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Changes to water quality and discharge in an urban stream in Southwest Jefferson County.

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CHANGES TO WATER QUALITY AND DISCHARGE IN AN URBAN STREAM IN SOUTHWEST JEFFERSON COUNTY

By

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A Thesis Approved on

June 30, 2023

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ABSTRACT

CHANGES TO WATER QUALITY AND DISCHARGE IN AN URBAN STREAM IN SOUTHWEST JEFFERSON COUNTY

Karina Henson

June 30, 2023

Mill Creek is the largest watershed in Southwest Jefferson County, where thousands of people live and work. Streams in the watershed have historically been channelized and altered to promote drainage, and stream health is of major concern. Louisville MSD is currently developing a watershed plan for Mill Creek by seeking understanding of current stream conditions. This paper will focus on historical trends in stream discharge and water quality. Peak and daily discharge, dissolved oxygen, specific conductance, and temperature data from USGS gages at Mill Creek and the Mill Creek Cutoff was analyzed to understand how water quality and flow rates have changed in the watershed in the past 20 years, as well as between 1990 and today. Similarities in discharge trends were found between the two watersheds, but there were differences in trends for dissolved oxygen and specific conductance that impacts on water quality in either stream.

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INTRODUCTION

Mill Creek has been a watershed of interest and importance throughout Louisville's history. In the early 1900s, a citizen's committee was formed to study the watershed, along with the Pond Creek watershed, and report to the County Fiscal Court any recommendations determined (Robinson, 1985). A report was made on June 7, 1910, with plans for a project to drain the upper half of the watershed (Robinson, 1985). Ultimately, it was decided that a manmade ditch could be created that would drain directly to the Ohio River through mostly undeveloped land (Robinson, 1985). This became known as the Mill Creek Cutoff, and a contract to construct the 7800-foot channel was awarded in 1910 (Robinson, 1985).

After World War II, development of residential subdivisions in Jefferson County took off, changing drainage patterns for the region (Robinson, 1985). This resulted in several drainage projects in Southwest Jefferson County, including channel improvements for Mill Creek and its tributaries in 1956 (Robinson, 1985). Channel improvements can include straightening, deepening, widening, and otherwise altering streams to increase capacity and flow.

The entire Mill Creek watershed has a drainage area of approximately 34 square miles in southwest Jefferson County (USACE, 2009) . The construction of the Mill Creek Cutoff split the watershed into two sections: the Upper and Lower Mill Creek watersheds

(USACE, 2009). The Upper Mill Creek watershed includes the cutoff, and has a 19 square mile drainage area, running west towards the Ohio River (Louisville MSD, 2021a). The Lower Mill Creek watershed includes Mill Creek, has a 15 square mile drainage area, and runs south, parallel to the Ohio River (Louisville MSD, 2021a). Both streams ultimately outlet to the Ohio River. This watershed is mostly residential land, with significant commercial use along Dixie Highway, and a mixture of commercial and industrial use along the river (Louisville MSD, 2021a). Figure 1 shows the area considered by Louisville MSD to be the Mill Creek Watershed, including the Upper and Lower Mill Creek areas.

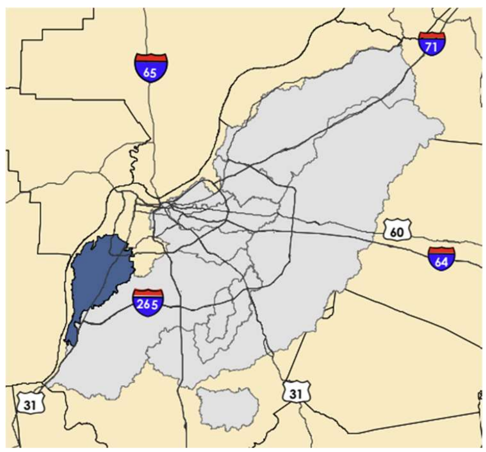

Figure 1: Map of the Mill Creek Watershed (Louisville MSD, 2021a)

Most of the wastewater treatment in the lower portion of the watershed is through septic systems and seepage pits (Louisville MSD, 2021a). A seepage pit is a circular pit filled with gravel, where wastewater is discharged to seep through the gravel to the surrounding soil (US EPA, 1982). A septic system consists of a tank that receives wastewater from a house and settles out solids before discharging to a disposal area (US EPA, 1982). A 1974 Water Quality Management Plan for Louisville recommended that septic systems, seepage pits, and small-area wastewater treatment plants in the Mill Creek area be replaced by a regional sewer system (US EPA, 1982). This proposal received significant backlash from the Southwest Jefferson County Homeowners Association, resulting the preparation of an Environmental Impact Study (EIS) by the Environmental Protection Agency (EPA), which examined the prevailing and potential water quality impacts in the area (US EPA, 1982). The study found that groundwater had been impacted by the use of septic tanks (US EPA, 1982). The study also reported that surface streams were "characterized by very low flow and run through densely populated residential neighborhoods" (US EPA, 1982), which highlights the importance of water quality in the Mill Creek watershed to public health. It was ultimately decided that due to estimated costs, community opinion, and availability of drinking water from the Louisville Water Company (instead of groundwater), septic tanks would remain in use, though a regional water treatment plant would be constructed, and future development could connect to the sewer system (US EPA, 1982). Septic systems and seepage pits are still in use in the watershed, which means the water quality impacts found in the EIS may still occur.

The Mill Creek watershed is in the separate sewer system of Louisville (Louisville MSD, n.d.). A separate sewer system collects only wastewater and transports this flow to wastewater treatment centers (US EPA, 2022a). In a separate sewer system, stormwater is conveyed through channels such as storm sewers and drainage ditches to reach bodies of water without treatment (Louisville MSD, n.d.). This means most runoff from rain events will drain to the Ohio River through Mill Creek. This is especially true in this watershed, where many tributaries of Mill Creek have been straightened or channelized to reduce drainage related flooding (Louisville MSD, 2021a).

Louisville Metropolitan Sewer District (MSD), at the time of this writing, is working on developing a watershed plan for the Mill Creek watershed (Louisville MSD, 2021a). This process will involve seeking understanding about stream conditions, land use, and community needs in order to develop projects and management practices that will manage impacts of non-point source pollution in the stream (Louisville MSD, 2021a). Point source pollution is defined by Section 502(14) of the Clean Water Act as "any discernible, confined and discrete conveyance…from which pollutants are or may be discharged," (Clean Water Act, 1972) essentially any pollution source that can be identified at a single location, such as an industrial discharge pipe. Non-point source pollution is used to describe pollutant sources that fall outside of this definition, typically pollutants that derive from a variety of sources or a large area. A 2001 assessment of the stream suggested that Mill Creek was unable to support aquatic life or swimming due to the presence of nutrients, decaying organic material, sedimentation, and fecal chloroform (KDOW, 2001).

Mill Creek runs through a large portion of Jefferson County, touching the places where a population of approximately seventy thousand people (Metro United Way, 2022) live and work. As these people are impacted by the health of Mill Creek, they also have an opportunity to impact the stream themselves. Mill Creek has the potential to experience water quality impacts from a variety of sources including runoff, individual wastewater treatment (i.e. infiltration from septic tanks and seepage pits), as well as channelization. This paper will examine what water quality and hydrologic indicators reveal about the watershed using historical data records.

METHODS AND MATERIALS

Data from two United States Geological Survey (USGS) gauging stations in the watershed was evaluated. The sensor for Mill Creek, representing the Lower Mill Creek watershed, is USGS 03294570, located at Orell Road (USGS, 2023a). The site was established in 1988, and has a drainage area of 13.5 square miles, which means it captures the majority of the 15 square mile watershed. Figure 2 displays the drainage area map for this sensor, as determined by USGS. This site sometimes experiences a backwater effect when Ohio River levels are high, which means water levels are high even though flow is stagnant, due to the back-up of flow from the Ohio River. This largely impacts gage height, which was not evaluated for this study. The sensor for the Mill Creek Cutoff, representing the Upper Mill Creek watershed, is USGS 03294550 (USGS, 2023b). This site was established in 1988 and has a drainage area of 24.4 square miles, which is a larger drainage area than identified by Louisville MSD. Figure 3 displays the drainage map for this sensor, as determined by USGS. Dates of data availability for each site are provided in , though data was not necessarily available for each date within the availability range.

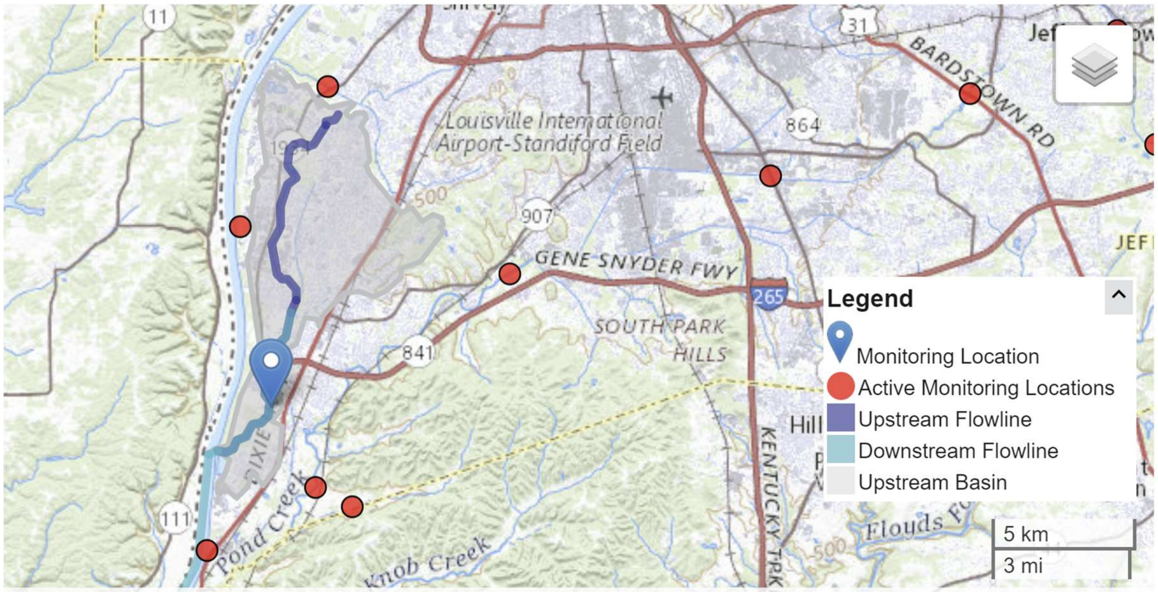

Figure 2: Mill Creek at Orell Rd USGS Drainage Map (USGS, 2023a)

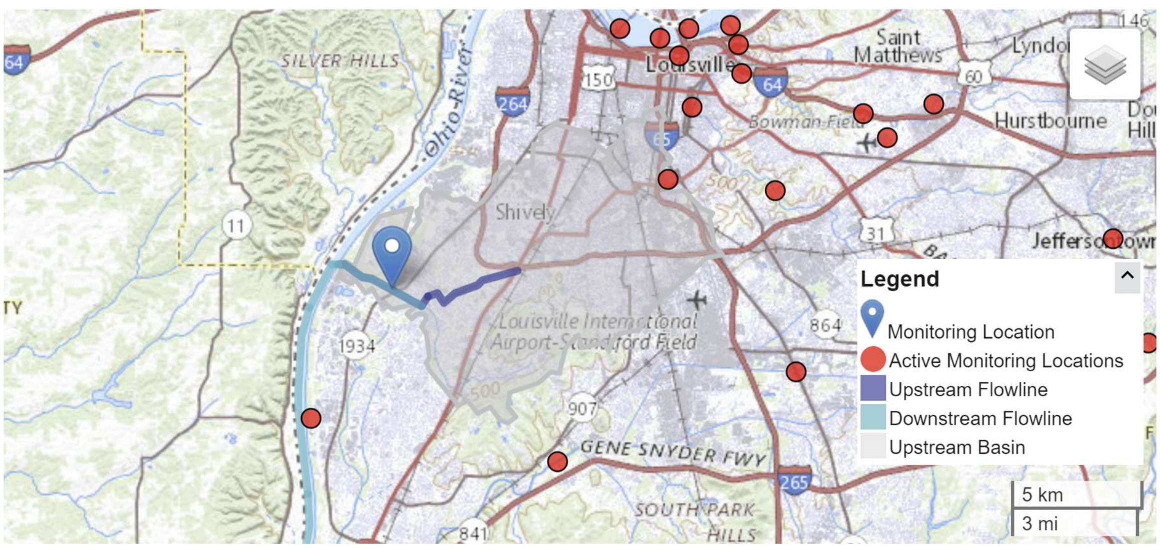

Figure 3: Mill Creek Cutoff USGS Drainage Map (USGS, 2023b)

Table 1: Data Availability

Parameter	Mill Creek at Orell Road: USGS 03294570	Mill Creek Cutoff: USGS 03294550
Discharge	August 1, 1999 – June 7, 2022	May 11, 1988 – February 10, 2022
Peak Discharge	January 4, 2000 – February 17, 2022	June 7, 1990 – February 28, 2021
Temperature	September 30, 2007 – June 16, 2022	November 29, 1988 – September 29, 1992
Dissolved Oxygen	September 30, 2007 – June 16, 2022	November 29, 1988 – September 29, 1992
Specific Conductance	December 6, 2014 – June 16, 2022	November 29, 1988 – September 29, 1992

Precipitation data was compiled from the National Oceanic and Atmospheric Association (NOAA) site at the Louisville airport site, which is USW00093821 (NOAA, 2023). This site is central to Jefferson County and has a period of record beginning in 1948.

Peak annual discharge data from USGS gages was used for further analysis (USGS, 2023a; USGS 2023b). Peak annual discharge values are the greatest streamflow values recorded at a site during a water year, which USGS considers as lasting from October 1 to September 30 (USGS, 2023c). Discharge values are calculated from instantaneous measurements of stream velocity and water height, and the value determined to be the maximum for the water year is the peak annual discharge (Water Science School, 2018). Gages measure at specific intervals, and intervals of 5 and 15 minutes were found to have been used for the data in this study.

The daily mean discharge data was also collected from the sensor. This data was compared to the peak annual discharge data for each date where peak discharge occured, to ensure that the mean discharge was always equal to or less than the peak annual discharge. Mean discharge is the mean of all discharge values of the day, whereas the peak annual discharge represents an instantaneous point in time of maximum flow. The mean discharge for the day on which peak annual discharge occurs should always be less than the peak annual discharge, as other flow values will occur throughout the recording period and diminish the mean discharge. A 1:1 ratio line was placed on the graph to provide a basis for comparison. From this, data that fell on or close to the 1:1 ratio line would indicate events where the daily mean discharge closely matches the peak discharge, which would mean the flow that day would have been consistently higher to create a greater average. Data that falls further from the 1:1 ratio line would indicate a shorter period of high flow, since there would have been less high flow values that day to drive the mean discharge upwards.

Flow data can hold significant information indicating hydrologic and environmental conditions for a stream and a watershed. In an urbanized watershed, there is less pervious area for rain to penetrate the soil, leading to greater surface runoff volumes. Urbanized watersheds also have less vegetation cover, decreasing opportunity for vegetation interception of flow, which reduces time of concentration, the time required for flow from the furthest point in the watershed to reach the outlet. The limited infiltration, lower time of concentration, channelization of flow, and greater compaction of soils contribute to greater volumes of overland flow at greater velocities, ultimately resulting in a shorter lag time for urbanized watersheds when compared to less developed watersheds (Hood et al., 2007). This can be evident in flow hydrographs, as a stream with a shorter lag time should demonstrate a more rapid and abrupt rise and fall in its hydrograph. Additionally, drainage systems are designed to help runoff leave a basin or given area faster (Anderson, 1970). Because of this, the Mill Creek Cutoff, which was initially designed with the purpose of drainage, will likely have much steeper hydrographs relative to a natural stream or a less developed watershed as flow will be able to reach the stream and be discharged at a faster rate (Anderson, 1970).

Dissolved oxygen and specific conductance data were available and evaluated for each stream to understand trends in water quality. Both parameters are impacted by water temperature, which was available for most of the dates when water quality parameters were measured by the gage. Water temperature data was used to normalize and contextualize general trends in dissolved oxygen and specific conductance. Temperature data from continuous monitoring site is typically measured by a thermistor, which can measure temperature to ±1°C (Wagner et al, 2006). pH data was available for each stream but was not evaluated in this study. A preliminary look at pH data did not indicate significant variation, though further studies could be done to evaluate pH changes in the stream.

Dissolved oxygen is an important measure of stream health. Oxygen in streams is necessary to break down organic matter, and for use in plant respiration (Langbein and Durum, 1967). Dissolved oxygen levels can be impacted by temperature, amounts of organic matter present, plant life, and physical properties of the stream (Langbein and Durum, 1967). Diminished dissolved oxygen values can indicate the presence of significant organic matter, or other pollutants that consume or process oxygen. Dissolved oxygen is typically measured by USGS using a polarographic membrane-type sensor, which can be very accurate but is sensitive to temperature and water velocity and can be susceptible to fouling (Wagner et al, 2006).

The dissolved oxygen deficit was used to evaluate dissolved oxygen data. This is a measure of expected dissolved oxygen values for specific temperature, barometric pressure, and salinity values. A USGS tool was used to determine expected dissolved oxygen values for a freshwater stream (salinity of zero) at a barometric pressure of 30 inches of mercury (USGS, 2022). The 30 inHg value for barometric pressure was determined by using the average annual barometric pressure value for Louisville as reported by the National Weather Service (National Weather Service, 2023). These values are provided in Table 2. The observed dissolved oxygen values were subtracted from the expected dissolved oxygen values to determine the dissolved oxygen deficit for each data point for each stream.

Table 2: Expected Dissolved Oxygen Levels for a Freshwater Stream with a Barometric Pressure of 29 inHg

Temperature (°C)	Dissolved Oxygen (mg/L)	Temperature (°C)	Dissolved Oxygen (mg/L)	Temperature (°C)	Dissolved Oxygen (mg/L)
0	14.66	12	10.81	25	8.29
1	14.25	13	10.56	26	8.14
2	13.87	14	10.33	27	7.99
3	13.5	15	10.11	28	7.85
4	13.14	16	9.9	29	7.71
5	12.8	17	9.69	30	7.58
6	12.48	18	9.49	31	7.45
7	12.17	19	9.3	32	7.33
8	11.87	20	9.12	33	7.2
9	11.59	21	8.94	34	7.08
10	11.32	22	8.77	35	6.97
11	11.06	23	8.6		

Specific conductance measurements can indicate the presence of particles and pollutants that would alter the conductivity of the water. It is also impacted by water temperature, as warmer water temperatures correspond to higher conductivity (EPA, 2022b). USGS gages typically measure specific conductance using contact sensors with electrodes. For multiparameter gages, which is what is assumed to be used by these sites, the temperature measurement is used to calculate the specific conductance at 25℃ (Wagner et al, 2006). Water temperature data was available for each USGS recording station and was compared to specific conductance data to determine if there is a positive relationship between the two parameters. If the expected relationship is not present, this may indicate particles and pollutants were present in the stream and may have impacted specific conductance levels.

RESULTS

Figure 4 shows the annual peak discharge data for the Mill Creek at the Orell Road gage. For Mill Creek at Orell Road, annual peak discharge from water years 2000-2021 were evaluated; there is one discharge value per water year as displayed in *Figure 4*.

Figure *5* shows the annual peak discharge data for the Mill Creek Cutoff gage. For the Mill Creek Cutoff, annual peak discharge from water years 1992-1993 and 2000-2021 were available and evaluated; there is one discharge value per water year. Generally, discharge values for the Mill Creek Cutoff were greater than those for Mill Creek at Orell Road and required a greater y-axis to display discharge data. The drainage area for the Mill Creek Cutoff gage is a little less than twice the size of the drainage area for the Mill Creek at Orell Road gage. This difference in drainage area impacts the overall volume of runoff that can reach the stream, as there is more surface area for precipitation to fall. Figure 6 combines peak discharge values for the Mill Creek Cutoff and Mill Creek at Orell Road gages, and demonstrates this impact on discharge, as peak streamflow values for the Mill Creek Cutoff are generally greater than peak streamflow values for Mill Creek at Orell Road. Figure 7 shows the annual peak discharge data for each stream divided by the drainage area according to USGS measurements. This allows comparisons to be made between the two watersheds for factors that impact streamflow beyond drainage area, such as land use. The correlation between the two streams for discharge values within the same water year is 0.308. This does not indicate significant correlation.

For the nine annual peak flow events that occur within one day of each other, there is a calculated correlation value of 0.09, indicating even less of a potential linear relationship.

Figure 8 provides a visual representation of this correlation, showing the scaled peak discharge values for Mill Creek at Orell Road against the scaled peak discharge values for the Mill Creek Cutoff. These values are paired by water year. There are some values that fall exactly on the 1:1 line, but many values fall to either side.

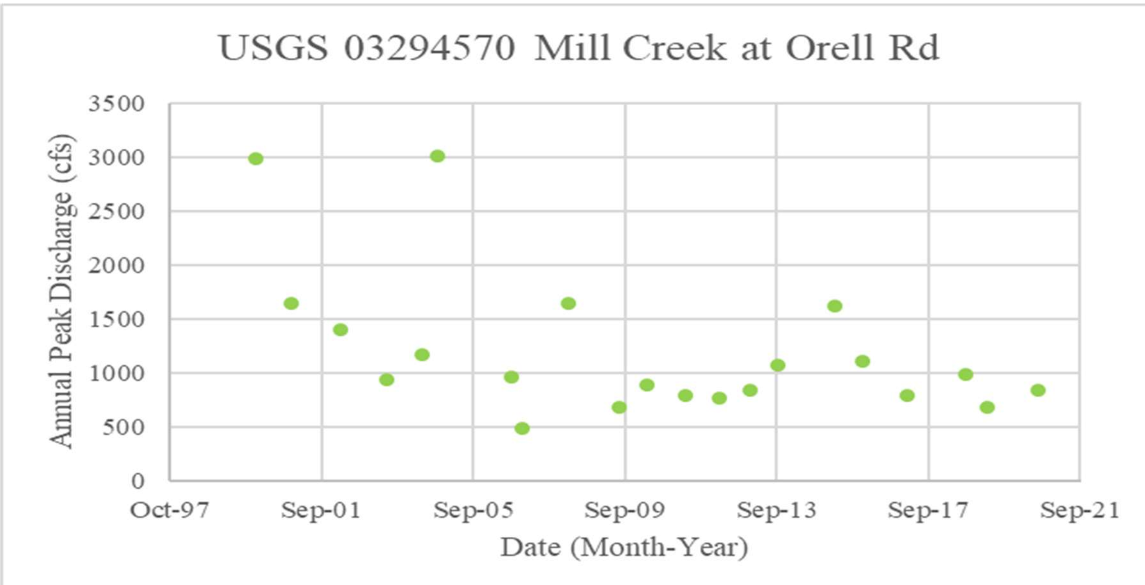

Figure 4: Mill Creek at Orell Road Annual Peak Discharge

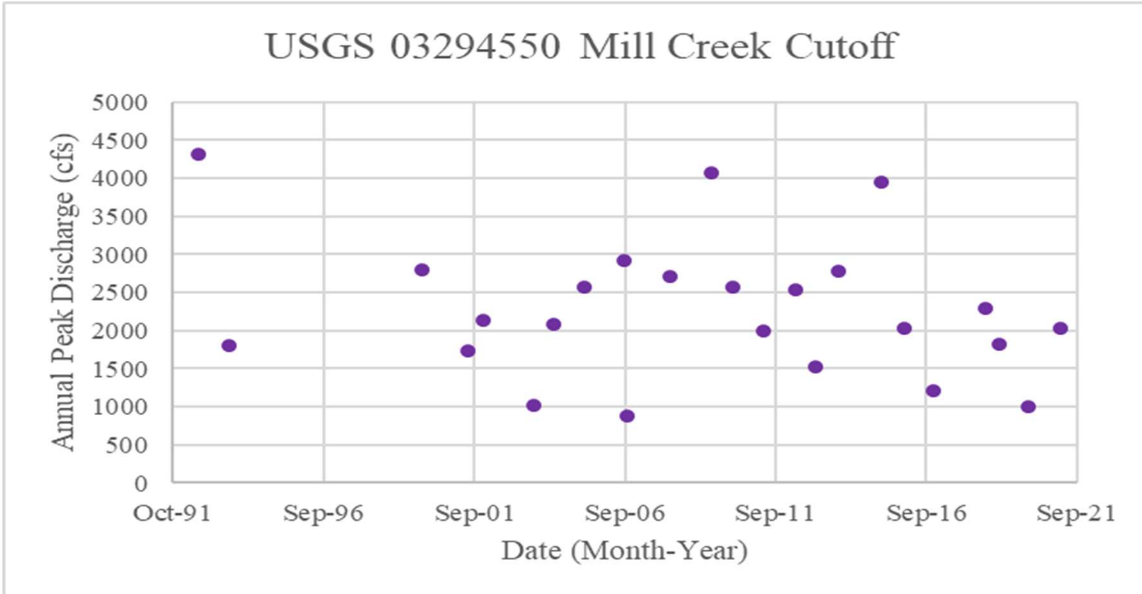

Figure 5: Mill Creek Cutoff Annual Peak Discharge

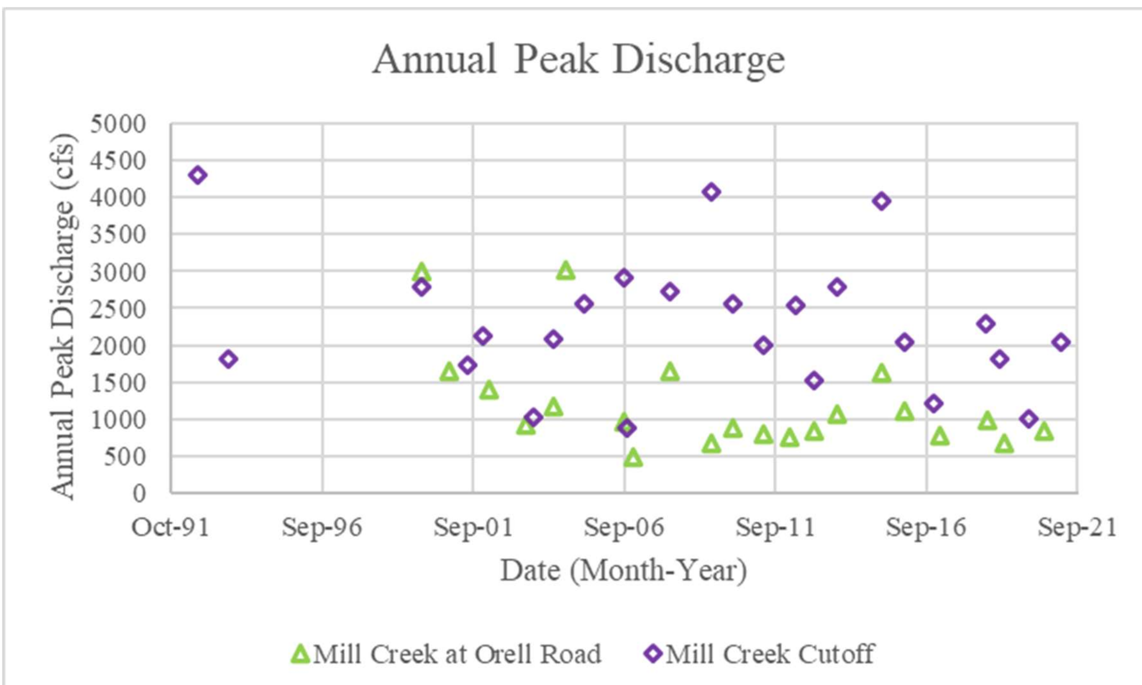

Figure 6: Annual Peak Discharge for Both Streams

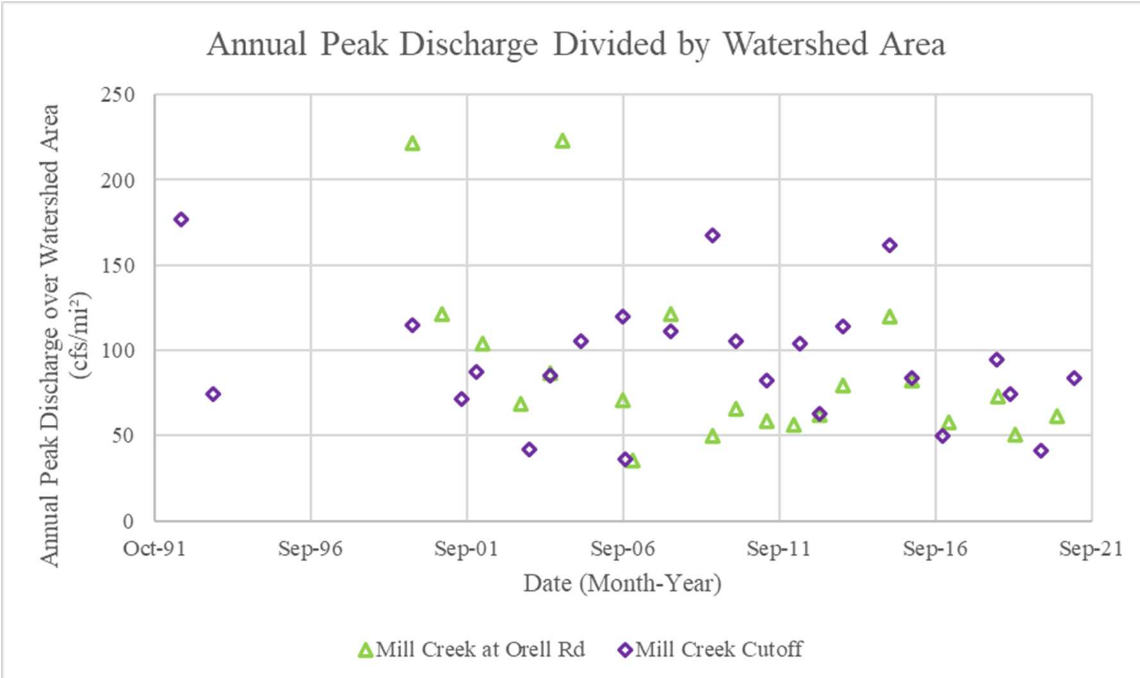

Figure 7: Annual Peak Discharge for both streams scaled by Watershed Area

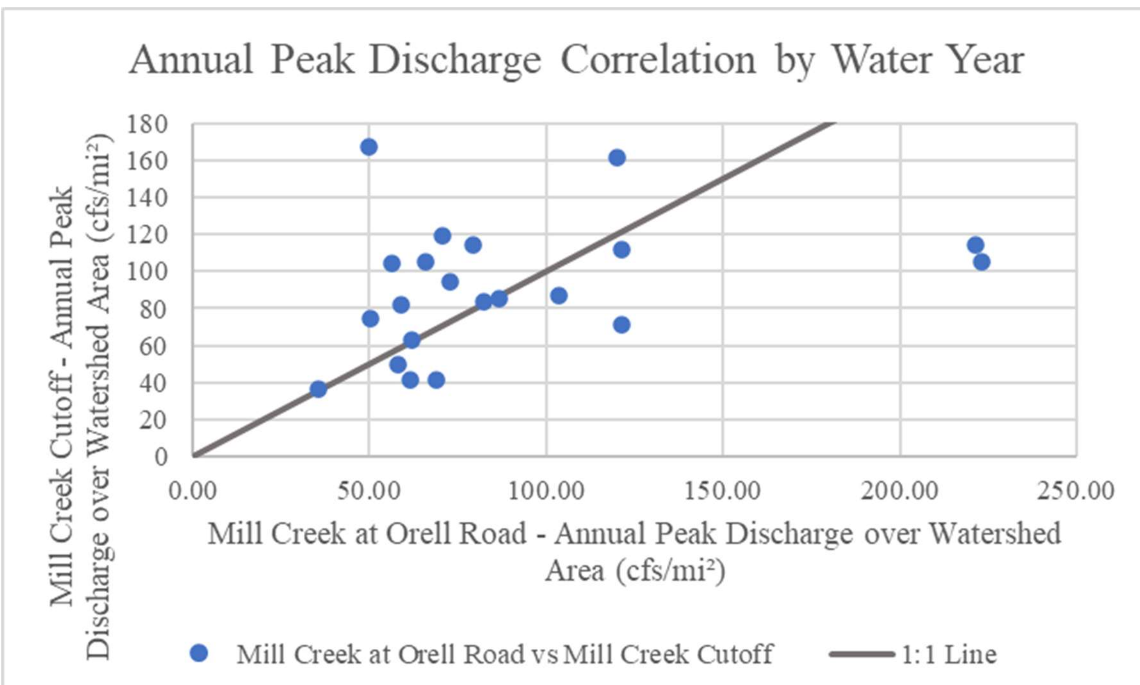

Figure 8: Annual Peak Discharge Correlation by Water Year

Figure 9 and Figure 10 show the daily discharge vs peak discharge on annual peak discharge dates for the Orell Road and Cutoff gages respectively. These graphs also have a 1:1 line for comparison.

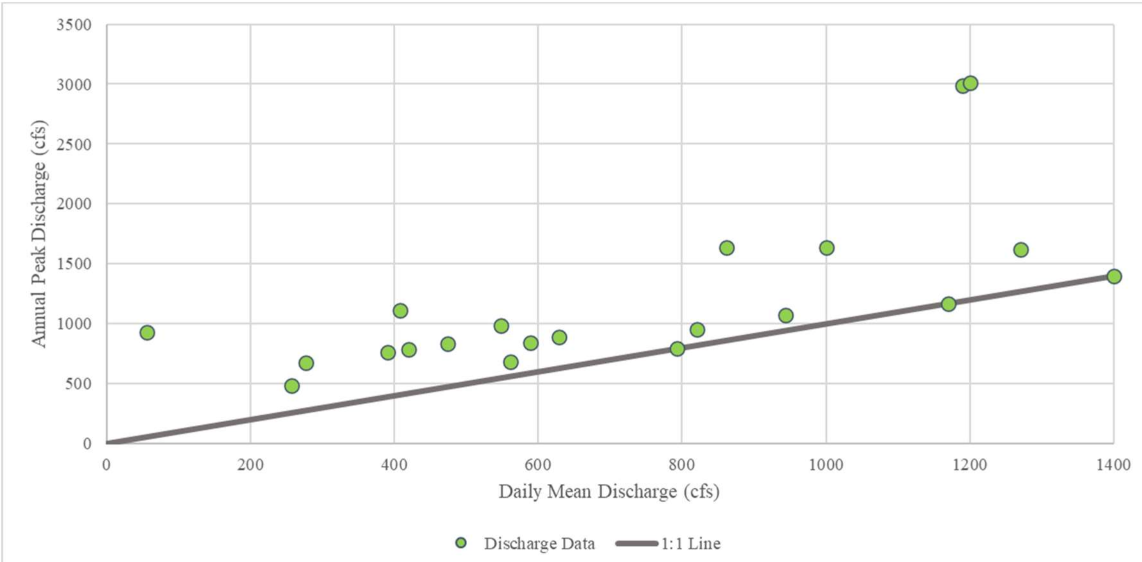

Figure 9: Annual Peak Discharge vs Daily Discharge for Mill Creek at Orell Rd

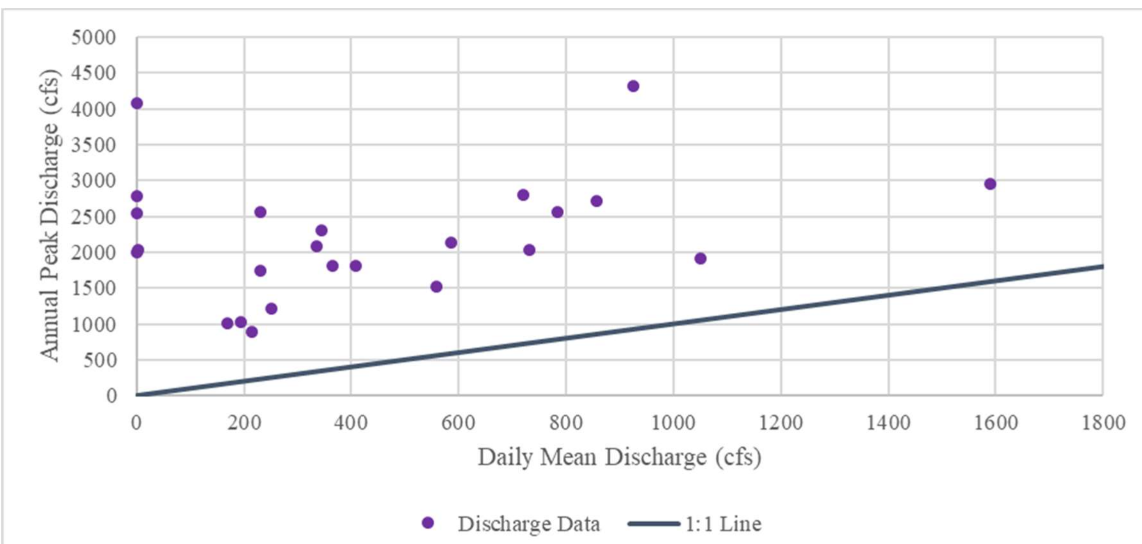

Figure 10: Annual Peak Discharge vs Daily Discharge for Mill Creek Cutoff

Table 3 shows the peak discharge, precipitation, and calculated runoff depth for each annual peak discharge date for Mill Creek at Orell Road. Table 4 shows the same data for the Mill Creek Cutoff. The precipitation for each discharge event was calculated by summing the NOAA rainfall data for the date of the peak discharge event, the date immediately prior, and the date immediately preceding. This allowed all potential precipitation that would be associated with the storm and potentially impact flow levels to be reflected in the data. The runoff depth for each event was calculated from finer discharge data points in intervals of 5 or 15 minutes, depending on data availability. The estimated baseflow of the stream was subtracted from each discharge data point so that only flow potentially associated with the rain event would be evaluated. The baseflow was estimated to be the minimum discharge value for each event within the evaluation period. From this, each modified discharge data point was multiplied by the time step to determine the volume of water passing through the stream at each time step. The runoff depth for each time step could then be calculated by dividing the runoff volume by the watershed area. These values were summed to determine the total runoff depth for the peak annual flow event. The flow in the stream is considered runoff, as it is the flow from precipitation that was not able to infiltrate and was not stored or intercepted elsewhere. The depth of precipitation that was lost, either through infiltration, storage elsewhere, interception, evaporation, or other methods, was determined by subtracting the runoff depth from the precipitation depth. A runoff ratio was also determined by dividing the runoff depth by the precipitation. This number indicates how much precipitation flows to the stream as runoff. A greater runoff ratio value indicated more flow results in runoff rather than as losses.

Table 3: Mill Creek at Orell Road Discharge, Runoff, and Losses

Date of Annual Peak	Peak Discharge (cfs)	Rain Event (in)	Runoff Depth (in)	Losses Depth (in)	Runoff Ratio (Runoff Depth/Precip)	Notes
1/4/2000	2990	3.64	3.16	0.48	0.87	
12/16/2000	1640	2.62	2.49	0.13	0.95	
3/26/2002	1400	2.4	-	-	-	no data available
6/16/2003	930	0.1	-	-	-	no data available
5/28/2004	1170	1.73	-	-	-	no data available
10/19/2004	3010	4.33	3.11	1.22	0.72	
9/23/2006	956	5.98	2.35	3.63	0.39	
1/14/2007	480	2.23	-	-	-	no data available
4/4/2008	1640	4.19	-	-	-	no data available
8/4/2009	675	4.53	1.49	3.04	0.33	
5/2/2010	887	4.76	2.20	2.56	0.46	
5/3/2011	793	2.35	-	-	-	no data available
3/16/2012	763	2.46	0.98	1.48	0.40	
1/13/2013	838	2.72	2.44	0.28	0.90	
10/6/2013	1070	7.11	3.30	3.81	0.46	
4/3/2015	1620	6.81	6.97	-0.16	1.02	incomplete data
12/27/2015	1110	3.24	0.36	2.88	0.11	incomplete data
3/1/2017	784	2.25	1.11	1.14	0.49	
9/24/2018	985	4.9	1.81	3.09	0.37	
4/20/2019	679	2.87	1.60	1.27	0.56	
8/14/2020	833	2.42	1.29	1.13	0.53	

Table 4: Mill Creek Cutoff Discharge, Runoff, and Losses

Date of Annual Peak	Peak Discharge (cfs)	Rain Event (in)	Runoff Depth (in)	Losses Depth (in)	Runoff Ratio (Runoff Depth/Precip)	Notes
1/3/2000	2800	5.19	0.54	4.65	0.10	
7/22/2001	1740	1.34	0.35	0.99	0.26	
1/24/2002	2130	2.23	0.78	1.45	0.35	
9/27/2003	1020	0.93	0.22	0.71	0.24	
5/27/2004	2080	3.02	0.61	2.41	0.20	
5/19/2005	2570	2.89	0.73	2.16	0.25	
9/23/2006	2920	5.98	1.09	4.89	0.18	
10/28/2006	884	1.54	0.41	1.13	0.27	
4/4/2008	2720	4.19	1.18	3.01	0.28	
8/4/2009	4080	4.53	1.84	2.69	0.41	
5/2/2010	2570	4.76	1.05	3.71	0.22	
4/27/2011	2000	3.41	-	-	-	no data available
5/29/2012	2540	3.17	0.70	2.47	0.22	
1/13/2013	1530	2.72	0.81	1.91	0.30	
10/16/2013	2790	0.06	-	-	-	data quality concerns
4/3/2015	3950	6.81	2.32	4.49	0.34	
12/27/2015	2040	3.24	0.47	2.77	0.15	
12/18/2016	1220	2.59	0.54	2.05	0.21	
9/8/2018	2300	3.94	0.72	3.22	0.18	
2/20/2019	1820	2.06	0.53	1.53	0.26	
2/12/2020	1010	1.43	0.25	1.18	0.17	
2/28/2021	2040	3.69	1.09	2.60	0.29	

Figure 11 and Figure 12 display the hydrographs for the January 4, 2000 peak discharge event. Appendix 1 provides plotted hydrographs for 32 additional annual peak discharge events at the Orell Road and Cutoff gage locations.

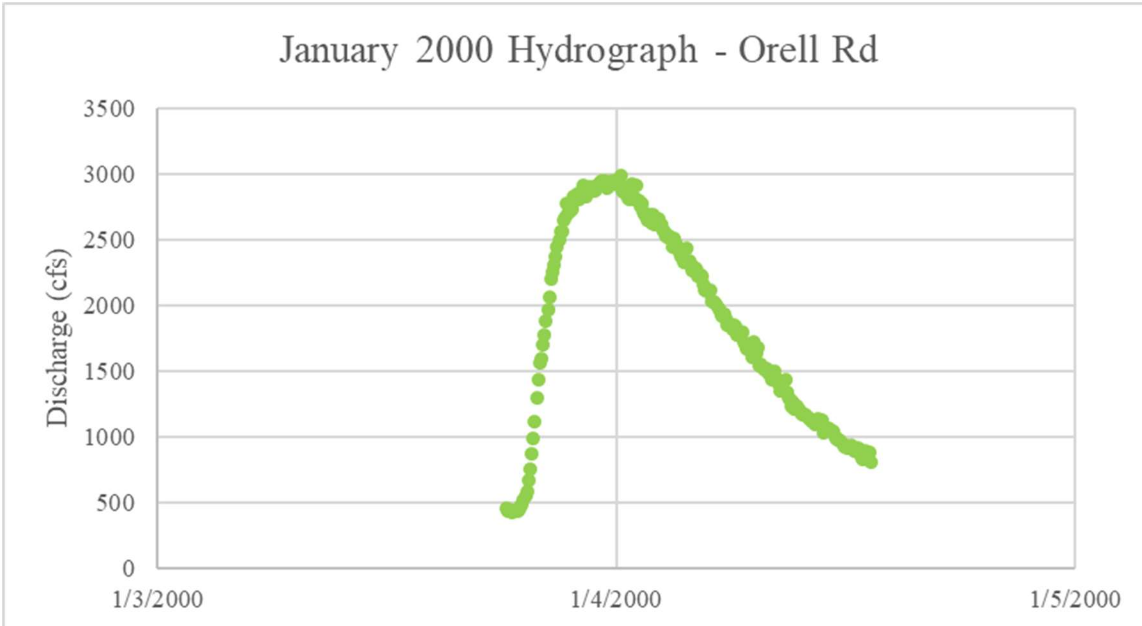

Figure 11: Mill Creek at Orell Road Hydrograph for January 2000 Peak Flow

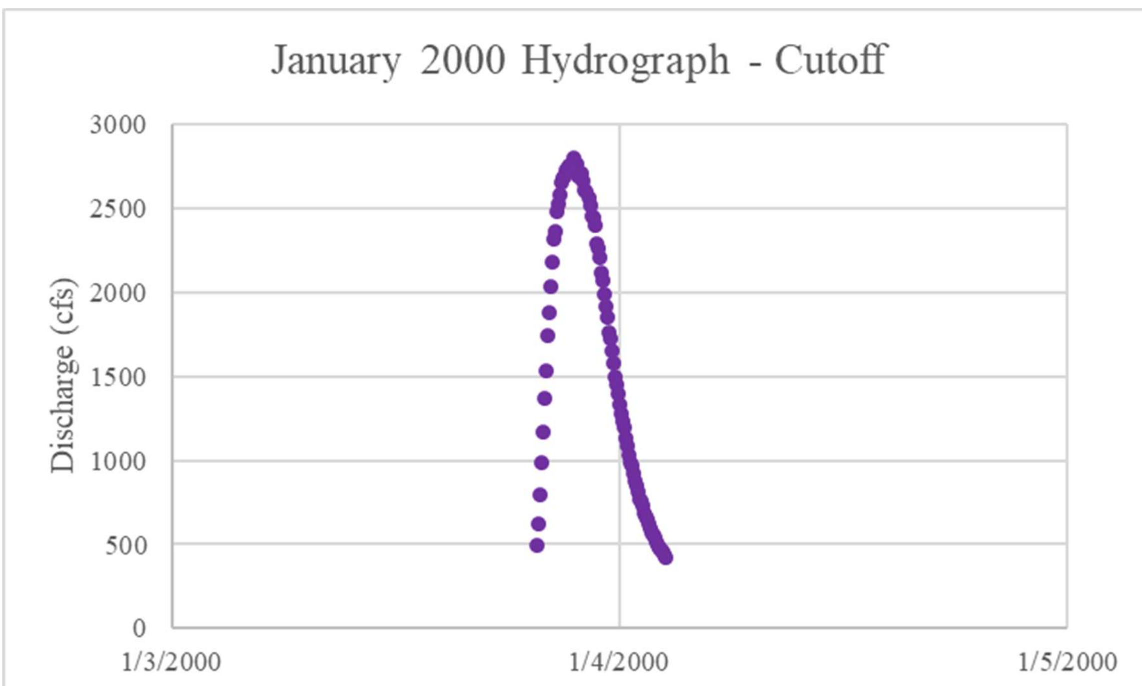

Figure 12: Mill Creek Cutoff Hydrograph for January 2000 Peak Flow

Figure 13 shows 1,938 daily mean dissolved oxygen levels plotted against the water temperature recorded for Mill Creek at Orell Rd. Table 5 summarizes this data by mean and standard deviation for 5℃ temperature windows. Figure 14 shows this data for the 866 values available for the Mill Creek Cutoff. Table 6 summarized this data by mean and standard deviation for 5℃ temperature windows. Louisville MSD has water quality criteria that average daily dissolved oxygen be greater than 5 mg/L (Louisville MSD, 2021b). For Mill Creek at Orell Road, 1,817 daily mean dissolved oxygen values, or 93% of the plotted values, fall above this limit. For the Mill Creek Cutoff, 822 daily mean dissolved oxygen values, or 95% of the plotted values, fall above this limit. Figure 15 compares dissolved oxygen values with discharge values for Mill Creek at Orell Road. Figure 16 displays the same data but limits discharge values to those less than 10 cfs. Figure 17 and Figure 18 display the same information for the Mill Creek Cutoff.

The calculated dissolved oxygen deficit was also evaluated when compared to temperature and discharge values. Figure 19 and Figure 20 show the dissolved oxygen deficit compared to the water temperature measured for Mill Creek at Orell Road and the Mill Creek Cutoff respectively. Figure 21 shows the dissolved oxygen deficit compared to the discharge measured for Mill Creek at Orell Road. Figure 22 shows the same relationship for the Mill Creek Cutoff.

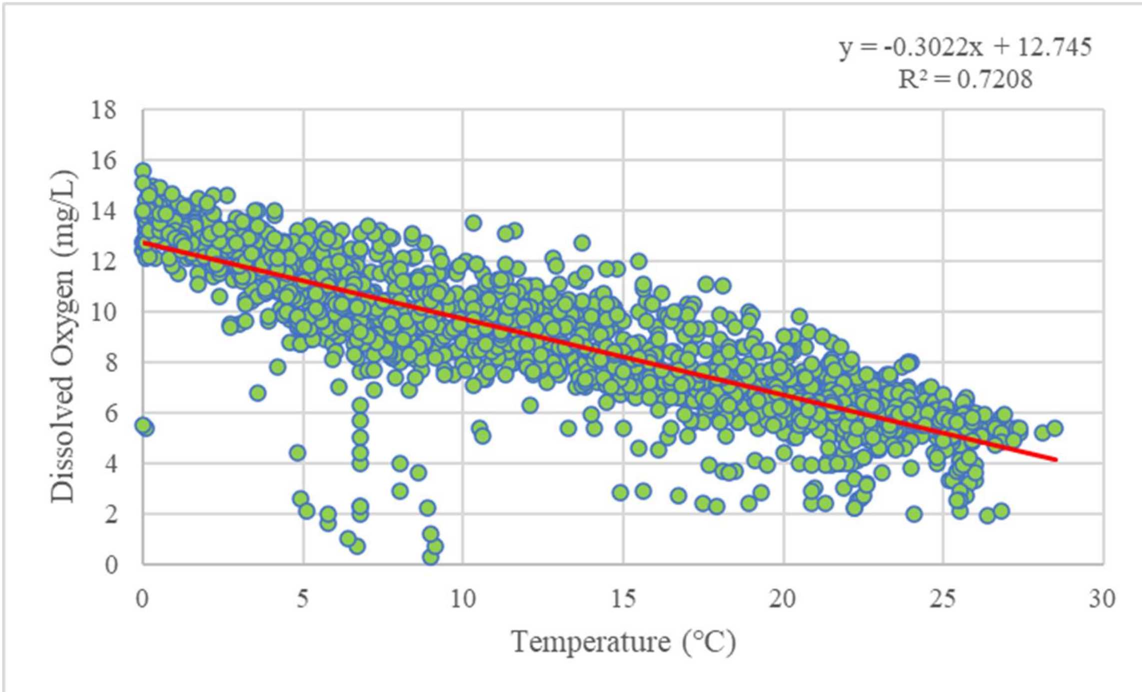

Figure 13: Dissolved Oxygen vs Temperature for Mill Creek at Orell Rd

Table 5: Dissolved Oxygen Measures of Dispersion for Mill Creek at Orell Rd

Temperature Range (°C)	Count	Mean (mg/L)	Standard Deviation (mg/L)
0-5	418	12.47105	1.497736
5-10	347	9.805187	2.263694
10-15	293	9.14744	1.431268
15-20	309	7.318123	1.477536
20-25	444	6.108559	1.162087
25-30	126	5.096825	0.966142

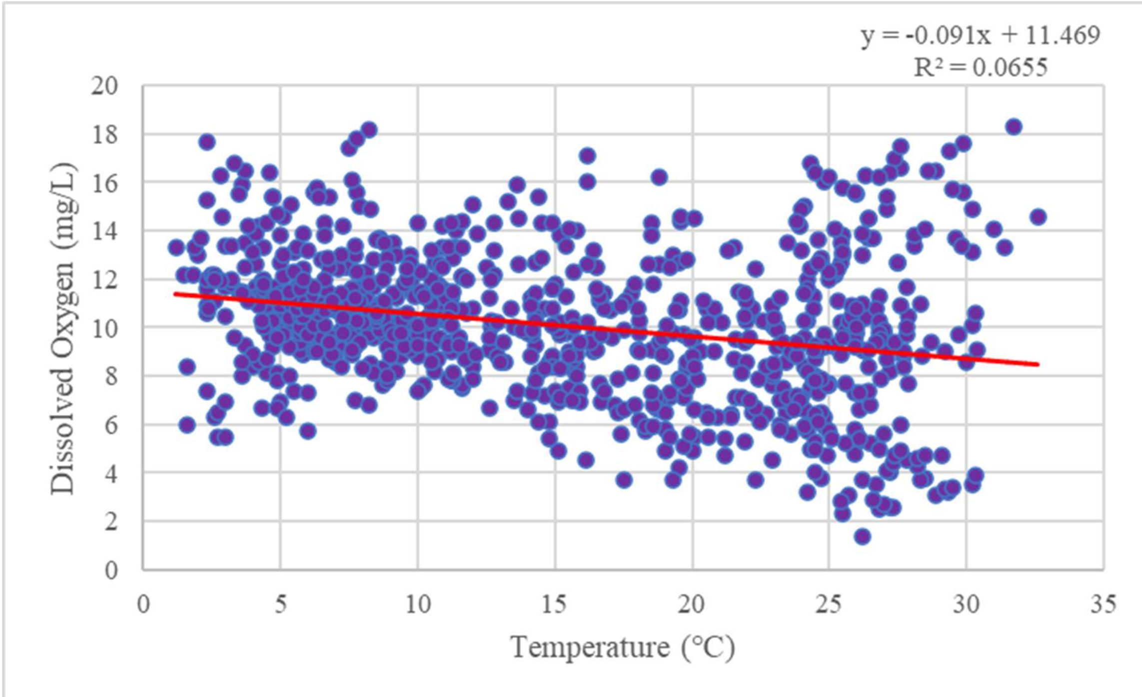

Figure 14: Dissolved Oxygen vs Temperature for Mill Creek Cutoff

Table 6: Dissolved Oxygen Measures of Dispersion for Mill Creek Cutoff

Temperature Range (°C)	Count	Mean (mg/L)	Standard Deviation (mg/L)
0-5	96	11.36354	2.665772
5-10	216	10.91574	2.004468
10-15	138	10.47101	2.223045
15-20	124	9.295161	2.766138
20-25	140	8.817143	2.818667
25-30	140	9.442143	4.202159
30-35	12	11.175	4.445657

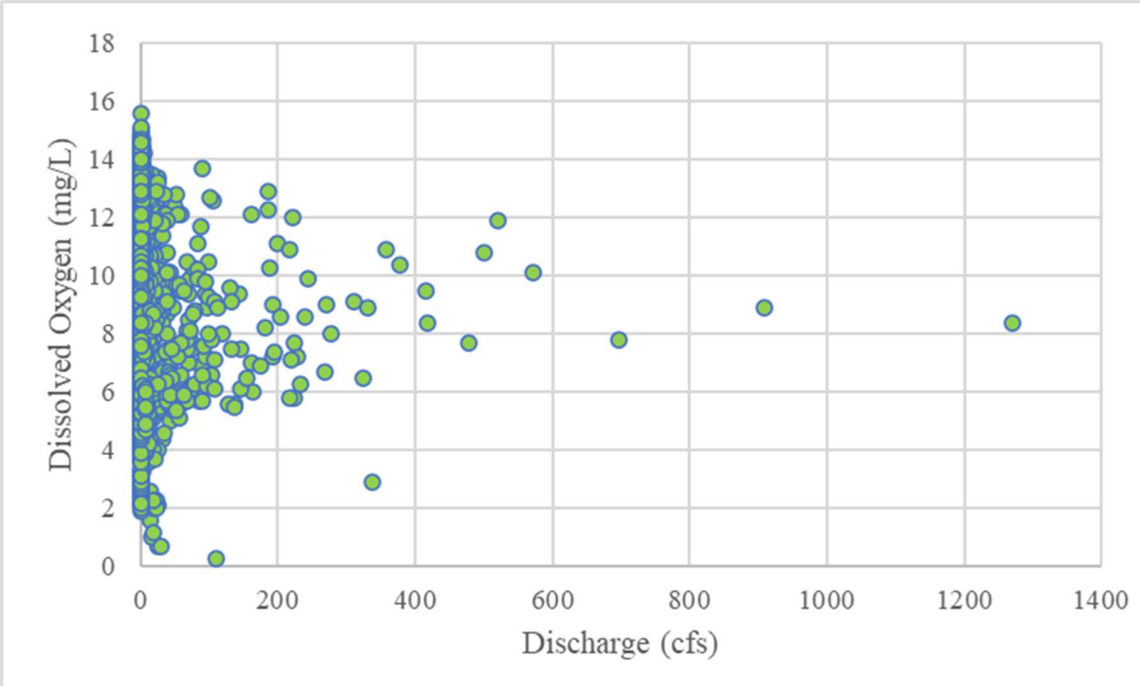

Figure 15: Dissolved Oxygen vs Discharge for Mill Creek at Orell Road

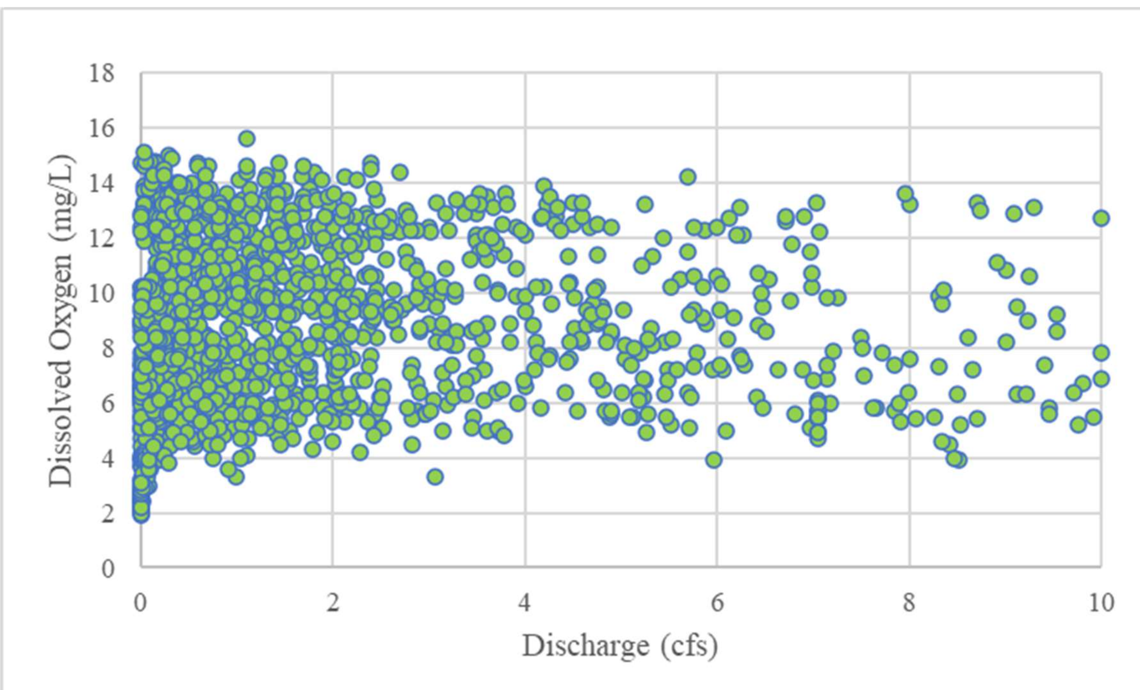

Figure 16: Dissolved Oxygen vs Discharge less than 10 cfs for Mill Creek at Orell Road

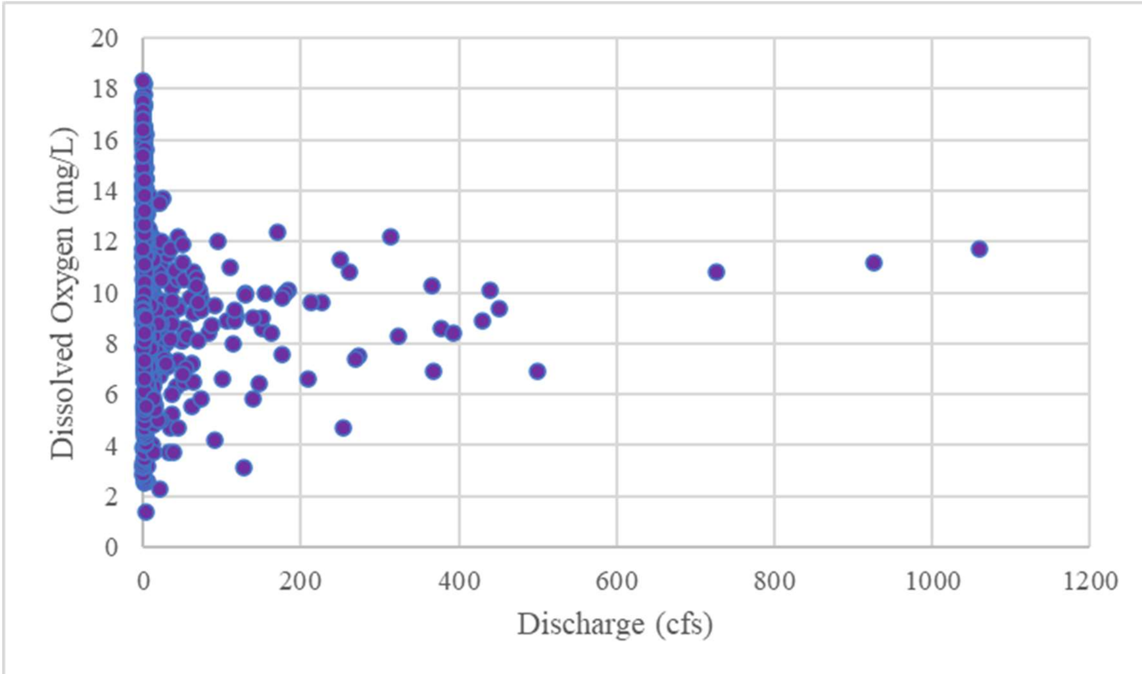

Figure 17: Dissolved Oxygen vs Discharge for Mill Creek Cutoff

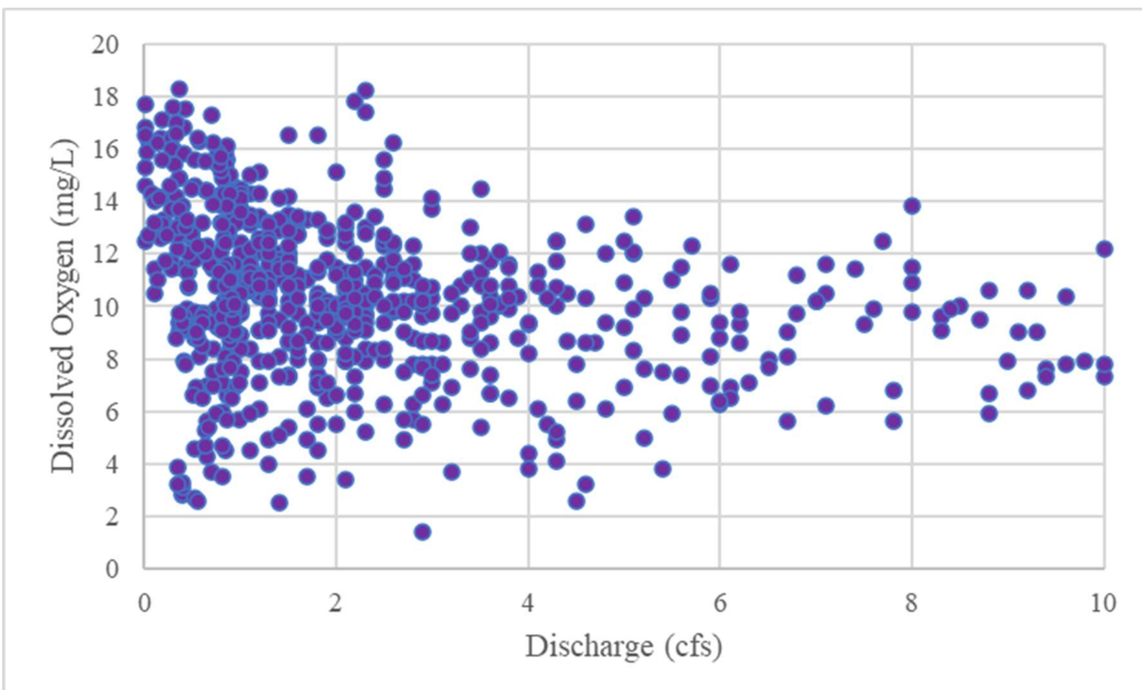

Figure 18: Dissolved Oxygen vs Discharge less than 10 cfs for Mill Creek Cutoff

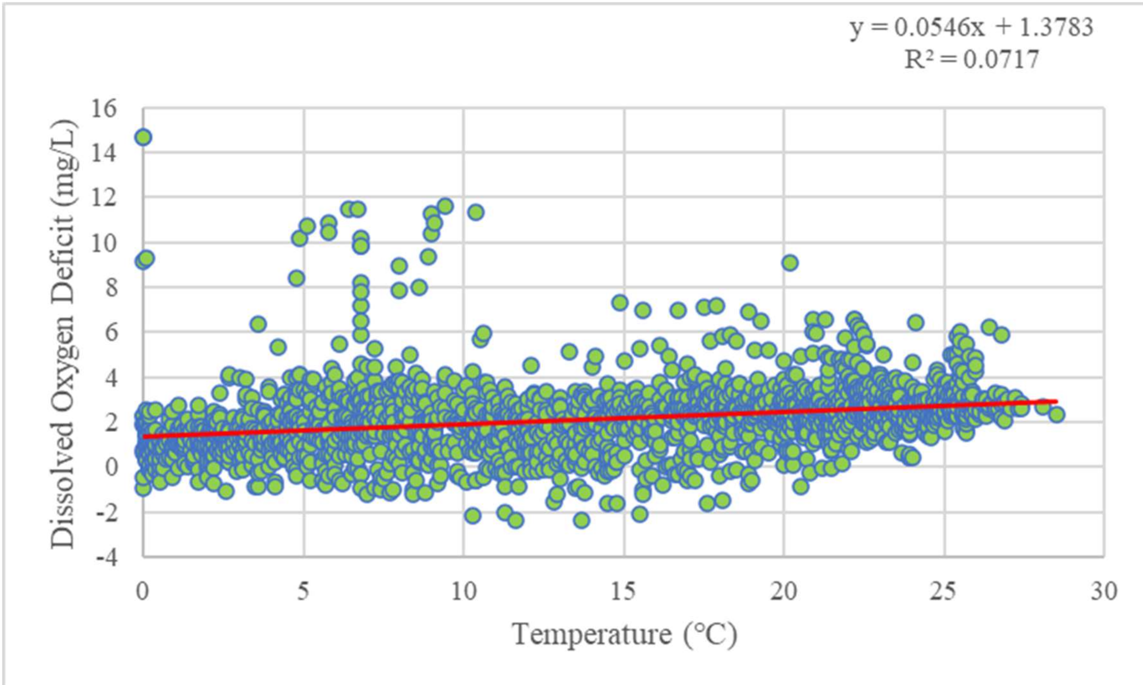

Figure 19: Dissolved Oxygen Deficit vs Temperature for Mill Creek at Orell Road

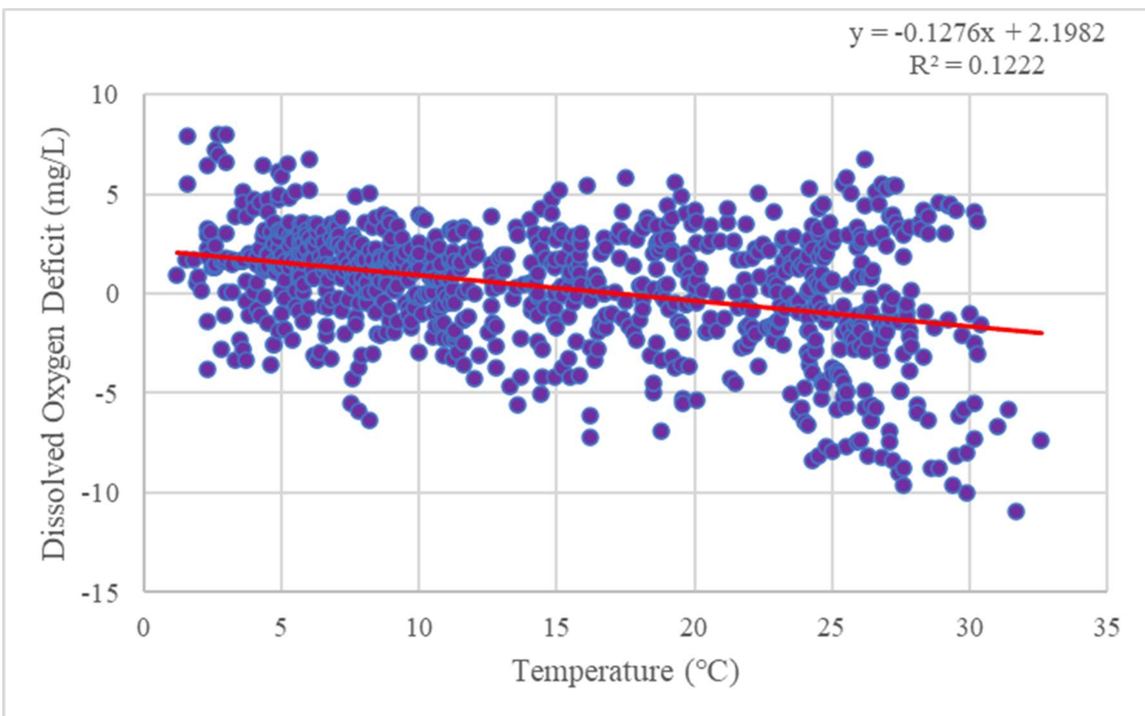

Figure 20: Dissolved Oxygen Deficit vs Temperature for Mill Creek Cutoff

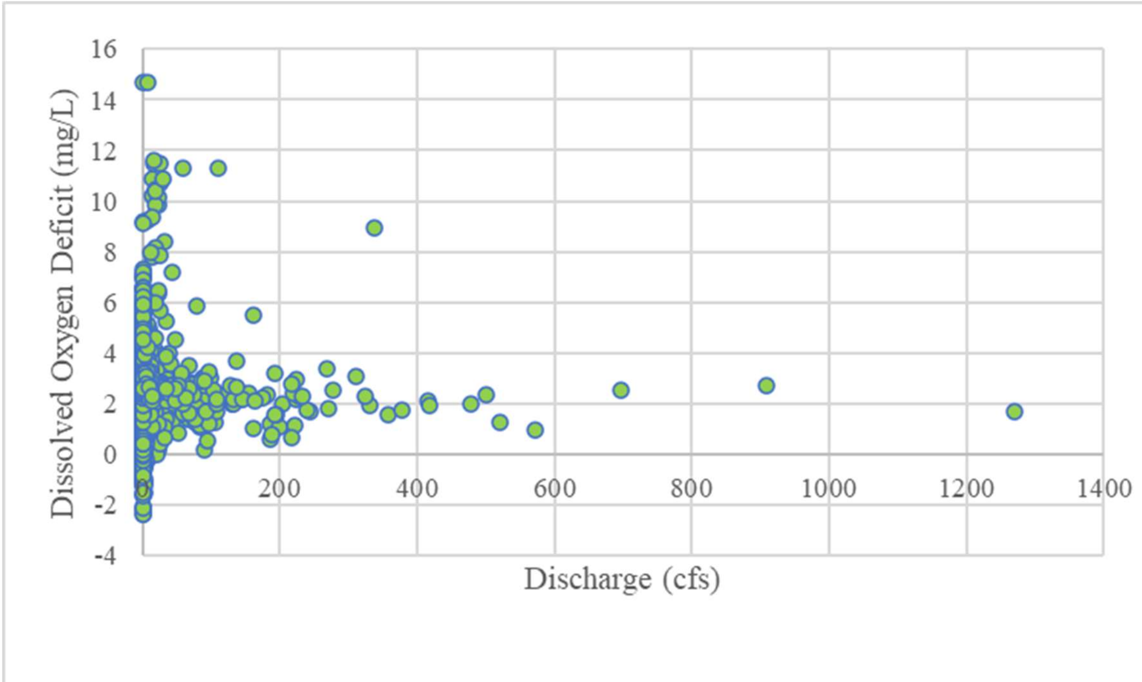

Figure 21: Dissolved Oxygen Deficit vs Discharge for Mill Creek at Orell Road

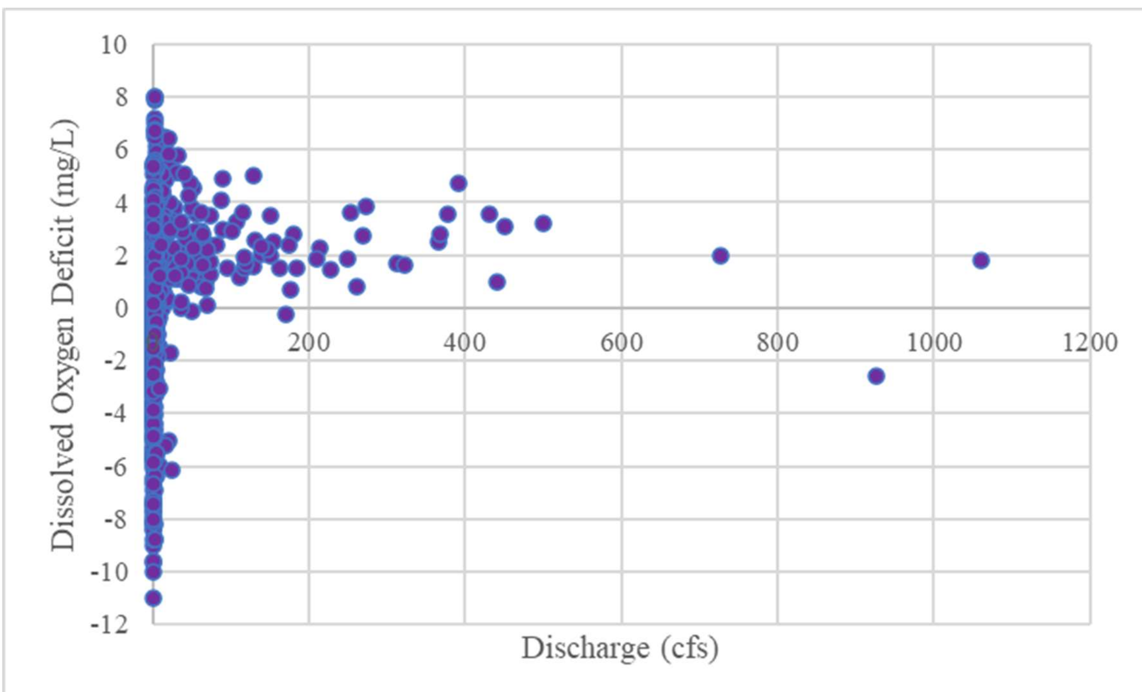

Figure 22: Dissolved Oxygen Deficit vs Discharge for Mill Creek Cutoff

Figure 23 shows specific conductance data for Mill Creek at Orell Rd, discharge data is plotted for the dates displayed, on a separate axis. For Mill Creek at Orell Rd, the correlation between specific conductance and discharge was calculated to be -0.122. Both daily and annual peak discharge data are included. Figure 24 shows the same data for the Mill Creek Cutoff. For the Mill Creek Cutoff, the correlation between specific conductance and discharge was calculated to be -0.422, indicating a greater negative relationship between specific conductance and discharge than Mill Creek at Orell Road. Annual peak discharge is not available for the Mill Creek Cutoff gage site for these dates. Figure 25 shows specific conductance against discharge for Mill Creek at Orell Rd. Figure 26 shows this relationship for the Mill Creek Cutoff. Figure 27 shows specific conductance against temperature for Mill Creek at Orell Rd. Figure 28 shows this relationship for the Mill Creek Cutoff.

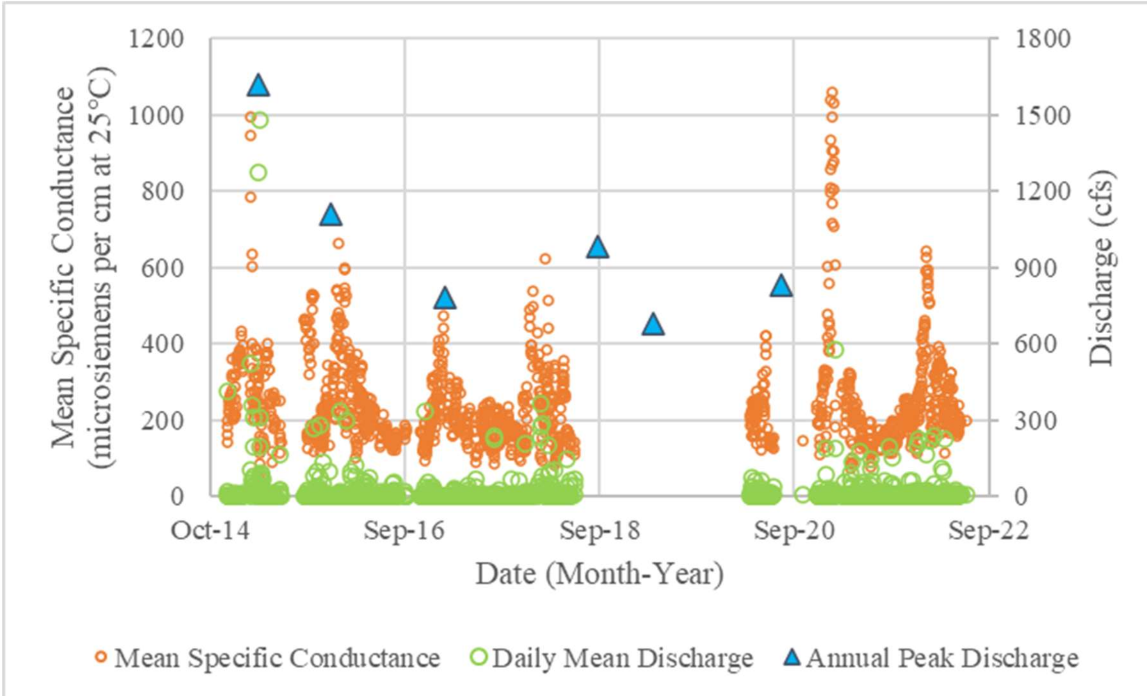

Figure 23: Specific Conductance for Mill Creek at Orell Rd

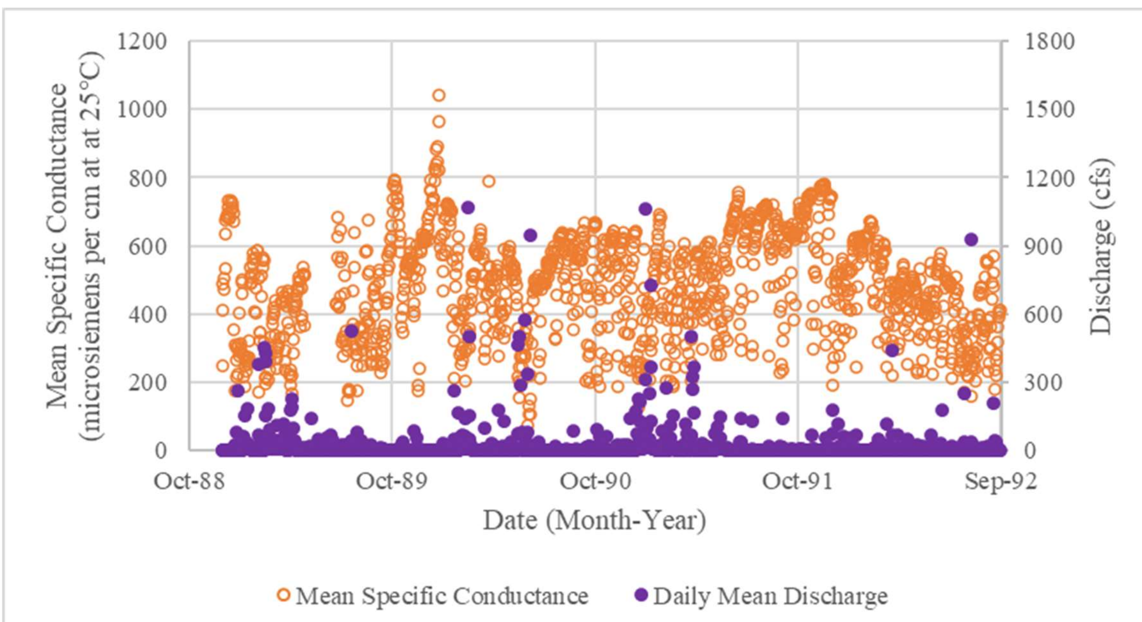

Figure 24: Specific Conductance for Mill Creek Cutoff

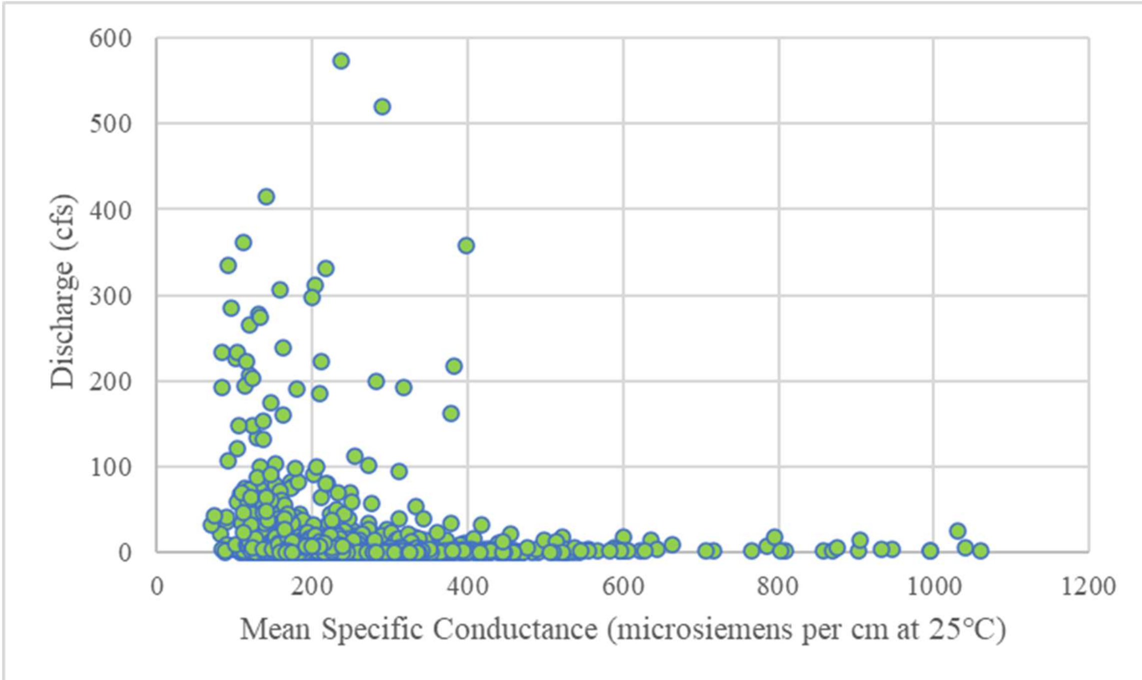

Figure 25: Discharge vs Specific Conductance for Mill Creek at Orell Rd

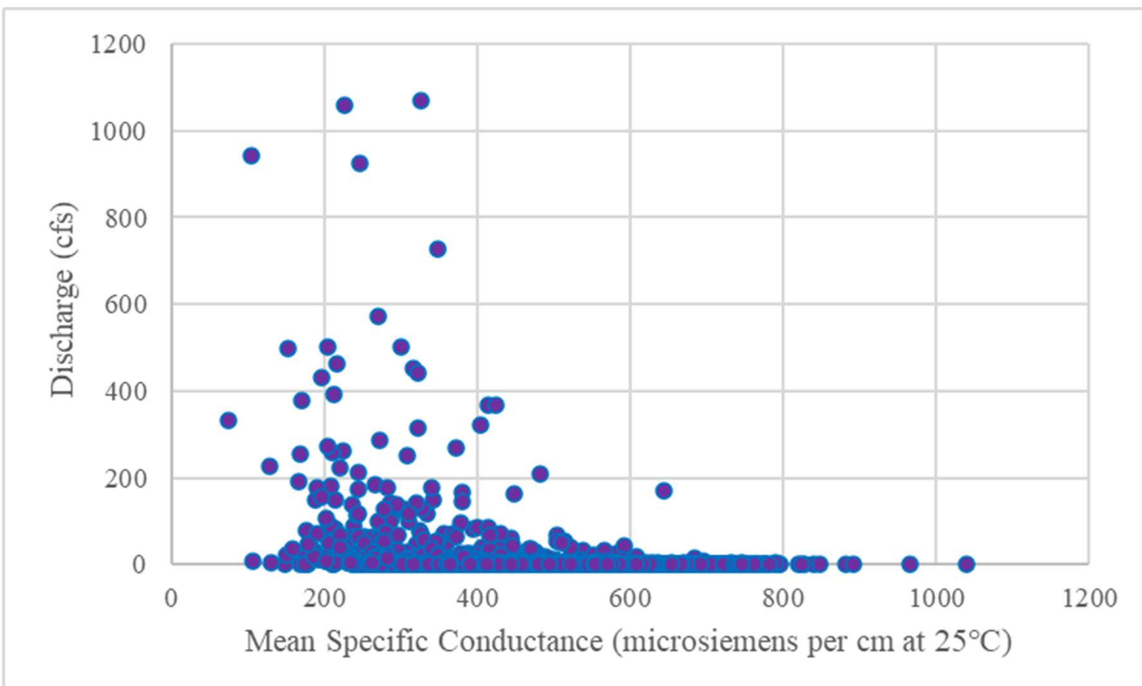

Figure 26: Discharge vs Specific Conductance for Mill Creek Cutoff

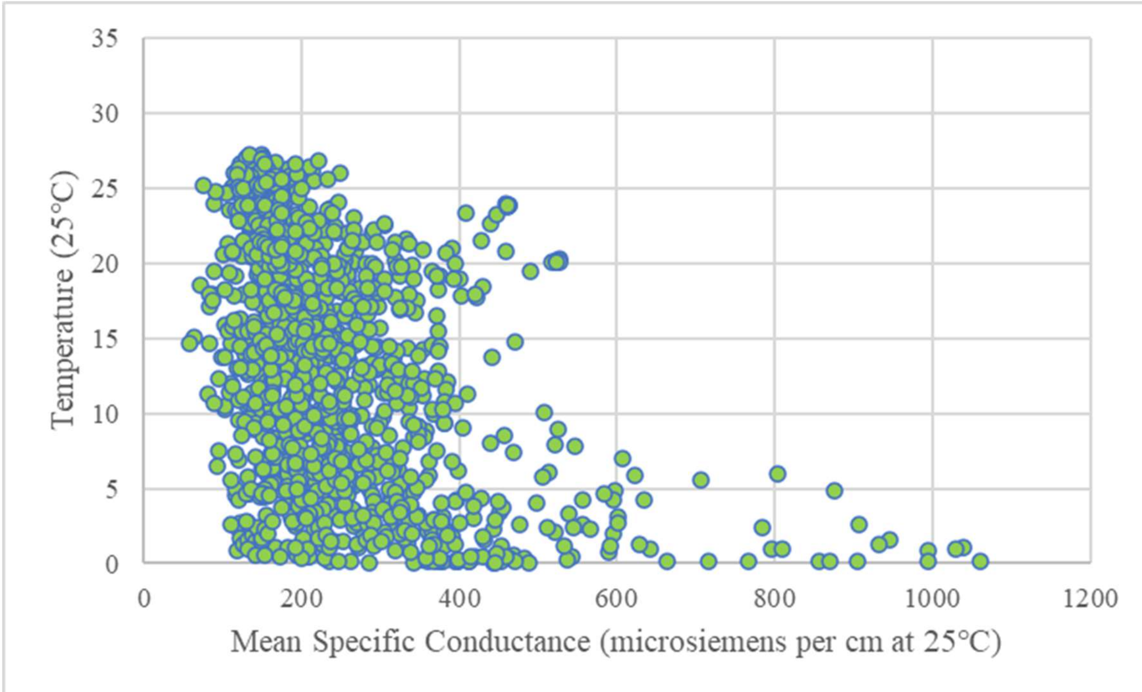

Figure 27: Temperature vs Specific Conductance for Mill Creek at Orell Rd

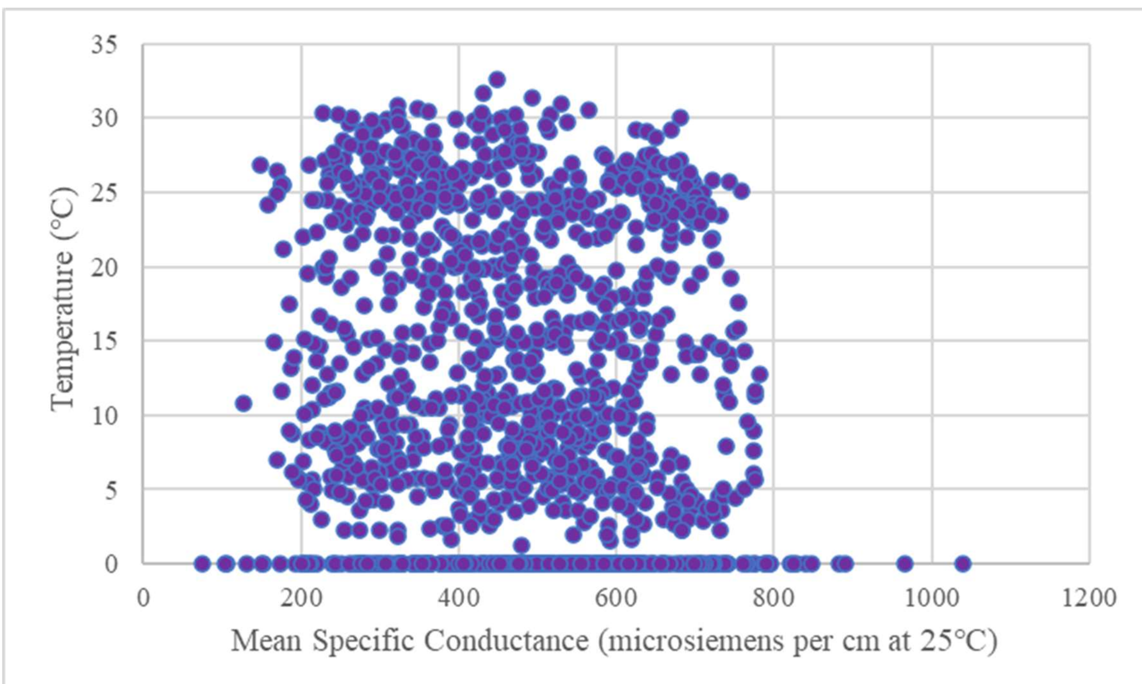

Figure 28: Temperature vs Specific Conductance for Mill Creek Cutoff

DISCUSSION

Data availability makes it difficult to draw concrete conclusions regarding potential impacts on water quality and flow in the Mill Creek watershed. The Mill Creek Cutoff gage does not have available water quality data from past 1992, meaning the data used in this study may not reflect the current water quality conditions and trends for the Mill Creek Cutoff. For Mill Creek at Orell Road, more recent water quality data was available from the USGS gage and was used in this study, however there were large gaps in the data at inconsistent intervals. Generally, discharge data was more robust, and available for a similar timespan for each watershed.

The discrepancy in data availability for the Mill Creek Cutoff and the Mill Creek at Orell Road gages may allow some general conclusions to be made about water quality changes in the general Mill Creek watershed, though these conclusions would need to be verified with more recent water quality data. The range of available temperature, specific conductance, and dissolved oxygen data is much shorter for the Mill Creek Cutoff gage than the Mill Creek at Orell Road gage, with only four years of data available compared to over ten years for these parameters. A smaller sample size will not represent general trends and characteristics as well as a larger sample size would, as smaller sample sizes are more likely to be influenced by outliers. Additionally, specific conductance and dissolved oxygen can both be influenced by water temperature, which means seasonality can have an impact on these values. A shorter sample range in this case means trends in seasonality are less evident as well.

Between Mill Creek at Orell Road and the Mill Creek Cutoff, nine annual peak flow occurrences were within one day of each other. This can serve as a possible quality control indicator for the data, as peak flow is often caused by significant, widespread, and locally areal-uniform precipitation, which typically appears as simultaneous runoff episodes from adjacent or neighboring watersheds. Scaling the peak streamflow data by watershed area allows comparison between the two watersheds; larger watersheds will typically see greater discharge volumes for the same precipitation event, which is the relationship shown in Figure 6. Figure 7 shows that discharge ranges, when scaled by watershed area, is similar between the two streams on dates where annual peak flow was recorded for each watershed. This is an indication of flow similarities between the two watersheds. If there was a great discrepancy between discharge for the same date, this may indicate further differences between the watersheds, such as impervious surface area and land use. However, the lack of correlation between peak annual discharge for the two watersheds indicates that changes in peak discharge over time are not consistent between the two. This could be due to differences in rainfall distribution or differing rates of land use change and development between the two watersheds.

Comparing annual peak discharge to daily discharge for peak events is also important for data quality control. Annual peak discharge is meant to be the maximum discharge level recorded for the water year. If mean daily discharge for the same date is ever greater than this value, this may indicate a discrepancy in annual peak discharge determination or daily discharge measurements. When the mean daily discharge is close to the annual peak discharge, such as for several data points from the Mill Creek at Orell Road gage, this can indicate events where the discharge levels were consistently very high and similar to the peak discharge value for the duration of the 24-hour period. For the Mill Creek Cutoff the greater difference between annual peak discharge and mean daily discharge can indicate a steeper hydrograph and less consistent flow values through the day, which is also tied to watershed size and runoff time of concentration.

In general, the hydrograph shapes are consistent with an urban watershed, specifically for streams that have been designed for drainage. Steep hydrographs, such as those generated for many of the peak flow events, indicate a watershed where flow is able to reach the stream and be discharged quickly. Several hydrographs in both watersheds have multiple peaks. In general, the runoff ratios for the Mill Creek Cutoff are less than those for Mill Creek at Orell Road, which may indicate that less water in the Mill Creek Cutoff watershed enters the stream as runoff, as compared to the Mill Creek at Orell Road watershed.

Comparing dissolved oxygen to temperature is an effective way to quality control the data. Dissolved oxygen levels are expected to decrease as water temperature increases. When water temperatures increase, the water molecules and dissolved oxygen molecules gain energy, allowing the dissolved oxygen molecules to break away and be released to the atmosphere. A strong negative correlation is shown for the Mill Creek at Orell Road data. A slight negative correlation is shown for the Mill Creek Cutoff data, but it is not as strong as the Orell Road relationship. For Mill Creek at Orell Road, mean dissolved oxygen values decrease with each 5°C-temperature window, which is not the case for the Mill Creek Cutoff data. Additionally, the Mill Creek Cutoff data has higher standard deviations for each temperature window than the Mill Creek at Orell Road data. The lack of a clear negative relationship between dissolved oxygen and temperature for the Mill Creek Cutoff data may indicate other factors in the stream that would increase dissolved oxygen levels regardless of temperature. Generally, these would be factors that promote aeration within the stream, such as turbulence. Turbulence is largely related to flow velocity but may also be influenced by stream channel characteristics such as rocks, bends, and other characteristics that would disrupt flow. However, both streams seem to have similar relationships between discharge and dissolved oxygen levels, where the most extreme discharge values correspond to dissolved oxygen values that are near the middle of the range of dissolved oxygen values. Even when considering only flows less than 10 cfs, there is not a clear relationship between dissolved oxygen and discharge demonstrated for either stream. Inconsistent dissolved oxygen levels also may indicate an increased amount of algae and macrophytes, which would contribute more oxygen during the day when water temperatures are higher, and have higher oxygen demand at night when water temperatures are lower (US EPA, 2023). If increased algae and macrophytes are present, this could indicate an unbalanced ecosystem, or nutrients in the stream from pollutants such as fertilizers that are allowing increased algae growth.

The dissolved oxygen deficit represents how much the expected dissolved oxygen values exceed the measured values. The greater the absolute value of the dissolved oxygen deficit is indicates more abnormal measured dissolved oxygen values. For Mill Creek at Orell Road, the dissolved oxygen deficit tends to be positive, and increases with increasing water temperature. This means that generally for the stream, the expected dissolved oxygen values are greater than those measured, and the amount that the measured values are less than expected increases as temperature increases. This may indicate a general deficit in dissolved oxygen within the stream, which may be caused by organic waste or septic seepage creating significant oxygen demand (EPA, 2023). The Mill Creek Cutoff has a negative relationship between the dissolved oxygen deficit and water temperature, and tends to have more negative dissolved oxygen deficit values. This indicates the measured dissolved oxygen values for the cutoff are generally greater than those expected, and the measured values are closer to those expected as temperature increased. This supports the possibility that the Mill Creek Cutoff experienced increased amounts of algae and macrophytes that would contribute more oxygen during the day and increase oxygen demand at night. Additionally, the trend line for dissolved oxygen deficit vs temperature for Mill Creek at Orell Road is most near zero at a temperature of 0°C, however the trend line for the Mill Creek Cutoff crosses the x-axis at a temperature of close to 17°C. This means that dissolved oxygen levels for the Mill Creek Cutoff are closer to the expected during conditions that would result in warmer water temperatures, such as during warmer months or during the day. In contrast, dissolved oxygen levels for Mill Creek at Orell Road are closer to those expected during conditions that would result in colder water temperatures, such as during the winter or at night. For both streams, a dissolved oxygen deficit of around 2 mg/L is associated with the greatest discharge values. Perhaps this could be related to increased turbidity from faster flow in the stream, however this may not entirely explain why the measured dissolved oxygen is still less than the expected value. This may also be due to the assumed barometric pressure. Greater discharge in streams is typically due to rainfall, and barometric pressure is related to weather events such as rainstorms. Since barometric pressure is not available data for the period of record, one average value was assumed, but this may be different for these days of high discharge value, resulting in an overestimation of expected dissolved oxygen values.

Specific conductance is expected to increase with temperature; however, a strong relationship is not indicated for Mill Creek at Orell Road or the Mill Creek Cutoff. Specific conductance may also increase with discharge, but no relationship is indicated for either stream either. This indicates other factors could be impacting specific conductance. It is interesting that for Mill Creek at Orell Road, Annual Peak Discharge occurrences seem to correspond with peaks in specific conductance. This is further demonstrated in Figure 29, which displays all specific conductance values during the recording period, and only discharge values that are less than 10 cfs and occurred when water temperature was less than 5°C. Every peak in specific conductance, except one, aligns exactly with discharge values that fit these boundaries. These lower discharge values likely represent the baseflow characteristics of the stream. During precipitation events, discharge increases as more water fills the stream. The increase in volume, without other influence from pollutants, typically results in a decrease in conductivity as there are less conductive particles per unit volume. However, this relationship is not true for all low flow conditions; it is only the discharge values that also have a water temperature of less than 5°C that relate to the peaks in specific conductance. The low temperature conditions that align with peak discharge values may relate to a pollutant or discharge that only occurs in the winter, such as road salt washing into the stream.

The Mill Creek Cutoff has less obvious peaks in specific conductance, and a similar relationship between discharge, temperature, and specific conductance is not evident.

However, for the specific conductance dates recorded for Mill Creek Cutoff, there may be an error in the temperature measurements. Figure 30 shows discharge and specific conductance values for discharge values that are less than 10 cfs when water temperature is equal to 0°C. It seems that temperature values of 0°C were recorded for the Mill Creek cutoff gage for most of the year between October 1989 and October 1990, including during the summer months. To contrast, the Mill Creek at Orell Road gage only measured fourteen temperature values of 0°C or less between 2007 and 2022. Specific conductance is measured in relation to water temperature measurements, making the specific conductance measurements for the Mill Creek Cutoff questionable. If water temperature values were incorrectly measured to be lower than they actually were, this would inflate measured specific conductance values, as the correction to 25°C would overcompensate for the low water temperature measured (USGS, 2019). The Mill Creek Cutoff seems to generally have greater specific conductance values than Mill Creek at Orell Road, which may be attributed to the lower water temperature measurements, but also could be due to a greater number of conductive pollutants in the stream.

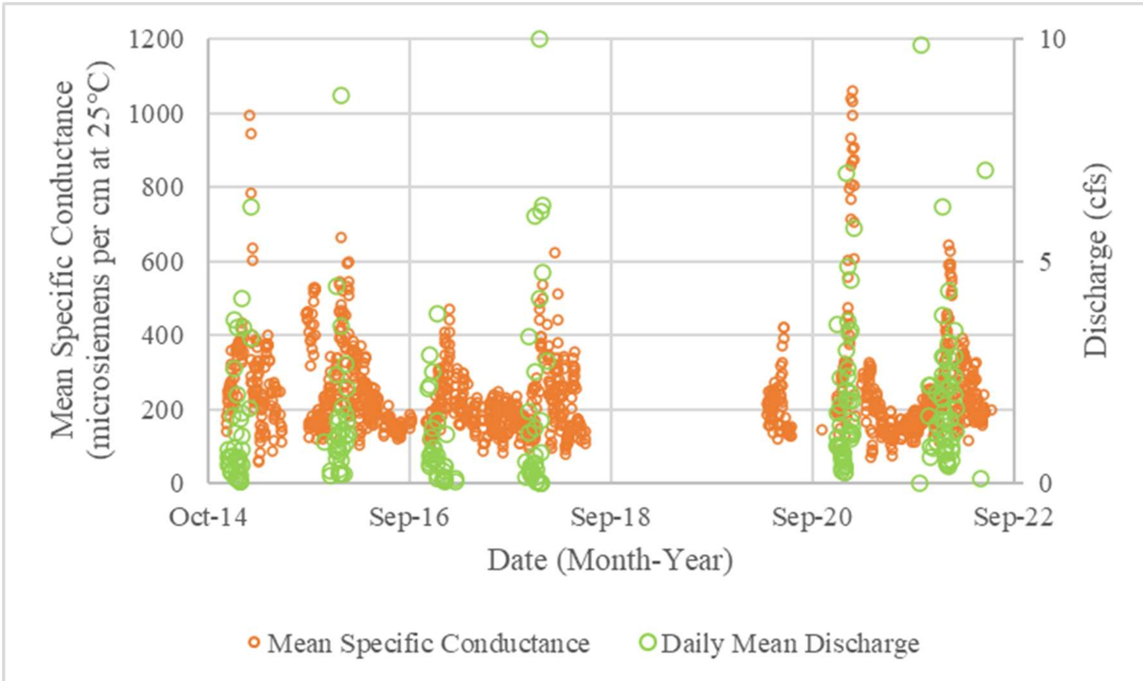

Figure 29: Mill Creek at Orell Road Specific Conductance and Discharge for Discharge Values Less Than 10 Cfs, and Water Temperature Values Less Than 5℃

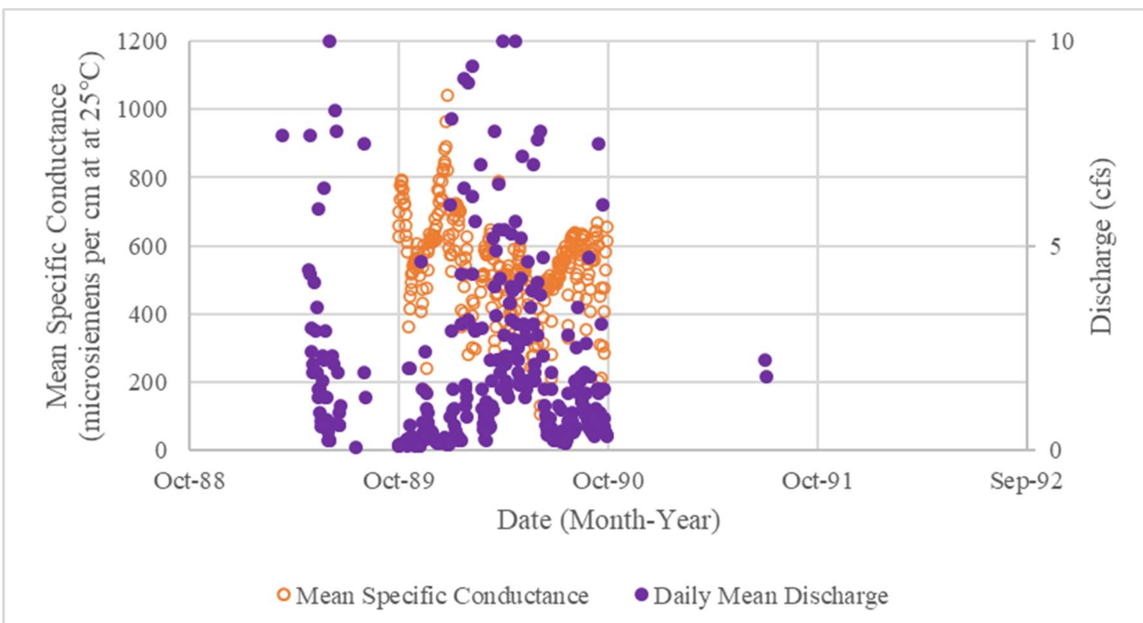

Figure 30: Mill Creek Cutoff Mean Specific Conductance and Discharge for Discharge Values Less Than 10 cfs, and Water Temperature Values of 0℃

CONCLUSION

The aim of this paper was to evaluate water quality and flow data for the Mill Creek watershed to determine what potential historical qualities and stressors may have been present in the watershed, and may still be present today.

The hydrographs generated for annual peak discharge events for each stream were steep, as expected for urban watersheds. The streams had similar scaled ranges for discharge, and some overlap for dates of peak discharge, however very little statistical correlation between peak discharge trends.

The Mill Creek Cutoff generally has higher specific conductance and dissolved oxygen values than data for Mill Creek at Orell Road. Expected relationships between data, such as a negative relationship between dissolved oxygen and temperature, were generally not present for the Mill Creek Cutoff data to the same degree they were for the Mill Creek at Orell Road data, if present at all. This could indicate improvement in water quality for the two watersheds, and there may be less pollutants in the Mill Creek watershed between 2007 and 2022 impacting specific conductance and dissolved oxygen levels than there were between 1988 and 1992. For Mill Creek at Orell Road, the peaks in specific conductance align with low discharge, low temperature conditions.

Some of the hydrographs developed, such as the January 2013 Hydrograph for Mill Creek at Orell Road, present two or more flow peaks, including the peak that corresponds to annual peak discharge. This may be related to antecedent soil moisture, which was not considered in this analysis, but would be useful in further research to understand flow patterns in the watershed. Antecedent soil moisture is the amount of moisture present in soil prior to a rain event. Precipitation intensity can be a factor in how much antecedent moisture impacts infiltration and runoff rates (Pearson et al 2014). For events with multiple peaks, it may be the case that precipitation intensity has varied throughout the day, and runoff rates are impacted differently by antecedent moisture throughout the course of the rain event. Evaluation of rainfall distribution for the same storm by local rain gages in each watershed may reveal typical patterns for rainfall and whether the lack of significant correlation between the two watersheds is due to land use or rainfall.

pH data was not evaluated in this study, but could be considered in future research, as low pH values can also impact specific conductance measurement.

Further analysis of current water quality impacts of septic tanks and seepage pits in the Lower Mill Creek watershed (Louisville MSD, 2021a) would be interesting. Sewage can impact specific conductivity, pH, and dissolved oxygen levels. Comparison to the 1982 Environmental Impact Statement may indicate if conditions are worsening, or if there is no increased impact.

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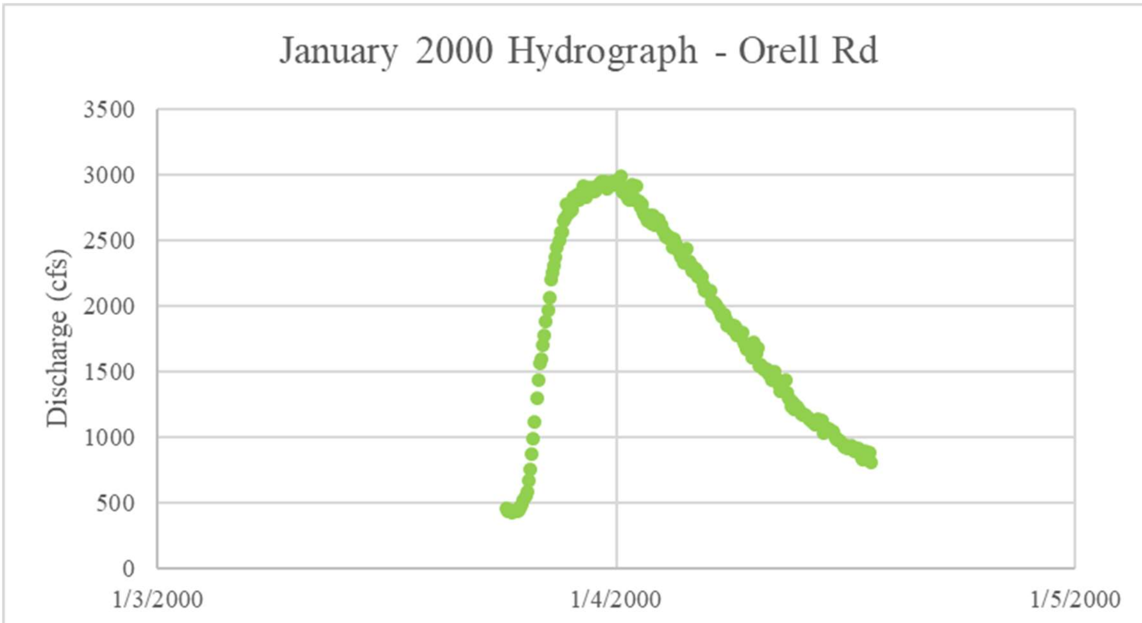
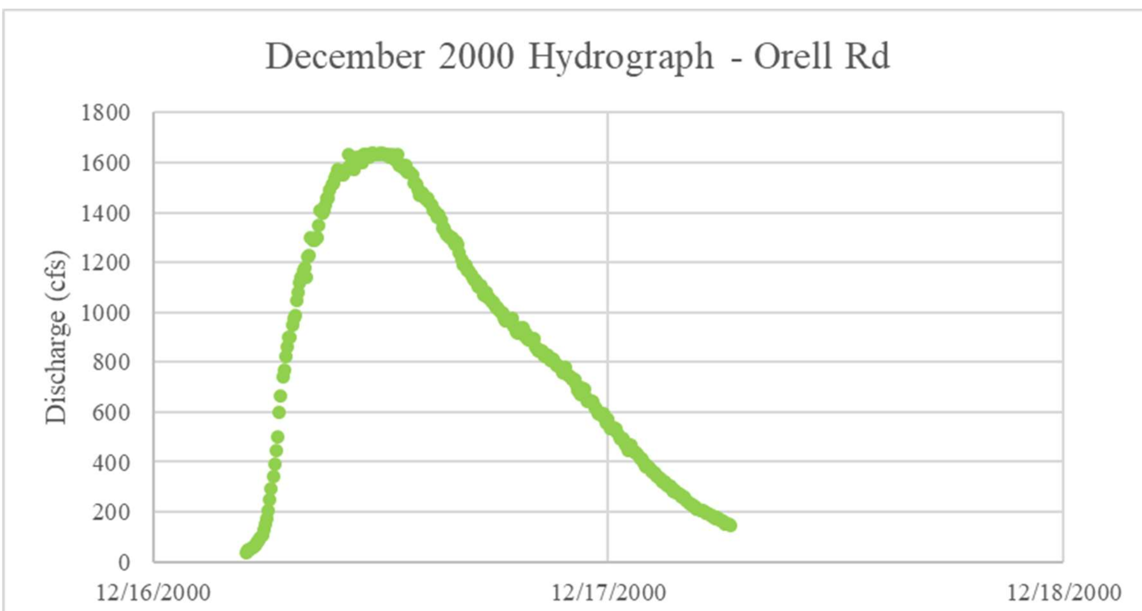
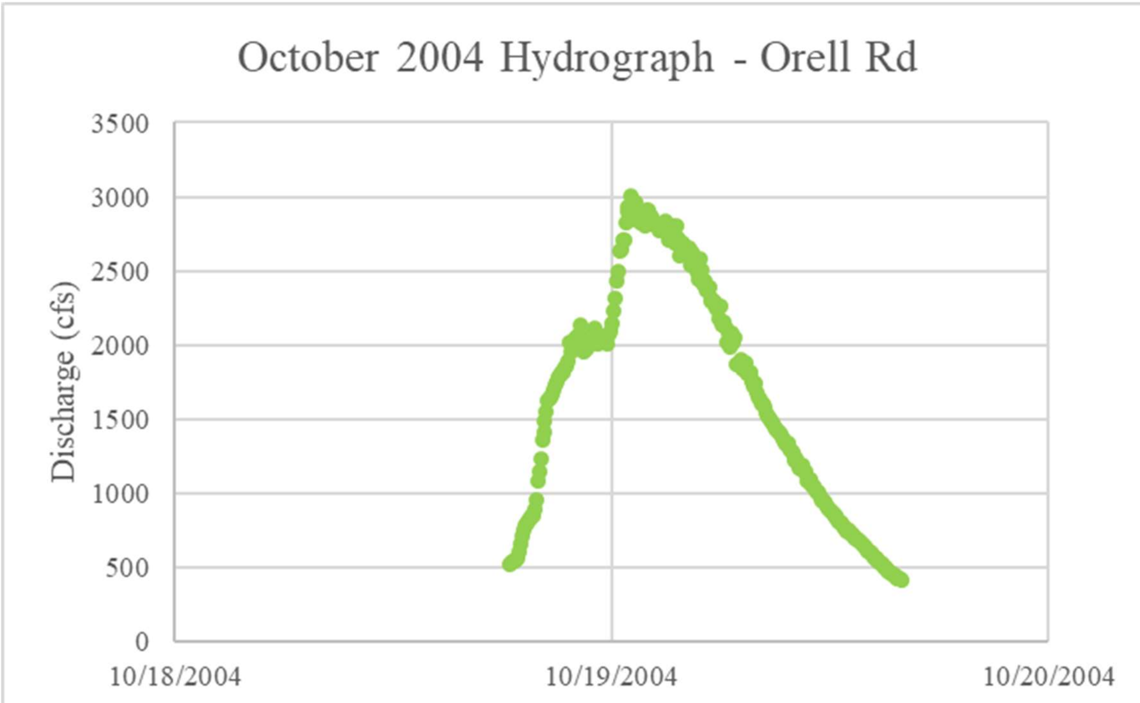
APPENDIX 1

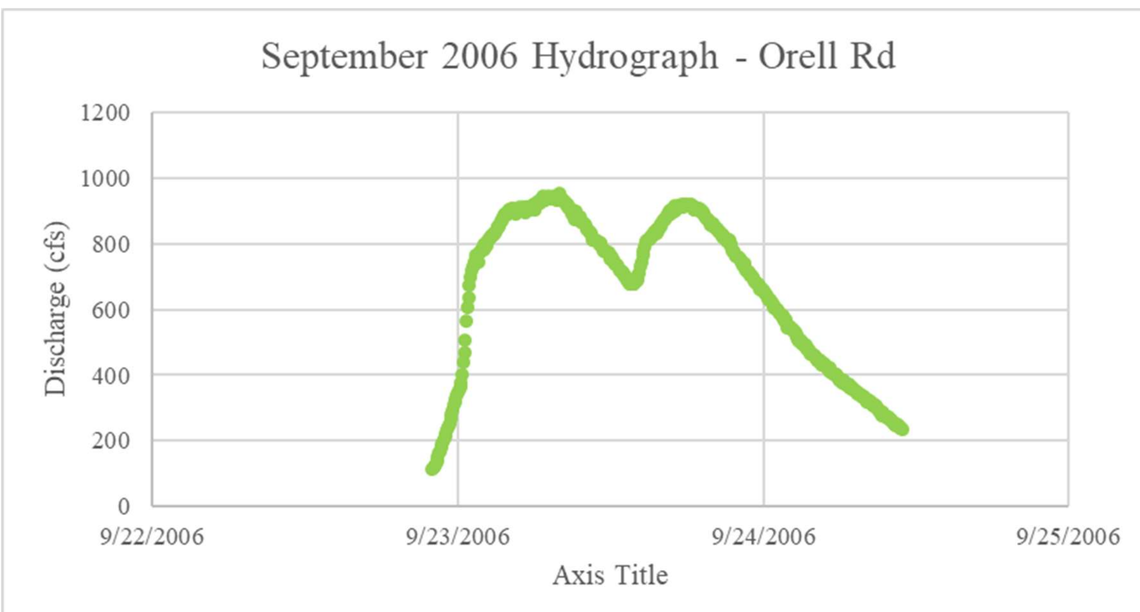


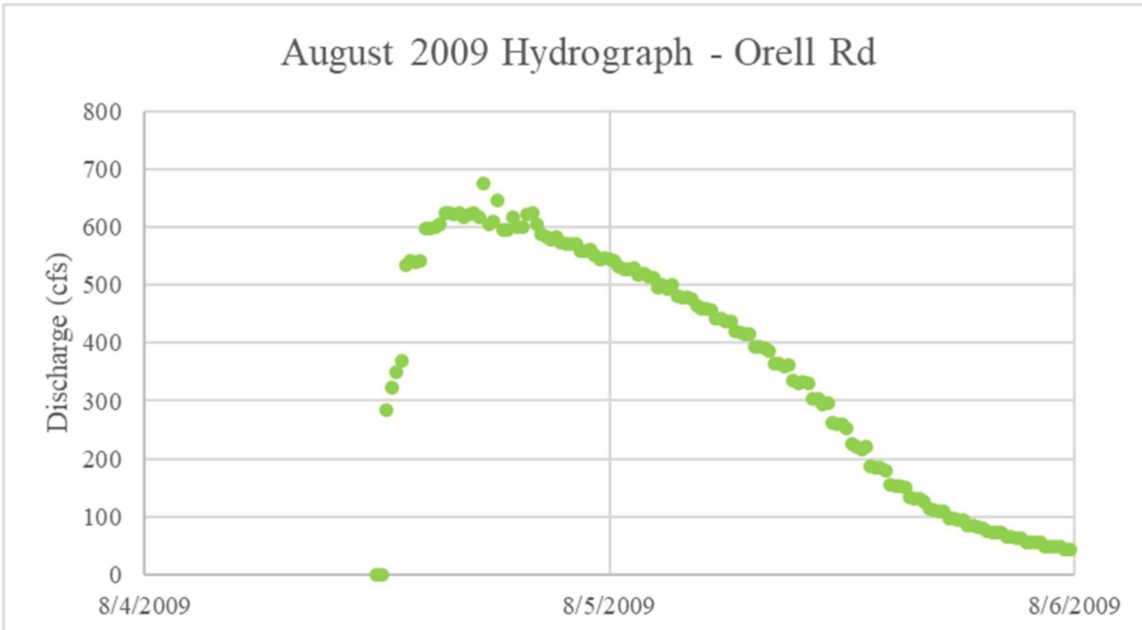
January 2000 Hydrograph - Orell Rd
Discharge (cfs)
3500
3000
2500
2000
1500
1000
500
0
1/3/2000
1/4/2000
1/5/2000

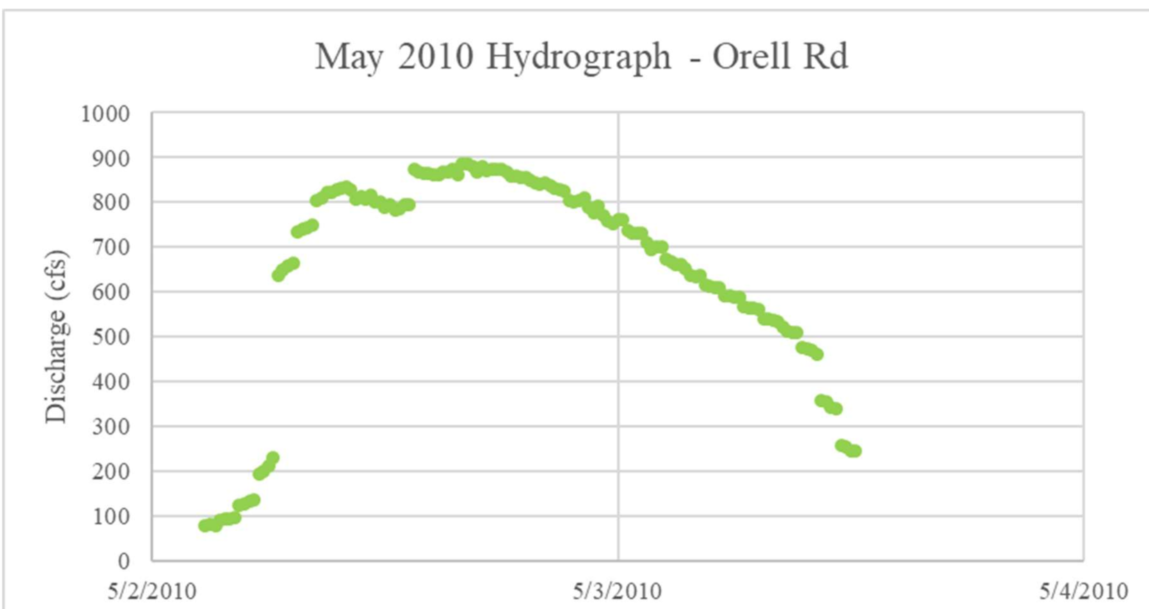


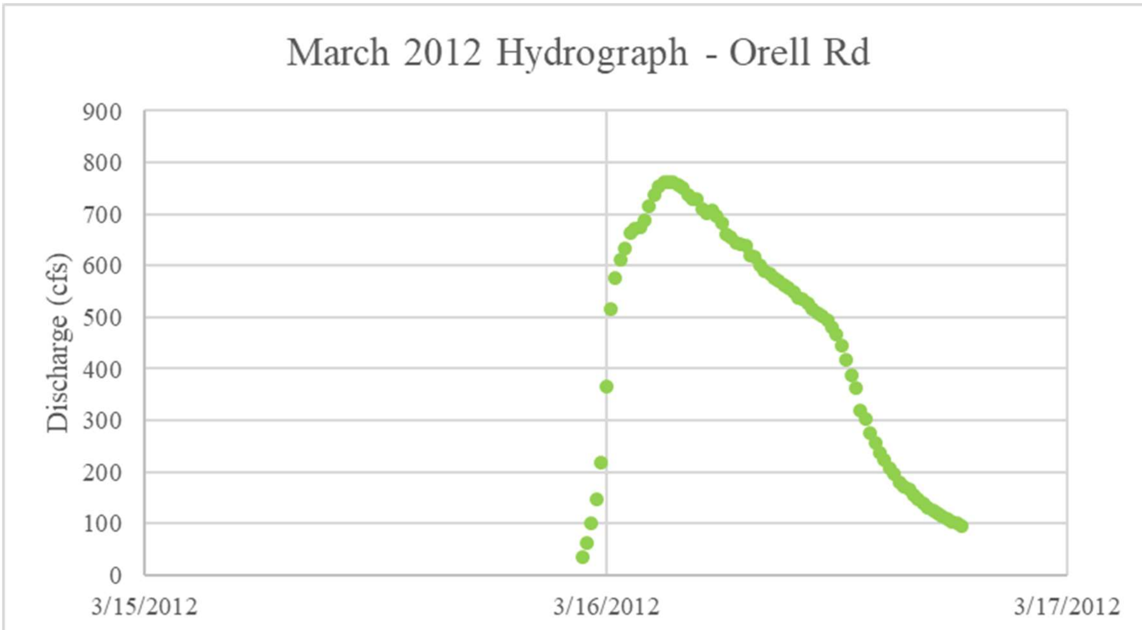
December 2000 Hydrograph - Orell Rd
Discharge (cfs)
1800
1600
1400
1200
1000
800
600
400
200
0
12/16/2000
12/17/2000
12/18/2000

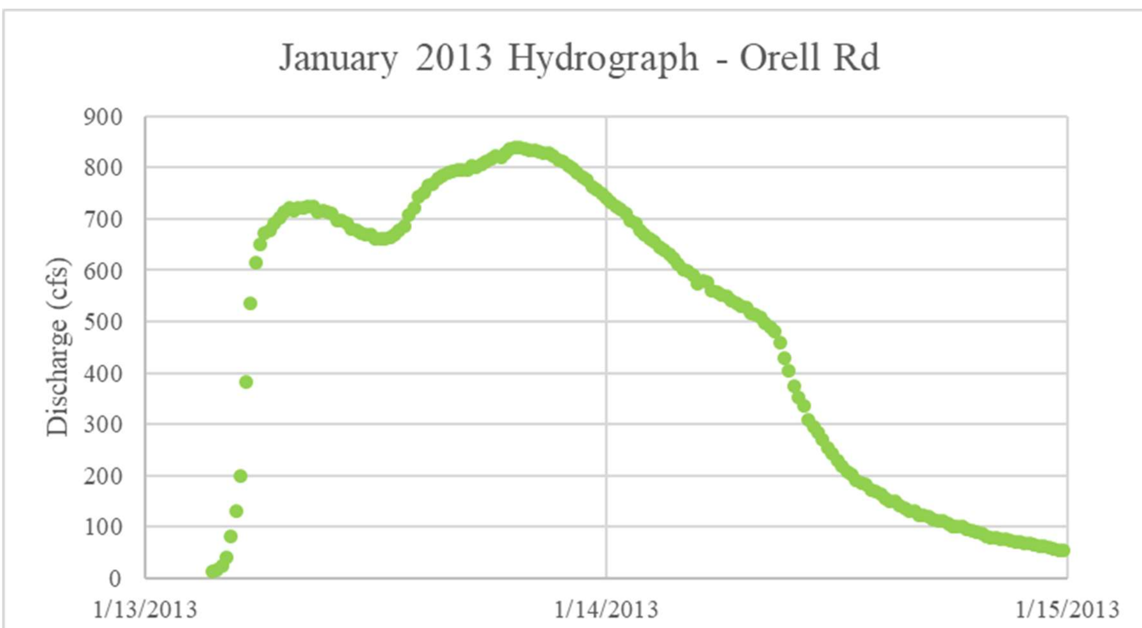

October 2004 Hydrograph - Orell Rd
Discharge (cfs)
3500
3000
2500
2000
1500
1000
500
0
10/18/2004
10/19/2004
10/20/2004

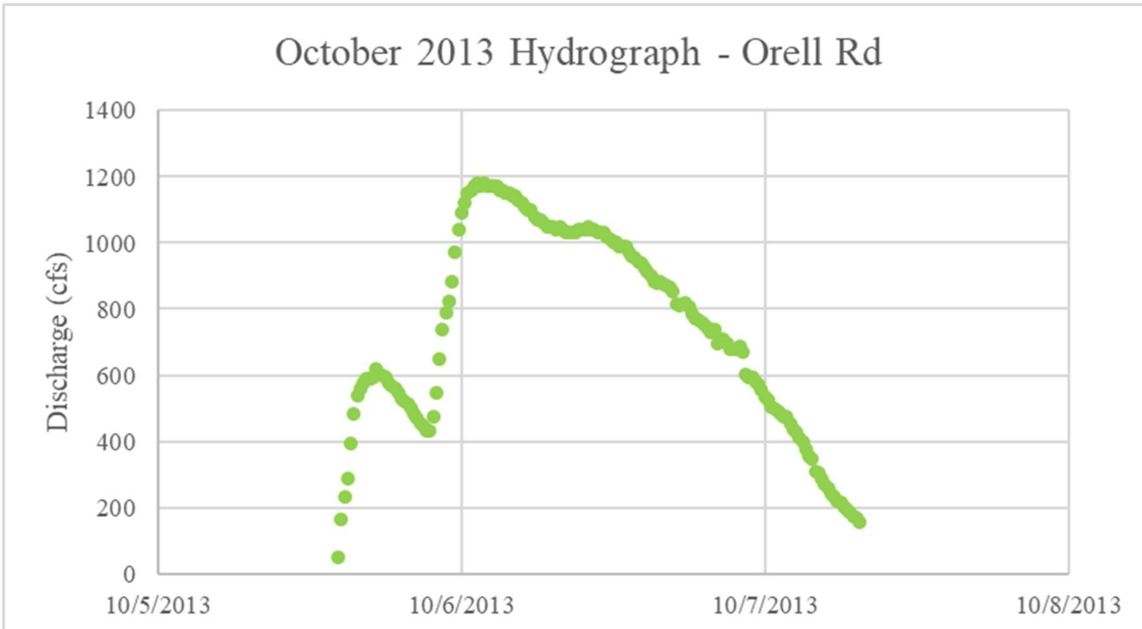

September 2006 Hydrograph - Orell Rd
Discharge (cfs)
1200
1000
800
600
400
200
0
9/22/2006
9/23/2006
9/24/2006
9/25/2006
Axis Title

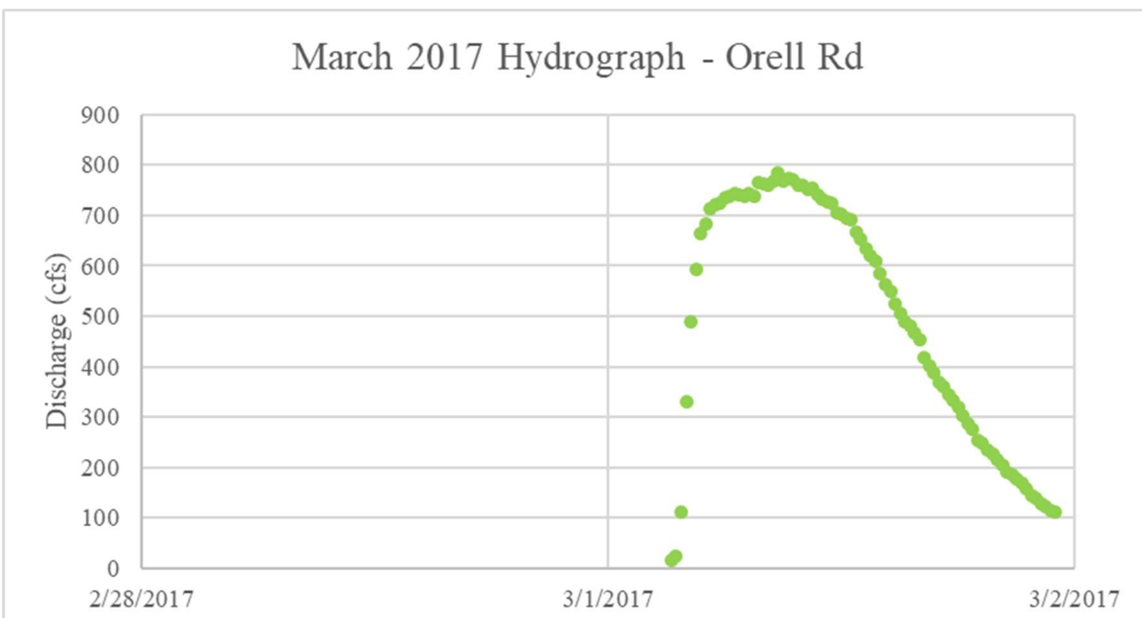

August 2009 Hydrograph - Orell Rd
Discharge (cfs)
800
700
600
500
400
300
200
100
0
8/4/2009
8/5/2009
8/6/2009

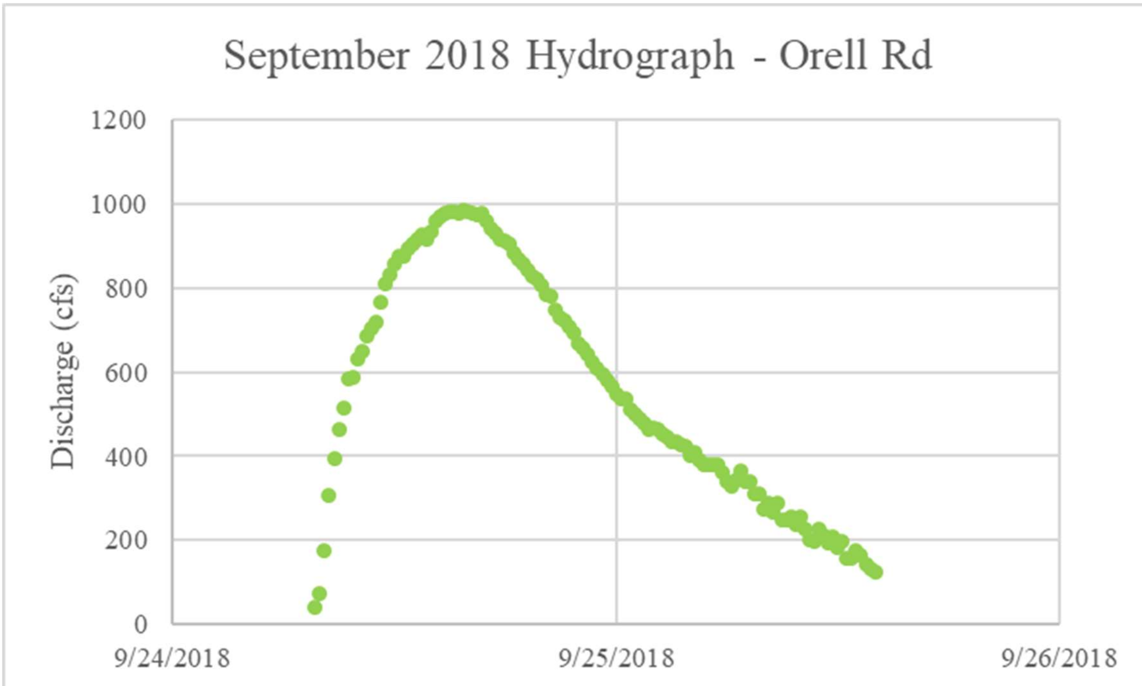

May 2010 Hydrograph - Orell Rd
Discharge (cfs)
1000
900
800
700
600
500
400
300
200
100
0
5/2/2010
5/3/2010
5/4/2010

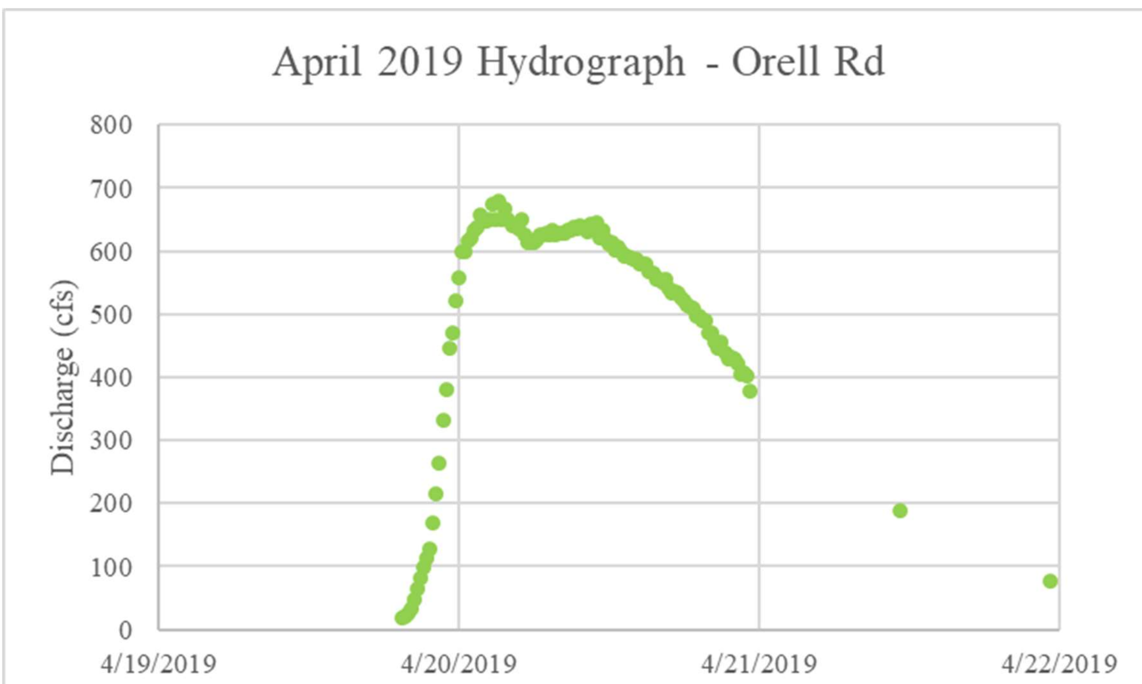

March 2012 Hydrograph - Orell Rd
Discharge (cfs)
900
800
700
600
500
400
300
200
100
0
3/15/2012
3/16/2012
3/17/2012

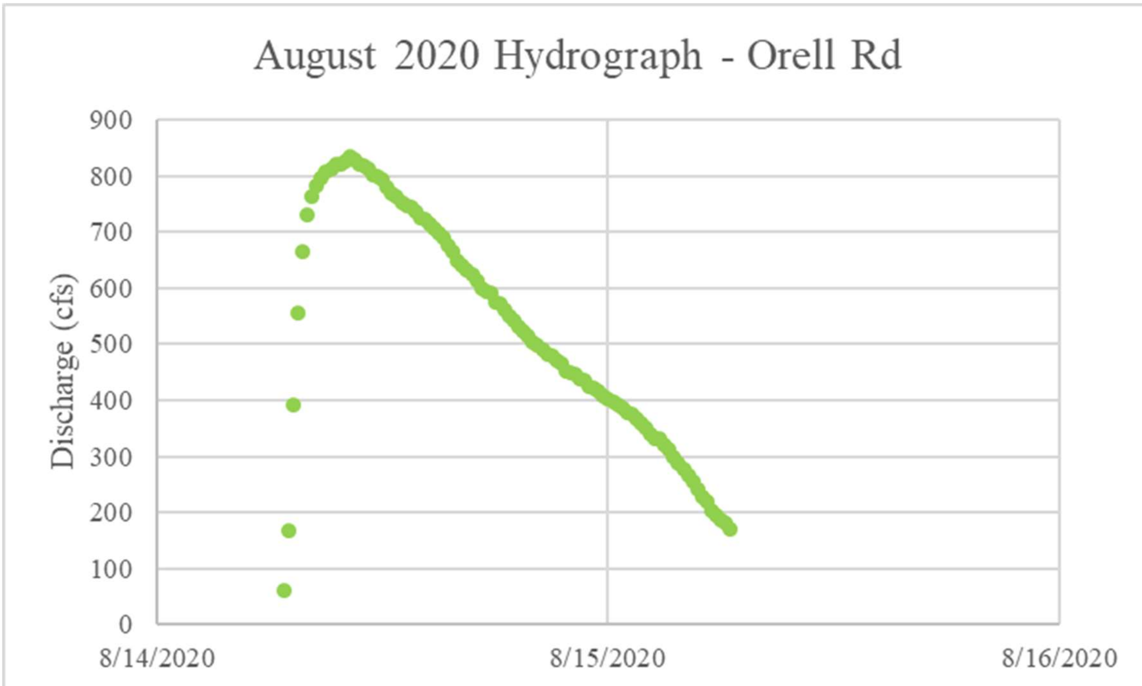

January 2013 Hydrograph - Orell Rd
Discharge (cfs)
900
800
700
600
500
400
300
200
100
0
1/13/2013
1/14/2013
1/15/2013


October 2013 Hydrograph - Orell Rd
Discharge (cfs)
0
200
400
600
800
1000
1200
1400
10/5/2013
10/6/2013
10/7/2013
10/8/2013

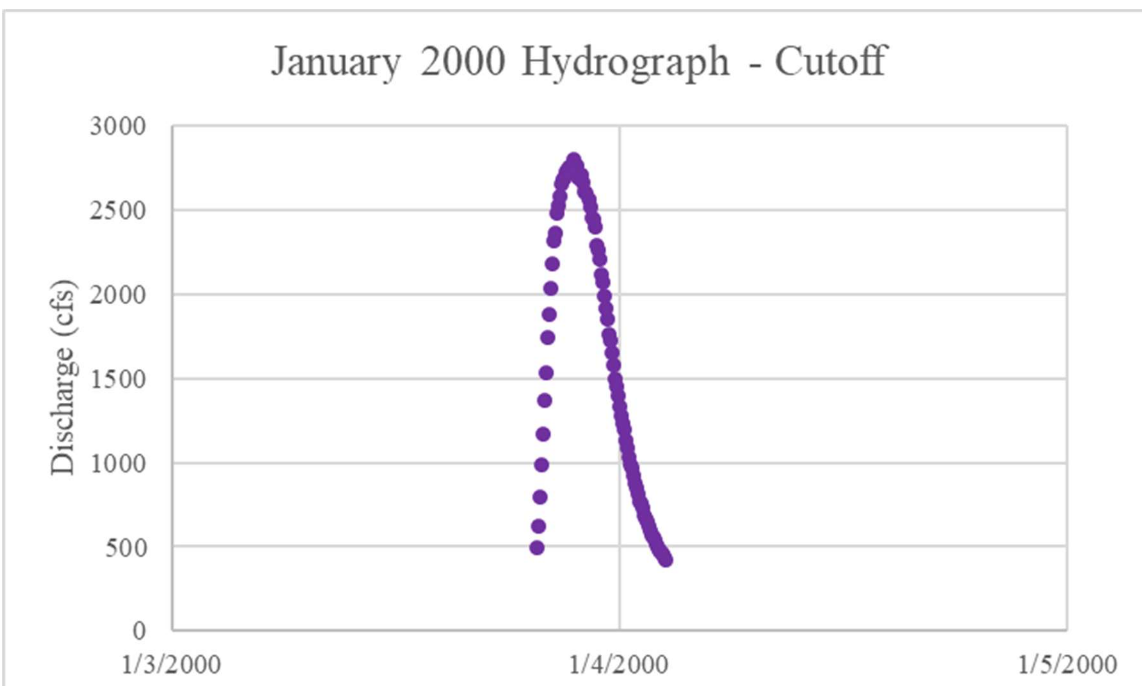

March 2017 Hydrograph - Orell Rd
Discharge (cfs)
0
100
200
300
400
500
600
700
800
900
2/28/2017
3/1/2017
3/2/2017


September 2018 Hydrograph - Orell Rd
Discharge (cfs)
1200
1000
800
600
400
200
0
9/24/2018
9/25/2018
9/26/2018

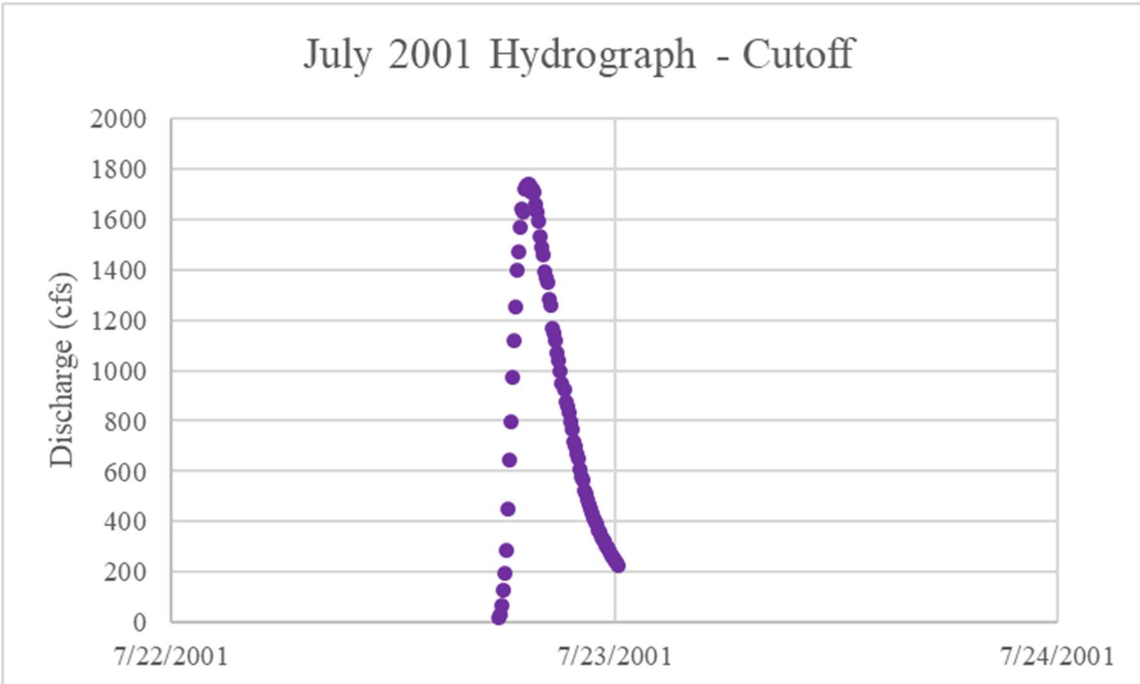

April 2019 Hydrograph - Orell Rd
Discharge (cfs)
800
700
600
500
400
300
200
100
0
4/19/2019
4/20/2019
4/21/2019
4/22/2019

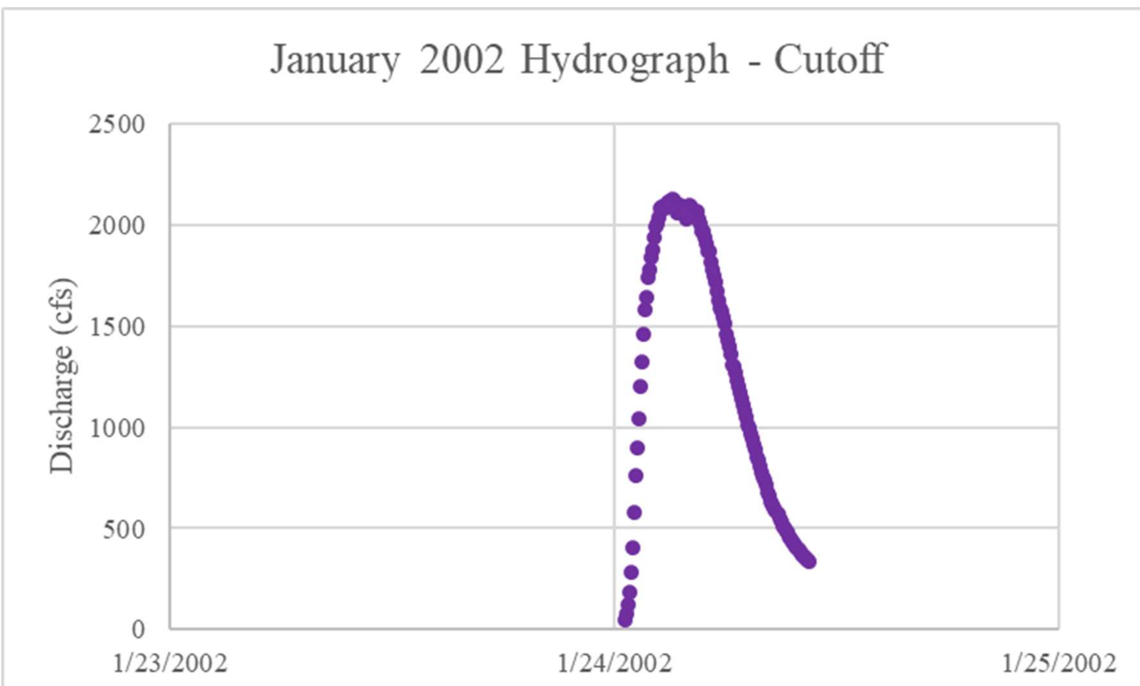


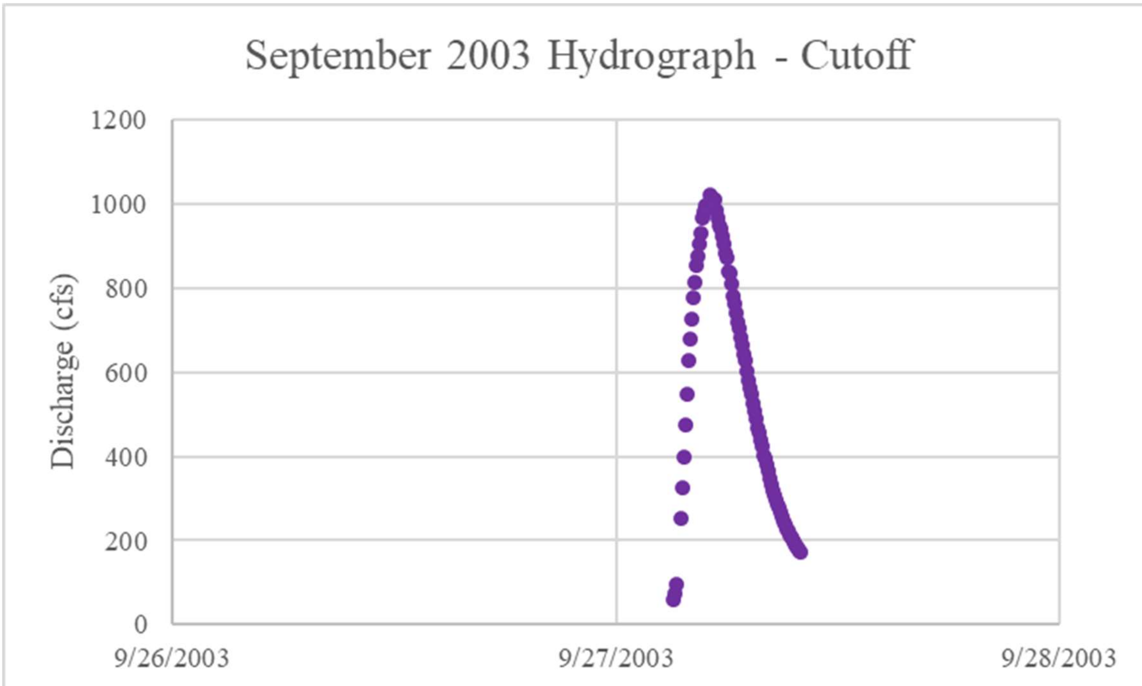
August 2020 Hydrograph - Orell Rd
Discharge (cfs)
900
800
700
600
500
400
300
200
100
0
8/14/2020
8/15/2020
8/16/2020

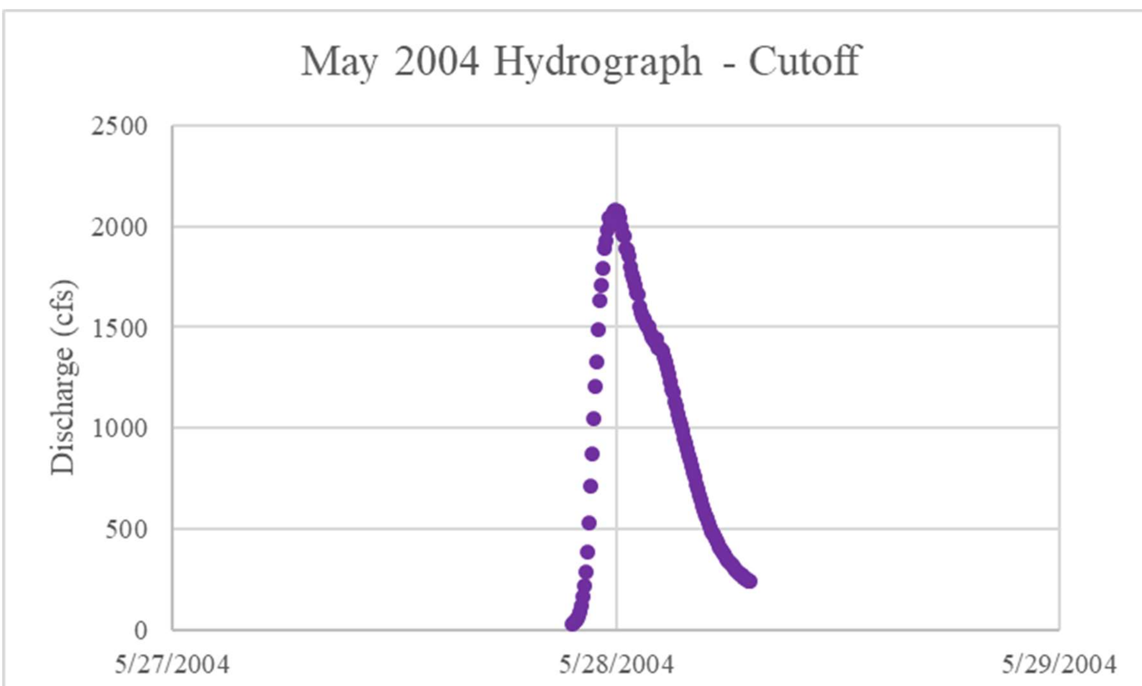


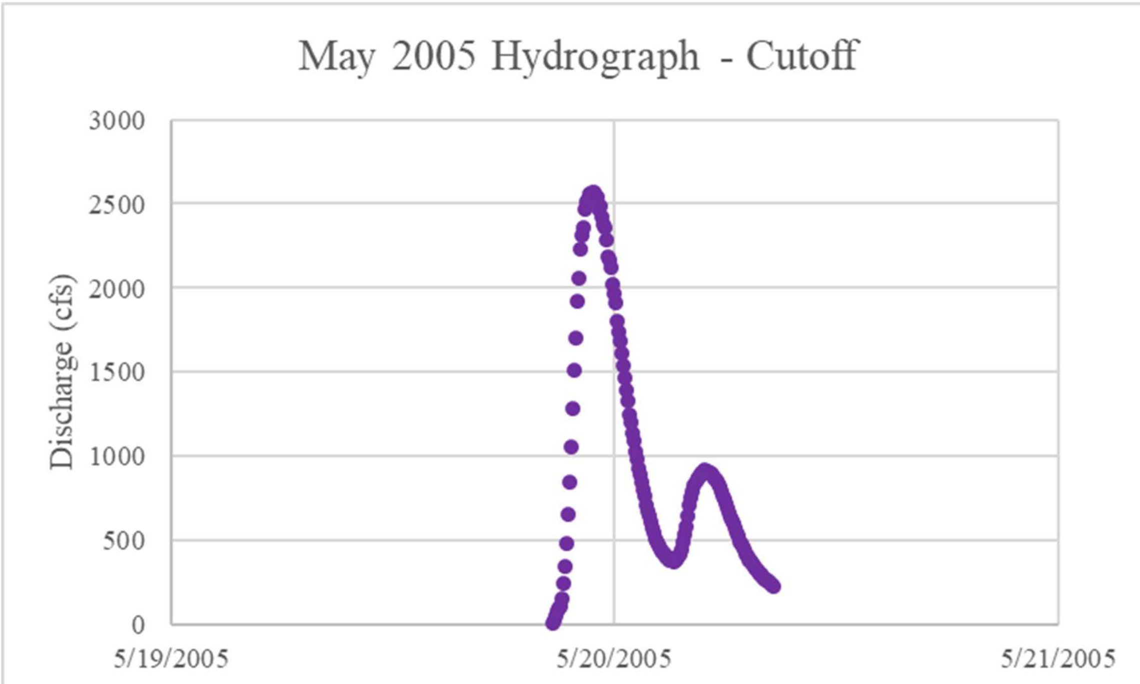
January 2000 Hydrograph - Cutoff
Discharge (cfs)
3000
2500
2000
1500
1000
500
0
1/3/2000
1/4/2000
1/5/2000

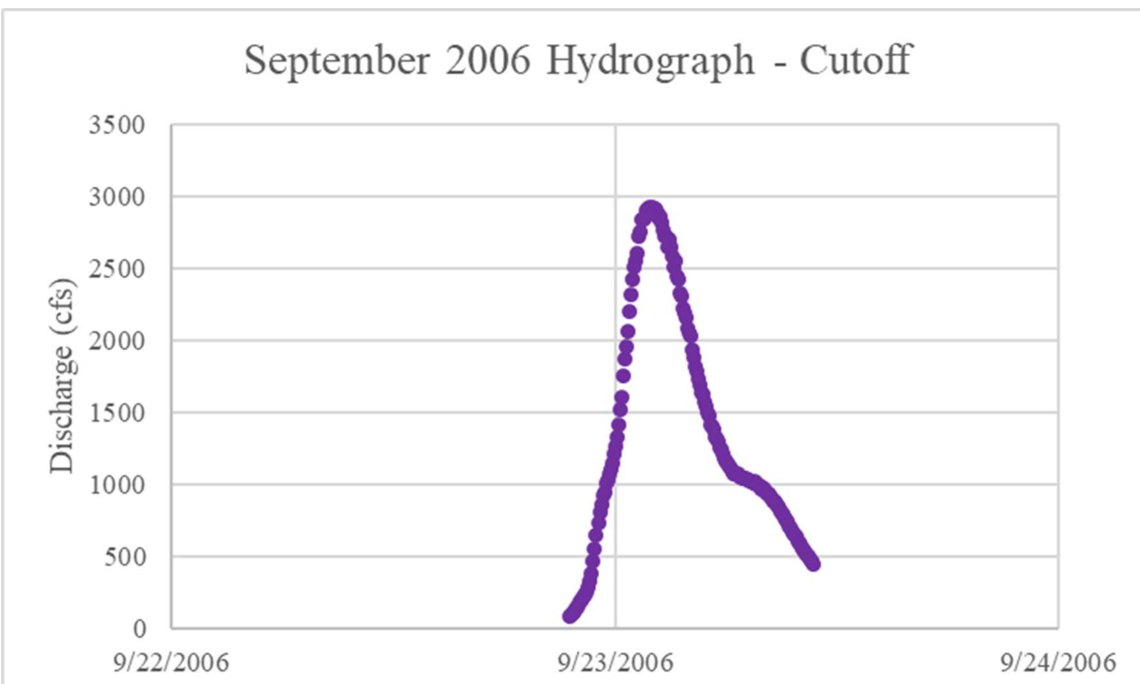

July 2001 Hydrograph - Cutoff
Discharge (cfs)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
7/22/2001
7/23/2001
7/24/2001

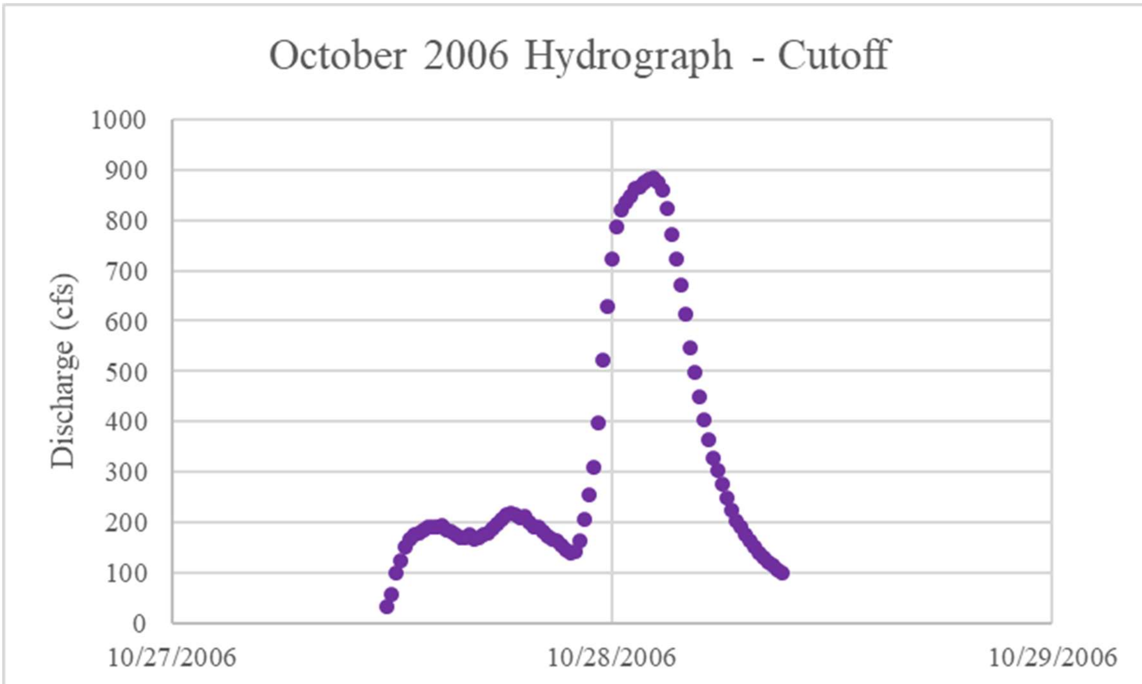

January 2002 Hydrograph - Cutoff
Discharge (cfs)
2500
2000
1500
1000
500
0
1/23/2002
1/24/2002
1/25/2002


September 2003 Hydrograph - Cutoff
1200
1000
800
600
400
200
0
Discharge (cfs)
9/26/2003
9/27/2003
9/28/2003

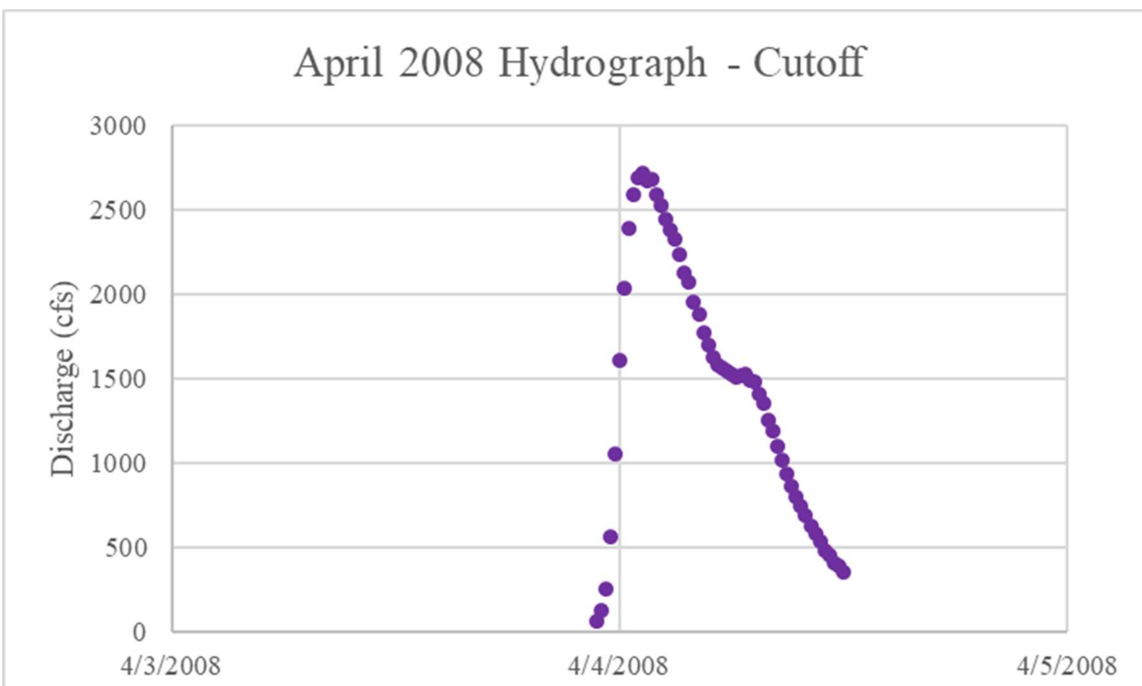

May 2004 Hydrograph - Cutoff
2500
2000
1500
1000
500
0
Discharge (cfs)
5/27/2004
5/28/2004
5/29/2004


May 2005 Hydrograph - Cutoff
Discharge (cfs)
3000
2500
2000
1500
1000
500
0
5/19/2005
5/20/2005
5/21/2005

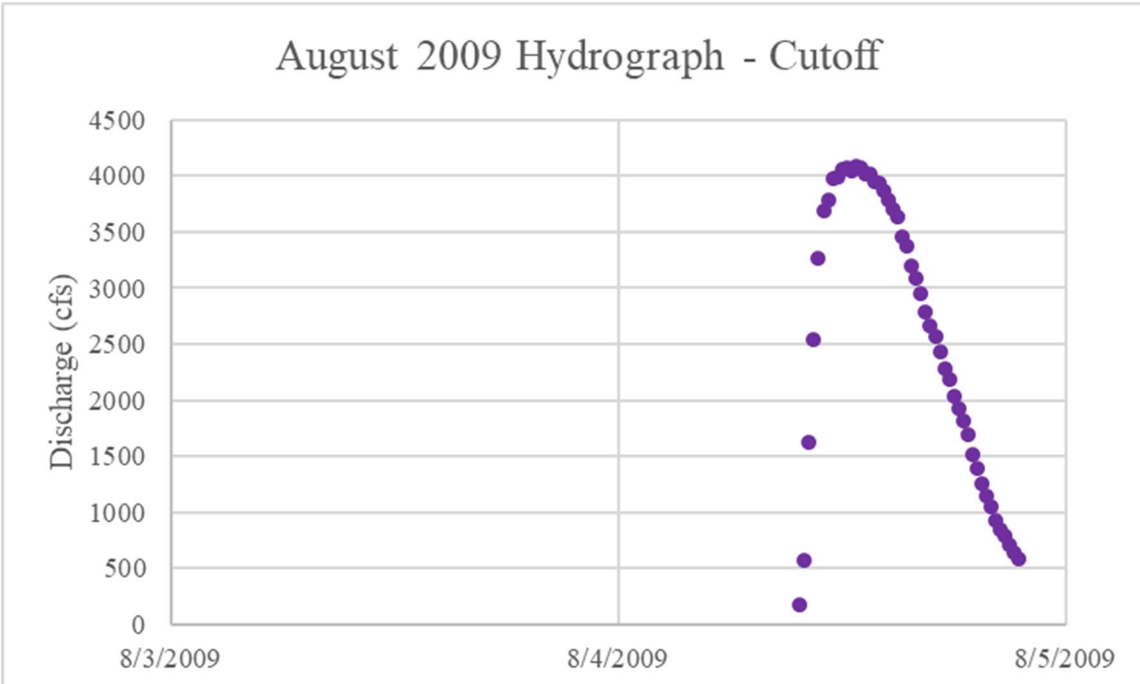

September 2006 Hydrograph - Cutoff
Discharge (cfs)
3500
3000
2500
2000
1500
1000
500
0
9/22/2006
9/23/2006
9/24/2006

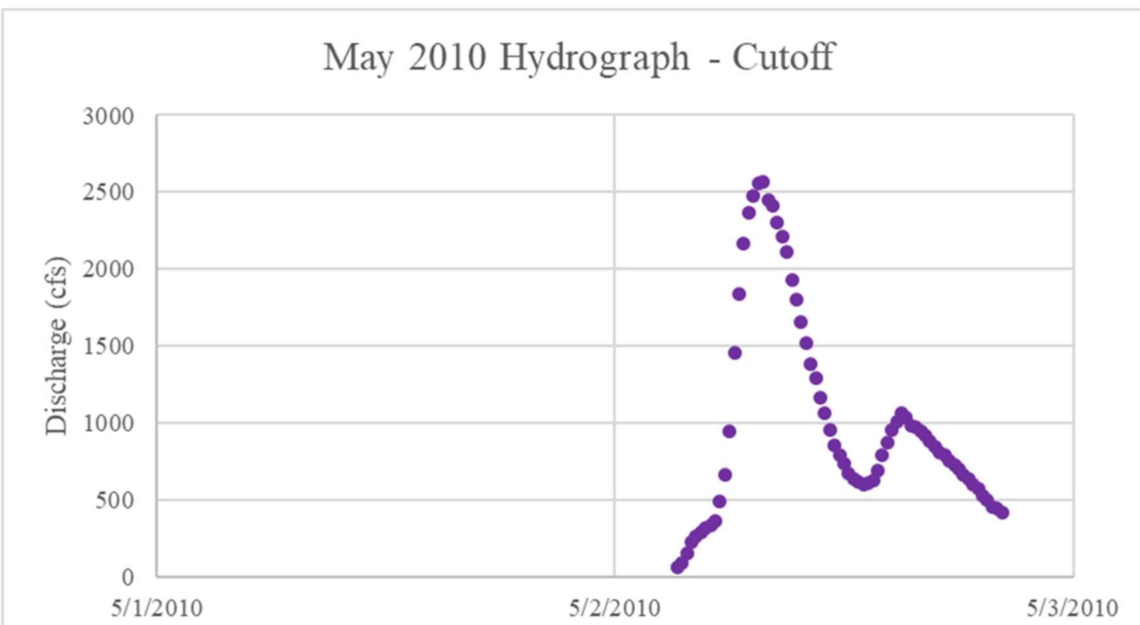


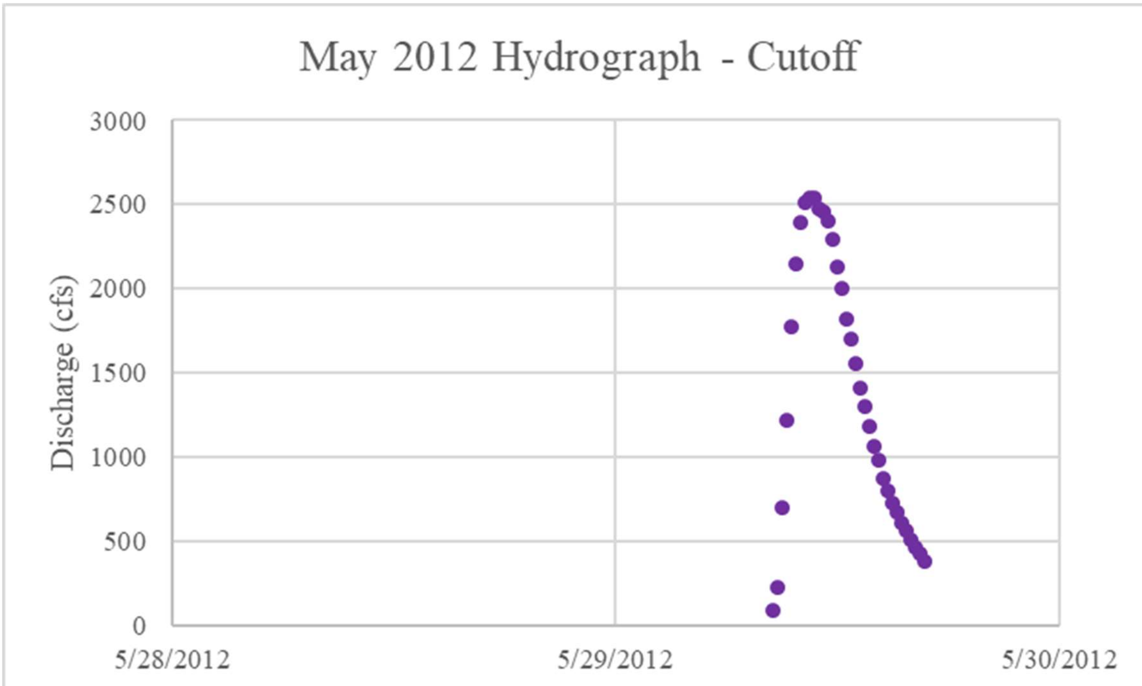
October 2006 Hydrograph - Cutoff
Discharge (cfs)
1000
900
800
700
600
500
400
300
200
100
0
10/27/2006
10/28/2006
10/29/2006

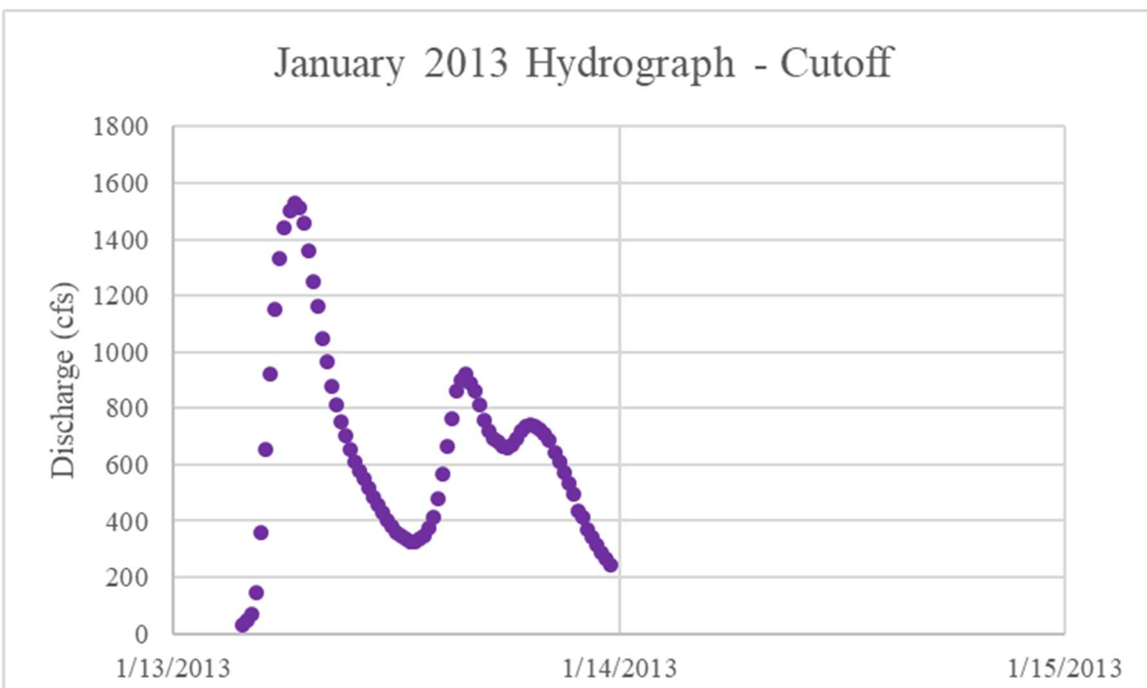


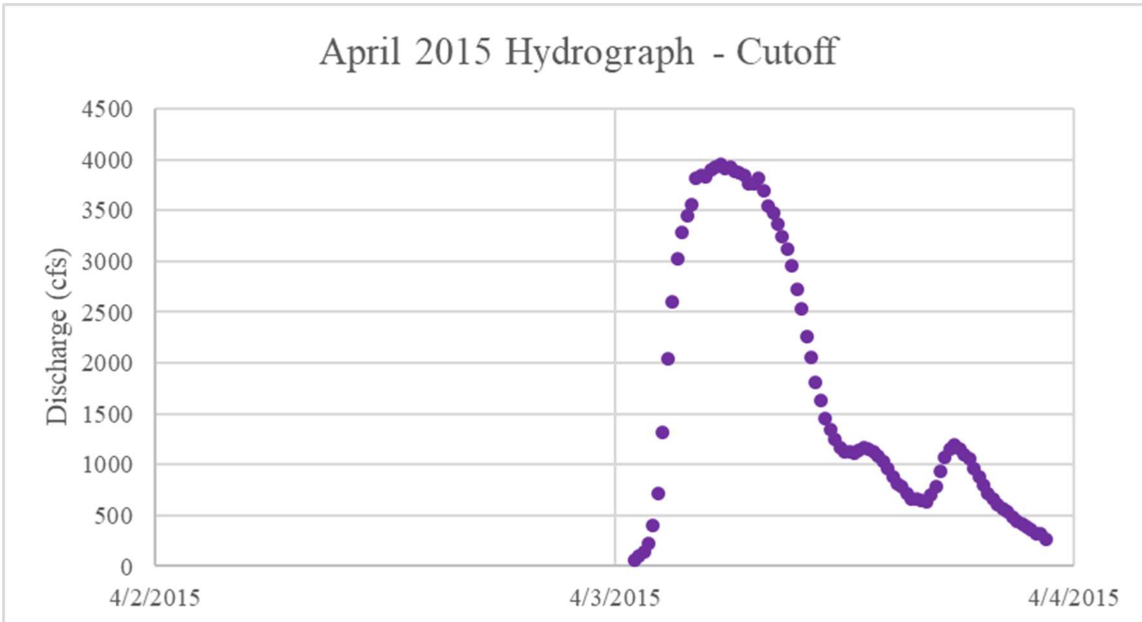
April 2008 Hydrograph - Cutoff
Discharge (cfs)
3000
2500
2000
1500
1000
500
0
4/3/2008
4/4/2008
4/5/2008

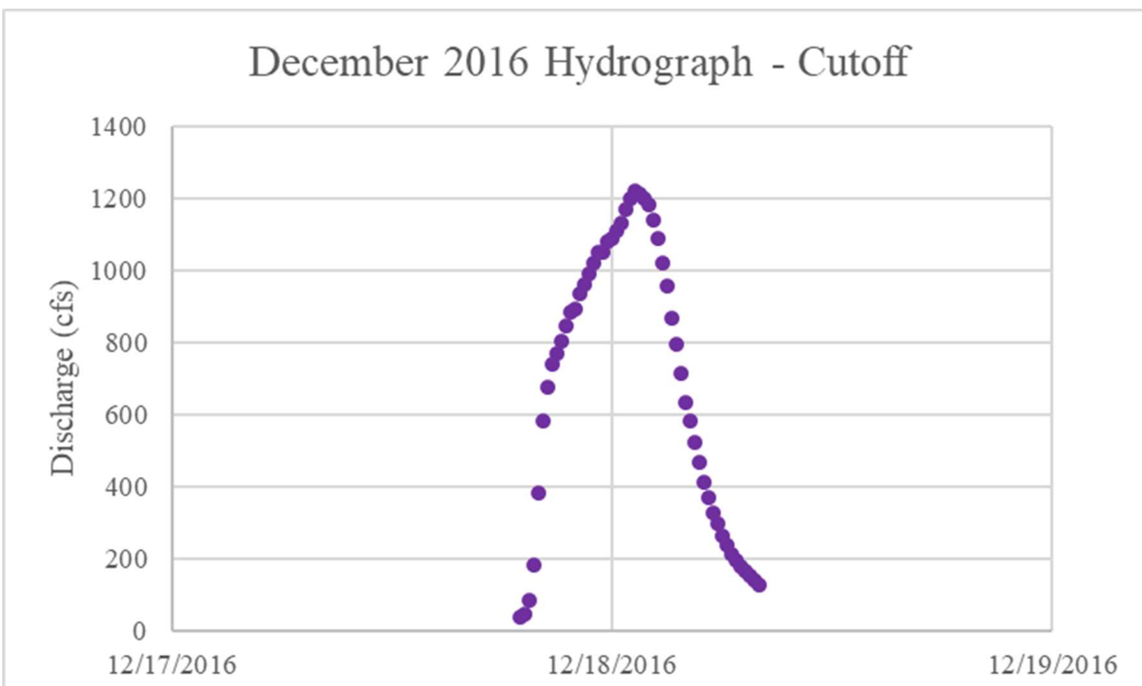

August 2009 Hydrograph - Cutoff
Discharge (cfs)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
8/3/2009
8/4/2009
8/5/2009

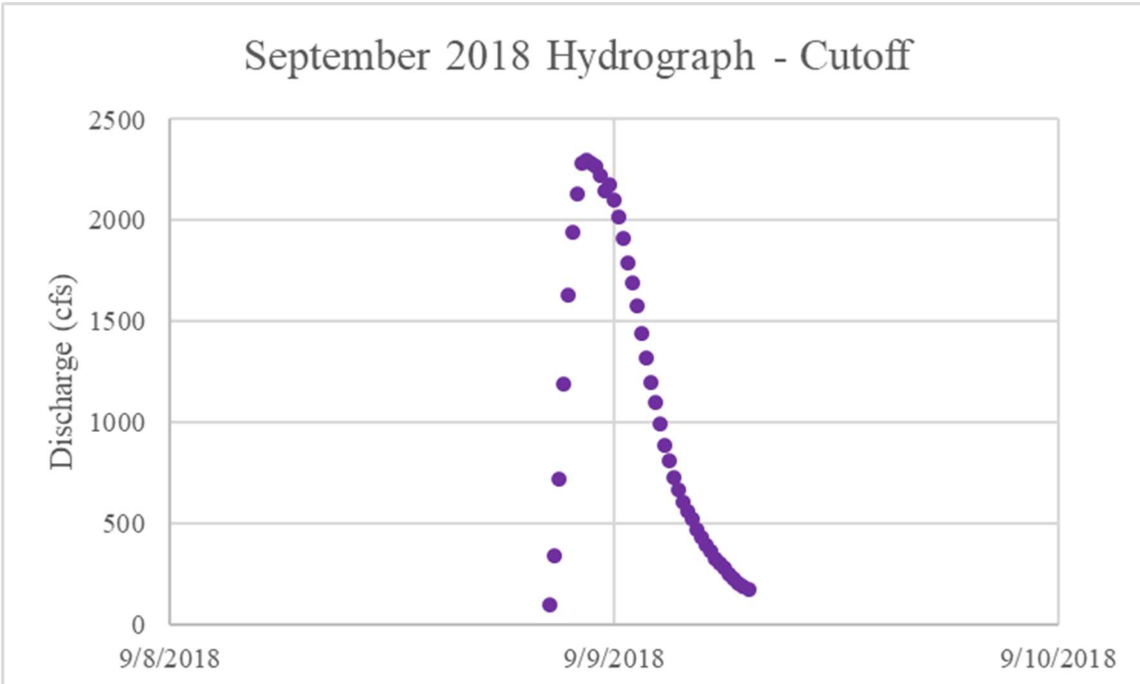

May 2010 Hydrograph - Cutoff
Discharge (cfs)
3000
2500
2000
1500
1000
500
0
5/1/2010
5/2/2010
5/3/2010

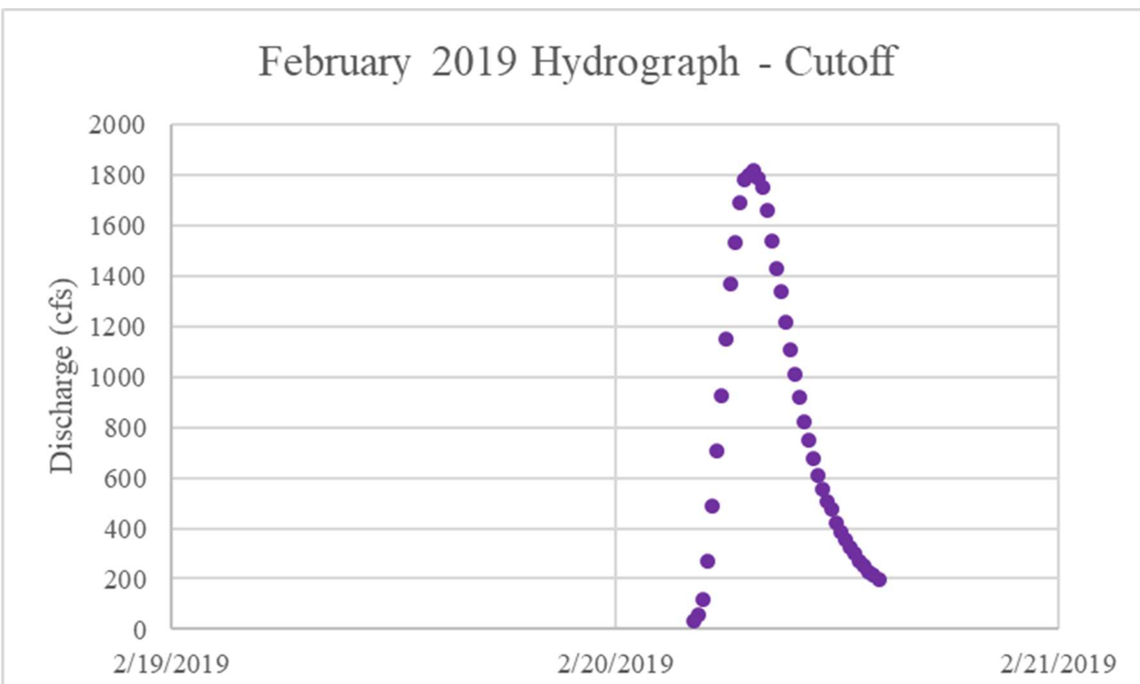

May 2012 Hydrograph - Cutoff
Discharge (cfs)
3000
2500
2000
1500
1000
500
0
5/28/2012
5/29/2012
5/30/2012

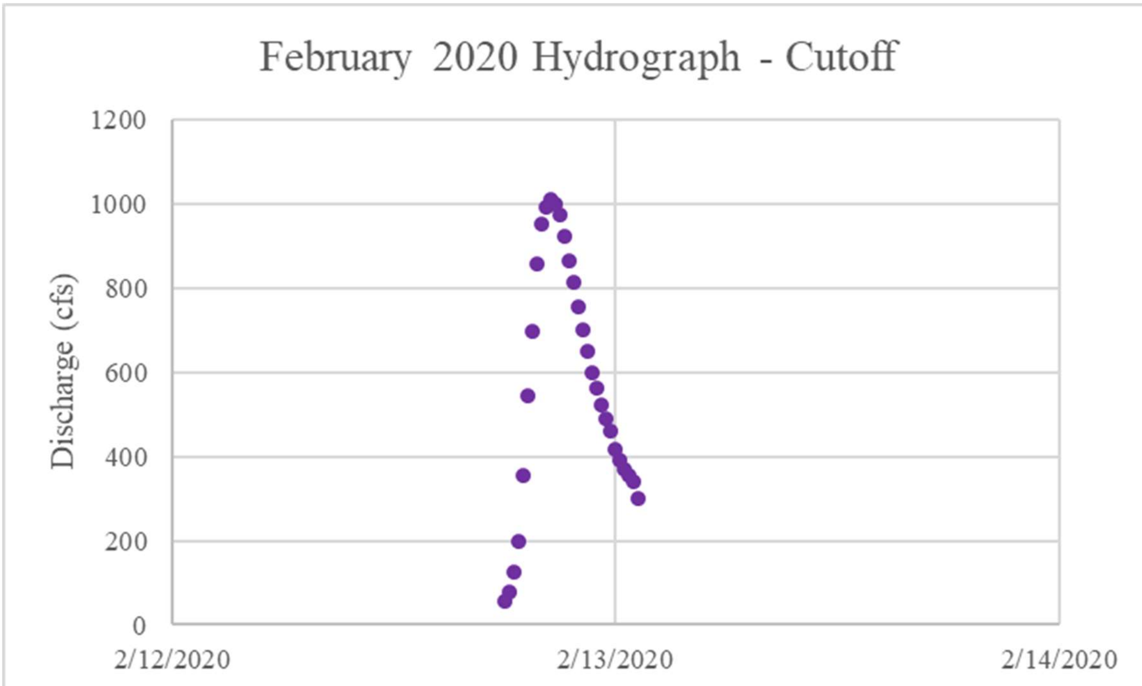

January 2013 Hydrograph - Cutoff
Discharge (cfs)
1800
1600
1400
1200
1000
800
600
400
200
0
1/13/2013
1/14/2013
1/15/2013

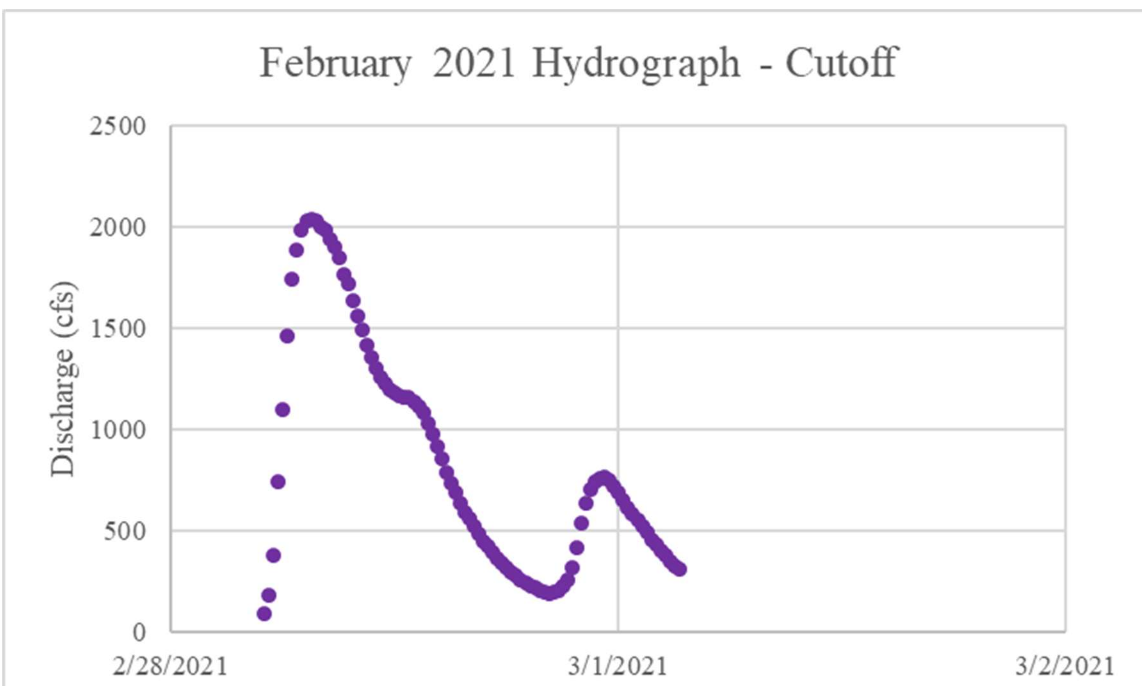

April 2015 Hydrograph - Cutoff
Discharge (cfs)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
4/2/2015
4/3/2015
4/4/2015


December 2016 Hydrograph - Cutoff
Discharge (cfs)
1400
1200
1000
800
600
400
200
0
12/17/2016
12/18/2016
12/19/2016


September 2018 Hydrograph - Cutoff
Discharge (cfs)
2500
2000
1500
1000
500
0
9/8/2018
9/9/2018
9/10/2018


February 2019 Hydrograph - Cutoff
Discharge (cfs)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
2/19/2019
2/20/2019
2/21/2019


February 2020 Hydrograph - Cutoff
Discharge (cfs)
1200
1000
800
600
400
200
0
2/12/2020
2/13/2020
2/14/2020


February 2021 Hydrograph - Cutoff
Discharge (cfs)
2500
2000
1500
1000
500
0
2/28/2021
3/1/2021
3/2/2021

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