Jordan River Water Quality Monitoring – 2017

Report prepared for Friends of the Jordan River Watershed

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SUMMARY

In 2017, Friends of the Jordan River Watershed partnered with Tip of the Mitt Watershed Council to perform water quality measurements in Jordan River Valley. Discharge measurements and water samples were collected from five sites during wet and dry conditions of June, September, and October. Water samples were analyzed for common ionic water quality parameters at the University of Michigan Biological Station. These parameters provide an overview of potential pollutants entering a waterbody. Estimated nutrient loadings were then calculated using discharge measurements collected at the time of water quality sampling. Overall, water quality of the Jordan River and tributaries remains high. However, similar to previous monitoring efforts, areas of increased total nitrogen were documented. Continual monitoring of nutrient and discharge values provide valuable data to document trends and identify changes over time within the Jordan River Watershed. Future monitoring could include isotopic analysis of water and soil samples that might highlight the source of increased nitrogen observed in the Watershed. The Jordan River is a unique system that deserves continual monitoring and protection status.

BASIC LIST OF FINDINGS

For the Jordan River:

- The Jordan River is a very nitrogen-rich system, even in the lower reaches near Fair Road.
    - Areas in the upper reaches, near and around the National Fish Hatchery, contain extremely high nitrogen levels relative to other areas monitored in the Watershed.
        - Total Nitrogen was over four times the United States Environmental Protection Agency (U.S. EPA) ambient water quality reference condition of 440µg/L for the region of Michigan.
    - Spring-fed Five Tile Creek contains very high levels of nitrogen.
    - Nitrogen needs to be monitored into the future.
        - Follow-up studies should identify sources of the increased nitrogen in upper reaches of the Watershed. Is the source groundwater?
- Total phosphorus loading below the hatchery in the Jordan River was estimated to be 1,373 pounds per year.
    - Total phosphorus in all but one location was measured below the U.S. EPA ambient water quality reference condition of 12µg/L.
    - Total phosphorus was overall not a concern in 2017 monitoring results.

For Bennett Creek:

- Bennett Creek showed elevated total phosphorus downstream of the trout pond.
    - Average total phosphorus was greater than the U.S. EPA ambient water quality reference conditions of 12µg/L.
    - However, only one monitoring sample under wet conditions was well above the standard reference condition.

For Deer Creek:

- Nutrients and chlorides are slightly elevated, indicating some impact from human activities that could be related to agriculture or winter road salt application.

All monitoring locations:

- Physio-chemical parameters of dissolved oxygen, conductivity, pH, and temperature are relatively consistent with previous monitoring efforts and indicative of good water quality.

INTRODUCTION

Background

Nonpoint source pollution is a continual threat to Michigan's pristine rivers and streams. Most nonpoint source pollution enters a water system from surface and ground water runoff. As water flows over the surface and underground, nutrients adhere to water molecules and travel to the water body. The easiest way to identify and mitigate impacts of nonpoint source pollution is through consistent and long-term monitoring of the watershed. Long-term datasets are important for the detection of excessive nutrients entering a water body and can guide mitigation action. What is considered excessive depends on the watershed in question and the ability to compare to previous monitoring efforts. Of the measured nutrients, nitrogen and phosphorus often receive the most attention as these have been linked to water quality issues in freshwater bodies of water.

Nitrogen and phosphorus are two key nutrients that are required for organismic growth. At excessive levels, these two nutrients can cause cascading impacts to a river system and become ecologically harmful. Excessive nitrogen and phosphorus can cause shifts in the aquatic food web and cause a river system to become eutrophic. Eutrophic simply means excessive nutrients for biological productivity to the point of nuisance algal and vegetative growth. Too much productivity can lead to reduced dissolved oxygen levels that cause cascading impacts which are harmful to fish populations.

This report documents monitoring efforts within the Jordan River, a high-quality system in the Lake Charlevoix Watershed. Fortunately, the Jordan River Watershed has a long-history of water quality monitoring projects. Data available from numerous organizations, dating back to 1967, indicate the Jordan River water quality is high and the ecosystem is healthy. However, some nutrient concerns have been documented in the Watershed.

Study Area

The Jordan River was the first river to receive the State of Michigan's "wild and scenic" designation under the Natural River Act of 1970. Sections of the River are considered high-quality Blue Ribbon Trout Stream by the Michigan Department of Natural Resources (MDNR). With a dense network of tributaries, the Jordan River flows from the headwaters in Antrim County to the South Arm of Lake Charlevoix in East Jordan. Encompassing 39% of the Lake Charlevoix Watershed, the Jordan River supplies roughly 60% of Lake Charlevoix's total water inflow (Tip of the Mitt Watershed Council, 2015). Moreover, some of the most productive and diverse natural areas in Northern Michigan are found within the Jordan River Watershed. The Jordan River Spreads is a highly productive and diverse natural area covering several hundred acres adjacent to the City of East Jordan. Moving upstream, the Jordan River transitions from the open waters of Lake Charlevoix through shallow submerged aquatic plant beds, emergent vegetation, wetlands dominated by shrubs, and then into upland areas (Figure 1). Land cover data from National Oceanic Atmospheric Administration's (NOAA) Costal Change Analysis Program depict the exceptional natural areas found in the Jordan River Watershed (Table 1, Figure 1).

Table 1. Land cover statistics for the Jordan River Watershed

Land Cover Type	2006 (%)	2010 (%)	2016 (%)
Agriculture	12.8	12.7	12.8
Barren	0.1	0.1	0.8
Forested	60.5	58.0	58.2
Grassland	6.4	6.7	6.7
Scrub/Shrub	2.7	2.8	2.6
Developed (Urban)	2.6	2.6	1.8
Water	0.7	0.8	0.8
Wetland	14.2	16.3	16.3
Total	100	100	100

As seen in Table 1, land cover has remained extremely consistent over the last decade with a large portion of the Watershed still forested (58.2%) and wetland (16.3%) (Figure 1). These areas are crucial to help filter nutrient runoff from surface and groundwater infiltration. Wetlands are often referred to as "nutrient sponges" because of their ability to filter surface and groundwater runoff. Maintaining forested and wetland areas are helpful in mitigating excessive nutrient runoff. Moreover, recognizing the water contribution from these two watershed types is important when describing nutrient input.

Water contribution to a river is largely characterized by the surface and ground water runoff. The area contributing to both types of runoff and draining to the river is described as a Watershed. The ground Watershed and surface Watershed are not always the same for a river. The ground Watershed for the Jordan River has been estimated to include areas outside of the Jordan River surface watershed (Walker, 2003; Hay and Meriwether, 2004). As such, areas outside the Jordan River Watershed boundary have potential to contribute groundwater to the Jordan River and associated nearby tributaries. Areas just outside of the Jordan River surface watershed are composed of varying land use, including agriculture. Any increased nutrient detection (i.e. nitrogen) in the Watershed might be related to land use practices of these areas. Another source of elevated nutrients could be the Jordan River National Fish Hatchery.

The hatchery, operated by the U.S. Fish and Wildlife Service (U.S. FWS), was established in 1963. The hatchery produces roughly 3 million trout for federal and state recreation and restoration programs annually (U.S. FWS, 2016). The Hatchery uses water from Five Tile and Six Tile Creeks to supply its operations and discharges water from the facility to the Jordan River. The hatchery's effluent is regulated through a National Pollutant Discharge Elimination System

(NPDES) permit administered by the Michigan Department of Environmental Quality (MDEQ). In addition to fish production, the Hatchery offers educational opportunities.

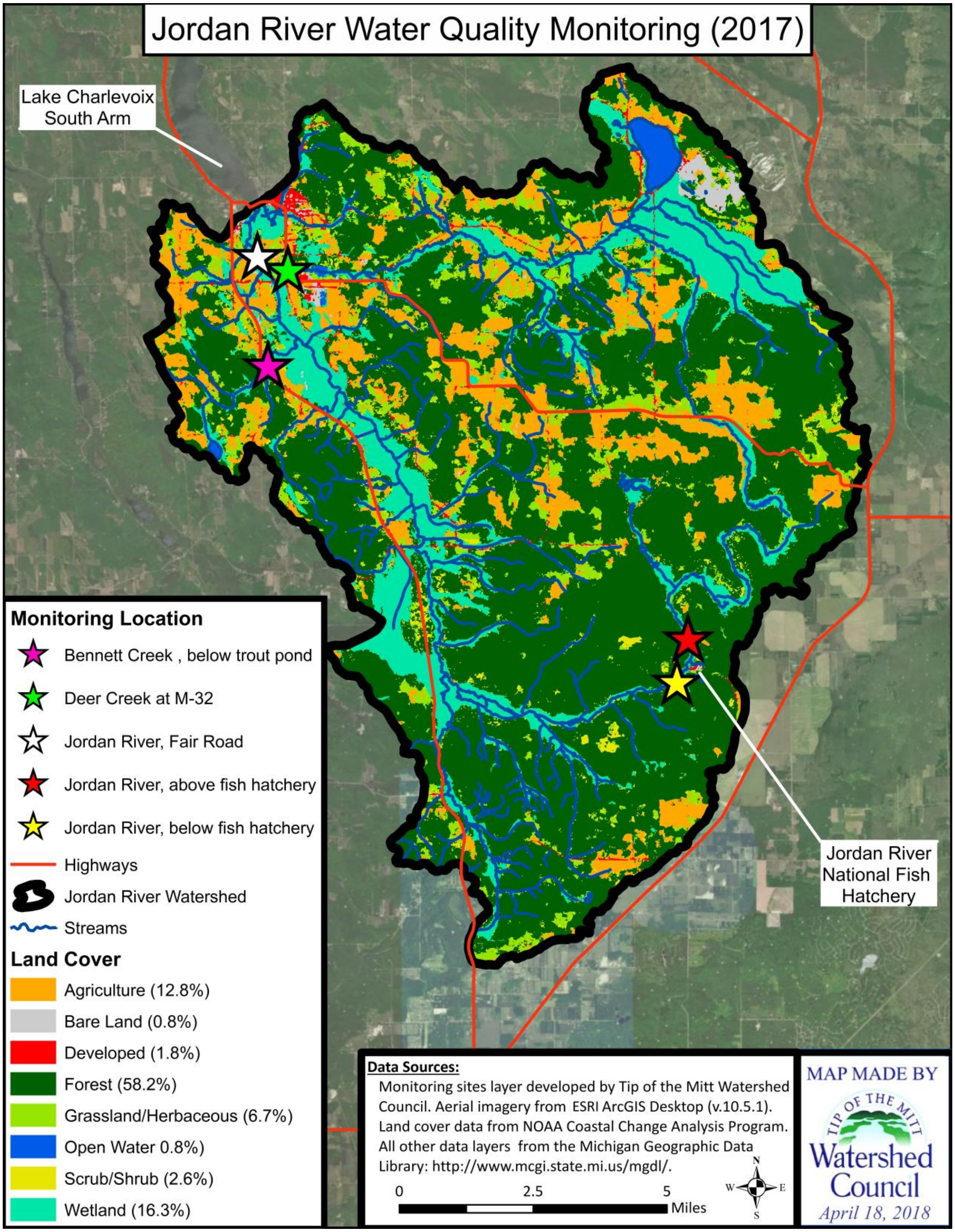

Figure 1. Jordan River Watershed land cover in 2016 overlaid with monitoring sites in 2017.

Past monitoring overview

Total Nitrogen and Phosphorus

Currently, the State of Michigan does not have an adopted water quality criteria for nitrogen and phosphorus values. However, the U.S. EPA has established ambient water quality criteria recommendations. The criteria are based on regional reference nutrient conditions. The ambient regional reference conditions provide a baseline of comparison for minimally impacted streams in Northern Michigan (U.S. EPA, 2001). Stated in a different way, regional reference conditions are natural nutrient conditions for the region and were established as a starting point for states and tribes to use if pursuing numeric nutrient water quality criteria. Just because a stream is above a reference condition does not imply the stream is impaired, as each system is unique with natural nutrient inputs. However, values above a reference condition highlight how atypical a system is within the region and certainly warrants continued monitoring for trends over time. Any deviation (increase) from the baseline conditions could be harmful to water quality and would warrant follow-up investigation to identify the source of increased nutrients. Nitrogen and phosphorus values have been documented and compared to the region reference conditions for the Northwestern Michigan region. Nutrient values above the reference conditions are a bit atypical for Northern Michigan streams.

The Jordan River has been documented as a very nitrogen rich system. Nearly all historical water quality samples, particularly in the upper reaches of the Watershed, are well above the U.S. EPA reference condition of 440 µg/L (Table 9 Appendix; U.S. EPA, 2001). Total Nitrogen values have historically been reported the highest in proximity with the hatchery, and lowest in the southernmost tributaries (MDEQ, 2003). The downstream decrease in concentration could be an indication of nutrient dilution and biological uptake before entering Lake Charlevoix. Monitoring in 2016 by Tip of the Mitt Watershed Council noted a similar trend. Although nitrogen values have been documented as atypical in the Jordan River, phosphorus has historically been below the U.S. EPA regional reference condition value.

Phosphorus has been monitored in the Jordan River since 1967, with annual total phosphorus monitored by the U.S. FWS since 2005 near the hatchery. The regional reference condition for the Northwestern Michigan region is 12 µg/L (U.S. EPA, 2001). As noted in Table 10 of the appendix, historical records indicate the Jordan River has been below the reference condition in most locations. However, a few samples near the upper reaches and in smaller tributaries, particularly Birney Creek, have been documented above 12 µg/L. Tip of the Mitt Watershed Council monitoring in 2016 also documented elevated phosphorus in the upper reaches, specifically the outfall of the fish hatchery.

Physio-chemical conditions

Physio-chemical measurements include dissolved oxygen, pH, conductivity, temperature, and alkalinity. Each of these parameters play an important role in the habitat for organisms and water quality. Dissolved oxygen is of crucial importance for respiration and ultimate survival of nearly all stream organisms. Conductivity, pH, and alkalinity provide an overview of ions (i.e. chloride) present in the water and can highlight areas of concern for nutrient pollution. Ions (H^+) impact the acidity of the water described by the pH while alkalinity provides a description of acid buffering capacity. High alkalinity indicates a high ability to resist changes in pH from sources such as acid rain.

Dissolved Oxygen

The Jordan River is a high quality cold water fishery. Cold water fisheries have a dissolved oxygen standard of at least 7.0 mg/L. From over 760 records in the Jordan River recorded by the MDEQ, U.S. FWS, and Tip of the Mitt Watershed Council, average dissolved oxygen has on average been high at 10.1 mg/L. Only four readings from the data collected between 1967 and 2016 were below the water quality cold water fishery standard: 1) 6.1 mg/L at the discharge from the Jordan River hatchery in 1977; 2) 6.5 at Landslide Creek in 2012; 3) 6.9 mg/L at the river mouth at Bridge Street in 1977; and 4) 6.9 mg/L at Cascade Creek in 2012. The aerobic digestion by bacteria of organic compounds from the Hatchery discharge and in the marshy area upstream of Bridge Street possibly contributed to the lower readings at these sites.

Table 2. Historic dissolved oxygen summary for the Jordan River.

Parameter	Low * (mg/L)	Low (year)	Low (site)	High* (mg/L)	High (year)	High (site)	Average*
Dissolved Oxygen	6.1	1977	Hatchery discharge	14.1	1978	Pinney Bridge	10.1

Conductivity, pH, and alkalinity

Conductivity, pH, and alkalinity provide an overview description of ions in the water. Alkalinity is measured in mg/L of calcium carbonate ($CaCO_3$), while pH is a value of H^+ ions in the water creating an acidic, neutral, or basic environment. When acidic material comes in contact with surface waters, such as acid rain, $CaCO_3$ in the water dissociates to neutralize the H^+ ions and helps to maintain a consistent pH. Conductivity is a measure of the ability for a material to conduct electricity. The ability for water to conduct electricity is directly related to the presence of dissolved electrolyte anions (negatively charged ions – chloride, nitrate, sulfate, and phosphate) and cations (positively charged ions – sodium, magnesium, calcium, iron, and aluminum).

Historical records of alkalinity, pH, and conductivity indicate the Jordan River is a stream with a high capacity to resist changes in pH, moderate level of ions, and very hard water. Alkalinity has ranged from 110mg/L to 235 mg/L $CaCO_3$, with an average of 176mg/L $CaCO_3$. Average pH from over 1380 measurements show a value of 8.3 within the Jordan River Watershed (Table 7 of Appendix). Conductivity from 125 records in the Watershed show a value of 333 µS/cm, which is consistent with streams in the region. Values under 500 µS/cm have been shown to support healthy well-mixed fisheries (U.S. EPA, 1997).

Since conductivity measurements serve as a surrogate of ion concentrations in the water, conductivity functions as an early indicator of water quality problems. Water samples within a drainage basin or watershed will have a relatively consistent range of conductivity. Once established, conductivity can be used as a baseline for comparison with regular conductivity measurements. A noticeable change in conductivity under similar environmental conditions (i.e. - seasonality) can indicate discharge within the drainage basin or watershed has changed. In particular, a significant change in conductivity can indicate a change in road salt, sewage, fertilizer, pesticide, or other pollutant accumulation within the drainage area.

Table 3. Historic alkalinity, pH, and conductivity summary for the Jordan River.

Parameter	Low (Value)	Low (Year)	Low (Site)	High (Value)	High (Year)	High (Site)	Average
Alkalinity (mg/L) ($CaCO_3$)	110	1973	Old St Rd	235	2011	Jones Creek	176
pH (units)	7.0	1968	Rogers Rd	8.7	1977	Jordan River Mouth	8.3
Conductivity (µS/cm)	162	1970	Webster Rd	483	2003	Birney Creek	356.2

The purpose of 2017 monitoring was to continue leading efforts by Friends of the Jordan River Watershed documenting baseline conditions and tracking nutrient trends over time within the Watershed. Monitoring sites were chosen based on previous work in the upper reaches, near the Jordan River hatchery, and further down in the Watershed near Fair Road. Following are important data that can be used to document nutrient conditions at five sites in the Jordan River Watershed during 2017.

METHODS

Field Data Collection

Overall, 36 water samples were collected in 2017. Thirty of these were from five locations in June, September, and October. Two samples were from the Green River, which was disbanded after June sampling due to rescinded access to the monitoring location. The remaining four samples included one sample from Five Tile Creek, a sample from the hatchery effluent, a *Cladophora* sample from above the hatchery, and a sample from where the effluent meets the Jordan River.

Monitoring was conducted in June, September, and October of 2017 during wet and dry conditions. Dry event monitoring was conducted after a period of dry weather, optimally at least one week with little to no precipitation. Wet event monitoring was conducted within six hours following a large precipitation event defined as at least 0.25 in. of rainfall. Sites chosen for monitoring included upper reaches near the National Fish Hatchery, as well as lower reaches before the Jordan River flows into Lake Charlevoix (Table 2 and Figure 1).

Table 4. Monitoring locations for water quality monitoring in 2017

Water Body	Road Crossing or Description	Latitude	Longitude
Jordan River	Above Fish Hatchery	45.135916°N	85.118497°W
Jordan River	Below Fish Hatchery	45.110005°N	85.126527°W
Bennett Creek	M66, Below trout pond	45.022914°N	84.971812°W
Deer Creek	M-32, before confluence with Jordan River	45.034616°N	84.967354°W
Jordan River	West end of Fair Road at preserve	45.139713°N	85.130070°W

Discharge Monitoring

Discharge was measured along a cross-sectional profile, recording channel width, water depth, and flow velocity at multiple locations in the cross section to calculate the volume of water per unit time passing through the site. Cross-sectional profiles were measured at each site in accordance with United States Geological Survey (USGS) Techniques and Methods 3-A8 of "Discharge Measurements at Gaging Stations" and the use of a flow – velocity meter (Marsh McBirney Flo-mate®).

Water Quality Monitoring

Physio-chemical parameters including dissolved oxygen, specific conductivity, pH, and temperature were monitored in-situ using a Hydrolab MiniSonde MS5 multiprobe (OTT Hydromet, 2010). Water samples for laboratory chemical analysis were collected using the grab sample method. One-liter plastic bottles, pre-washed with 10% sulfuric acid, were filled for each monitoring event, frozen, and transported to the University of Michigan Biological Station (UMBS) chemistry laboratory for analysis. Analysis was meant to provide an overview of major ions present in the Jordan River. As such, samples were analyzed for fluoride (Fl^-), chloride (Cl^-), nitrite (NO_2^-), nitrate (NO_3-), sulfate ($SO^{2-}{}_4$), phosphate (PO_4^{3-}), total suspended solids (TSS), nitrate-nitrogen (NO_3-N), orthophosphates (PO_4-P), total nitrogen (TN), and total phosphorus (TP). This suite of ionic analysis provides an overview that can highlight areas of concern for further investigation. Chemical analysis at UMBS included a triplicate quality control and assurance tests to verify precision for each sample.

Nutrient Loadings

Discharge and nutrient data were combined to estimate daily and annual nutrient loads at sampling locations. Estimated nutrient loading was calculated by multiplying discharge (m^3/s), the measured nutrient concentration (either mg/L or µg/L), and a conversion factor (190.48 for parameters measured in parts per million (mg/L) or 0.1905 for those in parts per billion (µg/L)). The conversion factor converts nutrient concentration at the time of sampling into estimated pounds passing a monitoring location per day. A major assumption of this calculation is discharge does not vary. However, discharge will vary throughout the year, so caution must be taken when expressing nutrient concentrations in pounds per day from this simple calculation. We did sample under wet and dry conditions in an attempt to capture what could be considered 'low' and 'high' loading periods of the Jordan River.

RESULTS

Physio-chemical and discharge

Unsurprisingly, average discharge was greatest at Fair road, the farthest downstream sampling location in the Watershed monitored in 2017 (Table 5). This location is just before the Jordan River flows into Lake Charlevoix. The small Bennett Creek tributary showed the lowest discharge. Most of the physio-chemical measurements were relatively similar to previous monitoring efforts. Average dissolved oxygen was 9.91 – 10.56 mg/L, which is above the standard for cold water fisheries in the State of Michigan. Conductivity was 314 – 356 µS/cm across monitoring locations. Average temperature varied slightly from 10.92°C just below the hatchery to 14.57°C in Deer Creek at M32. This variation could be a product of cool groundwater infiltration near the upper reaches of the Watershed.

Table 5. Average discharge and physio-chemical summary results

Location	Temp (°C)	Dissolved oxygen (mg/L)	Specific Conductivity (µS/cm)	pH (units)	Discharge (cf/s)
Bennett Creek M66	12.81	10.56	355.75	7.97	8.98
Deer Creek M32	14.57	9.91	326.40	8.27	98.37
Fair Road	12.56	10.10	324.57	8.24	380.62
Above Fish Hatchery	11.76	10.52	313.97	8.21	62.01
Below Fish Hatchery	10.92	10.54	335.23	8.17	83.35

Nitrogen and Phosphorus

All five locations monitored in 2017 were well above the U.S. EPA regional reference condition for total nitrogen (TN). Average TN was significantly higher in the upper reaches, near the hatchery, than anywhere else in the Watershed (Table 6). Nitrate (NO_3-) values were more than double above and below the hatchery than all other sites monitored in 2017. One sample taken from 5 Tile Creek, the hatchery effluent, where the hatchery meets the Jordan River, and *Cladophora* from above the hatchery were also elevated in nitrate. Total nitrogen from 5 Tile Creek was similar to locations above and below the hatchery (Table 6). Relatively high total phosphorus (TP) was documented in Bennett Creek. This may be due to one high sample collected under raining conditions. Bennett Creek was the only location above the regional reference condition for total phosphorus (Table 6).

Table 6. Nitrogen and phosphorus results

Location	TN (µg/L)	NO_2^- (mg/L)	NO_3- (mg/L)	NO_3-N (µg/L)	TP (µg/L)	PO_4^{3-} (mg/L)	PO_4-P (µg/L)
Bennett Creek - M66	861.020	0.046	2.163	407.244	26.140	0.028	2.136
Deer Creek - M32	702.992	0.047	1.113	159.502	9.023	0.006	0.981
Fair Road	1965.187	0.047	4.468	633.599	10.172	0.239	0.155
Above Fish Hatchery	3361.591	0.052	9.542	1387.945	10.126	0.008	1.958
Below Fish Hatchery	3658.143	0.053	10.792	1626.765	8.588	0.007	5.871
[1]5 Tile Creek Jordan River Rd	3731.868	0.044	14.241	3217.0419	1.6	*BDL	*BDL
[2]Hatchery Effluent	*N/A	0.070	20.905	4.723	*N/A	0.005	0.002
[2]Effluent Meets Jordan	*N/A	0.068	19.404	4.383	*N/A	0.01	0.003
[2]Above Hatchery *Cladophora*	*N/A	0.043	11.362	2.567	*N/A	0.007	0.002

*BDL = Below Detection Limit, N/A = Sample not tested
[1]Only one sample collected, 10/30/2017
[2]Only one sample collected, 6/21/2017

Chloride, Fluoride, Sulfate, and Total suspended solids

Common water quality ions monitored in 2017 included fluoride, chloride, and sulfate. Chloride was greatest near road crossings, particularly at M66 and M32 where the road crosses Bennett and Deer Creek, respectively. Chloride values would be expected to be higher near roadways due to winter snowfall and road salt application. Sulfates were elevated in the upper reaches of the Jordan River. Values around the National Fish Hatchery, the effluent, and 5 Tile Creek were nearly double than locations further down in the watershed. Total suspended solids were monitored for a description of sediment and other particles in the water column. Total suspended solids (TSS) were greatest in the Bennett Creek location and lowest at Deer Creek. The TSS measurement from Bennett Creek could explain the elevated phosphorus detected as phosphorus tends to adhere to soil particles

Table 7. Ions and suspended solids

Location	Fl^- (mg/L)	Cl^- (mg/L)	SO^{2-}_4 (mg/L)	TSS (mg/L)
Bennett Creek - M66	0.033	7.470	5.360	42.402
Deer Creek - M32	0.046	8.572	5.890	20.761
Fair Road	0.042	6.452	7.320	31.111
Above Fish Hatchery	0.038	4.731	9.387	37.056
Below Fish Hatchery	0.040	4.227	9.686	31.731
[1]5 Tile Creek Jordan River Rd	0.027	4.371	10.188	*N/A
[2]Hatchery Effluent	0.039	5.469	14.385	*N/A
[2]Effluent Meets Jordan	0.036	5.178	13.319	*N/A
[2]Above Hatchery *Cladophora*	0.048	4.152	10.169	*N/A

*N/A = sample not tested
[1]Only one sample collected, 10/30/2017
[2]Only one sample collected, 6/21/2017

Estimated Nutrient Loadings

Fair Road showed the highest estimated nutrient loadings for all ions monitored. This was unsurprising as nutrient loading is largely a function of discharge. The Fair Road location is just upstream of entry into Lake Charlevoix, offering a general representation of ions within the Jordan River Watershed. Although sites monitored above and below the hatchery contained less volume of water flowing, more nitrogen was estimated to be flowing downstream at the two locations.

Table 8. Estimated nutrient loadings in lbs/day

Location	NO3 - load (lbs N /day)	TN - load (lbs N /day)	TP - load (lbs P /day)	Cl - load (lbs/day)	TSS load (lbs/day)
Bennett Creek - M66	11.0389	64.683	3.335	336.945	1611.028
Deer Creek - M32	80.624	699.249	5.213	4751.314	7802.014
Fair Road	1166.009	3742.474	19.369	11983.537	57536.872
Above Fish Hatchery	521.886	866.824	2.476	1493.932	15820.824
Below Fish Hatchery	878.686	1254.825	3.761	1855.829	15015.564

DISCUSSION

Nutrient concentration(s), as they relate to pollution and river health, was the primary water quality parameter of concern for this project. Monitoring locations in the upper reaches of the watershed contained elevated nitrogen when compared to sites further down in the watershed. A small tributary, 5 Tile Creek, also showed high nitrogen values. This small tributary flows into the Jordan River between the above and below Hatchery monitoring locations. Sulfate was elevated in the same area of the watershed, while chloride was elevated near road crossings. Physio-chemical parameters of dissolved oxygen, pH, conductivity, and temperature were similar to previous monitoring efforts and indicate relatively good water quality.

Nutrients

Sulfate was higher at locations higher in the watershed. Naturally, sulfate in water comes from the breakdown of leaves that fall into the river or groundwater passing through rock or soil containing gypsum and other common minerals. Sulfate can also be deposited from the atmosphere. Sulfate can also enter a waterbody from sewage treatment plants, tanneries, pulp and textile mills, as well as runoff from fertilized agricultural lands. Although sulfate is naturally occurring and utilized by plants, the elevated values measured in the upper reaches may be related to land use practices in the ground watershed.

Chloride was slightly higher at Deer Creek and Bennett Creek, along M66 and M32, respectively. Chloride is a common component of road salt application during the winter time. Chloride would then be expected to be slightly higher at monitoring locations near roadways than at forested locations. This was the case as lower chloride locations were found in the upper reaches near heavily forested areas. Although chloride offers no direct harmful impact to aquatic organisms (until around 1000mg/L), chloride is not readily used in biological processes and can accumulate in a watershed. Chloride accumulation in lakes can change the natural turn over processes in the spring and fall season.

Lake turnover is an important natural process that mixes nutrients and dissolved oxygen with the surface and lake bottom. The whole process is governed by water temperature and water density. For example, as surface temperatures cool in the fall, the top layers of water are dense and sink to the bottom while wave action help circulate and mix the water. The same is true in spring as the ice melts the top layer is cooler than the bottom layers and another turnover event occurs. However, chloride increases the density of lake water. As density increases, the ability for lakes to turnover is reduced. Chloride loading from the Jordan River does not appear to be at a significant level high enough to influence Lake Charlevoix processes. Nonetheless, this is one aspect to be aware of when discussing chloride accumulation.

The Jordan River is a very nitrogen rich system. Elevated nitrogen in the Watershed has been documented by independent monitoring events and organizations. Water quality remains high in the Jordan River Watershed, however nitrogen-related water quality issues can arise, particularly if nitrogen inputs increase with other nutrients (i.e. – phosphorus). Most rivers and streams are phosphorus limited. Meaning, biological productivity (i.e. algal growth) and potential water quality issues (i.e. low dissolved oxygen) can be limited by the amount of phosphorus in the water. Low phosphorus and high nitrogen with relatively high water quality indicate the Jordan River could also be phosphorus limited. Future monitoring and research could identify and support or refute this claim. Chloride and Sulfate were also higher at some locations than others.

Nutrients from the Fish Hatchery

Nutrient loading from the Hatchery has been well documented by the MDEQ, U.S. EPA, Tip of the Mitt Watershed Council, and other organizations. The purpose of monitoring near the Hatchery in the upper reaches is not to answer if nutrient pollution from the Hatchery exists. Nutrients are already known to be entering the Jordan from the hatchery. Rather, the monitoring focus is to document the amount of nutrients flowing through this sections of the Jordan River Watershed and identify potential areas of concern for future mitigation. Monitoring in 2017 indicates although the Hatchery releases nutrients (nitrogen and phosphorus in particular) into the Jordan River, the Hatchery is not likely the sole nor main contributor of nutrients, particularly nitrogen, to the Jordan River.

If the hatchery was the main nitrogen source, nitrogen values measured upstream of the hatchery would be much lower than downstream. Nitrogen was measured to be greater below the hatchery. However, nitrogen was measured to be over four times the U.S. EPA reference condition at both locations. This indicates nitrogen is likely entering the Jordan River from the hatchery and other sources, associated with either groundwater or surface runoff. The upper reaches of the Jordan River are heavily forested where surface water is likely percolated and filtered into the ground before reaching the river. Therefore an alternative explanation is groundwater input. Groundwater has previously been described as a considerable source accounting for Jordan River discharge and hypothesized as a source of nitrogen (MIDEQ, 2003, 2004). The ground watershed has been estimated beyond the surface watershed, likely into heavily agricultural areas or nearby septic fields. Water infiltration across these areas could enter the upper reaches of the Jordan River via groundwater. Future monitoring and investigative work could support or refute this claim.

Previous phosphorus monitoring has documented the hatchery does release phosphorus into the Jordan River. Monitoring in 2017 was similar to 2016, where phosphorus measurements below the hatchery were greater than above the hatchery. This indicates the fish hatchery is releasing phosphorus into the Jordan River. The hatchery is permitted to discharge effluent with up to 2,000 pounds of phosphorus per year. As described in the 2016 monitoring report by Tip of the Mitt Watershed Council, a nutrient loading value is largely a function of discharge.

Total phosphorus loading was estimated to be 1,373 pounds per year at the monitoring location downstream of the hatchery. This is well below the NDPES hatchery permit of 2,000 pounds per year. Regardless of the nutrient source, surface waters assimilate nutrients through biological processes. The premise for documenting, monitoring, and regulating nutrient inputs into waterways lies in this very concept.

Biological activity (and associated water quality issues) increases with a surplus of nutrients, water temperature, and available sunlight. An important note is that plants and algae often require a ratio of nutrients. If one increases without a required nutrient counterpart, productivity and growth is stalled. This is common for nitrogen and phosphorus. Given the elevated nitrogen, care should be taken to ensure excess phosphorus does not enter the Jordan River as conditions could be suitable for related water quality issues to develop. Even a modest increase in phosphorus can lead to an undesirable chain of events. The Jordan River is a relatively shallow and very clear river. The clarity allows sunlight to readily penetrate down to the substrate. Temperature may be regulated via cool groundwater entry. However, with a warming climate, potential exists for average water temperatures to increase during the season(s). Nutrients, in particular nitrogen and phosphorus, are the remaining ingredient. Given that nitrogen has been documented as elevated in certain areas for a number of years and the Jordan River retains relatively high water quality, phosphorus might be the limiting nutrient.

Phosphorus Consideration

Phosphorus is commonly the limiting nutrient in freshwater systems as a majority of the natural phosphorus exists in bedrock and trapped in sediments or organic material. Within a river system, phosphorus is available as organic (attached to carbon material, plant or animal tissue) or inorganic (not attached to carbon material) form. When plants and animals die or excrete waste, the associated organic material is decomposed by bacteria and converted back to inorganic phosphorus. Inorganic phosphorus is the readily consumable form by algae and plants. The amount of readily available phosphorus is measured as the amount of “orthophosphate” (PO_4^{3-}). Orthophosphate is one phosphorus attached to four oxygen atoms. As shown in table 6 of this report, orthophosphate can be broken down into the amount of phosphorus (P) in the compound called “orthophosphate-as-phosphorus”, (PO_4-P). The distinction is PO_4-P is the amount of just phosphorus (P) available (without the oxygen). Total phosphorus (TP) is different and is an aggregate measure of both organic and inorganic in a sample. Monitoring in 2017 offers another baseline measure of phosphorus available for uptake in the Jordan River. Continual monitoring of total phosphorus (TP) and orthophosphate (PO_4^{3-}) would be beneficial into the future.

Nitrogen Consideration

Similar to phosphorus, nitrogen exists in various chemical forms in the Jordan River (Table 6). Nitrogen undergoes a complex cycle in rivers, involving numerous types of bacteria and environmental conditions. The nitrogen cycle goes beyond the scope of this report. However generally speaking, the common biologically available forms of nitrogen are ammonia (NH_3), nitrite (NO_2^-), and nitrate ($NO3^-$). Ammonia (NH_3) is converted to nitrite (NO_2^-) that is then converted to nitrate (NO_3^-) and readily assimilated by plants. As these forms are biologically utilized, they are often common constituents of fertilizers but also find their way into surface waters via septic drain fields, and natural soil erosion. Monitoring for these different forms of nitrogen can offer insight to potential sources of elevated nitrogen as large discrepancies within a watershed can be a result of local land use practices. Of particular note are the levels of nitrate and nitrate – nitrogen observed in the upper reaches of the Jordan River near the Hatchery and in 5 Tile Creek. These values were three to four times greater than anywhere else monitored in 2017. Nitrate and nitrite are highly soluble in water and when not used can leach into groundwater.

Excessive nitrates in well drinking water can be harmful to infants and pregnant women. Nitrate is one of the most common groundwater contaminants in rural areas. The problem arises as excess nitrate consumption can cause a condition known as methemoglobinemia, or “blue baby syndrome”. Blood in the human body contains an iron-based compound called hemoglobin. The hemoglobin is what carries oxygen to vital parts of the body. When the body converts ingested nitrate into nitrite, the hemoglobin is converted to methemoglobin, which cannot carry oxygen. Newborn infants are the most at risk while adults tend to not feel the effects as they have more enzymes readily converting methemoglobin back into hemoglobin. Nonetheless, the U.S. EPA has a drinking water standard of 10mg/L for nitrates. Monitoring locations in the upper reaches of the Jordan River did contain nitrates above this threshold (Table 6). Above the Hatchery nitrates were just below the EPA standard at 9.542mg/L. Nitrates were above the 10mg/L EPA drinking water standard below the Hatchery, in 5 Tile Creek, as well as the Hatchery effluent and where the effluent meets the Jordan River. The Jordan River is not a direct drinking water source. However, the elevated nitrates in the surface water does potentially raise a question of well-water in the area connected to the groundwater as a drinking water source. Future investigation could support or refute any concern for well-water and subsequent testing in the area.

Conclusion and Recommendations

Baseline conditions within areas of the Jordan River Watershed have now been monitored by Tip of the Mitt Watershed Council for two years. Overall in 2017, nitrogen was elevated in the upper reaches near the National Fish Hatchery and in 5 Tile Creek. Values were similar above and below the Hatchery, indicating the Hatchery is not the main nor sole contributor of nutrients. Identifying the source of nitrogen influx would be valuable information for monitoring and to help mitigate any future water quality issues. Additionally, identifying areas of the River with high nutrient uptake and retention would be valuable for conserving areas in the Watershed. High uptake areas in the Watershed are where nutrients are readily used for biological productivity and show where nutrients in a river system are readily being utilized. These areas could provide insight to 'hot spots' in the watershed that may show the first signs of water quality issues. Although few concerns have been documented in the Jordan River, continued monitoring (in particular phosphorus) is valuable for detecting issues within the Watershed. Below is a list of potential actions and recommendations based on monitoring in the Jordan River Watershed.

RECOMMENDATIONS

1. Share the results of this study. Friends of the Jordan River is free to share this document and Tip of the Mitt Watershed Council would also like to publicize results of the monitoring efforts with governmental agencies and other environmental organizations.

2. Investigate sources of groundwater-fed nutrients, in particular nitrogen. A thorough understanding of this issue will inform possible mitigation actions and partnerships with agricultural operations and local municipalities.

3. Investigate nutrient uptake throughout the Jordan River's channel to identify areas with high and low nutrient uptake. Evaluate river habitat upstream and downstream of the hatchery to assess algal/plant growth and other possible effects of elevated nutrient concentrations. One option is to contact the University of Michigan Biological Station to explore the possibility of a student project studying nutrient dynamics within the system.

4. Explore possible options for mitigating the impacts of the Patricia Lake impoundment, including dam removal.

5. Work with the hatchery to reduce pollutant loads to receiving water bodies, where feasible. New technologies may further reduce nutrient concentrations with minimal investment on the aquaculture operations part.

6. Engage in watershed management through involvement in the Lake Charlevoix Watershed Advisory Committee.

7. Develop and implement a plan to reduce nutrient inputs to Bennett and Deer Creeks by working with agricultural producers to implement BMPs. Extend outreach and education efforts to all agricultural producers and hobby farms, with a focus on the largest agricultural operations. Specifically, these producers could volunteer to be verified

through the Michigan Agricultural Environmental Assurance Program, which is a comprehensive, voluntary, proactive program designed to reduce farmers' legal and environmental risks through a three-phase process: 1) education; 2) farm-specific risk assessment and practice implementation; and 3) on-farm verification that ensure the farmer has implemented environmentally sound practices.

8. Work with local municipalities to identify potential septic system problems or illicit connections to the Jordan River ground watershed.

9. Work with MDOT and county road commissions to minimize nonpoint source pollution (i.e. sediment) entry at road/stream crossings. Direct road runoff away from surface waters where feasible. Municipal and private stormwater sources may exist as well.

10. Maintain river protection efforts by commenting on MDEQ permit applications, remaining active in local government, and ensure upholding of the Wild and Scenic Rivers Act.

11. Assess algal communities in Lake Charlevoix to determine if changes are occurring as a result of excessive nitrogen inputs from its tributaries.

12. Repeat this monitoring project every three to five (maximum of eight) years to evaluate changes in the Jordan River. Expand the monitoring to include additional tributaries. Select monitoring sites in sub watersheds up and downstream of best management practice installations in the watershed to help assess longitudinal changes.

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APPENDIX

Table 9. Total Nitrogen monitoring historical records within the Jordan River Watershed

Location	Data Sources	Time Period	Num. of Samples	Low (μg/L)	High (μg/L)	Avg. (μg/L)
Hatchery, downstream	Tip of Mitt	2016	6	2642.2	5,586	4,318
Hatchery, upstream	Tip of Mitt	2016	6	2772.4	4,972	3,543
5 Tile Creek, River Rd.	DEQ	2003	1	2900	2,900	2,900
Unnamed Creek, Pinney Bridge	DEQ	2003	1	2800	2,800	2,800
Hatchery, discharge	DEQ*	1977-78	12	2230	3,050	2,422
6 Tile Creek, Spring Pond	DEQ*	1977-1978	12	2042	2,205	2,106
5 Tile Creek, Spring Pond	DEQ*	1977-1978	12	1873	2,283	2,028
Hatchery, downstream	DEQ	2003	1	1920	1,920	1,920
Birney Creek	DEQ	2003	1	1790	1,790	1,790
Hatchery, upstream	DEQ	2003	1	1610	1,610	1,610
Mill Creek	DEQ	2003	1	1540	1,540	1,540
Graves Crossing	DEQ	2003	1	1370	1,370	1,370
Webster Rd.	DEQ	2003	1	1270	1,270	1,270
Green River, Pinney Bridge	DEQ*	1972-78, 2003	15	710	1,740	1,122
Jordan River Rd.	DEQ*	1977-78	12	952	1,252	1,095
Old State Rd.	DEQ*	1973-75	20	860	1,310	1,085
Fair Rd.	Tip of Mitt	2004-2013	4	745	1,567	1,052
Bridge St.	DEQ*	1973-78, 1993	17	680	1,979	1,019
Rogers Rd.	DEQ*	1974-1978	24	781	1,685	995
Bennet Creek	DEQ	2003	1	950	950	950
Bennett Creek, M66	Tip of Mitt	2016	6	669.14	1,052	896
Landslide Creek, Pinney Bridge	DEQ	2003	1	650	650	650
Deer Creek, M32	Tip of Mitt	2016	6	310.52	777	465
Green River, Green River Rd.	DEQ	2003	1	460	460	460
Green River, Pinney Bridge Rd.	DEQ	2003	1	460	460	460
Cascade Creek	DEQ	2003	1	440	440	440
Green River, Pinney Bridge	Tip of Mitt	2016	6	294.46	402	350
Landslide Creek, Cascade Rd.	DEQ	2003	1	325	325	325

Table 10. Total Phosphorus monitoring historical records within the Jordan River Watershed

Location	Data Sources	Time Period	Num. of Samples	Low (µg/L)	High (µg/L)	Avg. (µg/L)
Hatchery, discharge	DEQ*	1977-1978	12	69	550	164.2
Graves Crossing	DEQ	2003	1	120	120	120
Old State Rd.	DEQ*	1967-1975	22	0.0†	100	29.5
Birney Creek	DEQ	2003	1	22	22	22
Bridge St.	DEQ*	1968-77, 1993	22	7	50	20.1
Rogers Rd.	DEQ	1968-78	31	0	70	17.2
Landslide Creek, Cascade Rd.	DEQ	2003	1	17	17	17
Marvon Creek, Rogers Rd.	DEQ	2003	1	17	17	17
Pinney Bridge	DEQ*	1968-78, 2003	16	9	33	15.1
Hatchery, downstream	DEQ	2003	1	14	14	14
Deer Creek, M32	DEQ*	1974-78, 2003	25	4	20	13.5
Mill Creek	DEQ	2003	1	13	13	13
Unnamed creek, Pinney Bridge	DEQ	2003	1	13	13	13
Collins Creek	DEQ	2003	1	13	13	13
Landslide Creek, Pinney Bridge	DEQ	2003	1	12	12	12
Eaton Creek, Deer Creek	DEQ	2003	1	12	12	12
Webster Rd.	DEQ	2003	1	11	11	11
Hatchery, downstream	Tip of Mitt	2016	6	7.4	16.8	10.75
Bennett Creek, M66	Tip of Mitt	2016	6	5.1	16.9	10.43
Bennet Creek	DEQ	2003	1	10	10	10
Deer Creek, Barber Rd.	DEQ	2003	1	10	10	10
Green River, Green River Rd.	DEQ	2003	1	9	9	9
Green River, Pinney Bridge	Tip of Mitt	2016	6	3.7	13.4	8.28
Cascade Creek	DEQ	2003	1	8	8	8
Green River, Pinney Bridge Rd	DEQ	2003	1	8	8	8
Deer Creek, Bergman Rd.	DEQ	2003	1	8	8	8
Deer Creek, Marvon Rd.	DEQ	2003	1	8	8	8
Deer Creek, Pearsall Rd.	DEQ	2003	1	8	8	8
Deer Creek, M32	Tip of Mitt	2016	6	4.6	8.7	7.5
5 Tile Creek, River Rd.	DEQ	2003	1	7	7	7
Deer Creek, CR626	DEQ	2003	1	7	7	7
Hog Creek, Deer Creek	DEQ	2003	1	7	7	7
Jordan River (Site 01)	DEQ*	1977-1978	12	2	18	6.7

Fair Rd.	Tip of Mitt	2004-2013	4	5.3	8.3	6.2
Hatchery, upstream	DEQ	2003	1	6	6	6
Hatchery, upstream	Tip of Mitt	2016	6	1.5	11.5	5.52
5 Tile Creek, Spring	DEQ*	1977-1978	12	2	7	3.5
6 Tile Creek, Spring	DEQ*	1977-1978	12	1	6	3.2

Table 11. Conductivity monitoring historical records within the Jordan River Watershed

Location	Data sources	Time Period	Number of Samples	Low (µS/cm)	High (µS/cm)	Avg. (µ/cmS)
Birney Creek	DEQ	2003	1	483.0	483.0	483.0
Bennett Creek, M66	Tip of Mitt	2016	6	419.1	465.1	431.8
Deer Creek, Marvon Rd.	DEQ	2003	1	389.0	389.0	389.0
Deer Creek, Pearsall Rd.	DEQ	2003	1	388.0	388.0	388.0
Deer Creek, M32	Tip of Mitt	2016	6	375.7	403.3	384.1
Mill Creek	DEQ	2003	1	384.0	384.0	384.0
Landslide Creek, Cascade Rd.	DEQ	2003	1	361.0	361.0	361.0
Hatchery, downstream	Tip of Mitt	2016	6	340.8	377.1	359.7
Hatchery, downstream	DEQ	2003	1	356.0	356.0	356.0
Landslide Creek, Pinney Bridge	DEQ	2003	1	355.0	355.0	355.0
Hatchery, upstream	DEQ	2003	1	353.0	353.0	353.0
Hatchery, upstream	Tip of Mitt	2016	6	319.3	380.4	352.5
Bridge St.	DEQ*	1973, 1993	9	320.0	368.0	349.9
Rogers Rd.	DEQ*	1974-1975	12	320.0	360.0	343.3
Green River, Pinney Bridge	Tip of Mitt	2016	6	330.6	358.9	339.6
Graves Crossing	DEQ*, USGS	1968-69, 2003	12	300.0	400.0	339.3
Cascade Creek	DEQ	2003	1	335.0	335.0	335.0
Old State Rd.	DEQ*, USGS	1967-1975	19	295.0	355.0	333.4
Deer Creek, M32	DEQ*	1974-1975	12	230.0	365.0	330.0
Fair Rd.	Tip of Mitt	2004-2013	4	279.2	359.0	325.1
Jordan River Rd.	USGS	1971	1	325.0	325.0	325.0
Pinney Bridge	DEQ*, USGS	1971, 2003	6	295.0	358.0	324.7
Webster Rd.	DEQ*, USGS	1966-71, 2003	32	162.0	380.0	314.5
Deer Creek, CR 626	DEQ	2003	1	291.0	291.0	291.0