**LITTLE MANITOWOC RIVER WATER QUALITY REPORT, 2013 – 2015**

**INTRODUCTION**

The purpose of this report is to summarize the water quality data collected at four sites in the Little Manitowoc River during the summers of 2013-2015. In general, the effects of rain events could be clearly observed on the graphs of the water quality data. The differences between baseflow (non-rain time periods) and stormflow (24-72 hours following a rain event of greater than 0.5 inch) levels for most water quality parameters were significantly different, while differences between the sites was not. This suggests that runoff from a developed watershed during rain events are impacting the water quality of the Little Manitowoc River.

**STUDY AREA**

The Little Manitowoc River is approximately 14.7 km (9.13 miles) long and flows into Lake Michigan about one mile north of the mouth of the Manitowoc River, in the city of Manitowoc. The total length of the river, including tributaries, in the watershed is 38.2 km (23.74 mi) and the total area of the watershed covers 36.1 square km (22.43 mi2; McKay et al. 2012). Near the mouth of the Little Manitowoc River is a 38 acre coastal wetland that is expected to be restored in the summer of 2016. Water quality samples were collected at four sites in the lower Little Manitowoc River (Figure 1). The Waldo Boulevard site is closest to the mouth of the river at Lake Michigan and located on the northern edge of the restoration project. The next site upstream is Reed Avenue followed by the Magnolia Avenue site. The County Road B site is furthest upstream site from Lake Michigan. These sites are all located in the lower two miles of the river.

The Little Manitowoc River Watershed is 58.17% agricultural and 30.46% developed (Table Appendix C – 1). The agricultural land is primarily upstream and the developed land downstream closer to the mouth in the City of Manitowoc. Compared to other smaller rivers in southern Manitowoc County, the Little Manitowoc River has more developed land than the other watersheds (Figure Appendix C - 1).

**METHODS**

Student interns working with faculty at UW Manitowoc collected water samples during the summers of 2013, 2014, and 2015 at four sites on the Little Manitowoc River (Figure 1). Samples were taken weekly late May through the end of August. Samples were also taken following rain events greater than a half inch at both 24 and 48 hours (Tables 1 and 2). Rain event sample dates are labeled as “stormflow” while non-rain event sample dates are labeled as “baseflow” in this report.

Physical indicators were measured by field probes –

•Dissolved Oxygen (YSI 550A DO Probe)  
•Temperature/pH  
•Turbidity (LaMotte 2020 we)  
•Stream Velocity (Global Water Instrumentation, Inc)  
•Conductivity

Nutrient indicators –

•Ammonia (NH3/NH4) measured with Hach field kit for Ammonia Nitrogen  
•Total Orthophosphate (TP) and Total Dissolved Phosphate (TDP)  
•Acid hydrolysis with H2SO4  
•Colorimetric analysis via ammonium molybdate-stannous chloride method

Biological Indicators –

•E. coli fecal coliform analysis (Colilert-24)  
•Aquatic macroinvertebrate survey via Water Action Volunteers (WAV) Stream

Monitoring Program biotic indexmethod (subsamples only; 2013 and 2014)

(See Appendix A).

•Wetland Fish Survey (2014 and 2015; See Appendix B)

Statistical Analysis -

Differences in site, year, and rain events were tested using the standard least squares analysis. Mean monthly values between sites were also tested using a blocked Analysis of Variance (ANOVA). The block design allowed for testing over all three years, when there was some question about the year to year variation (e.g., total phosphorus). All statistical analyses were done in JMP Pro Version 11 (SAS Institute Inc., Cary, NC). Mapping and watershed analysis completed using ArcMap Version 10.1 (ESRI, Redlands, CA).

**Table 1.** Number of days sampled each summer in the Little Manitowoc River, Summer 2013 – 2015. Storm events are rainfalls greater than a half inch, sampled at both 24 and 48 hours.

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**Table 2.** Sample dates for the Little Manitowoc River, Summer 2013 – 2015. Storm events are rainfalls greater than a half inch, sampled at both 24 and 48 hours.



**RESULTS**

**Temperature**

* Water temperature influences both biological activity and growth, including fish, insects, zooplankton, and phytoplankton have a preferred temperature range in which they thrive (USGS 2015).
* Water temperature also influences water chemistry, especially dissolved oxygen, which have a lower capacity to hold oxygen at higher temperatures (USGS 2015).
* Little Manitowoc River temperatures were significantly different by site (Table 3), however temperatures were not significantly different by year.
* In general, sites located upstream had cooler temperatures while sites located further downstream, at the mouth at Lake Michigan, had warmer temperatures.

**Table 3.** Average temperature (oC) for all three years at the four sites in the Little Manitowoc River. The letters in Column 3 are the results of the Standard Least Squares analysis, where sites connected by the same letter are not significantly different.

|  |  |  |
| --- | --- | --- |
| **Site** | **Temperature (oC)** |  |
| Waldo Blvd. | 19.5 | A |
| Reed Ave. | 18.7 | AB |
| Magnolia Ave. | 17.9 | BC |
| County Rd. B | 16.8 | C |

**Turbidity**

* Turbidity is defined as the presence of suspended solids in water (Lind 19) and is reported in NTU. Lower turbidity levels mean that the water is clearer, which generally means there is better water quality.
* In general, Little Manitowoc River baseflow turbidity levels (Figure 2) were lower than stormflow turbidity levels (Figure 3).
* In 2015, both baseflow and stormflow turbidity levels were lower than levels in 2013 and 2014.
* Stormflow turbidity levels in 2013 and 2014 were significantly different from all others, including 2015 stormflow (Table 4).
* Turbidity levels were not significantly different between sites.

**Table 4.** Average turbidity levels (NTU) for baseflow and stormflow, separated by year, for the Little Manitowoc River. The letters in Column 3 are the results of the Standard Least Squares analysis, where sites connected by the same letter are not significantly different.

|  |  |  |  |
| --- | --- | --- | --- |
| **Year** | **Rain** | **Turbidity (NTU)** |  |
| 2014 | Yes | 42.0 | A |
| 2013 | Yes | 40.6 | A |
| 2013 | No | 9.0 | B |
| 2014 | No | 7.8 | B |
| 2015 | Yes | 5.7 | B |
| 2015 | No | 3.1 | B |

**Total Phosphorus**

* Phosphorus is an essential nutrient for both aquatic plants and animals. In most fresh water systems, phosphorus is often the nutrient in lowest concentrations. Therefore, even a small increase in phosphorus can cause “accelerated plant growth, algae blooms, low dissolved oxygen levels, and the death of certain fish, invertebrates, and other aquatic animals” in streams, rivers, and lakes (EPA 2015).
* There are natural (soil and rocks) and human sources of phosphorus, including, wastewater treatment plants, runoff from fertilized lawns and cropland, failing septic systems, runoff from animal manure storage areas, disturbed land areas, drained wetlands, and water treatment (EPA 2015).
* Total phosphorus concentrations measure all forms of phosphorus in the water and is the sum of the soluble phosphorus (PO4; dissolved phosphorus) and particulate phosphorus (Horne & Goldman 155). Soluble phosphorus is the amount of phosphorus available for plants and algae to take up.
* For this report, total phosphorus levels were analyzed and are reported in mg/L.
* In Wisconsin, small streams and rivers are considered impaired if total phosphorus levels exceeds 0.075 mg/L. Large rivers, such as the Fox River, are considered impaired at 0.1 mg/L (NR 102.06 (3) WDNR).
* All three years have baseflow total phosphorus concentrations greater than 0.075 mg/L.
* In the Little Manitowoc River, baseflow phosphorus concentrations (Figure 4) were lower than stormflow concentrations (Figure 5).
* Because the 2013 total phosphorus concentrations were lower than the other years, to see the variation, separate graphs were made at the lower scale

(Figure 6).

* Figure 7 is a statistical explanation on the total phosphorus distributions in Figures 8 and 9. The 2014 baseflow total phosphorus levels had the smallest range of values, 2015 was a larger range, and 2014 had the largest range of concentrations (Figure 8). The same trend was seen in the stormflow data (Figure 9).
* Mean (average) and median (the central number in a distribution of data) values are included because outliers have less influence on median than on the average. Total phosphorus concentrations at each site are reported in Table 5. The Waldo boulevard site had higher values for both baseflow and stormflow total phosphorus levels.
* Total phosphorus was not significantly different by site. Significant differences were seen between years and between baseflow and stormflow levels. 2014 stormflow levels were significantly different from all others (Table 6).

**Table 5.** Baseflow and stormflow mean and median total phosphorus concentrations (mg/L) by year.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Baseflow |  |  |  |  |  |
|  | 2013 |  | 2014 |  | 2015 |  |
|  | Mean | Median | Mean | Median | Mean | Median |
| County Rd. B | 0.05 | 0.05 | 0.36 | 0.29 | 0.14 | 0.12 |
| Magnolia Ave. | 0.06 | 0.07 | 0.39 | 0.35 | 0.21 | 0.16 |
| Reed Ave. | 0.06 | 0.05 | 0.46 | 0.18 | 0.14 | 0.15 |
| Waldo Blvd. | 0.08 | 0.06 | 0.65 | 0.38 | 0.25 | 0.19 |
|  |  |  |  |  |  |  |
|  | Stormflow |  |  |  |  |  |
|  | 2013 |  | 2014 |  | 2015 |  |
|  | Mean | Median | Mean | Median | Mean | Median |
| County Rd. B | 0.11 | 0.13 | 1.62 | 0.85 | 0.45 | 0.28 |
| Magnolia Ave. | 0.12 | 0.12 | 1.49 | 1.62 | 0.33 | 0.25 |
| Reed Ave. | 0.19 | 0.21 | 1.11 | 0.96 | 0.44 | 0.15 |
| Waldo Blvd. | 0.24 | 0.21 | 1.10 | 0.88 | 0.86 | 0.55 |

**Table 6.** Average baseflow and stormflow total phosphorus levels (mg/L), separated by year, for the Little Manitowoc River. The letters in Column 3 are the results of the Standard Least Squares analysis, where sites connected by the same letter are not significantly different.

|  |  |  |  |
| --- | --- | --- | --- |
| **Year** | **Rain** | **Total phosphorus (mg/L)** |  |
| 2014 | Yes | 1.33 | A |
| 2015 | Yes | 0.52 | B |
| 2014 | No | 0.49 | B |
| 2015 | No | 0.18 | BC |
| 2013 | Yes | 0.17 | BC |
| 2013 | No | 0.06 | C |

**Relationship of Turbidity and Phosphorus**

* Phosphorus is readily bound to soil particles and large amounts of total phosphorus in rivers and streams results from erosion of soil in floods and storms (Horne & Goldman 153).
* In the Little Manitowoc River, there was not a relationship between turbidity levels and phosphorus concentrations at most sites in most years (Table 7).
* When looking at year and baseflow/stormflow, turbidity levels correlated with phosphorus levels during baseflow 2013, stormflow 2013, and stormflow 2014 (Table 8).

**Table 7.** Significant regression results of total phosphorus vs turbidity in baseflow and stormflow events by site.



**Table 8.** Significant regression results of total phosphorus vs turbidity in baseflow and stormflow events by year for all sites combined.

|  |  |  |
| --- | --- | --- |
| Storm | Year | P value |
| No | 2013 | 0.0293 |
| No | 2014 | N |
| No | 2015 | N |
| Yes | 2013 | 0.0001 |
| Yes | 2014 | 0.0163 |
| Yes | 2015 | N |

**Nitrogen (NH4)**

* Ammonia (NH4) is the preferred form of nitrogen for plant growth in aquatic systems (Horne & Goldberg 133).
* NH4 is reported in mg/L and is commonly present in concentrations less than 1 mg/L (Lind, 84).
* In the Little Manitowoc River, stormflow NH4 levels were only slightly higher than baseflow NH4 levels (Figure 10 & 11).
* NH4 levels for 2013 stormflow were significantly different from all other sampling periods (Table 9).
* NH4 levels were not significantly different by site.
* While 2013 stormflow levels were the highest, the 2015 stormflow levels were the lowest of all sample times.

**Table 9.** Average baseflow and stormflow Ammonia (NH4) levels (mg/L), separated by year, for the Little Manitowoc River. The letters in Column 3 are the results of the Standard Least Squares analysis, where sites connected by the same letter are not significantly different.

|  |  |  |  |
| --- | --- | --- | --- |
| **Year** | **Rain** | **Ammonia (NH4; mg/L)** |  |
| 2013 | Yes | 0.55 | A |
| 2014 | Yes | 0.35 | B |
| 2013 | No | 0.26 | BC |
| 2014 | No | 0.22 | C |
| 2015 | No | 0.20 | C |
| 2015 | Yes | 0.16 | C |

***E. Coli***

* Escherichia coli (*E. coli*) are bacteria that, when found in water in high concentrations, can be an indicator that pathogenic bacteria may be present. Pathogenic bacteria can cause serious illness in humans. *E. coli* is reported as CFU/ml or MPN/ml (used interchangeably).
* The EPA recommends that advisories at beaches be issued when *E. coli* levels in the water reach 235 CFU/100ml (WDNR)
* In the Little Manitowoc River, differences between the sites were not observed. *E. coli* levels were significantly different only between 2014 and 2015 (Table 10).
* Baseflow and stormflow *E. coli* levels were significantly different (Table 11).
* In general, baseflow *E. coli* levels (Figure 12) were lower than stormflow *E. coli* levels (Figure 13).
* There was a large peak in *E. coli* concentrations at the Waldo Boulevard site in late August 2015.
* When analyzing *E. coli*, the detection limit for the method used is 2419.6 CFU/100ml. When samples reach the limit, they are recorded as 2419.6 CFU/100ml and it is not known how much larger the count for the sample could actually be. The statistical analyses used the detection limit, which adds bias to the testing but does not affect the numbers that exceed health standards. The number of samples exceeding the detection limit can be seen in Table 12.
* More stormflow samples exceed the detection limit than baseflow samples.
* All stormflow samples, except one, exceeded the advisory beach warning level. Approximately one third of baseflow samples fell within the safe beach *E. coli* level (Table 12).

**Table 10.** Comparison of *E. coli* concentrations by year for all sites combined. The letters in Column 3 are the results of the Standard Least Squares analysis, where sites connected by the same letter are not significantly different.

|  |  |  |  |
| --- | --- | --- | --- |
| Year | Level |  | *E. Coli* (CFU/100 ml) |
| 2014 | A |  | 1396.9 |
| 2013 | A | B | 1231.4 |
| 2015 |  | B | 1036.5 |

**Table 11.** Results all sites and years grouped of E. coli in baseflow and stormflow events. The letters in Column 3 are the results of the Standard Least Squares analysis, where sites connected by the same letter are not significantly different

|  |  |  |  |
| --- | --- | --- | --- |
| Rain y/n | Level |  | *E. Coli* (CFU/100 ml) |
| Y | A |  | 1878.7 |
| N |  | B | 564.5 |

**Table 12.** Mean *E. coli* values by site and year for the Little Manitowoc River. Advisory level (235 CFU/100 ml) based on standards for Wisconsin beaches. Maximum detection level was 2419.6 CFU/100 ml.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Site | Year | Mean Baseflow | # Samples | # Below Advisory Level | # Exceed Detection Limit | Mean Stormflow | # Samples | # Below Advisory Level | # Exceed Detection Limit |
| County Rd. B | 2013 | 429.9 | 10 | 1 | 0 | 1843.2 | 4 | 0 | 2 |
|  | 2014 | 762.1 | 12 | 2 | 1 | 1850.4 | 5 | 0 | 3 |
|  | 2015 | 490.2 | 10 | 2 | 0 | 1516.7 | 8 | 0 | 0 |
| Magnolia Ave. | 2013 | 401.7 | 10 | 3 | 0 | 2115.5 | 4 | 0 | 2 |
|  | 2014 | 625.0 | 12 | 3 | 1 | 2008.8 | 5 | 0 | 4 |
|  | 2015 | 522.4 | 10 | 2 | 0 | 1605.9 | 7 | 0 | 0 |
| Reed Ave. | 2013 | 426.5 | 10 | 5 | 0 | 2168.1 | 4 | 0 | 3 |
|  | 2014 | 691.3 | 12 | 3 | 1 | 2089.7 | 5 | 0 | 4 |
|  | 2015 | 479.3 | 10 | 2 | 0 | 1631.9 | 7 | 1 | 0 |
| Waldo Blvd. | 2013 | 498.3 | 10 | 4 | 0 | 1967.9 | 4 | 0 | 2 |
|  | 2014 | 901.9 | 10 | 4 | 2 | 2246.3 | 5 | 0 | 3 |
|  | 2015 | 546.0 | 10 | 3 | 0 | 1500.0 | 8 | 1 | 0 |

**Statistical Analysis of Mean Monthly Averages**

Table: Site comparison results from blocked ANOVA of mean monthly values for summer 2013-2015 in the Little Manitowoc River. When significant, the > symbol indicates the highest value.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Baseflow |  |  |  |  | Stormflow |  |  |  |
|  | Waldo Blvd. | Reed Ave. | Magnolia Ave. | County Rd. B |  | Waldo Blvd. | Reed Ave. | Magnolia Ave. | County Rd. B |
| Turbidity | ns |  |  |  |  | ns |  |  |  |
| Total Dissolved Phosphorus | ns |  |  |  |  | ns |  |  |  |
| Total Phosphorus | ns |  |  |  |  | ns |  |  |  |
| Ammonia (NH3) | A (>) | AB | AB | B |  | ns |  |  |  |
| Ammonia (NH4) | A (>) | AB | B | B |  | ns |  |  |  |
| *E. coli* | ns |  |  |  |  | ns |  |  |  |

We used a block design to compare six water quality variables. Although there were some concerns about the TP values in 2014, the analysis compared the differences between sites for each block (month). This allowed for the comparison of sites using all years and showed that most of the variables did not statistically differ between sites. There was a trend with the most downstream site (Waldo) having higher values than the most upstream sites for NH3 (County Rd. B) and for NH4 (Country Rd. B and Magnolia Ave.).

**CONCLUSION**

Turbidity, total phosphorus, and nitrogen trends in the water quality data had similar statistical patterns for the three years. Showing no differences in the sites and significant differences in between baseflow and stormflow levels. Differences were also seen between years, mainly driven by 2013 and 2014 levels. Total phosphorus and E. coli levels exceeded levels at which the water is considered unimpaired.

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**APPENDIX A – Little Manitowoc River Biotic Index**

The biotic index is a benthic macroinvertebrate index, using the organisms that live in or on the bottom of the river. Macroinvertebrates are organisms without a spine and large enough to be seen by the naked eye, including flatworms, snails, clams, crayfish, and insects.

The biotic index followed the Water Action Volunteers (WAV) Stream Monitoring Program biotic indexmethod (subsamples only). This was performed in 2013 and 2014 only.

The index is a measure of stream health determined by the presence of specific benthic macroinvertebrates, which are indicators of water quality. Organisms that are less tolerant of degraded water quality will be present in lower numbers while tolerant species will be more abundant. By determining which oxygen tolerant organism are present, the stream can be given a numerical score, the Biotic Index value, which ranges from poor to excellent stream quality. Unlike water quality measurements (measurements at a single point in time), biotic indices provide some insight into the overall conditions of water and habitat over a longer time period (i.e., during the life of the organisms).

The WAV method was developed to make statewide comparisons and may not be specific enough to make comparisons between sites of the same river or rivers close to each other. A more complete understanding of the habitat quality in these sites would require a more in depth macroinvertebrate study.

The values obtained for the Little Manitowoc River in 2013 and 2014 indicated that the water quality and habitat in the river was poor. County Road B had a fair index both years and this may be attributed to the differences in habitat between the sites. County Road B has more favorable habitat conditions (fast moving riffle) than the other locations (slow moving pools).

**Table Appendix A-1.** Benthic Index values and data for the Little Manitowoc River sites for the summers of 2013 and 2014.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Site** | **Year** | **# Samples** | **Range** | **Average** | **Median** | **Index** |
| Waldo | 2014 | 4 | 1.71 - 2.0 | 1.87 | 1.88 | Poor |
| Reed | 2014 | 4 | 1.83 - 2.18 | 2.01 | 2.01 | Poor |
| Magnolia | 2014 | 3 | 1.86 - 2.4 | 2.16 | 2.22 | Fair |
| Cty Rd B | 2014 | 4 | 2.25 - 2.55 | 2.38 | 2.37 | Fair |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| Waldo | 2013 | 10 | 1.33 - 2.3 | 1.87 | 1.88 | Poor |
| Reed | 2013 | 10 | 1.57 - 2.27 | 1.85 | 1.9 | Poor |
| Magnolia | 2013 | 10 | 1.75 - 2.5 | 2.04 | 1.9 | Poor |
| Cty Rd B | 2013 | 10 | 1.77 - 3 | 2.31 | 2.28 | Fair |

**APPENDIX B - Little Manitowoc River wetland fish community**

Table B-1: Fish captured in Little Manitowoc River between Memorial Drive and Waldo Boulevard.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Common Name** | **Species** | **Nonnative** | **10/2014** | **7/2015** | **10/2015** |
| Alewife | *Alosa pseudoharengus* | Y | 1 |  |  |
| Banded Killifish | *Fundulus diaphanous* |  | 35 |  |  |
| Brook Stickleback | *Culaea inconstans* |  | 4 | 2 | 2 |
| Common Carp | *Cyprinus carpio* | Y |  | 1 |  |
| Northern Pike | *Esox Lucius* |  |  |  | 2 |
| Round Goby | *Neoglobius melanostomus* | Y | 66 | 18 | 2 |
| Smallmouth Bass | *Micropterus dolomieu* |  | 1 |  |  |
| Spottail Shiner | *Notropis hudsonius* |  | 8 |  |  |
| White Sucker | *Catastomus commersonii* |  | 3 | 1 |  |

Methods

Fish were sampled in 2014 and 2015 with a beach seine. In 2014 25 ft and 50 ft seines were used, while all 2015 sampling was done with a 25 ft seine. Sampling took place between Memorial Drive and Waldo Boulevard. Sampling will also be done in 2016 with fyke nets both downstream and upstream of Waldo Blvd.

Results

Limited sampling in the Little Manitowoc River has found nine species (6 native and 3 nonnative). More extensive sampling is likely to produce more species. Juvenile species (e.g., white sucker, smallmouth bass) indicate that the wetland complex in the Little Manitowoc provides spawning and nursery habitat. We captured several species that are indicators of good water quality (Seilheimer and Chow-Fraser 2007) such as the Banded Killifish, Brook Silverside and Smallmouth Bass. An adult Pacific salmon was observed in the Little Manitowoc in 2014, during sampling but not captured. Spawning was confirmed within the system when a juvenile Coho salmon was captured in August 2014 in the Little Manitowoc at Highway 310.

The lack of wetland habitat along the Lake Michigan coast near Manitowoc (especially to the south), means that the marsh in the Little Manitowoc, though small in size, is an important and unique fish habitat. Habitat restoration will enhance the fish assemblage within the wetlands and also at the larger scale outside the site. Many Great Lakes species rely on wetlands for part of their life cycle or for producing their prey (Jude and Pappas 1992).

References  
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