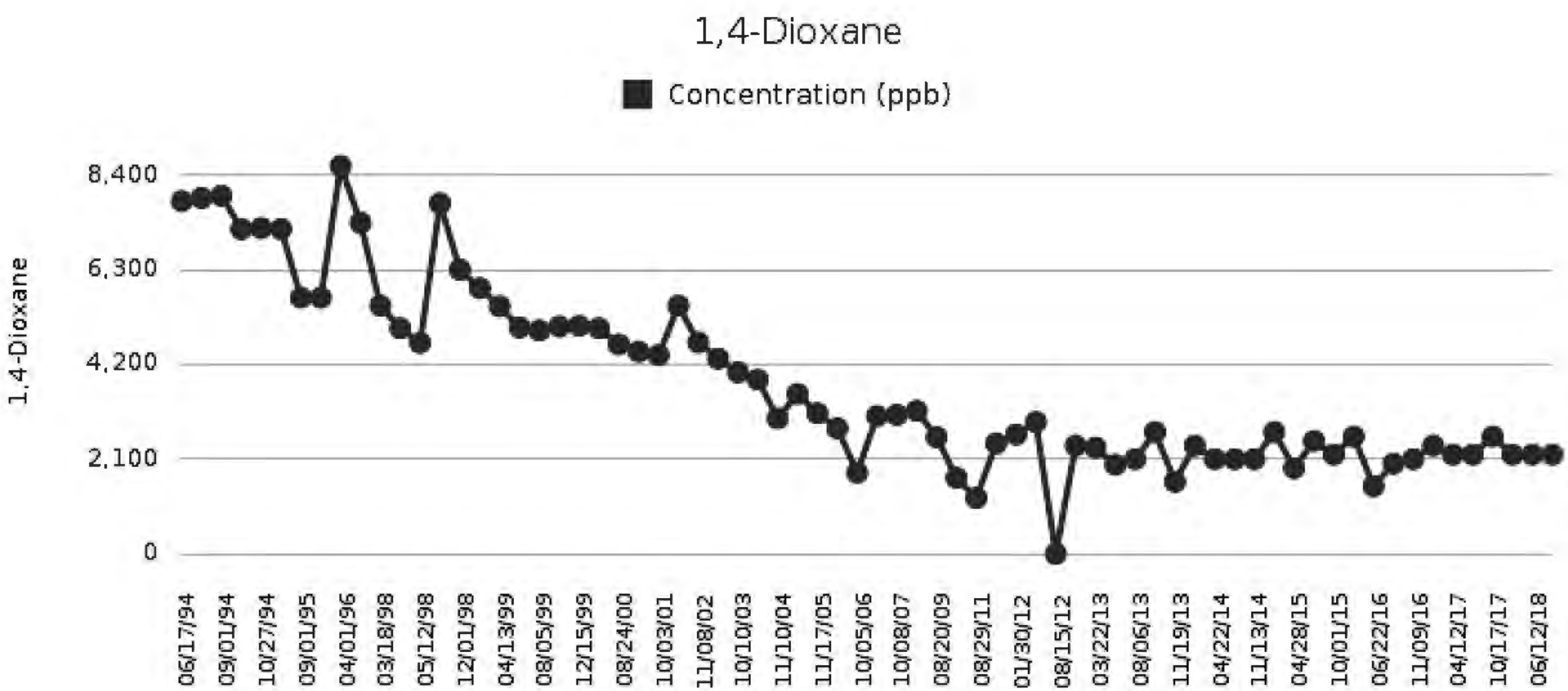
Analytical Data Graph

Printed: 11/29/2018

Well Name: NMW-2s

Aquifer:	Marshy	Date Installed:	03/16/1994	Boring Depth:	7.00 Feet bgl	Screen 1:	7.00 to 4.00 Feet
Map Location:	N-15	Well Driller:	Alpha Geoscience	Ground Elevation:	Unknown Feet	Screen Length:	3.00
X Coordinate:	13275727.98	Well Type:	Monitoring Wells	TOC Elevation:	903.94 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	284217.37	Sampling Interval:	Quarterly	TOC to screen bottom:	10.00 Feet		
Comments:							



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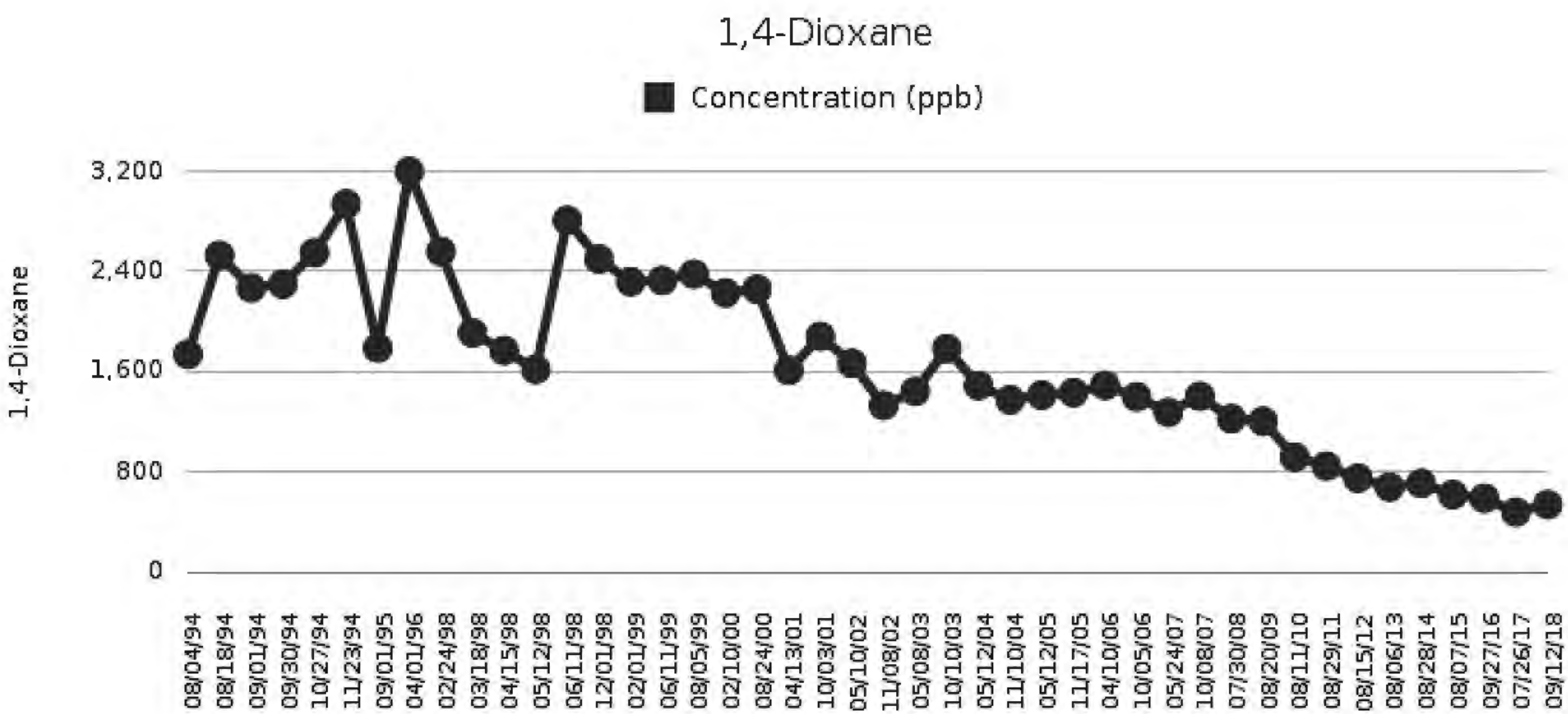
Well Name: NMW-3d

Aquifer:	Marshy	Date Installed:	08/03/1994	Boring Depth:	8.00 Feet bgl	Screen 1:	8.00 to 5.00 Feet
Map Location:	N-16	Well Driller:	Alpha Geoscience	Ground Elevation:	Unknown Feet	Screen Length:	3.00
X Coordinate:	13275983.18	Well Type:	Monitoring Wells	TOC Elevation:	905.85 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	284237.22	Sampling Interval:	Annual	TOC to screen bottom:	11.00 Feet		
Comments:							



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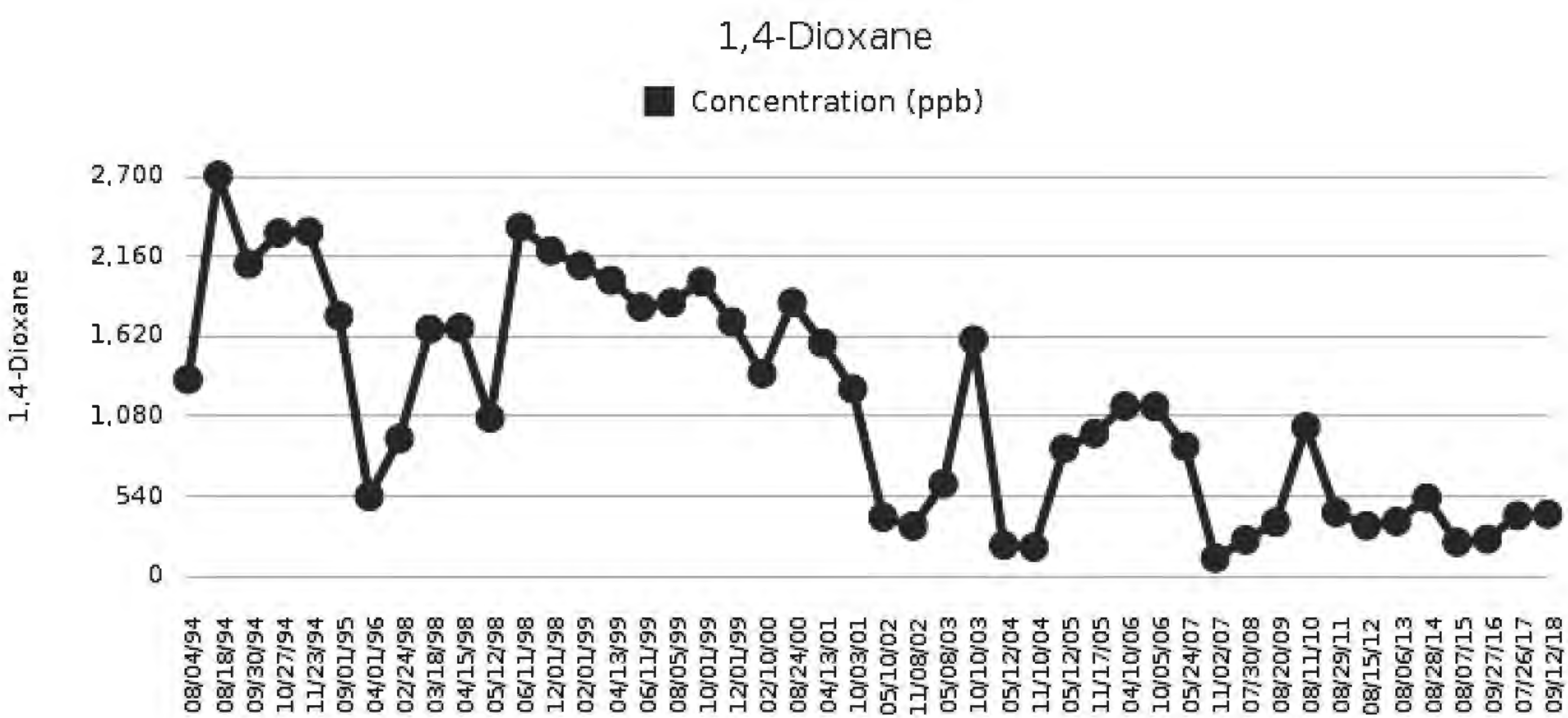
Well Name: NMW-3s

Aquifer:	Marshy	Date Installed:	08/03/1994	Boring Depth:	5.00 Feet bgl	Screen 1:	5.00 to 2.00 Feet
Map Location:	N-16	Well Driller:	Alpha Geoscience	Ground Elevation:	Unknown Feet	Screen Length:	3.00
X Coordinate:	13275983.18	Well Type:	Monitoring Wells	TOC Elevation:	905.72 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	284237.20	Sampling Interval:	Annual	TOC to screen bottom:	8.00 Feet		
Comments:							



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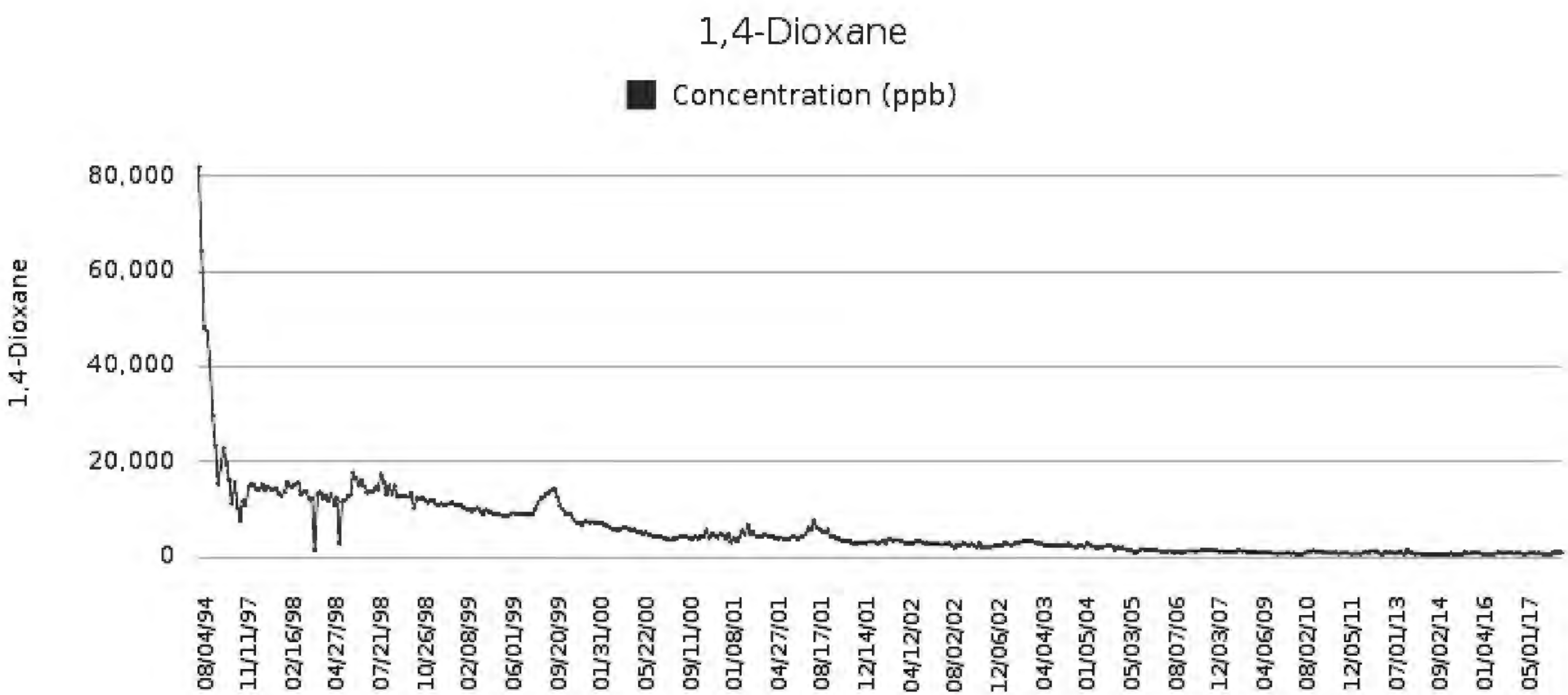
Well Name: PW-1

Aquifer:	Marshy	Date Installed:	03/16/1994	Boring Depth:	15.50 Feet bgl	Screen 1:	15.50 to 9.50 Feet
Map Location:	O-16	Well Driller:	Alpha Geoscience	Ground Elevation:	Unknown Feet	Screen Length:	6.00
X Coordinate:	13275823.00	Well Type:	Extraction Wells	TOC Elevation:	905.56 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	284035.00	Sampling Interval:	Extraction Monthly	TOC to screen bottom:	18.00 Feet		
Comments:							



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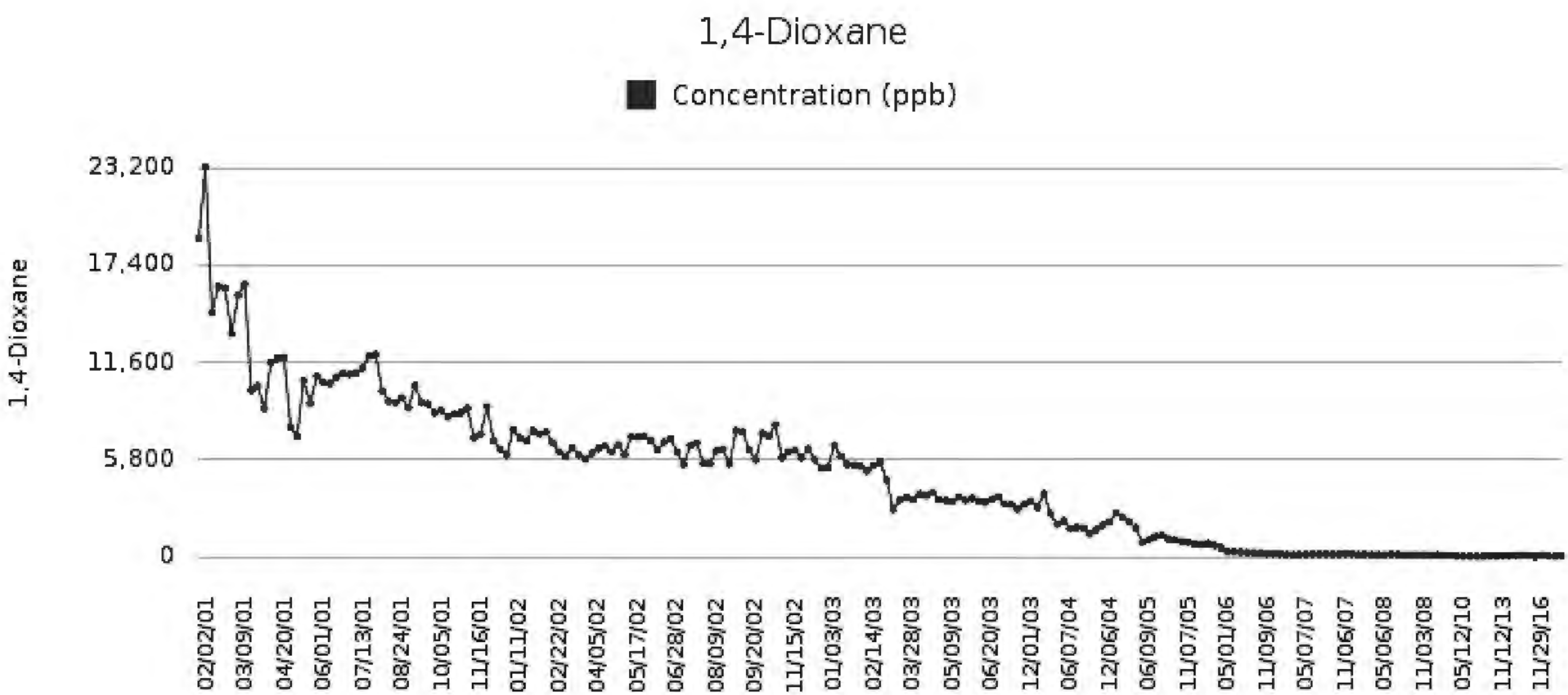
Well Name: TW-6

Aquifer:	C3	Date Installed:	01/23/2001	Boring Depth:	64.00 Feet bgl	Screen 1:	64.00 to 54.00 Feet
Map Location:	N-16	Well Driller:	Ohio Drilling	Ground Elevation:	907.00 Feet	Screen Length:	10.00
X Coordinate:	13275925.4	Well Type:	Extraction Wells	TOC Elevation:	906.7 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	284305.0	Sampling Interval:	Semi-Annual	TOC to screen bottom:	Unknown Feet		
Comments:							



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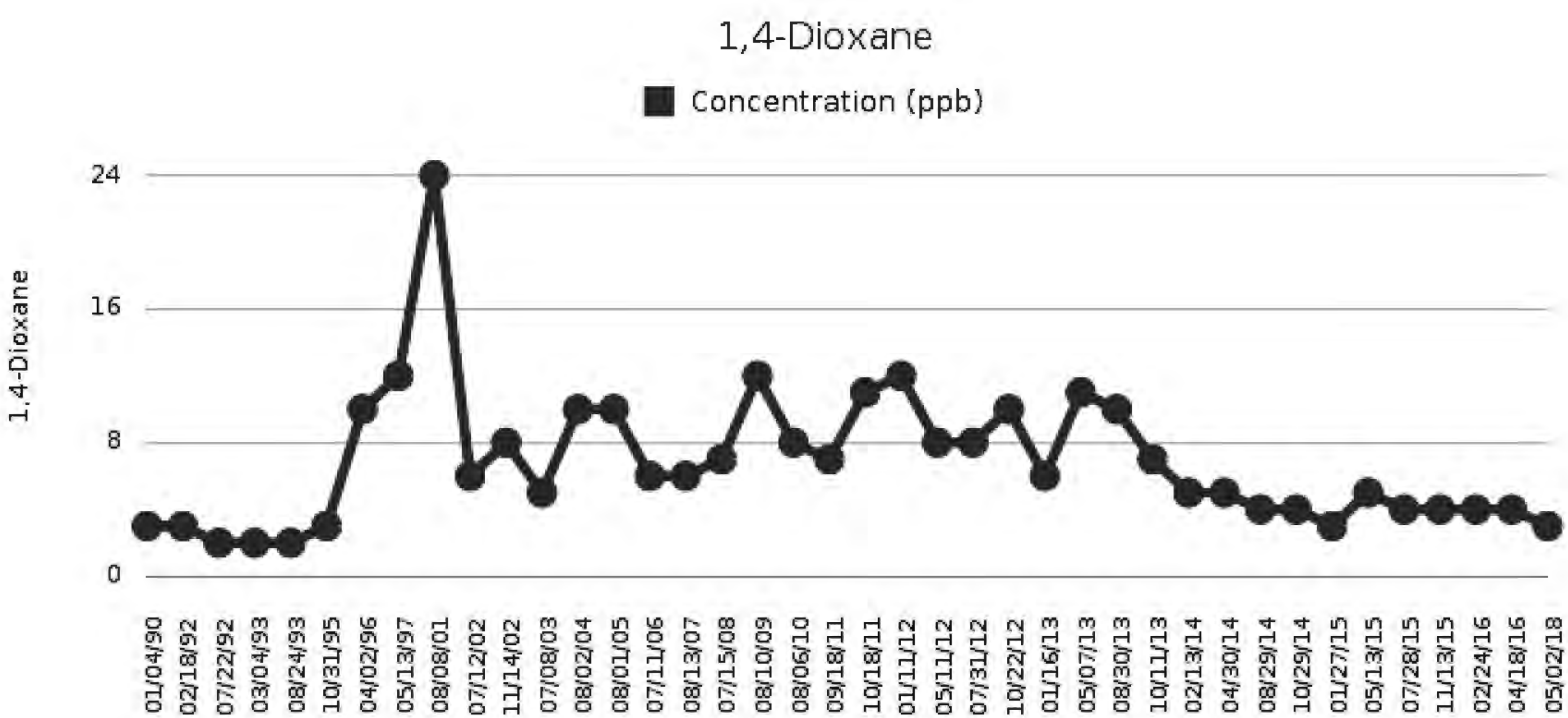
Well Name: MW-35

Aquifer:	C3	Date Installed:	01/03/1990	Boring Depth:	44.00 Feet bgl	Screen 1:	42.00 to 39.00 Feet
Map Location:	L-13	Well Driller:	T & T Drilling	Ground Elevation:	909.40 Feet	Screen Length:	3.00
X Coordinate:	13274474.00	Well Type:	Monitoring Wells	TOC Elevation:	911.96 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	285304.00	Sampling Interval:	Quarterly	TOC to screen bottom:	45.04 Feet		
Comments:							



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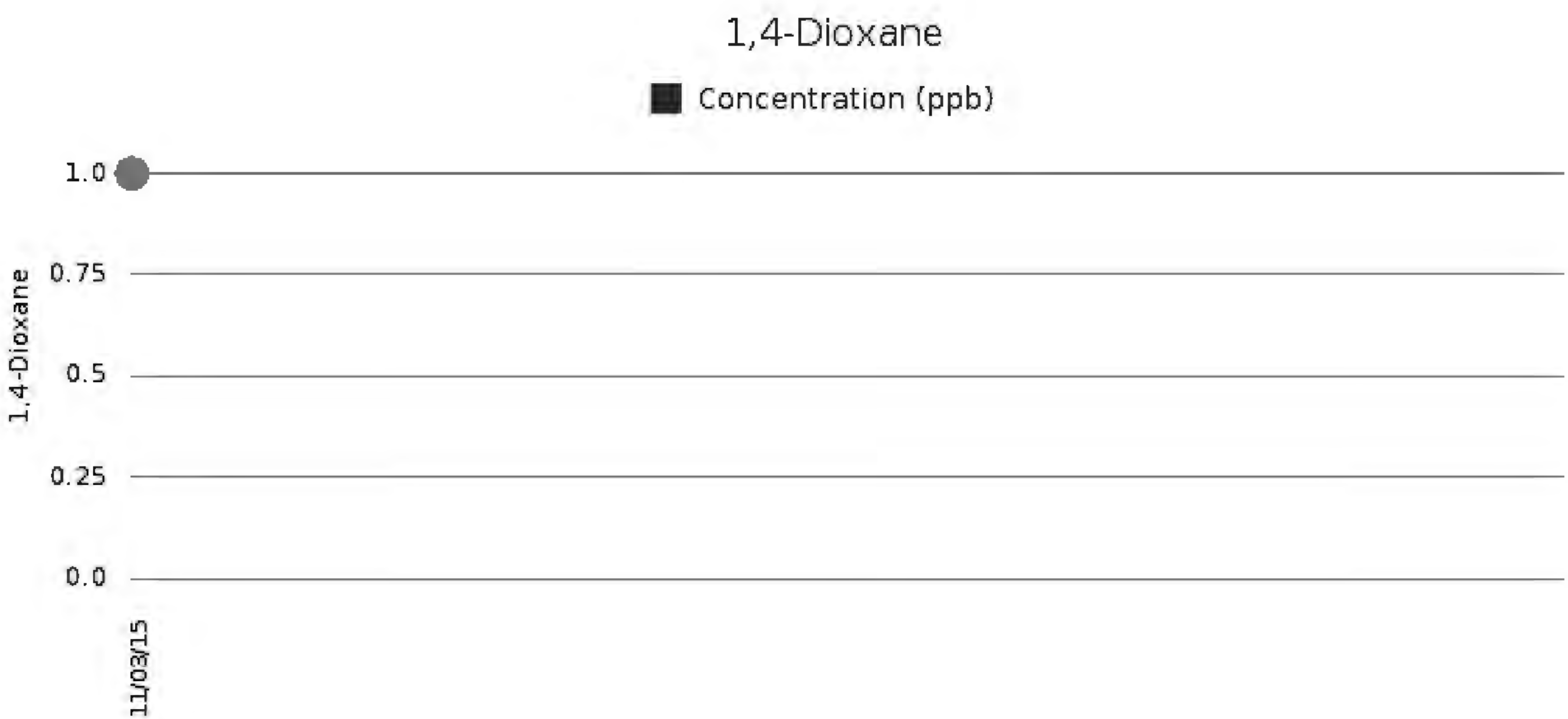
Well Name: MW-51

Aquifer:	D0	Date Installed:	02/16/2000	Boring Depth:	165.00 Feet bgl	Screen 1:	35.00 to 25.00 Feet
Map Location:	M-9	Well Driller:	Stearns	Ground Elevation:	898.60 Feet	Screen Length:	10.00
X Coordinate:	13272641.91	Well Type:	Monitoring Wells	TOC Elevation:	898.24 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	284766.83	Sampling Interval:	Quarterly	TOC to screen bottom:	35.00 Feet		
Comments:							



Analytical Data Report: MW-51

Aquifer: D0	**Date Installed:** 02/16/2000	**Boring Depth:** 165.00 Feet bgl	**Screen 1:** 35.00 to 25.00 Feet
Map Location: M-9	**Well Driller:** Stearns	**Ground Elevation:** 898.60 Feet	**Screen 1 Length:** 10.00
X Coordinate: 13272641.91	**Well Type:** Monitoring Wells	**TOC Elevation:** 898.24 Feet	**Screen 2:** NA to NA Feet
Y Coordinate: 284766.83	**Sampling Interval:** Quarterly	**TOC to screen bottom:** 35.00 Feet	
	Static Interval: Semi-Annual	**Notes:**	

Date Collected	Time Collected	1,4-Dioxane Results (ppb)	R.L.	Bromate Results	R.L.	Bromide Results	R.L.	Static Time	Static Reading	Comments
10/16/2018	09:48	nd	1.0					09:20	15.69	
09/24/2018	11:40	nd	1.0					11:15	15.44	
09/17/2018	16:42							16:42	15.46	
06/21/2018	14:05	nd	1.0					13:43	14.44	
03/22/2018	14:06	nd	1.0							
03/21/2018	14:46							14:46	15.35	
11/16/2017	10:40	nd	1.0					10:24	15.99	
09/20/2017	11:37							11:37	15.96	
09/13/2017	14:00	nd	1.0					13:43	15.85	
05/18/2017	14:43	nd	1.0					14:20	15.26	
03/21/2017	15:25							15:25	16.11	
02/22/2017	14:10	nd	1.0					13:50	16.27	
12/28/2016	11:41	nd	1.0					11:23	16.76	

Date Collected	Time Collected	1,4-Dioxane Results (ppb)	R.L.	Bromate Results	R.L.	Bromide Results	R.L.	Static Time	Static Reading	Comments
09/27/2016	10:20	nd	1.0					09:54	16.69	
09/21/2016	14:35							14:35	16.69	
05/04/2016	12:00	nd	1.0					11:43	16.07	
03/08/2016	11:50	nd	1.0					11:27	16.58	
02/05/2016	12:10	nd	1.0					11:52	16.61	
01/06/2016	11:56	nd	1.0					10:51	16.53	
12/03/2015	13:36	nd	1.0					13:14	16.46	
11/03/2015	11:27	1	1.0					11:09	16.37	
10/19/2015	11:12	nd	1.0					10:53	16.29	
09/16/2015	13:24							13:24	16.08	
08/04/2015	08:47	nd	1.0					08:21	15.81	
03/30/2015	14:08							14:08	16.44	
02/24/2015	10:14							10:14	16.42	
01/20/2015	10:39							10:39	16.32	
09/17/2014	10:09							10:09	15.95	
08/18/2014	10:51	nd	1.0					10:26	15.89	
03/31/2014	09:56							09:56	16.68	
09/18/2013	14:10							14:10	16.47	
07/10/2013	14:15	nd	1.0					13:50	16.0	
03/15/2013	10:55							10:55	16.61	
09/19/2012	09:41							09:41	16.50	
07/18/2012	14:35	nd	1.0					14:15	15.96	
03/14/2012	10:08							10:08	15.35	

Date Collected	Time Collected	1,4-Dioxane Results (ppb)	R.L.	Bromate Results	R.L.	Bromide Results	R.L.	Static Time	Static Reading	Comments
09/22/2011	13:37							13:37	16.31	
08/05/2011	13:15	ND	1.0					13:05	16.7	
03/17/2011	09:59							09:59	18.65	
09/01/2010	10:00							10:00	17.97	
07/13/2010	10:35	nd	1.0					10:20	17.72	
03/09/2010	09:37							09:37	18.37	
09/24/2009			1.0					11:08	17.68	
07/13/2009	13:10	nd	1.0					12:55	17.04	
03/17/2009			1.0					10:34	18.05	
09/17/2008			1.0					10:01	18.49	
07/25/2008	09:10	nd	1.0					08:40	18.02	
02/25/2008			1.0					09:59	18.63	
10/09/2007	12:45	nd	1.0					12:25	19.03	
09/13/2007			1.0					16:50	18.8	
04/03/2007	14:25	nd	1.0					14:05	18.25	
03/13/2007			1.0					10:17	18.42	
10/09/2006	10:05	nd	1.0					09:55	19.3	
09/15/2006			1.0					09:50	19.32	
05/03/2006	11:30	nd	1.0					11:00	19.05	
03/20/2006			1.0					09:21	19.24	
10/25/2005	13:26	nd	1.0					13:18	19.55	
09/13/2005			1.0					09:40	19.29	
04/06/2005	17:27	nd	1.0					17:08	18.94	

Date Collected	Time Collected	1,4-Dioxane Results (ppb)	R.L.	Bromate Results	R.L.	Bromide Results	R.L.	Static Time	Static Reading	Comments
03/14/2005			1.0					09:45	19.22	
10/07/2004	12:04	nd	1.0					11:55	19.34	
09/15/2004			1.0					11:31	19.33	
04/15/2004	15:31	nd	1.0					15:09	19.11	
04/12/2004			1.0					11:17	19.12	
03/10/2004			1.0					10:10	19.31	
02/03/2004	14:30	nd	1.0					14:20	19.42	
10/03/2003	09:19	nd	1.0							
10/01/2003			1.0					10:24	19.16	
07/25/2003	09:10	nd	1.0							
07/02/2003			1.0					10:57	18.8	
04/04/2003	10:45	nd	1.0							
04/02/2003			1.0					09:29	18.62	
01/28/2003	12:56	nd	1.0							
01/09/2003			1.0						18.24	
10/15/2002	08:50	nd	1.0							
10/02/2002			1.0						17.75	
07/23/2002	14:29	nd	1.0							
07/02/2002			1.0					14:24	16.81	
04/26/2002	09:18	nd	1.0							
04/04/2002			1.0					08:15	16.14	
01/30/2002	08:55	nd	1.0							
01/07/2002		NSP	1.0					13:56	16.44	

Date Collected	Time Collected	1,4-Dioxane Results (ppb)	R.L.	Bromate Results	R.L.	Bromide Results	R.L.	Static Time	Static Reading	Comments
11/05/2001	13:40	nd	1.0							
10/11/2001			1.0					11:22	16.75	
07/25/2001	08:42	nd	1.0							
07/19/2001			1.0					13:11	16.41	
05/10/2001	16:12	nd	1.0							
05/08/2001		NSP	1.0					15:18	16.42	
02/19/2001	14:33	nd	1.0							
01/19/2001		NSP	1.0						16.77	
09/21/2000		NSP	1.0						16.0	
08/16/2000		nd	1.0						15.79	
06/07/2000		NSP	1.0						16.28	
04/24/2000		nd	1.0						16.63	
03/21/2000		nd	1.0						16.5	
02/16/2000		nd	1.0						16.9	

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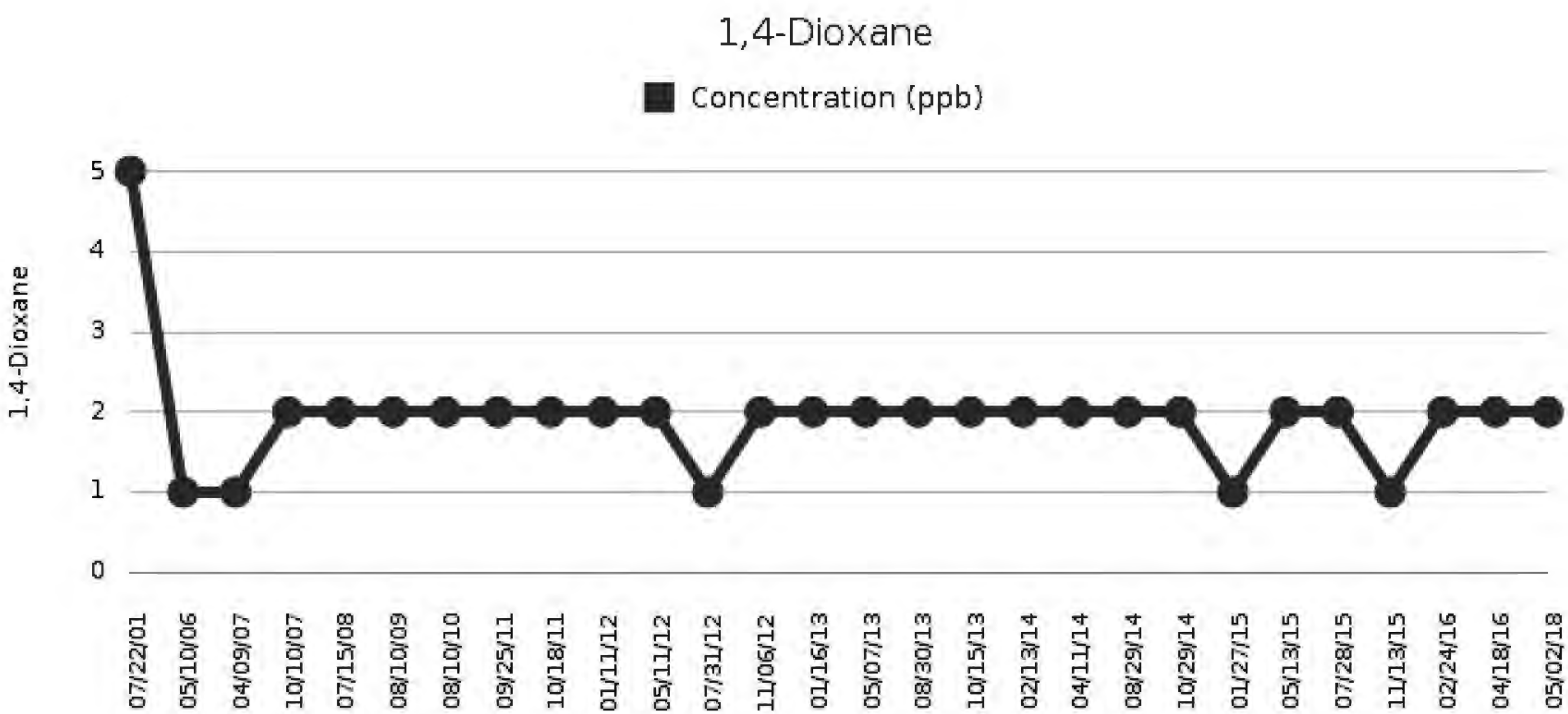
Well Name: MW-66

Aquifer:	E	Date Installed:	07/19/2001	Boring Depth:	197.00 Feet bgl	Screen 1:	190.00 to 180.00 Feet
Map Location:	L-13	Well Driller:	Stearns	Ground Elevation:	910.00 Feet	Screen Length:	10.00
X Coordinate:	13274470.06	Well Type:	Monitoring Wells	TOC Elevation:	911.25 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	285316.29	Sampling Interval:	Quarterly	TOC to screen bottom:	191.73 Feet		
Comments:							



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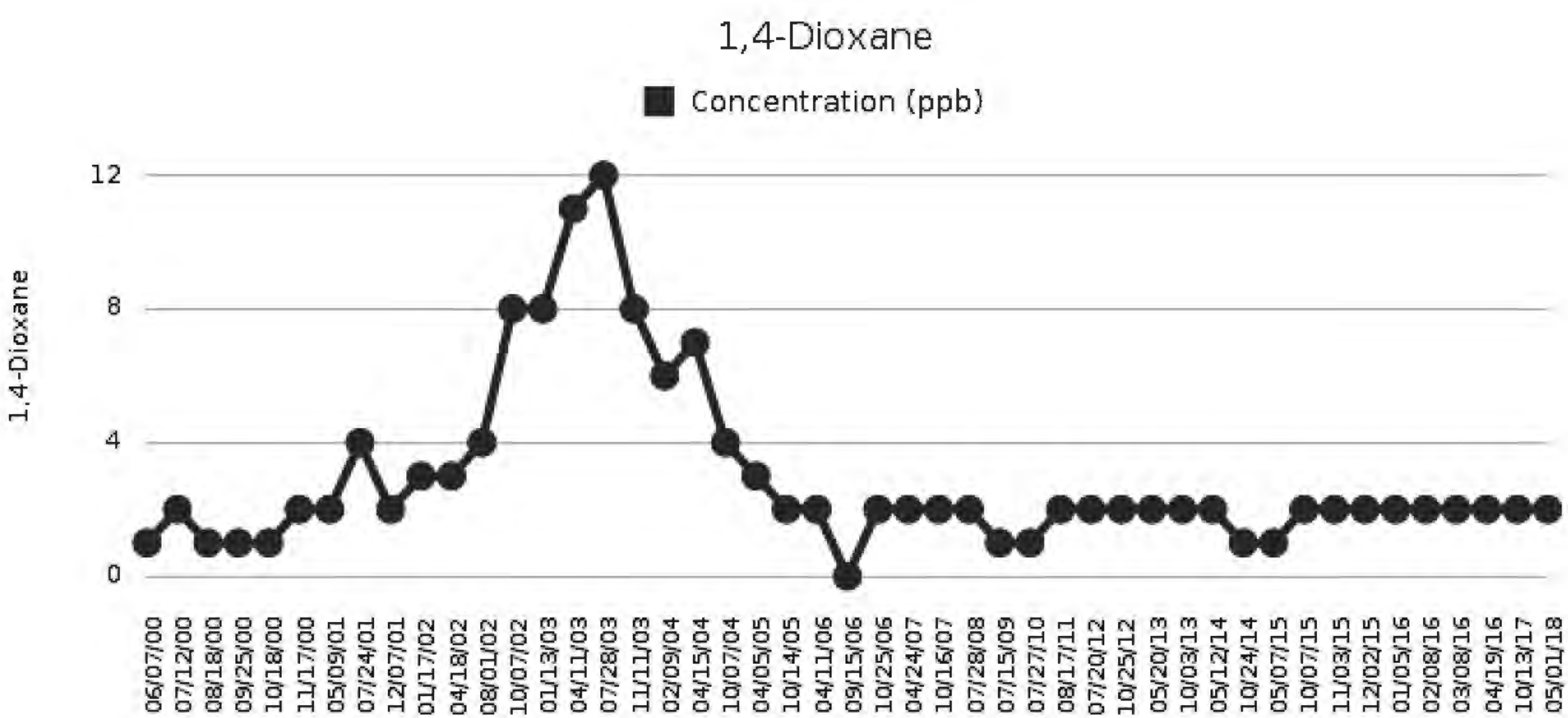
Well Name: 4601 Park 4 inch

Aquifer:	D0	Date Installed:		Boring Depth:	Unknown Feet bgl	Screen 1:	47 to Unknown Feet
Map Location:	L-6	Well Driller:		Ground Elevation:	895.79 Feet	Screen Length:	Unknown
X Coordinate:	13271193.02	Well Type:	Residential Wells	TOC Elevation:	899.91 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	285587.23	Sampling Interval:	Semi-Annual	TOC to screen bottom:	52.00 Feet		
Comments:	Resurveyed By Atwell LCC on 2/24/2015;						



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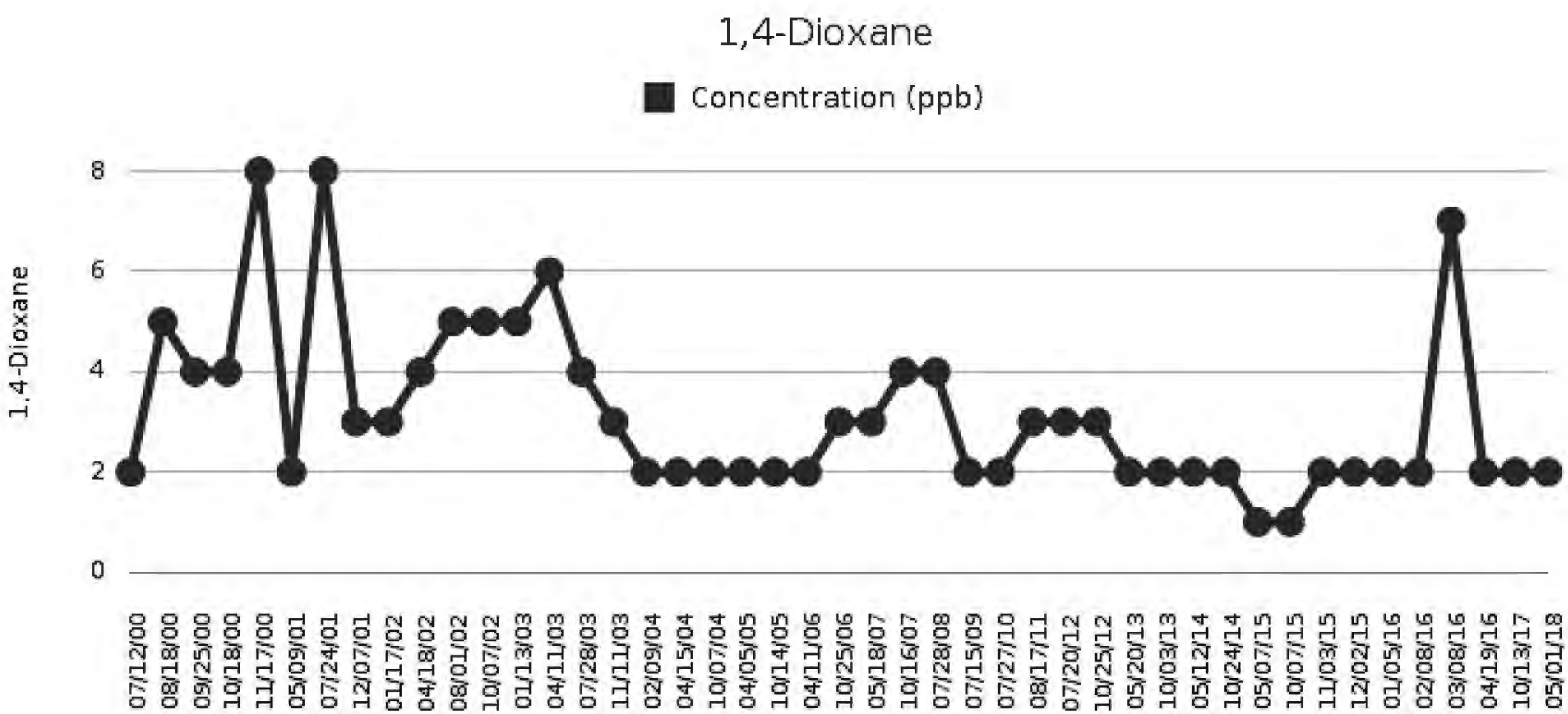
Well Name: 4601 Park 6 inch

Aquifer:	D0	Date Installed:		Boring Depth:	Unknown Feet bgl	Screen 1:	40 to Unknown Feet
Map Location:	K-6	Well Driller:		Ground Elevation:	892.14 Feet	Screen Length:	Unknown
X Coordinate:	13271184.73	Well Type:	Residential Wells	TOC Elevation:	896.26 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	285734.56	Sampling Interval:	Semi-Annual	TOC to screen bottom:	42.00 Feet		
Comments:	Resurveyed By Atwell LCC on 2/24/2015;						



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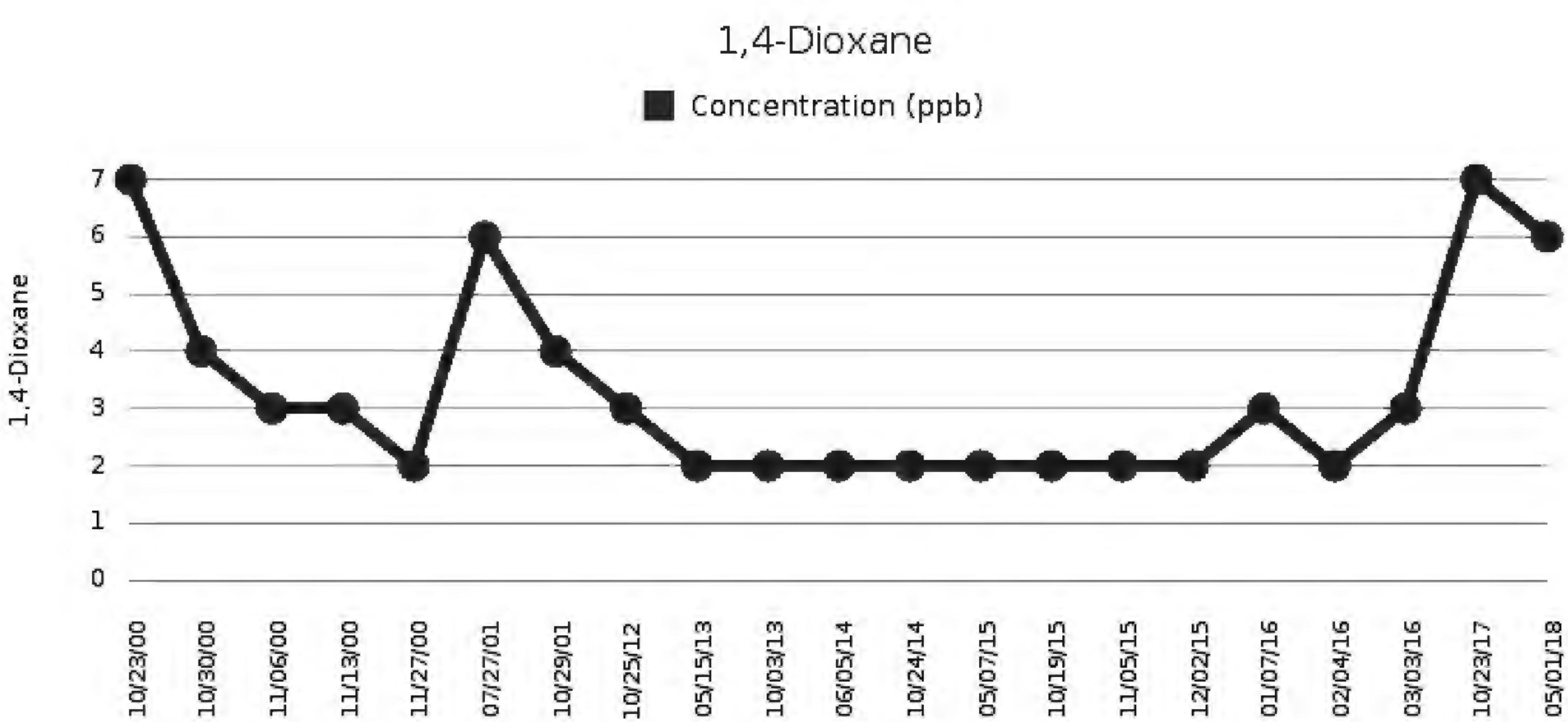
Well Name: MW-61d

Aquifer:	D0	Date Installed:	09/07/2000	Boring Depth:	171.00 Feet bgl	Screen 1:	136.00 to 126.00 Feet
Map Location:	J-7	Well Driller:	Stearns	Ground Elevation:	923.40 Feet	Screen Length:	10.00
X Coordinate:	13271323.30	Well Type:	Monitoring Wells	TOC Elevation:	922.37 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	286173.32	Sampling Interval:	Semi-Annual	TOC to screen bottom:	135.45 Feet		
Comments:							



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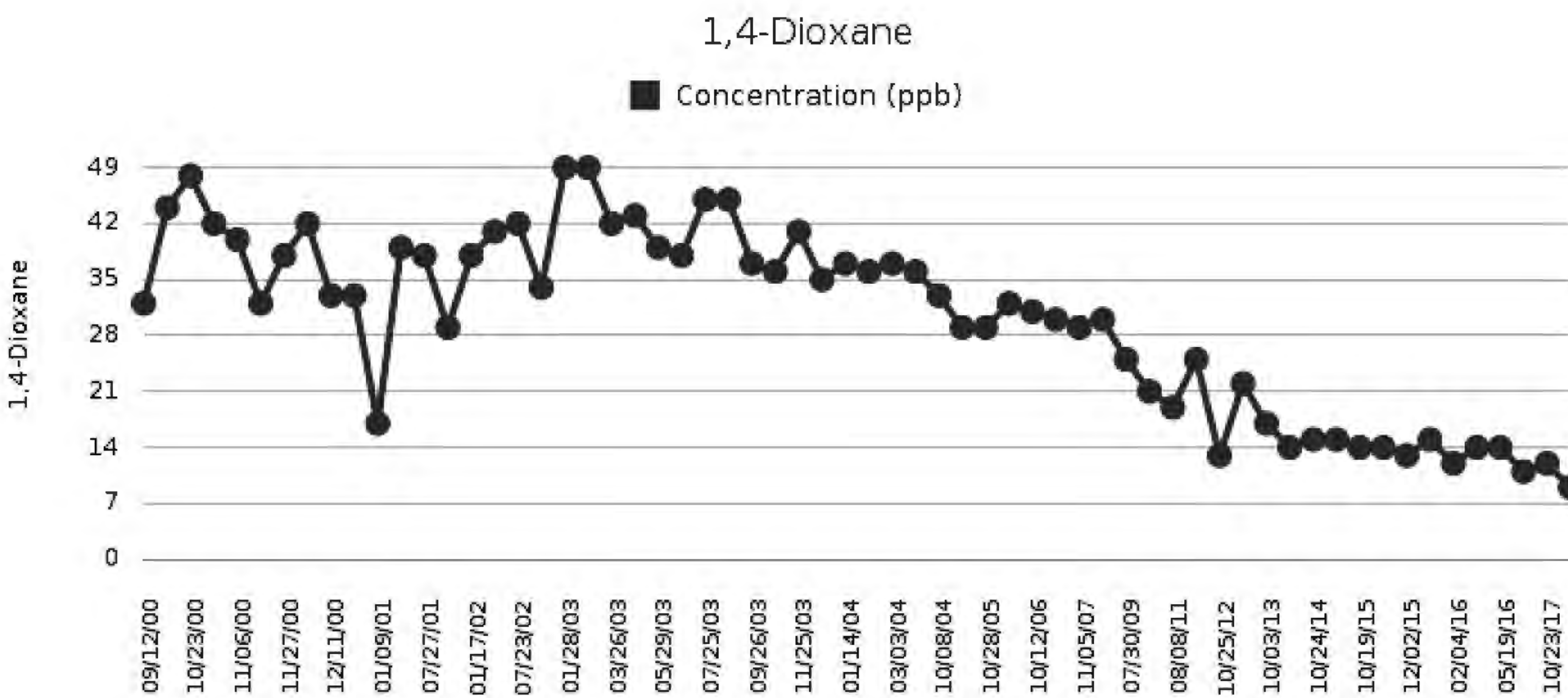
Well Name: MW-61s

Aquifer:	D0	Date Installed:	09/07/2000	Boring Depth:	78.00 Feet bgl	Screen 1:	78.00 to 68.00 Feet
Map Location:	J-7	Well Driller:	Stearns	Ground Elevation:	923.50 Feet	Screen Length:	10.00
X Coordinate:	13271309.11	Well Type:	Monitoring Wells	TOC Elevation:	922.51 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	286194.58	Sampling Interval:	Semi-Annual	TOC to screen bottom:	77.49 Feet		
Comments:							



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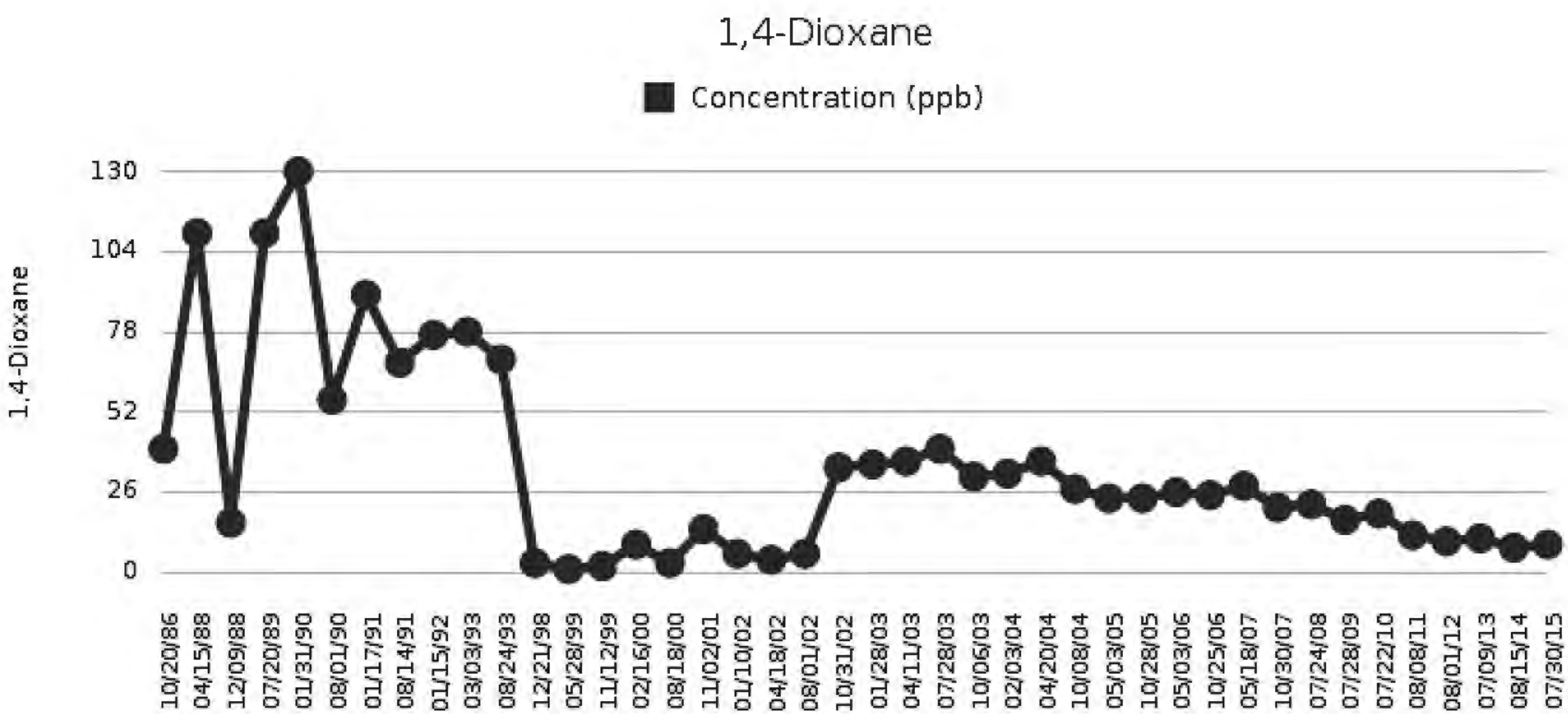
Well Name: 4742 Park Rd

Aquifer:	D0	Date Installed:	10/10/1983	Boring Depth:	50.00 Feet bgl	Screen 1:	50.00 to 46.00 Feet
Map Location:	J-5	Well Driller:	Ann Arbor Well	Ground Elevation:	888.23 Feet	Screen Length:	4.00
X Coordinate:	13270453.00	Well Type:	Monitoring Wells	TOC Elevation:	888.75 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	286419.50	Sampling Interval:	Annual	TOC to screen bottom:	51.00 Feet		
Comments:							



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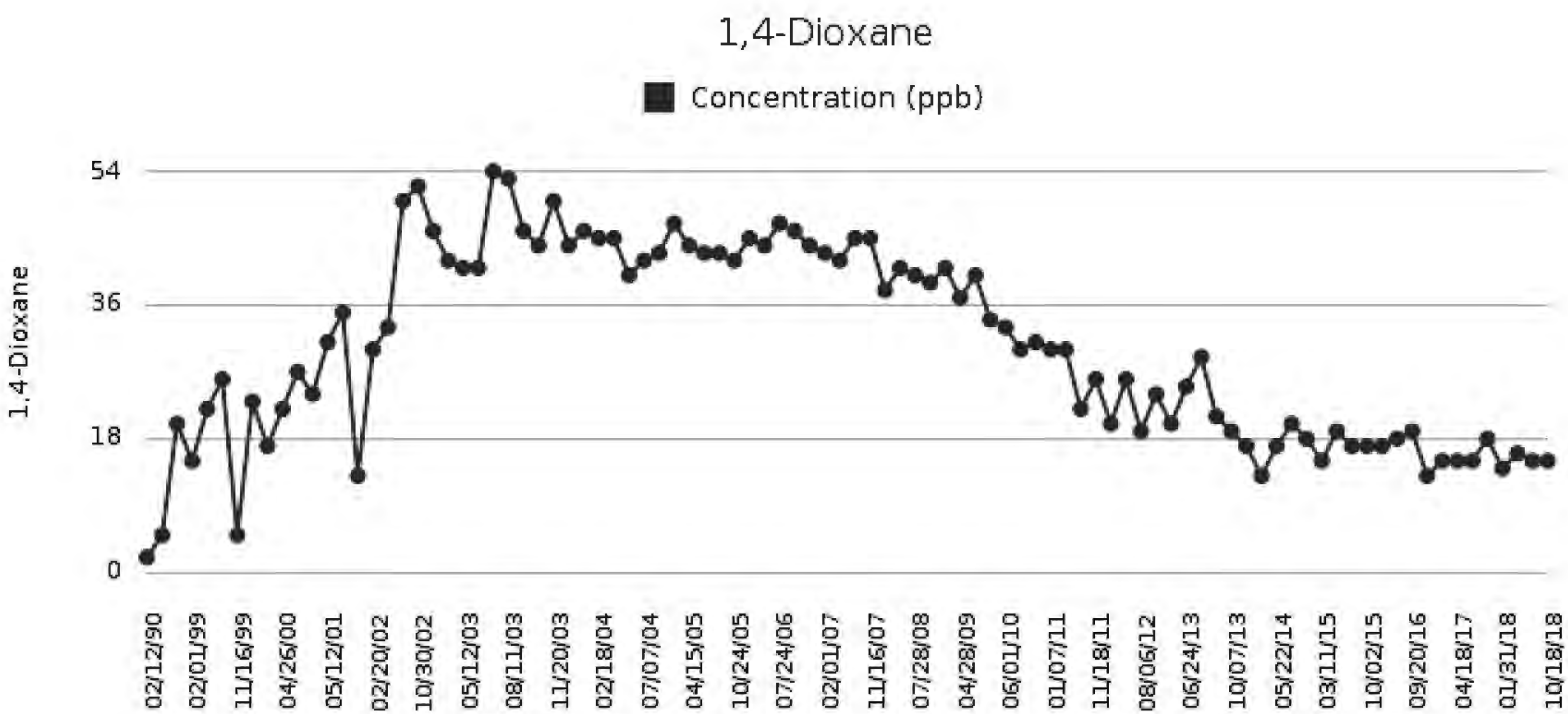
Well Name: 5005 Jackson Rd

Aquifer:	D0	Date Installed:		Boring Depth:	Unknown Feet bgl	Screen 1:	Unknown to Unknown Feet
Map Location:	I-3	Well Driller:		Ground Elevation:	Unknown Feet	Screen Length:	Unknown
X Coordinate:	13269676.00	Well Type:	Residential Wells	TOC Elevation:	Unknown Feet	Screen 2:	NA to NA Feet
Y Coordinate:	287089.00	Sampling Interval:	Quarterly	TOC to screen bottom:	Unknown Feet		
Comments:	2016 Connected to Municipal water service.						



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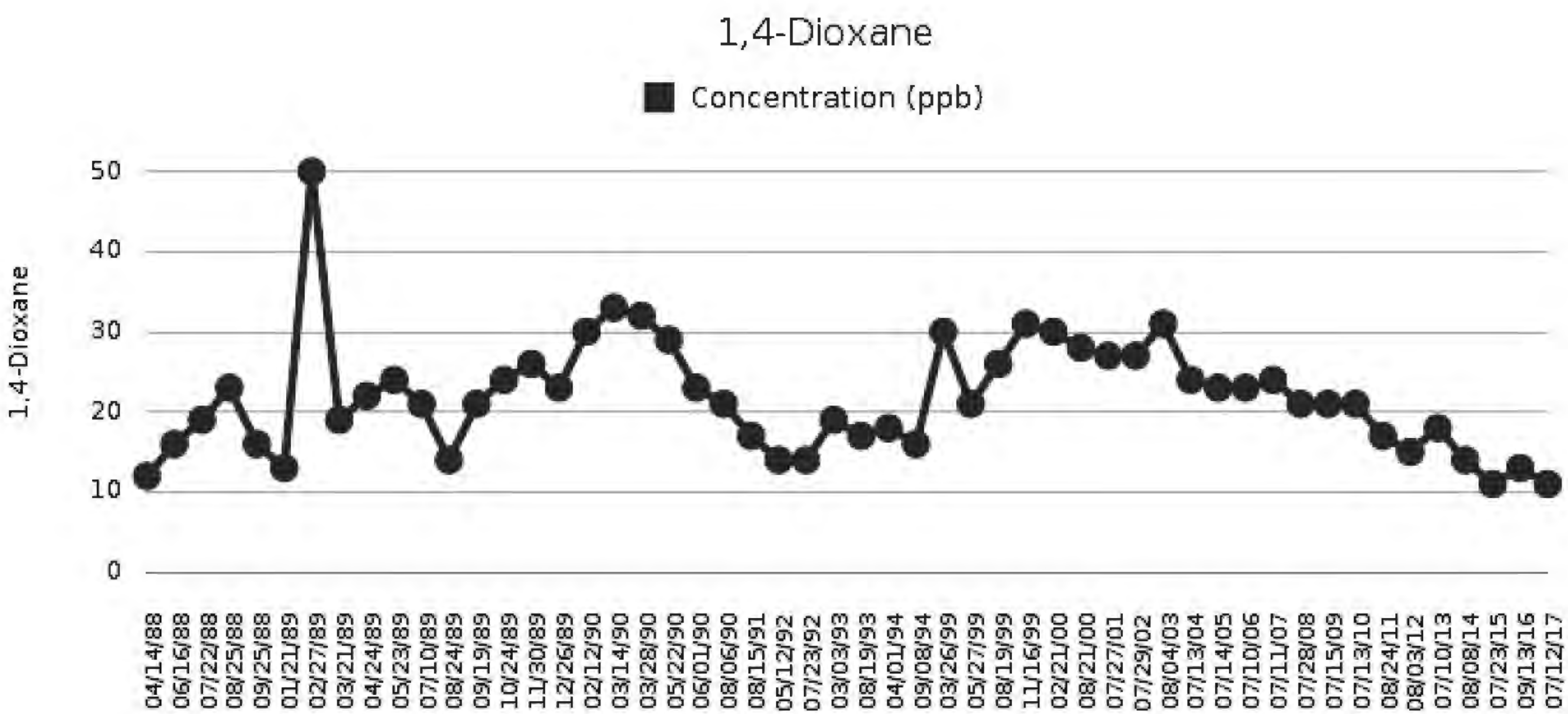
Well Name: ARTESIAN #3

Aquifer:	D0	Date Installed:		Boring Depth:	Unknown Feet bgl	Screen 1:	Unknown to Unknown Feet
Map Location:	I-5	Well Driller:		Ground Elevation:	Unknown Feet	Screen Length:	Unknown
X Coordinate:	13270318.69	Well Type:	Miscellaneous Wells	TOC Elevation:	Unknown Feet	Screen 2:	NA to NA Feet
Y Coordinate:	286941.48	Sampling Interval:	Annual	TOC to screen bottom:	Unknown Feet		
Comments:							



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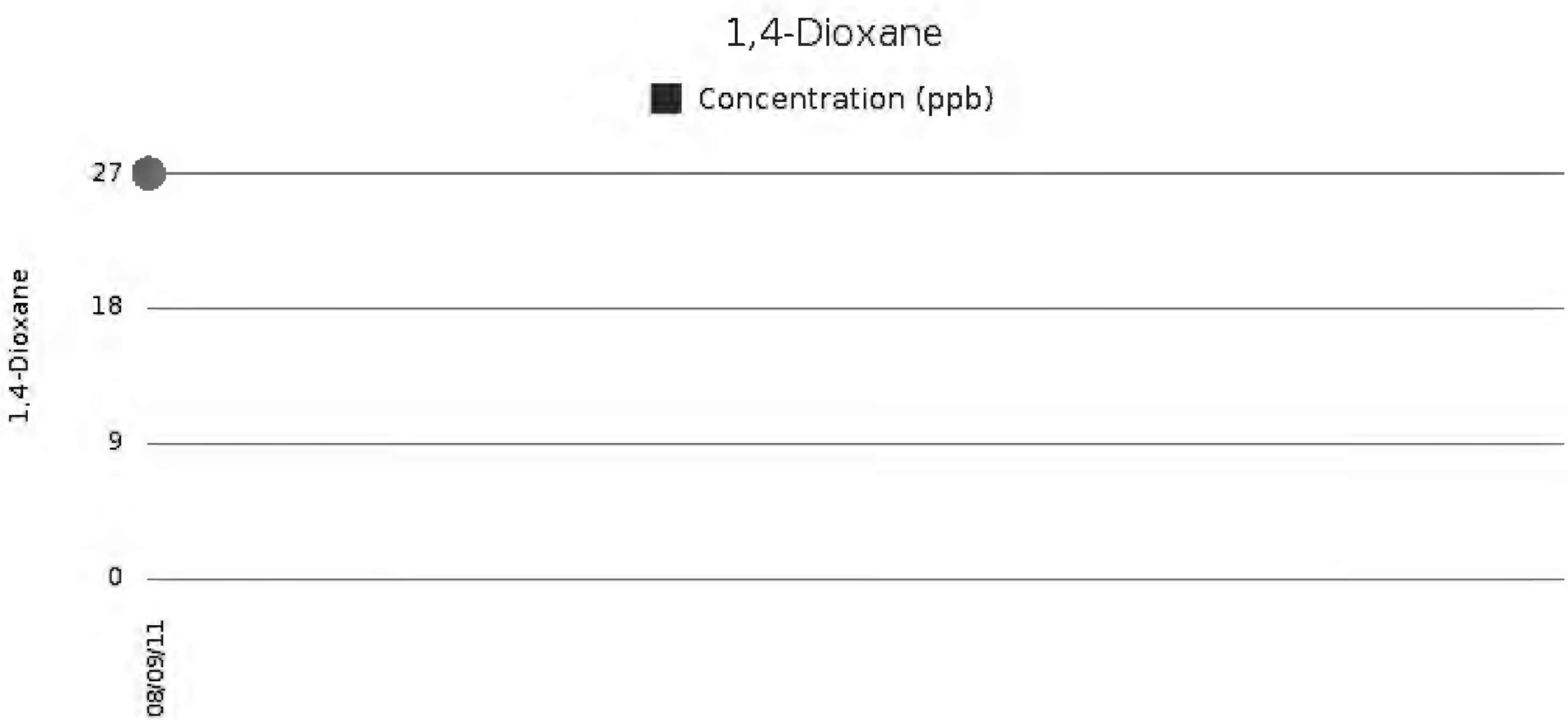
Well Name: HCMW-2d

Aquifer:	SH	Date Installed:	06/02/1994	Boring Depth:	16.00 Feet bgl	Screen 1:	16.00 to 13.00 Feet
Map Location:	I-94 & H Creek	Well Driller:	Alpha Geoscience	Ground Elevation:	Unknown Feet	Screen Length:	3.00
X Coordinate:	13269162.93	Well Type:	Miscellaneous Wells	TOC Elevation:	857.46 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	288020.67	Sampling Interval:	Not Set	TOC to screen bottom:	19.00 Feet		
Comments:	Surveyed by Atwell LCC on 2/24/2015						



Analytical Data Report: HCMW-2d

Aquifer: SH	**Date Installed:** 06/02/1994	**Boring Depth:** 16.00 Feet bgl	**Screen 1:** 16.00 to 13.00 Feet
Map Location: I-94 & H Creek	**Well Driller:** Alpha Geoscience	**Ground Elevation:** Unknown Feet	**Screen 1 Length:** 3.00
X Coordinate: 13269162.93	**Well Type:** Miscellaneous Wells	**TOC Elevation:** 857.46 Feet	**Screen 2:** NA to NA Feet
Y Coordinate: 288020.67	**Sampling Interval:** Not Set	**TOC to screen bottom:** 19.00 Feet	
	Static Interval: Not Set	**Notes:** Surveyed by Atwell LCC on 2/24/2015	

Date Collected	Time Collected	1,4-Dioxane Results (ppb)	R.L.	Bromate Results	R.L.	Bromide Results	R.L.	Static Time	Static Reading	Comments
02/24/2015	11:45							11:45	5.19	
01/20/2015	14:44							14:44	5	
08/09/2011	11:35	27	1.0					11:20	30.45	

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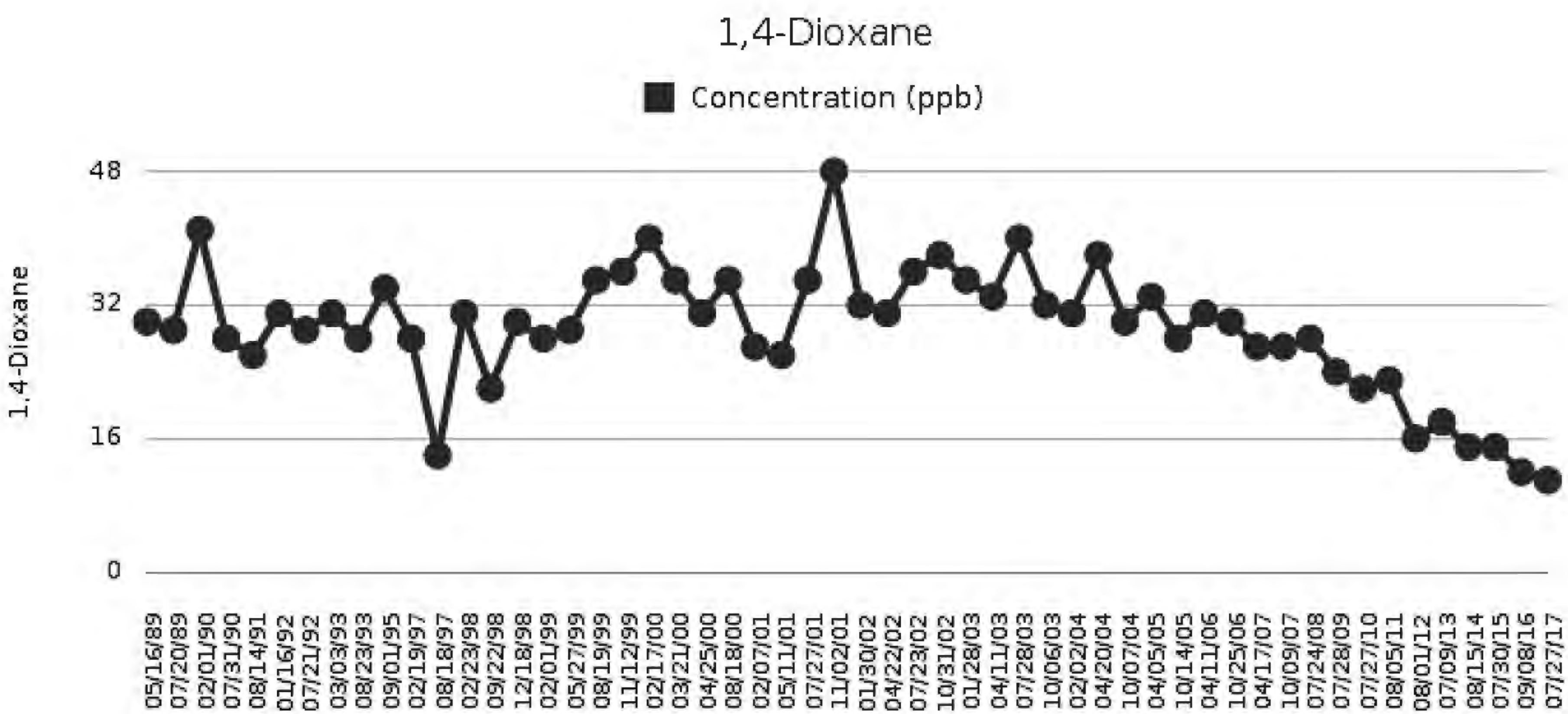
Analytical Data Graph

Printed: 11/30/2018

Well Name: MW-31

Aquifer:	D0	Date Installed:	06/16/1989	Boring Depth:	65.00 Feet bgl	Screen 1:	65.00 to 60.00 Feet
Map Location:	J-6	Well Driller:	T & T Drilling	Ground Elevation:	884.08 Feet	Screen Length:	5.00
X Coordinate:	13270905.00	Well Type:	Monitoring Wells	TOC Elevation:	887.05 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	286465.00	Sampling Interval:	Annual	TOC to screen bottom:	68.00 Feet		
Comments:							



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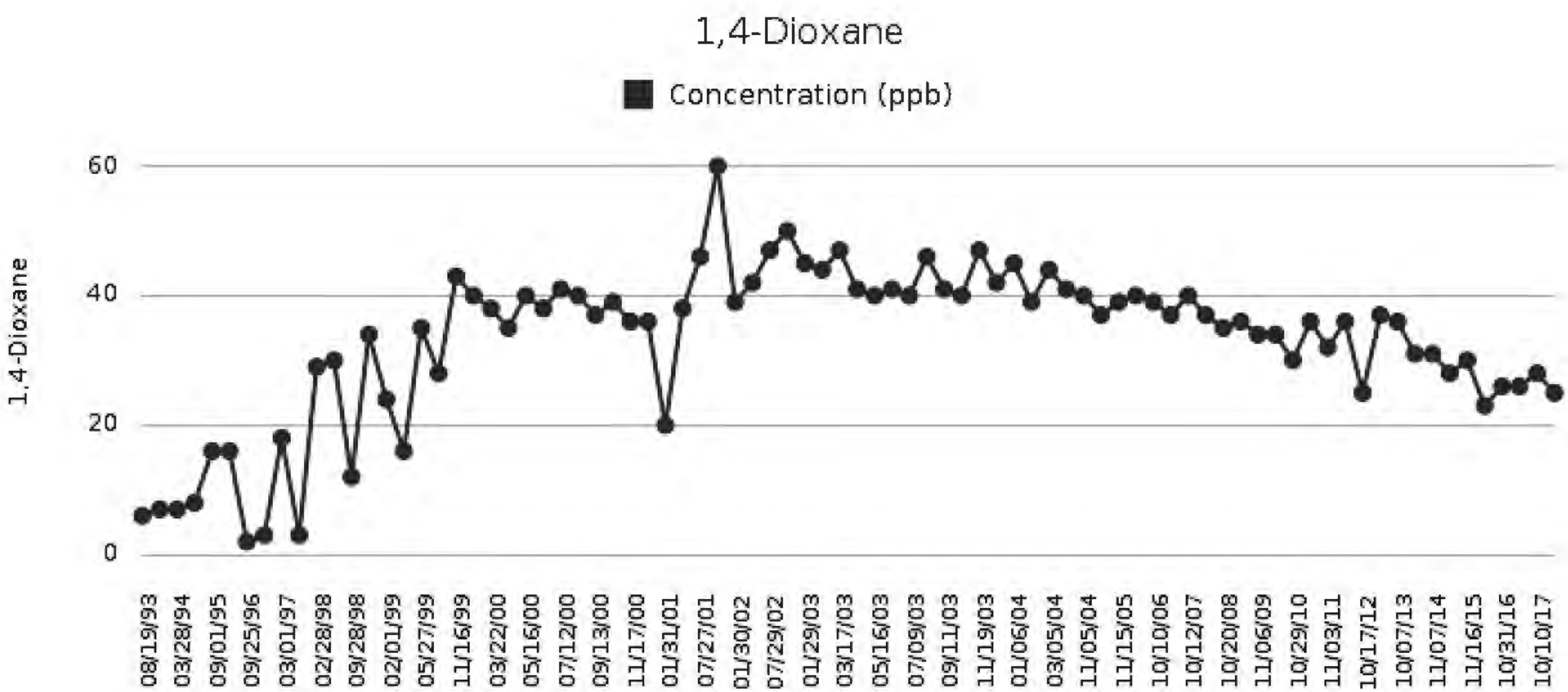
Printed: 11/30/2018

Well Name: MW-41d

Aquifer:	D0	Date Installed:	05/18/1993	Boring Depth:	92.00 Feet bgl	Screen 1:	91.00 to 86.00 Feet
Map Location:	H-3	Well Driller:	T & T Drilling	Ground Elevation:	866.32 Feet	Screen Length:	5.00
X Coordinate:	13269671.12	Well Type:	Monitoring Wells	TOC Elevation:	866.73 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	287363.45	Sampling Interval:	Semi-Annual	TOC to screen bottom:	91.00 Feet		
Comments:	Resurveyed By Atwell LCC on 2/24/2015						



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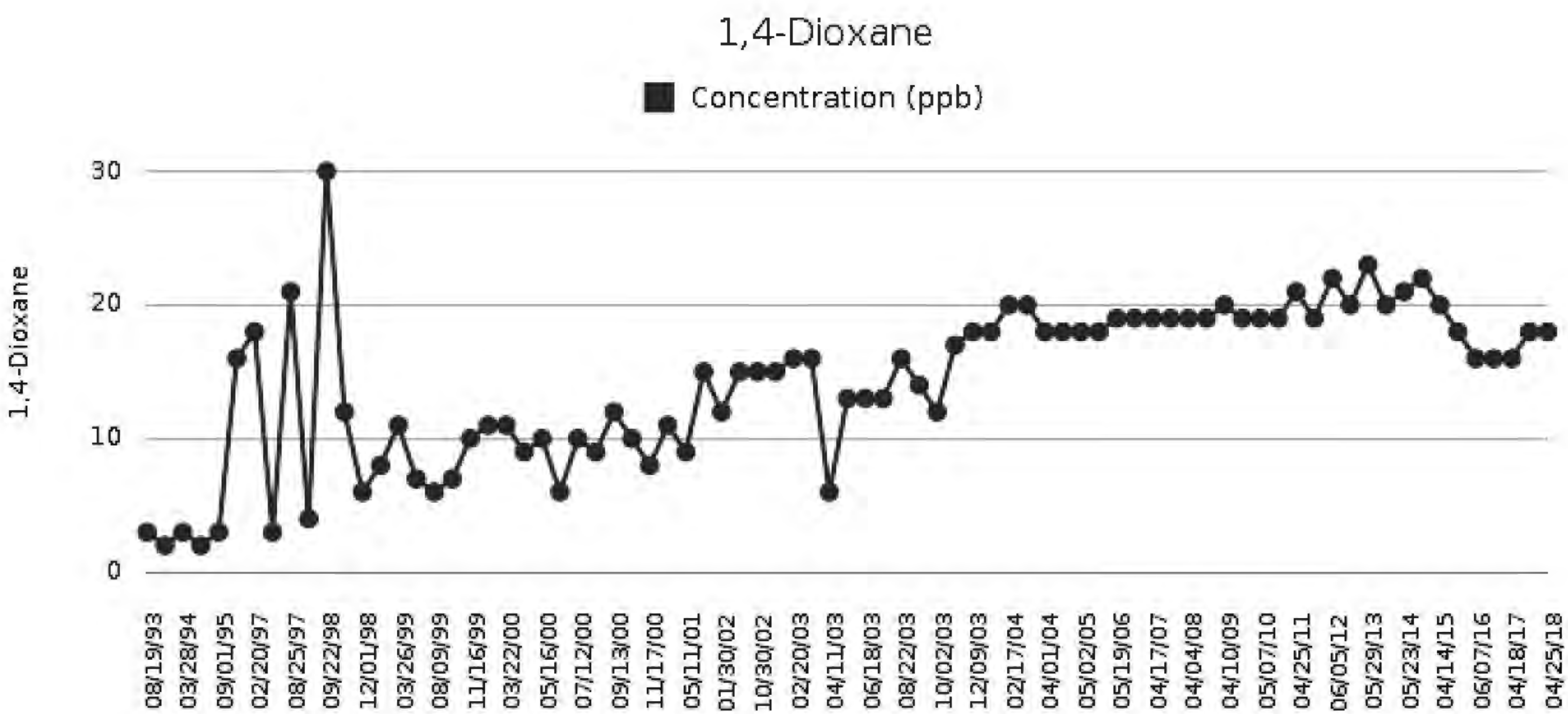
Analytical Data Graph

Printed: 11/30/2018

Well Name: MW-41s

Aquifer:	D0	Date Installed:	05/17/1993	Boring Depth:	92.00 Feet bgl	Screen 1:	50.00 to 45.00 Feet
Map Location:	H-3	Well Driller:	T & T Drilling	Ground Elevation:	865.68 Feet	Screen Length:	5.00
X Coordinate:	13269705.34	Well Type:	Monitoring Wells	TOC Elevation:	864.46 Feet	Screen 2:	NA to NA Feet
Y Coordinate:	287363.69	Sampling Interval:	Semi-Annual	TOC to screen bottom:	50.00 Feet		
Comments:	Resurveyed By Atwell LCC on 2/24/2015						



APPENDIX 5

Appendix 5 - Huron River Flow Data
806500 - Gelman Sciences, Inc.
Summary of Daily Mean Values by Year for Ann Arbor and Dexter Stations, 10/1/1914 - 9/30/2018
February, 2019

	Ann Arbor Station 04174500 (cfs)			Dexter Station 04173000 (cfs)		
Year	***Mean*** of Daily Mean Values	***Max*** of Daily Mean Values	***Min*** of Daily Mean Values	***Mean*** of Daily Mean Values	***Max*** of Daily Mean Values	***Min*** of Daily Mean Values
1914	479	3270	133	ND	ND	ND
1915	508	2050	193	ND	ND	ND
1916	633	3950	22	ND	ND	ND
1917	424	1670	85	ND	ND	ND
1918	505	5840	18	ND	ND	ND
1919	481	3090	18	ND	ND	ND
1920	365	2480	20	ND	ND	ND
1921	419	1140	66	ND	ND	ND
1922	431	3360	6	ND	ND	ND
1923	263	1230	6	ND	ND	ND
1924	325	1750	6	ND	ND	ND
1925	294	1040	6	ND	ND	ND
1926	517	2950	32	ND	ND	ND
1927	384	942	55	ND	ND	ND
1928	356	920	53	ND	ND	ND
1929	494	1930	44	ND	ND	ND
1930	424	1820	37	ND	ND	ND
1931	165	467	4	ND	ND	ND
1932	310	957	73	ND	ND	ND
1933	348	1300	53	ND	ND	ND
1934	187	2590	6	ND	ND	ND
1935	263	1160	63	ND	ND	ND
1936	241	1040	6	ND	ND	ND
1937	426	1960	73	ND	ND	ND
1938	411	2140	71	ND	ND	ND
1939	346	1920	39	ND	ND	ND
1940	291	1280	57	ND	ND	ND
1941	272	922	15	ND	ND	ND
1942	383	2090	19	ND	ND	ND
1943	708	3450	108	ND	ND	ND
1944	341	1300	24	ND	ND	ND
1945	418	2890	102	ND	ND	ND
1946	313	1410	6	225	1060	56
1947	786	5170	115	558	3090	150
1948	289	663	100	476	1750	105
1949	503	3050	44	371	1450	100
1950	889	4170	116	639	2340	122
1951	706	2330	144	520	1550	113
1952	577	2090	82	404	1070	105
1953	331	928	22	238	530	74
1954	525	1820	70	386	924	74
1955	423	1530	69	304	894	82
1956	552	2690	120	435	2250	136
1957	449	1090	146	366	874	138
1958	261	825	84	205	653	90
1959	468	2110	48	353	1130	42
1960	453	1680	90	354	1110	96
1961	359	2030	63	265	944	89
1962	330	2500	40	243	1100	82
1963	226	1000	57	176	738	52
1964	193	524	50	150	400	42
1965	337	1820	42	239	830	53
1966	287	1140	63	214	657	41
1967	418	1710	72	312	951	58
1968	691	4010	168	479	2030	168
1969	640	2200	111	459	1190	58
1970	454	1240	60	332	868	88
1971	351	2590	25	270	1130	45

Appendix 5 - Huron River Flow Data
806500 - Gelman Sciences, Inc.
Summary of Daily Mean Values by Year for Ann Arbor and Dexter Stations, 10/1/1914 - 9/30/2018
February, 2019

	Ann Arbor Station 04174500 (cfs)			Dexter Station 04173000 (cfs)		
Year	***Mean*** of Daily Mean Values	***Max*** of Daily Mean Values	***Min*** of Daily Mean Values	***Mean*** of Daily Mean Values	***Max*** of Daily Mean Values	***Min*** of Daily Mean Values
1972	404	1520	22	263	755	89
1973	685	1830	62	ND	ND	ND
1974	768	3900	101	ND	ND	ND
1975	631	2430	56	429	800	115
1976	645	3510	88	479	2500	98
1977	353	1390	64	253	895	73
1978	372	2300	40	ND	ND	ND
1979	397	1430	55	ND	ND	ND
1980	535	1710	98	ND	ND	ND
1981	559	2230	45	ND	ND	ND
1982	562	3080	93	ND	ND	ND
1983	500	2660	58	ND	ND	ND
1984	407	1620	58	ND	ND	ND
1985	614	2630	96	ND	ND	ND
1986	594	2160	129	ND	ND	ND
1987	373	1160	72	ND	ND	ND
1988	429	1530	18	ND	ND	ND
1989	462	1890	120	ND	ND	ND
1990	696	2370	96	ND	ND	ND
1991	501	1700	82	ND	ND	ND
1992	575	1810	136	ND	ND	ND
1993	661	2380	95	ND	ND	ND
1994	518	1380	128	ND	ND	ND
1995	534	1800	108	ND	ND	ND
1996	493	1430	89	ND	ND	ND
1997	634	2000	160	ND	ND	ND
1998	548	1930	90	ND	ND	ND
1999	322	1670	54	ND	ND	ND
2000	472	1530	78	ND	ND	ND
2001	645	2310	47	ND	ND	ND
2002	396	1300	49	ND	ND	ND
2003	292	1120	38	ND	ND	ND
2004	476	2310	86	ND	ND	ND
2005	447	2080	72	ND	ND	ND
2006	611	1810	60	ND	ND	ND
2007	567	1850	33	ND	ND	ND
2008	681	2410	88	ND	ND	ND
2009	799	2800	148	ND	ND	ND
2010	503	2050	103	ND	ND	ND
2011	841	3270	124	ND	ND	ND
2012	454	1830	57	ND	ND	ND
2013	523	2060	143	ND	ND	ND
2014	576	2150	191	ND	ND	ND
2015	424	1920	112	ND	ND	ND
2016	422	1030	69	ND	ND	ND
2017	592	2540	96	ND	ND	ND
2018 (P)	643	2890	112	ND	ND	ND
2019 (P)	587	816	379	ND	ND	ND
OVERALL	**470**	**5840**	**4**	**346**	**3090**	**41**

Notes:

P = Based on provisional data subject to revision.

ND = No data.

Source: United States Geological Survey (USGS) National Water Information System
Web Interface (waterdata.usgs.gov)
Washtenaw County, Michigan
Hydrologic Unit Code 04090005
Ann Arbor Station Drainage Area: 729 square miles, Gage Datum: 744.81 feet above NGVD29
Dexter Station Drainage Area: 522 square miles, Gage Datum: 837.11 feet above NGVD29

APPENDIX 6

Date	Result	Units	Laboratory
4/13/1992	<0.001	mg/L	ATS
4/12/1993	<0.001	mg/L	ATS
5/10/1994	<0.001	mg/L	ATS
8/23/1994	<0.001	mg/L	ATS
11/3/1994	<0.001	mg/L	ATS
3/11/1997	<0.001	mg/L	ATS
7/17/1997	<0.001	mg/L	ATS
5/14/1998	<0.001	mg/L	ATS
10/27/1998	<0.001	mg/L	ATS
6/28/2000	<0.001	mg/L	ATS
8/21/2000	<0.001	mg/L	ATS
11/1/2000	<0.001	mg/L	ATS
2/16/2001	<0.001	mg/L	ATS
3/7/2001	<0.001	mg/L	ATS
4/9/2001	<0.001	mg/L	ATS
5/18/2001	<0.001	mg/L	ATS
6/14/2001	<0.001	mg/L	ATS
7/16/2001	<0.001	mg/L	ATS
8/8/2001	<0.001	mg/L	ATS
9/14/2001	<0.001	mg/L	ATS
10/17/2001	<0.001	mg/L	ATS
11/7/2001	<0.001	mg/L	ATS
12/13/2001	<0.001	mg/L	ATS
1/31/2002	<0.001	mg/L	ATS
2/25/2002	<0.001	mg/L	ATS
3/18/2002	<0.001	mg/L	ATS
4/2/2002	<0.001	mg/L	ATS
4/22/2002	<0.001	mg/L	ATS
5/13/2002	<0.001	mg/L	ATS
6/25/2002	<0.001	mg/L	ATS
7/22/2002	<0.001	mg/L	ATS
8/12/2002	<0.001	mg/L	ATS
9/9/2002	<0.001	mg/L	ATS
9/24/2002	<0.001	mg/L	ATS
10/16/2002	<0.001	mg/L	ATS
11/19/2002	<0.001	mg/L	ATS
12/9/2002	<0.001	mg/L	ATS
1/14/2003	<0.001	mg/L	ATS
2/12/2003	<0.001	mg/L	ATS
3/21/2003	<0.001	mg/L	ATS
4/15/2003	<0.001	mg/L	ATS
5/19/2003	<0.001	mg/L	ATS
6/11/2003	<0.001	mg/L	ATS
7/9/2003	<0.001	mg/L	ATS
7/10/2003	<0.001	mg/L	ATS
8/6/2003	<0.001	mg/L	ATS
9/30/2003	<0.001	mg/L	ATS
10/27/2003	<0.001	mg/L	ATS
11/20/2003	<0.001	mg/L	ATS
1/26/2004	<0.001	mg/L	ATS
3/9/2004	<0.001	mg/L	ATS

Date	Result	Units	Laboratory
4/8/2004	<0.001	mg/L	ATS
5/19/2004	<0.001	mg/L	ATS
6/16/2004	<0.001	mg/L	ATS
7/15/2004	<0.001	mg/L	ATS
8/17/2004	<0.001	mg/L	ATS
10/13/2004	<0.001	mg/L	ATS
11/24/2004	<0.001	mg/L	ATS
12/6/2004	<0.001	mg/L	ATS
12/6/2004	<0.001	mg/L	ATS
1/4/2005	<0.001	mg/L	ATS
2/15/2005	<0.001	mg/L	ATS
3/17/2005	<0.001	mg/L	ATS
4/7/2005	<0.001	mg/L	ATS
5/11/2005	<0.001	mg/L	ATS
6/17/2005	<0.001	mg/L	ATS
7/6/2005	<0.001	mg/L	ATS
8/4/2005	<0.001	mg/L	ATS
9/1/2005	<0.001	mg/L	ATS
10/13/2005	<0.001	mg/L	ATS
11/17/2005	<0.001	mg/L	ATS
12/8/2005	<0.001	mg/L	ATS
1/8/2006	<0.001	mg/L	ATS
2/7/2006	<0.001	mg/L	ATS
3/6/2006	<0.001	mg/L	ATS
4/14/2006	<0.001	mg/L	ATS
5/3/2006	<0.001	mg/L	ATS
6/9/2006	<0.001	mg/L	ATS
7/7/2006	<0.001	mg/L	ATS
8/11/2006	<0.001	mg/L	ATS
9/11/2006	<0.001	mg/L	ATS
10/12/2006	<0.001	mg/L	ATS
11/20/2006	<0.001	mg/L	ATS
12/12/2006	<0.001	mg/L	ATS
1/19/2007	<0.001	mg/L	ATS
2/8/2007	<0.001	mg/L	ATS
3/8/2007	<0.001	mg/L	ATS
4/2/2007	<0.001	mg/L	ATS
5/8/2007	<0.001	mg/L	ATS
6/20/2007	<0.001	mg/L	ATS
7/13/2007	<0.001	mg/L	ATS
8/14/2007	<0.001	mg/L	ATS
9/25/2007	<0.001	mg/L	ATS
10/10/2007	<0.001	mg/L	ATS
11/14/2007	<0.001	mg/L	ATS
12/5/2007	<0.001	mg/L	ATS
1/14/2008	<0.001	mg/L	ATS
2/11/2008	<0.001	mg/L	ATS
3/5/2008	<0.001	mg/L	ATS
4/21/2008	<0.001	mg/L	ATS
5/6/2008	<0.001	mg/L	ATS
6/11/2008	<0.001	mg/L	ATS

Date	Result	Units	Laboratory
7/16/2008	<0.001	mg/L	ATS
8/15/2008	<0.001	mg/L	ATS
9/22/2008	<0.001	mg/L	ATS
10/10/2008	<0.001	mg/L	ATS
11/13/2008	<0.001	mg/L	ATS
12/3/2008	<0.001	mg/L	ATS
1/20/2009	<0.001	mg/L	ATS
2/9/2009	<0.001	mg/L	ATS
3/3/2009	<0.001	mg/L	ATS
4/23/2009	<0.001	mg/L	ATS
5/13/2009	<0.001	mg/L	ATS
5/15/2009	<0.001	mg/L	ATS
6/5/2009	<0.001	mg/L	ATS
7/22/2009	<0.001	mg/L	ATS
8/10/2009	<0.001	mg/L	ATS
9/17/2009	<0.001	mg/L	ATS
10/9/2009	<0.001	mg/L	ATS
11/1/2009	<0.001	mg/L	ATS
12/9/2009	<0.001	mg/L	ATS
1/8/2010	<0.001	mg/L	ATS
2/10/2010	<0.001	mg/L	ATS
3/5/2010	<0.001	mg/L	ATS
4/7/2010	<0.001	mg/L	ATS
5/12/2010	<0.001	mg/L	ATS
6/4/2010	<0.001	mg/L	ATS
7/22/2010	<0.001	mg/L	ATS
8/4/2010	<0.001	mg/L	ATS
9/22/2010	<0.001	mg/L	ATS
10/12/2010	<0.001	mg/L	ATS
11/5/2010	<0.001	mg/L	ATS
12/9/2010	<0.001	mg/L	ATS
1/7/2011	<0.001	mg/L	ATS
2/11/2011	<0.001	mg/L	ATS
3/11/2011	<0.001	mg/L	ATS
4/8/2011	<0.001	mg/L	ATS
5/4/2011	<0.001	mg/L	ATS
6/10/2011	<0.001	mg/L	ATS
7/14/2011	<0.001	mg/L	ATS
8/12/2011	<0.001	mg/L	ATS
9/10/2011	<0.001	mg/L	ATS
10/21/2011	<0.001	mg/L	ATS
11/3/2011	<0.001	mg/L	ATS
12/7/2011	<0.001	mg/L	ATS
1/5/2012	<0.001	mg/L	ATS
2/9/2012	<0.001	mg/L	ATS
3/22/2012	<0.001	mg/L	ATS
4/4/2012	<0.001	mg/L	ATS
5/4/2012	<0.001	mg/L	ATS
6/14/2012	<0.001	mg/L	ATS
7/10/2012	<0.001	mg/L	ATS
8/10/2012	<0.001	mg/L	ATS

Appendix 6 - Summary of 1,4-Dioxane Data for City of Ann Arbor Drinking Water Intake at Barton Pond
806500 - Gelman Sciences, Inc.
February, 2019

Date	Result	Units	Laboratory
9/4/2012	<0.001	mg/L	ATS
10/11/2012	<0.001	mg/L	ATS
11/5/2012	<0.001	mg/L	ATS
12/7/2012	<0.001	mg/L	ATS
1/8/2013	<0.001	mg/L	ATS
2/8/2013	<0.001	mg/L	ATS
3/7/2013	<0.001	mg/L	ATS
4/5/2013	<0.001	mg/L	ATS
5/24/2013	<0.001	mg/L	ATS
6/13/2013	<0.001	mg/L	ATS
7/19/2013	<0.001	mg/L	ATS
8/27/2013	<0.001	mg/L	ATS
9/10/2013	<0.001	mg/L	ATS
10/22/2013	<0.001	mg/L	ATS
11/20/2013	<0.001	mg/L	ATS
12/17/2013	<0.001	mg/L	ATS
1/8/2014	<0.001	mg/L	ATS
2/5/2014	<0.001	mg/L	ATS
3/4/2014	<0.001	mg/L	ATS
4/8/2014	<0.001	mg/L	ATS
5/6/2014	<0.001	mg/L	ATS
6/3/2014	<0.001	mg/L	ATS
7/10/2014	<0.001	mg/L	ATS
8/5/2014	<0.001	mg/L	ATS
9/10/2014	<0.001	mg/L	ATS
10/2/2014	<0.001	mg/L	ATS
11/4/2014	<0.07	µg/L	EE
12/3/2014	<0.07	µg/L	EE
1/5/2015	<0.07	µg/L	EE
2/5/2015	<0.07	µg/L	EE
3/4/2015	<0.07	µg/L	EE
4/7/2015	<0.07	µg/L	EE
5/5/2015	<0.07	µg/L	EE
6/9/2015	<0.07	µg/L	EE
7/6/2015	<0.07	µg/L	EE
8/3/2015	<0.07	µg/L	EE
9/9/2015	<0.07	µg/L	EE
10/5/2015	<0.07	µg/L	EE
11/5/2015	<0.07	µg/L	EE
12/8/2015	<0.07	µg/L	EE
1/5/2016	<0.07	µg/L	EE
2/8/2016	<0.07	µg/L	EE
3/9/2016	<0.07	µg/L	EE
4/4/2016	<0.07	µg/L	EE
5/3/2016	<0.07	µg/L	EE
6/7/2016	<0.07	µg/L	EE
7/6/2016	<0.07	µg/L	EE
8/9/2016	<0.07	µg/L	EE
9/29/2016	<0.07	µg/L	EE
10/5/2016	lab contamination - analysis invalidated		
11/8/2016	<0.07	µg/L	EE