Monitoring to Address 7 of 11 BUI's – Milwaukee River Estuary AOC
Task 2: Water Quality Sampling
Final Project Report

Final Report for the Great Lakes Restoration Initiative Grant #GL-00E00607-0

Funded by the Great Lakes Restoration Initiative and the United States Environmental Protection Agency

Ozaukee County Planning and Parks Department
121 West Main Street
PO Box 994
Port Washington, WI 53074

Authors:

Andrew T. Struck, Matt Aho, Luke Roffler, Ryan McCone, Beth Stuhr, Kristina Kroening, and Tom Dueppen

March 31, 2015

Table of Contents

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

Acknowledgements

The authors thank the following people for their opinions, guidance, creative insight and constructive criticism during all phases of this project from conception to completion: Rajen Patel and Louis Blume (United States Environmental Protection Agency), Steve Galarneau, Will Wawrzyn, Marsha Burzynski, and Donalee Dinsmore, (Wisconsin Department of Natural Resources), Dale Buser (Ozaukee County resident), Stantec (formerly Bonestroo, Inc.) and Cheryl Nenn (Milwaukee Riverkeeper), Ozaukee County Environment and Land Use Committee (2009 – 2010 County Board Supervisors Donald Dohrwardt, John Hazelwood, William Niehaus, Glenn Stumpf, Timothy Kaul), Ozaukee County Natural Resources Committees (2010 – 2011 County Board Supervisors William Neihaus, Donald Dohrwardt, Timothy Kaul, Joeseph Dean, John Slater), (2011 – 2012 County Board Supervisors Patrick Marchese, Jennifer Rothstein, Joseph Dean, Glenn Stumpf, Timothy Kaul, Rose Hass Leider), (2012 – 2013 County Board Supervisors Patrick Marchese, Jennifer Rothstein, Glenn Stumpf, John Slater, Donald Korinek), (2013 – 2014 County Board Supervisors Donald Dohrwardt, Jennifer Rothstein, Glenn Stumpf, John Slater, Donald Korinek), (2014 – 2015 County Board Supervisors Jennifer Rothstein, Donald Dohrwardt, Barbara Jobs, Richard Bauzenberger, Thomas Grabow).

Contact for Further Information

Andrew T. Struck
Ozaukee County – Planning and Parks Department
121 West Main Street, PO Box 994, Port Washington, WI 53074
Phone: (262) 238-8275 Fax: (262) 238-8269
Email: astruck@co.ozaukee.wi.us

Introduction

The Ozaukee County (County) Planning and Parks Department (Department) Fish Passage Program (Program), a part of the Department's Ecological Division, and its project partners began monitoring activities during 2011 (Project) to address seven of the Milwaukee Estuary Area of Concern (AOC) Beneficial Use Impairments (BUI's). These activities were federally funded through the Great Lakes Restoration Initiative (GLRI) and administered by the United States Environmental Protection Agency (USEPA) under grant #GL-00E00607-0, entitled "Monitoring to Address 7 of 11 BUI's – Milwaukee River Estuary AOC." The Project included water quality monitoring, sediment contamination sampling, and fish community surveys with analyses in portions of the AOC within Ozaukee County and other relevant reaches of the Milwaukee River Watershed in Ozaukee County. Significant benefits for portions of the AOC beyond Ozaukee County are anticipated. **This final report documents the progress and results for Task 2, Water Quality Sampling, under the aforementioned grant.**

The Project directly pertains to two BUIs for the Milwaukee Estuary AOC:

- Eutrophication or Undesirable Algae
- Beach Closings and Body Contact

Information pertinent to specific BUI delisting targets and actions was garnered through discrete water quality sampling at 30 strategically chosen sites in the Milwaukee River and its tributaries in Ozaukee County, as well as continuous water quality monitoring in the Milwaukee River to "establish baseline conditions and trends" for various nutrients and pollutants, address "traditional point sources, non-point sources, and stormwater" and potentially identify "known sources of bacterial contamination to the AOC and tributary watershed" (SEH and ECT 2008).

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

Project Implementation Personnel

Personnel involved in Project implementation are listed in Table 1.

Table 1: Project Implementation Personnel

Individual	Role in Project	Organizational Affiliation
Rajen Patel	Project Officer	U.S. Environmental Protection Agency
Louis Blume	QA Manager	U.S. Environmental Protection Agency
Andrew Struck	Project Coordinator (Department Director)	Ozaukee County Planning and Parks Department
Thomas Dueppen	Planning & Parks Specialist	Ozaukee County Planning and Parks Department
Matt Aho	Program Manager and QA/QC Manager/Officer	Ozaukee County Planning and Parks Department
Ryan McCone	Program Assistant	Ozaukee County Planning and Parks Department
Luke Roffler	Program Assistant	Ozaukee County Planning and Parks Department
Beth Stuhr	Program Assistant	Ozaukee County Planning and Parks Department
Kristina Kroening	Program Assistant	Ozaukee County Planning and Parks Department
Cynthia DeGroot	Administrative Manager	Ozaukee County Planning and Parks Department
Multiple	Fish Passage Program and Planning and Parks Intern(s)	Ozaukee County Planning and Parks Department
Primary Consultant	Project Management	AECOM
Sub Consultant	Water Quality Sampling	Himalayan Consultants, LLC
Certified Laboratory	Sample Analysis	Northern Lake Service

Project Timeline

On 1/20/10, the Ozaukee County Environment and Land Use Committee authorized the Ozaukee County Planning and Parks Department (Department) to submit a grant application to USEPA for water quality monitoring, sediment contamination sampling, and fish community surveys in Milwaukee River Watershed in Ozaukee County. On 8/30/10, the Department, with the support of several Program partners, submitted a grant application to the United States Environmental Protection Agency (USEPA) Region V Offices entitled “Monitoring to Address 7 of 11 BUI’s – Milwaukee Estuary AOC” under the 2010 Great Lakes Restoration Initiative (GLRI) Request For Proposals (RFP). On 9/30/10, USEPA announced that Ozaukee County was awarded $491,000 in GLRI funding for its “Monitoring to Address 7 of 11 BUI’s – Milwaukee Estuary AOC” project (Project). The Ozaukee County Board of Supervisors formally accepted this award at its 10/6/10 meeting and the contract was executed by the Ozaukee County Administrator on 10/10/10.

2012 No Cost Time Extension

The original project end date listed in the initial award document was 12/31/12. After discussions with USEPA staff, Ozaukee County submitted a formal no-cost one year time extension request to USEPA

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

staff on 9/14/12. The request extended the project period from 1/1/13 through 12/31/13, outlined remaining work to be completed and addressed scheduling deficiencies caused by:

- Equipment and consultant procurement delays as a result of the QAPP approval process.
- 2012 drought conditions and abnormally low water levels throughout the entire year, which likely resulted in non-baseline fisheries and continuous water quality data, did not produce necessary "high flow" conditions and rain events to complete discrete water sampling activities, and delayed access to sediment sampling sites and activities.

The no-cost time extension was formally approved by USEPA on 10/25/12.

2013 No Cost Time Extension

After additional discussions with USEPA staff, Ozaukee County submitted a formal no-cost one year time extension request to USEPA staff on 11/13/13. The request extended the project period from 1/1/14 through 12/31/14, outlined remaining work to be completed and addressed scheduling deficiencies caused by:

- 2013 abnormal spring precipitation and summer drought conditions not producing field conditions safe or adequate to preform Task 2 discrete water sampling activities per the standard operating procedures outlined in the QAPP.

The no-cost time extension was formally approved by USEPA on 11/14/13. Both time extensions and approval letters are included as Appendix A.

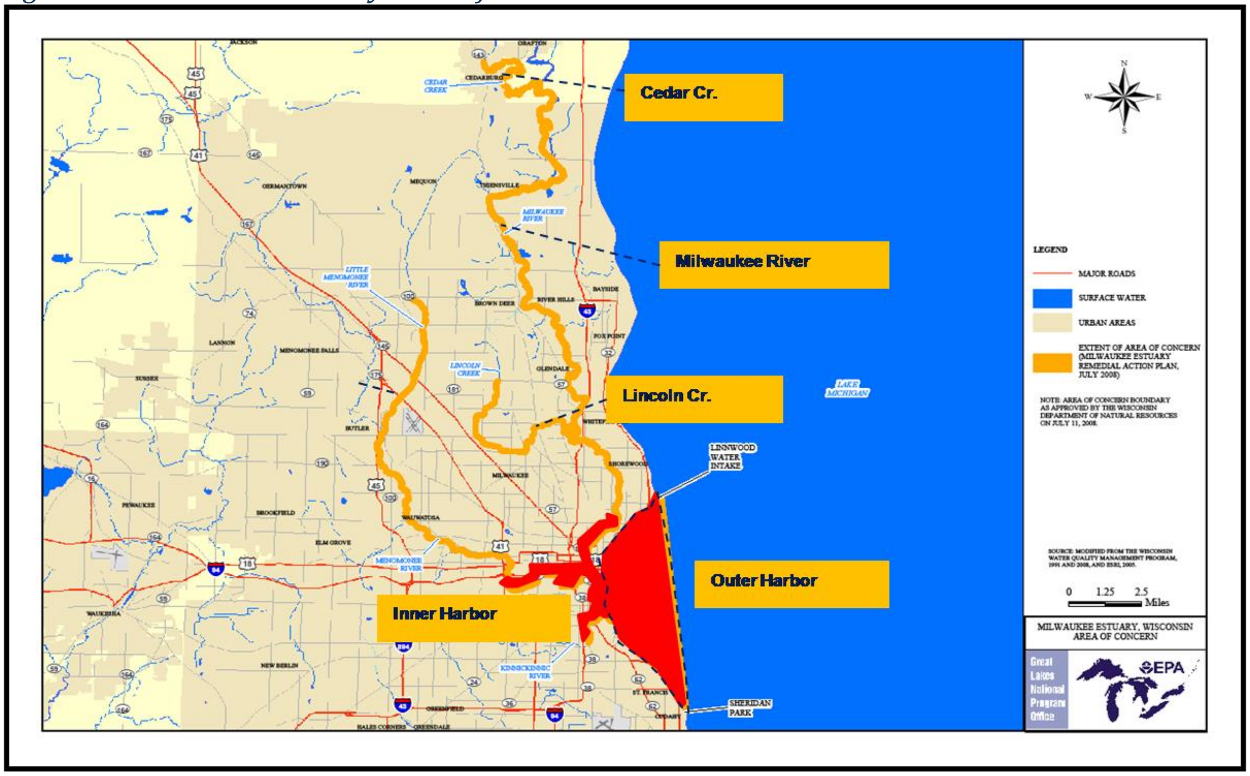
Problem Definition/Background:

Milwaukee Estuary Area of Concern (AOC) Beneficial Use Impairments (BUI's)

The Milwaukee Estuary was designated an Area of Concern (AOC) during the 1980s due to historical modifications and pollutant loads. The Milwaukee Estuary Remedial Action Plan and Delisting Targets Report have been subsequently released and updated. They document 11 beneficial use impairments (BUIs) effecting the AOC as well as proposed delisting targets and actions for each BUI. The original boundaries of the AOC included the lower 5 km of the Milwaukee River downstream of 35th Street; the lower 4 km of the Kinnickinnic River downstream of Chase Avenue; the inner and outer harbors; and the nearshore waters of Lake Michigan, bounded by a line extending north from Sheridan Park to the city of Milwaukee's Linnwood water intake (WDNR 2014). In 2008, the boundaries were expanded to address sites that contributed significant loads of contaminated sediments to the estuary, including Cedar Creek downstream of Bridge Road to the confluence with the Milwaukee River, in Ozaukee County (WDNR 2014). Figure 1 shows the original and expanded boundaries of the Milwaukee Estuary Area of Concern.

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

Figure 1. Milwaukee Estuary Area of Concern



Various water quality contaminants are closely tied to many of the BUI's listed for the Milwaukee Estuary AOC, particularly those related to algal blooms and exposure to bacteria and other pathogens (SEH and ECT 2008). Poor water quality and excessive nutrient loading adversely affect benthic organisms, fish, wildlife, and plankton (WDNR 2014). Eutrophic conditions caused by excessive nutrient levels often lead to large algal blooms, which can result in low dissolved oxygen levels, fish kills, and poor aesthetics (WDNR 2014). Influxes of pathogens into the system, particularly during high flow events, can have a direct effect on fish and wildlife populations and are a major concern for safe public enjoyment of affected waterbodies (SEH and ECT 2008).

Sampling strategic locations on the mainstem Milwaukee River and its tributaries yielded baseline nutrient and pathogen information for baseflow conditions, helped identify potential sources of nutrient and/or pathogen loading, and gauged the effect of various flow events throughout the Milwaukee River Watershed reaches in Ozaukee County (Project Area). Continuous in-stream monitoring stations were placed at three locations on the mainstem Milwaukee River to assess standard parameters including water temperature, depth, dissolved oxygen concentration, pH, and conductivity. Together, this information provides preliminary baseline water quality for the Project Area, establishes spatial trends for nutrient and pathogen loading within the system during and/or immediately after rain (surface runoff) events, and provides information about water quality changes that occur in the Milwaukee River as it passes through Ozaukee County.

Project Objectives

The Project, through a measured and science-based approach, began targeted water quality sampling and continuous in-stream monitoring in Ozaukee County portions of the Milwaukee River Watershed to provide baseline water quality information and preliminary trends. Specifically, the Project aimed to address the following objectives:

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

- Collecting baseline data for select chemical or physical water quality parameters and pathogens at strategic points within the mainstem Milwaukee River and select tributary streams in Ozaukee County.
- Monitoring basic water quality parameters (e.g., water temperature, dissolved oxygen, water depth, etc.) continuously in the mainstem Milwaukee River to evaluate baseflow conditions and high flow trends.

Monitoring Design

The Project was constituted of a monitoring design, not an experimental design, for providing preliminary baseline water quality for the Project Area, while establishing spatial trends for nutrient and pathogen loading within the system during and/or immediately after rain (surface runoff) events. As such, the measurement and data quality objectives were largely based on the precision and accuracy limits specified in the SOPs of the Certified Laboratory chosen for this project. Generated data was shared with Milwaukee Metropolitan Sewerage District staff and local WDNR AOC staff for consideration while developing BUI delisting criteria. Applying robust statistical inferences to the entire Project Area or AOC was not a Project objective. Thus, the data quality objectives were that data collected in the field, generated in the field, or generated in a laboratory conforms to the items below to ensure it provides accurate representation of water quality at the time of sampling/measurement.

Results from water quality samples were considered data of acceptable quality if the samples were:

- Collected in accordance with Sub-Consultant SOPs
- Preserved (if required) in accordance with certified laboratory SOPs
- Documented in accordance with certified laboratory SOPs
- Analyzed in accordance with certified laboratory SOPs

Discrete water quality samples were collected and analyzed for:

- Total Phosphorus
- Total Kjeldahl Nitrogen (TKN)
- Ammonia
- Nitrites/Nitrates
- Fecal Coliform
- Total Suspended Solids (TSS)
- Orthophosphate
- Chlorophyll a

Continuous water quality monitoring was performed using deployable systems designed to measure:

- Water temperature
- Water depth
- Dissolved Oxygen (DO) Concentration
- Hydrogen Ion Concentration (pH)
- Conductivity

Quality Assurance Project Plan Approvals

A Quality Assurance Project Plan (QAPP) was required for all project tasks per the USEPA contract award document. Department staff met with numerous Program partners and performed significant research to determine specific data collection metrics and procedures to provide the most benefit to AOC

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

BUI delisting criteria. Staff initiated a conference call with the local WDNR AOC coordinator on 12/17/10. WDNR did not provide specific comments or recommendations on the fish survey component during workplan development. A draft QAPP was submitted to WDNR on 2/15/11. General WDNR comments were received on 3/9/11, and a meeting with WDNR staff was held on 3/15/11. Elements of WDNR's recommendations were included in the final draft QAPP. The QAPP was submitted in three individual QAPP's per WDNR's recommendation on 3/15/11 (Revision 1) and the final draft QAPP was submitted for USEPA approval on 4/1/11 (Revision 2) and approved by USEPA on 5/24/11. QAPP Revision 3 was submitted to USEPA on 10/14/11, which included minor modifications in the QA/QC manager role, scheduling, and references to the final consultant workplans and SOP's, and was approved by USEPA on 10/17/11. QAPP Revision 4 (Appendix B) was submitted to USEPA on 1/4/13, which included timeline modifications and other changes as part of the approved 2012 no-cost one year time extension request, and was approved by USEPA on 1/17/13. All workplan activities followed procedures as outlined in the QAPP's and no data-gathering activities occurred until the initial QAPP was approved.

Project Locations

The collection of baseline and trend data for nutrients and pathogens throughout the County was designed to incorporate impounded and free-flowing stretches of the mainstem Milwaukee River, as well as the influence of multiple tributary streams (subwatersheds) within the watershed (Table 2 and Appendix C and D). Specific tributaries were designated for sampling based on land use (agricultural, residential, high percentage of impervious surfaces, etc.), known contaminants (e.g., PCB's in Cedar Creek) or concerns raised by County personnel based on previous field visits (e.g., high turbidity and atypical smell in Hawthorne Drive Creek).

Continual monitoring of basic water quality parameters occurred at three distinct locations in the mainstem Milwaukee River (Appendix C and D). These included:

1. Immediately upstream of the Riveredge Creek terminal confluence in the Village of Newburg, approximately river mile (RM) 55
2. Downstream of the Bridge Street Dam in the Village of Grafton, approximately RM 31
3. Immediately downstream of the Trinity Creek terminal confluence in the City of Mequon, approximately RM 17

These three locations were largely chosen to provide full spatial distribution across the major sections of the Milwaukee River in Ozaukee County. County staff determined specific locations for each monitoring station based on accessibility, site safety, low likelihood of equipment tampering, and equipment logistics (e.g., cable lengths, etc.).

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

Table 2. Water Quality Sampling Sites, Descriptions, and Locations

Site	Description	Location[1]	Selection
1	Milwaukee River at Newburg Dam tailwater	Fireman's Park (43° 26' 3.32", -88° 2' 54.93")	Most upstream location in County
2	N. Branch Milwaukee River near terminus	Riverside Road (43° 28' 52.47", -88° 2' 26.12")	Major tributary
3	Milwaukee River upstream of River Road Creek	River Road (43° 28' 38.12", -88° 0' 31.50")	Major tributary confluence
4	Milwaukee River downstream of Fredonia Wastewater Plant discharge	Waubedonia Park (43° 28' 1.51", -87° 58' 1.85")	Wastewater plant discharge
5	Fredonia Creek near terminus	Waubedonia Park (43° 28' 0.61", -87° 57' 57.76")	Major tributary
6	Milwaukee River downstream of Fredonia Creek	Waubedonia Park (43° 27' 58.91", -87° 58' 0.29")	Major tributary confluence
7	Hawthorne Drive Creek near terminus	Hawthorne Drive (43° 26' 26.28", -87° 58' 16.72")	Major tributary
8	Milwaukee River downstream of Hawthorne Drive Creek	Hawthorne Drive (43° 26' 26.28", -87° 58' 16.72")	Major tributary confluence
9	Riverside Drive Creek near terminus	Evergreen Lane (43° 25' 11.22", -87° 56' 28.79")	Major tributary
10	Milwaukee River downstream of Riverside Drive Creek	Evergreen Lane (43° 25' 11.22", -87° 56' 28.79")	Major tributary confluence
11	Milwaukee River upstream of Saukville Wastewater Plant discharge	West Riverside Park (43° 22' 33.78", -87° 56' 31.58")	Upstream of wastewater plant discharge
12	Milwaukee River downstream of Saukville Wastewater Plant discharge	West Riverside Park (43° 22' 33.78", -87° 56' 31.58")	Wastewater plant discharge
13	Mole Creek	Pleasant Valley Road (43° 21' 7.18", -87° 52' 16.16")	Major tributary
14	Mole Creek near terminus	N. Green Bay Road (43° 20' 12.10", -87° 56' 57.39")	Major tributary
15	Milwaukee River downstream of Mole Creek	N. Green Bay Road (43° 20' 12.10", -87° 56' 57.39")	Major tributary confluence

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

16	Milwaukee River at downstream extent of Bridge Street impoundment	Riverwalk Platform (43° 19' 7.78", -87° 56' 57.79")	Impoundment effects
17	Milwaukee River at Bridge Street Dam tailwater	14th Avenue (43° 19' 6.21", -87° 56' 56.39")	Dam effects
18	Milwaukee River downstream of Grafton Wastewater Plant discharge	Falls Road (43° 18' 33.15", -87° 57' 6.12")	Wastewater plant discharge
19	Milwaukee River upstream of Cedar Creek	Lakefield Road (43° 17' 40.25", -87° 56' 39.84")	Upstream of confluence of tributary with known contamination
20	Cedar Creek	Grafton Lions Park (43° 19' 15.71", -87° 58' 40.05")	Major tributary with known contamination
21	Cedar Creek near terminus	City of Cedarburg property (43° 17' 24.41", -87° 57' 3.39")	Major tributary with known contamination
22	Milwaukee River downstream of Cedar Creek	City of Cedarburg property (43° 17' 24.41", -87° 57' 3.39")	Downstream of confluence of tributary with known contamination
23	Ulao Creek near terminus	Bonniwell Road (43° 15' 55.89", -87° 56' 2.95")	Major tributary
24	Milwaukee River downstream of Ulao Creek	Highland Road (43° 15' 3.75", -87° 56' 29.08)	Downstream of major tributary
25	Milwaukee River at downstream extent of Mequon-Thiensville impoundment	Village Park (43° 13' 51.11", -87° 58' 42.70")	Impoundment effects
26	Milwaukee River at Mequon-Thiensville Dam tailwater	Village Park (43° 13' 50.10", -87° 58' 46.66")	Dam effects
27	Pigeon Creek near terminus	Green Bay Road (43° 13' 50.08", -87° 59' 0.53")	Major tributary
28	Milwaukee River downstream of Pigeon Creek	Donges Bay Road (43° 12' 25.35", -87° 58' 12.23")	Downstream of major tributary
29	Trinity Creek near terminus	Highway 57 (43° 12' 1.31", -87° 58' 4.90")	Major tributary
30	Milwaukee River downstream of Trinity Creek	River Barn Park (43° 11' 51.02", -87° 57' 49.92")	Downstream of major tributary

1 – Site location coordinates measured using the Ozaukee County GIS

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

Methods

Per the Quality Assurance Project Plan (QAPP) and grant narrative, the number of discrete water quality samples (153) and continuous water quality monitoring systems (three) were dictated by a balance between the best biological and ecological outcome and the available funding, staffing, and timeline. The collection of baseline and trend data for nutrients and pathogens throughout the County was designed to incorporate impounded and free-flowing stretches of the mainstem Milwaukee River, as well as the influence of multiple tributary streams within the watershed (Table 2 and Appendix C and D). Specific tributaries were designated for sampling based on land use (agricultural, residential, high percentage of impervious surfaces, etc.), known contaminants (e.g., PCB's in Cedar Creek) or concerns raised by County personnel based on previous field visits (e.g., high turbidity and atypical smell in Hawthorne Drive Creek). Applying robust statistical inferences to the entire Project Area or AOC was not a Project objective. This Project was an initial effort or pilot project to describe water quality sampled or measured in the Project Area, both qualitatively and with some quantified sample statistics. All measurement and analysis parameters are for information only. Estimates of sample variability for many of the monitored parameters may prove useful for estimating requisite sample sizes for subsequent projects. Such examination of Project data, however, was not a direct Project objective and is not a focus of the Project or this report.

General Water Quality Sampling Method Requirements & Quality Assurance/Quality Control

Per the QAPP and SOPs, all water samples were collected in containers, field preserved, labeled, and submitted for analysis in accordance with approved SOPs. General sampling requirements were as follows:

- Samples were collected in containers approved by the WDNR laboratory certification program.
- Sampling was performed with an emphasis on avoiding contamination throughout the process (e.g., did not touch the inside of the container; did not put caps on the ground during sampling, fully rinse sampling equipment between sites, etc.).
- To provide accurate and reliable results, sample preservation and holding times were strictly adhered to throughout the process (e.g., labeling and preserving/icing samples immediately followed collection, promptly delivered samples to the laboratory to ensure analysis within a given hold time, etc.).
- Complete sampling information was obtained and documented for most samples including location, date, time, air and water temperature, average flow velocity, and other relevant field conditions at each sampling site. During sampling under high flows, completing cross sectional measurements was considered too dangerous and partial data was collected. Alternatively, during extreme low flow periods, velocities could not be accurately measured at some locations. At these locations, the discharge was estimated based on calculations taken under similar conditions or the discharge rates at the nearest USGS stream gauging station (station 04086600 near Cedarburg) were used. Together with cross section measurements performed by laboratory staff at most sampling sites, average flow velocity provided an estimation of discharge during sampling periods. Flow velocity measurement methods were consistent with those outlined in Bain and Stevenson (1999). The Program Manager/QA/QC Manager/Officer was responsible for all sampling corrective actions. Program Coordinator (Planning and Parks Director) approval of all sampling corrective actions was required.

The equipment used for continuous water quality monitoring was calibrated by the manufacturer and/or County staff prior to each yearly deployment to confirm proper function. The stations were located at sites providing safe access and a low likelihood of tampering. The monitoring probes and cords were weighted to ensure submersion throughout the duration of sampling. Weekly and/or monthly checks at

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

each station included battery replacement, general maintenance, data download, and recalibration as necessary. The monitoring stations and probes were maintained and calibrated as needed in accordance with manufacturer recommendations as cited in operating manuals and other supporting documents. Calibration data from the continuous monitoring stations was downloaded at least every month by County staff onto external memory and immediately transported to the County offices and uploaded to the Ozaukee County network server.

All water quality samples were sealed, preserved/iced, and transported to the laboratory in a prompt timeframe to ensure analysis occurrf within necessary hold times per the Sub-Consultant and Certified Laboratory SOPs. The Certified Laboratory conformed to industry-standard Level 2 requirements, including analytical reports, QA/QC reports, and chain of custody documentation (Ohio EPA 2006). The Certified Laboratory assumed custody of each sample it received and was responsible for forwarding all sample analysis results to the Project Coordinator (or designee) following the completion of analysis.

Data Quality Review

A limited Level 2 data quality review (Appendix E) was submitted by AECOM reporting on methods used, holding time, method blanks, surrogate recoveries, laboratory control samples, matrix spikes, matrix spike duplicates, quantitation limits, and field duplicates. Based on the review, the data are valid as reported and may be used for decision making purposes. Notable though, the phosphorus limit of quantitation (LOQ) and nitrate/nitrite limit of detection (LOD) were slightly above work plan limits, but do not pose a threat to a sample validity and all duplicate sample relative percent difference (RPDs) were within the 30 percent limit with the exception of fecal coliform with an RPD of 86%. The explanation for this RPD was that the variability of gathering samples in the stream environment and the stability of fecal coliform contributed to sample variation.

Discrete Water Quality Sampling Methods

Sampling of four distinct sampling events occurred during late-spring through fall of 2011 through 2013. The fifth distinct sampling event occurred in late spring of 2014 due to irregular weather complications that made sampling unsafe to complete in the original sampling period. All sites were sampled during baseflow conditions in 2012 and 2013 (i.e., 60 total sample collections) to establish baseline conditions, as well as following three rain events (i.e., 90 total sample collections) during 2012, 2013 and 2014 to sample conditions influenced by surface runoff within the watershed. Sampling baseflow conditions as well as confining sampling to the late-spring through autumn time period was requested by the WDNR (D. Dinsmore, M. Burzynski, and M. O'Shea, personal communication, March 15, 2011). Sub-Consultant staff determined cross section measurements at most sampling sites during the initial low flow event and final high flow event and took multiple flow measurements during the collection of most water quality samples (Bain and Stevenson 1999). These measurements facilitated the estimation of discharge during sampling.

The assessed parameters during these sampling events were based on guidance from WDNR (2010), as well as conversations with WDNR Water Resources and Great Lakes staff (D. Dinsmore, M. Burzynski, and M. O'Shea, personal communication, March 15, 2011). Final detection and reporting limits used for water quality sample analysis for each parameter are outlined below (Table 3). To the extent possible, locations that returned high fecal coliform counts (i.e., 200-400 CFU/100 mL) were to be re-tested for *Escherichia coli* (E. coli) during later sampling (WDNR 2010), but initial re-testing of water at locations with high fecal coliform counts had low re-test results, not warranting further testing. In addition, the holding time for testing a sample for E. coli is 24 hours and initial results were not provided by the lab for several days after testing.

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

Table 3. Water Quality Parameters and Laboratory Limits

Test	Detection Limit	Reporting Limit	Total Samples[1]
Total Phosphorus	0.005 mg/L	0.016 mg/L	150
Total Kjeldahl Nitrogen (TKN)	0.18 mg/L	0.68 mg/L	150
Ammonia	0.07 mg/L	0.23 mg/L	150
Nitrites/Nitrates	0.025 mg/L	0.061 mg/L	150
Fecal Coliform	10 CFU/100mL	Does Not Apply	150
E. coli	1 CFU/100mL	Does Not Apply	TBD[2]
Total Suspended Solids (TSS)	2 mg/L	7 mg/L	150
Orthophosphate	0.007 mg/L	0.010 mg/L	150
Chlorophyll a	0.26 µg/L	0.87 µg/L	150

1 – Sample size is largely dependent on the number of high flow events during the sampling period

2 – E. coli sample size is dependent on fecal coliform "hotspots" identified that require further quantification

Continuous Water Quality Sampling Methods

The three continuous water quality monitoring units were installed in locations that provided full spatial distribution across the major sections of the Milwaukee River in Ozaukee County. County staff determined specific locations for each monitoring station based on accessibility, site safety, low likelihood of equipment tampering, and equipment logistics (e.g., cable lengths, etc.). Appendix F shows a summary of continuous water quality monitoring system checks at each station including deployment and removal, battery replacement, general maintenance and troubleshooting, data downloads, and recalibration as necessary.

Each monitoring station recorded water temperature (accurate within 0.1°C), water depth (accurate within 0.015 ft), dissolved oxygen concentration (accurate within 0.5% saturation), pH (accurate within 2% of full scale) and conductivity (accurate within 20 µs) approximately every twenty minutes. County staff visited each station at least monthly per the QAPP for data downloading, battery replacement, general maintenance and cleaning, and requisite calibration. All monitoring equipment was maintained in accordance with manufacturer recommendations.

Monitoring these parameters continuously allowed County staff to establish baseline data and trends related to various flow conditions during the sample period. The data collected from continuous monitoring can be cross referenced to the larger, discrete water quality sampling data set, allowing inference of water quality changes as they related to specific events or time periods. Water quality data collected throughout the Project has been consistent with those entered into WDNR's Surface Water Integrated Monitoring Systems (SWIMS), making for efficient data management and comparability (WDNR 2010).

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

Figure 3: Summary of Discrete Water Quality Sampling Events

Round	Dates	Parameters Analyzed	Wet/Dry
R1	5/31/2012, 6/1/2012	All	Dry
S1	6/12/2012	Fecal Re-test	Dry
R2	8/6/2013	All	Dry
R3	10/7/2013	All	Wet
R4	11/7/2013	All	Wet
R5	4/29/2014, 4/30/2014	All	Wet

Summary of Water Quality Sampling Data Analysis

Analysis of Project Goals and Objectives

The Project, through a measured and science-based approach, began targeted water quality sampling and continuous in-stream monitoring in the Ozaukee County portions of the Milwaukee River Watershed. The water quality assessments provide baseline water quality information and preliminary trends within the Milwaukee River Watershed in Ozaukee County. Specifically, the Project aimed to address the following objectives:

- Collecting baseline data for select chemical or physical water quality parameters and pathogens at strategic points within the mainstem Milwaukee River and select tributary streams in Ozaukee County.
- Monitoring basic water quality parameters (e.g., water temperature, dissolved oxygen, water depth, etc.) continuously in the mainstem Milwaukee River to evaluate baseflow conditions and high flow trends.

As mentioned above, applying robust statistical inferences to the entire Project Area or AOC was not a Project objective. This Project was an initial effort or pilot project to describe water quality sampled or measured in the Project Area, both qualitatively and with some quantified sample statistics. All measurement and analysis parameters are for information only. Estimates of sample variability for many of the monitored parameters may prove useful for estimating requisite sample sizes for subsequent projects. Such examination of Project data, however, was not a direct Project objective and is not a focus of the Project or this report.

Raw data from the discrete water quality sampling and continuous water quality monitoring has been converted to a format usable for entering into the WDNR SWIMS database and is available to WDNR and USEPA upon request. This data may facilitate characterization and estimation of baseline water quality conditions and changes throughout the County, as well as any trend-related water quality concerns related to contemporary sources of nutrient or pathogen loading in the system. Future water quality testing results can be compared to data collected under this Project and others to assess water quality changes due to future management, restoration, or regulatory actions within the Milwaukee River Watershed.

Results of data collected for the Project were compared to state and federal standards or recommendations for each parameter (as available) in an initial effort to highlight sampling locations with results that may warrant further examination. However, these standards are often generalized for larger water bodies or systems and thus are not always directly applicable in all systems (e.g., the Milwaukee River and its tributary streams in Ozaukee County). As such, discrete monitoring data was normalized using mass balance calculations based on estimated discharge rates to facilitate location comparisons. Results were

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

also compared to show upstream to downstream trends, trends due to seasonal weather conditions, wet sampling vs. dry sampling patterns, and subwatershed influences on the mainstem Milwaukee River.

The data collected during discrete and continuous water quality monitoring was utilized to generate tables and graphs depicting raw and notable results for each parameter that was analyzed, mass balance and mass per area calculations, and maps depicting subwatershed/tributary influences on the mainstem Milwaukee River (Appendices G through L).

Discrete Water Quality Sampling Results

Parameter: Fecal Coliform

High bacteria concentrations can have a negative effect on streams as well as human health. Wisconsin State Recreational Use Standards state that fecal coliform levels should never exceed 200 CFU/100 mL (colony forming units/100 milliliter sample) (WDNR 1973). Samples with results higher than 200 CFU/100 mL are shown in Table 4. WDNR recommended retesting for sites with results higher than 400 CFU/100 mL. Sites with high fecal analysis results in the first round of discrete sampling were retested and the results were significantly lower, not warranting further E.coli testing. It is possible that the lag time and changing conditions between the initial and retest resulted in a lower result. In addition, the holding time for testing a sample for E. coli is 24 hours and initial results were not provided by the lab for several days after testing. As such, retesting for fecal coliform and E. coli did not occur subsequent to the remaining four sampling events due to the timeframe lag between the field sampling and lab analysis and results delivery. Appendix G shows fecal coliform results against Wisconsin State Recreational Use Standards.

In summary:

- 14 sites had at least one result higher than 200 CFU/100 mL
- 10 sites had at least one result higher than 400 CFU/100 mL
- 18 of the 25 high fecal coliform samples were taken under dry conditions
- Sites L1 (Milwaukee River at Newburg Dam tailwater), L5 (Fredonia Creek near terminus), L7 (Hawthorne Drive Creek near terminus), L13 (Mole Creek), L27 (Pigeon Creek near terminus), L29 (Trinity Creek near terminus), and L30 (Milwaukee River downstream of Trinity Creek) had two results higher than 200 CFU/100 mL
- Sites L2 (N. Branch Milwaukee River near terminus) and L23 (Ulao Creek near terminus) each had 3 tests come back higher than 200 CFU/10 mL
- There were no high results on the 11/7/2013 (wet) sampling day and many of the results came back with zero fecal coliform detection

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

Table 4. Summary of fecal coliform results higher than 200 CFU/100 mL

Laboratory Description	Location Description From Upstream to Downstream	Collected	Sampling Location Condition Dry=low flow Wet=high flow	Results (CFU/100 mL)	Retest Results (CFU/100 mL)
SW-L1-R2-13	Milwaukee River at Newburg Dam tailwater	8/6/2013	Dry	360	
SW-L1-R3	Milwaukee River at Newburg Dam tailwater	10/7/2013	Wet	550	
SW-L2-R1-12	N. Branch Milwaukee River near terminus	5/31/2012	Dry	360	
SW-L2-R3	N. Branch Milwaukee River near terminus	10/7/2013	Wet	460	
SW-L2-R2-13	N. Branch Milwaukee River near terminus	8/6/2013	Dry	560	
SW-L3-R2-13	Milwaukee River upstream of River Road Creek	8/6/2013	Dry	330	
SW-L5-R1-12	Fredonia Creek near terminus	5/31/2012	Dry	260	
SW-L5-R2-13	Fredonia Creek near terminus	8/6/2013	Dry	300	
SW-L7-R1-12	Hawthorne Drive Creek near terminus	5/31/2012	Dry	590	10
SW-L7-R2-13	Hawthorne Drive Creek near terminus	8/6/2013	Dry	760	
SW-L9-R2-13	Riverside Drive Creek near terminus	8/6/2013	Dry	740	
SW-L13-R2-13	Mole Creek	8/6/2013	Dry	280	
SW-L13-R1-12	Mole Creek	5/31/2012	Dry	1000	84
SW-L14-R2-13	Mole Creek near terminus	8/6/2013	Dry	450	
SW-L16-R3	Milwaukee River at downstream extent of Bridge Street impoundment	10/7/2013	Wet	480	
SW-L18-R3	Milwaukee River downstream of Grafton	10/7/2013	Wet	260	
SW-L23-R5-13	Ulao Creek near terminus	4/30/2014	Wet	210	
SW-L23-R2-13	Ulao Creek near terminus	8/6/2013	Dry	490	
SW-L23-R1-12	Ulao Creek near terminus	5/31/2012	Dry	710	46
SW-L27-R2-13	Pigeon Creek near terminus	8/6/2013	Dry	230	
SW-L27-R1-12	Pigeon Creek near terminus	6/1/2012	Dry	370	
SW-L29-R2-13	Trinity Creek near terminus	8/6/2013	Dry	7500	
SW-L29-R5-13	Trinity Creek near terminus	4/30/2014	Wet	11000	
SW-L30-R2-13	Milwaukee River downstream of Trinity Creek	8/6/2013	Dry	710*	
SW-L30-R5-13	Milwaukee River downstream of Trinity Creek	4/30/2014	Wet	2500	

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

*This sample was part of a split field duplicate sample that came back at only 100 CFU/100 mL. The Data Quality Review report from the lab suggested that the variability of gathering the sample in a stream environment and the stability of the fecal coliform may have contributed to the sample variation.

Parameter: Chlorophyll a

Chlorophyll a levels can provide information about the productivity of a water body as it relates to nutrient availability. The raw data results show chlorophyll for all species, which are then used to correct chlorophyll a levels in the presence of other chlorophyll species. Corrected chlorophyll a results were used for this analysis. There is currently no state or federal regulations or standards for chlorophyll a levels, but the general ranges for assessing concentrations are as follows:

<7 µg/L = desirable
7-15 µg/L = less than desirable
>15 µg/L = problematic.

According to the "Ambient Water Quality Criteria Recommendations" (USEPA 2000) document for the ecoregion relevant to the project area, potential reference conditions for chlorophyll a is 3.52 µg/L. All samples with chlorophyll a results higher than 7 µg/L are summarized in Table 5. Appendix G shows total corrected chlorophyll a results against USEPA reference conditions.

In Summary:

- 18 sites had at least 1 sample with "less than desirable" results
- L17 (Milwaukee River at Bridge Street Dam tailwater) and L18 (Milwaukee River downstream of Grafton) had 2 results above 7 µg/L
- L9 (Riverside Drive Creek near terminus) and L29 (Trinity Creek near terminus) had 3 results above 7 µg/L
- L9 (Riverside Drive Creek near terminus), L16 (Milwaukee River at downstream extent of Bridge Street impoundment), and L29 (Trinity Creek near terminus) had a sample with a "problematic" result (>15µg/L)

Table 5 Summary of chlorophyll a results higher than 7 µg/L

Laboratory Description	Location Description From Upstream to Downstream	Collected	Sampling Location Condition Dry=low flow Wet=high flow	Result (µg/L)
SW-L1-R3	Milwaukee River at Newburg Dam tailwater	10/7/2013	Wet	10.00
SW-L5-R1-12	Fredonia Creek near terminus	5/31/2012	Dry	14.00
SW-L6-R1-12	Milwaukee River downstream of Fredonia Creek	5/31/2012	Dry	8.80
SW-L7-R5-13	Hawthorne Drive Creek near terminus	4/29/2014	Wet	7.80
SW-L8-R1-12	Milwaukee River downstream of Hawthorne Drive Creek	5/31/2012	Dry	7.80
SW-L9-R1-12	Riverside Drive Creek near terminus	5/31/2012	Dry	110.00
SW-L9-R2-13	Riverside Drive Creek near terminus	8/6/2013	Dry	9.10
SW-L9-R5-13	Riverside Drive Creek near terminus	4/29/2014	Wet	8.20

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

SW-L11-R1-12	Milwaukee River upstream of Saukville Wastewater Plant discharge	5/31/2012	Dry	9.70
SW-L12-R1-12	Milwaukee River downstream of Saukville Wastewater Plant discharge	5/31/2012	Dry	13.00
SW-L14-R1-12	Mole Creek near terminus	5/31/2012	Dry	10.00
SW-L16-R4-13	Milwaukee River at downstream extent of Bridge Street impoundment	11/7/2013	Wet	18.00
SW-L17-R1-12	Milwaukee River at Bridge Street Dam tailwater	5/31/2012	Dry	7.60
SW-L17-R3	Milwaukee River at Bridge Street Dam tailwater	10/7/2013	Wet	9.50
SW-L18-R1-12	Milwaukee River downstream of Grafton	5/31/2012	Dry	7.60
SW-L18-R3	Milwaukee River downstream of Grafton	10/7/2013	Wet	8.80
SW-L19-R4-13	Milwaukee River upstream of Cedar Creek	11/7/2013	Wet	7.90
SW-L21-R5-13	Cedar Creek near terminus	4/30/2014	Wet	7.10
SW-L22-R5-13	Milwaukee River downstream of Cedar Creek	4/30/2014	Wet	8.10
SW-L25-R2-13	Milwaukee River at downstream extent of Mequon-Thiensville impoundment	8/6/2013	Dry	11.00
SW-L26-R1-12	Milwaukee River at Mequon-Thiensville Dam tailwater	6/1/2012	Dry	7.40
SW-L28-R5-13	Milwaukee River downstream of Pigeon Creek	4/30/2014	Wet	7.50
SW-L29-R3-13	Trinity Creek near terminus	10/7/2013	Wet	18.00
SW-L29-R4-13	Trinity Creek near terminus	11/7/2013	Wet	10.00
SW-L29-R5-13	Trinity Creek near terminus	4/30/2014	Wet	10.00

Parameter: Nitrogen

Nitrogen was analyzed as ammonia, total kjeldahl nitrogen (TKD) (ammonia, organic and reduced nitrogen) and as total inorganic nitrogen (nitrates (NO_3^-) and nitrites (NO_2^-)). Total nitrogen was calculated by adding TKD to the total inorganic nitrogen. There are no state established numerical standards for any forms of nitrogen in surface water, but the USEPA's "Ambient Water Quality Criteria Recommendations" for rivers and streams in Nutrient Ecoregion VII (subecoregion 53) (USEPA 2000) suggest reference conditions for TKD, inorganic nitrogen, and total nitrogen that were used as a comparison to Project data. Similarly, USEPA published a separate document in 2013 with updated national recommended ambient water quality criteria for the protection of aquatic life from toxic effects of ammonia (USEPA 2013) that was used as a comparison to Project data.

Ammonia

The USEPA 2013 criterion for ammonia is temperature and pH dependent, and recommends at a pH of 7 and 20°C, acute criterion (1 hr average) of 17 mg/L and chronic criterion (30 day-rolling average) as 1.9 mg/L. Our analysis was not conducted to compare to this criterion exactly, but none of our individual or averaged results reach the acute or chronic ammonia criterion. Although none of the results reach the 1.9 mg/L USEPA criterion, elevated levels of ammonia can be seen at L2 (N. Branch Milwaukee River near

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

terminus), L3 (Milwaukee River upstream of River Road Creek), L7 (Hawthorne Drive Creek near terminus), L9 (Riverside Drive Creek near terminus), L11 (Milwaukee River upstream of Saukville Wastewater Plant discharge), L17 (Milwaukee River at Bridge Street Dam tailwater), L21 (Cedar Creek near terminus), L23 (Ulao Creek near terminus), L26 (Milwaukee River at Mequon-Thiensville Dam tailwater) and L29 (Trinity Creek near terminus). USEPA literature (USEPA 1986) suggests that at 0.06 mg/L fish can suffer gill damage, 0.1 mg/L can indicate polluted waters and that at 0.2 mg/L, sensitive fish like trout and salmon begin to die. Table 6 below summarizes sampled ammonia levels and associated effects according to the USEPA:

Table 6 Ammonia Levels and Associated Effects on Fish

NH_3 (Ammonia) Level	Effects	Range	Number of samples in Range
		0.00 - 0.05	18
0.06 mg/L	Fish can suffer gill damage	0.06 - 0.099	13
0.1 mg/L	Usually indicative of polluted waters	0.1 - 0.19	67
0.2 mg/L	Sensitive fish like trout and salmon begin to die	0.2 - 1.9	52 (5 samples were in the 0.3-0.6)
2.0 mg/L	Ammonia-tolerant fish like carp begin to die	At or above 2.0	0

In general, higher pH levels and warmer water temperatures increase ammonia toxicity. Appendix G shows total ammonia results against USEPA reference conditions that could indicate polluted waters.

Nitrogen – Total Kjeldahl Nitrogen

Total Kjeledahl Nitrogen (TKN) is the sum of organic nitrogen, ammonia (NH_3) and ammonium (NH_4). Project data was compared to USEPA's (USEPA 2000) TKN reference conditions of 0.65 mg/L. 126 of 150 (84%) samples were above USEPA's reference conditions. Appendix G shows TKN results against USEPA reference conditions.

Nitrogen – Total Nitrates (NO_2) and Nitrites (NO_3)

Total nitrite and nitrate (referred to as total nitrates) results were compared to USEPA's (USEPA 2000) total nitrite and nitrate reference conditions of 0.94 mg/L. 129 of 150 (86%) samples were above USEPA's reference condition. Appendix G shows total nitrite and nitrate results against USEPA reference conditions.

Nitrogen – Total Nitrogen

Total nitrogen is the sum of total Kjeldahl nitrogen and total inorganic nitrogen (nitrate/nitrite). TKN and nitrate/nitrite were added to calculate total nitrogen. Project data was compared to USEPA's (USEPA 2000) reference conditions of 1.59 mg/L. 129 of 150 (86%) samples were above USEPA's reference conditions. Appendix G shows total nitrogen results against USEPA reference conditions.

Parameters: Total Phosphorus and Orthophosphate

Phosphorus was analyzed in samples as total phosphorus and total reactive orthophosphate. Wisconsin has established regulations for total phosphorus under NR 102. The Milwaukee River downstream of the Cedar Creek confluence has a total phosphorus criterion of 100 μg/L (0.1 mg/L) (sampling locations L22,

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

L24, L25, L26, L28, and L30). The Milwaukee River upstream of Cedar Creek and all other streams have a total phosphorus criterion of 75 µg/L (0.075 mg/L). Wisconsin does not have standards for orthophosphate, but the USEPA (1986) recommends no more than 0.05 mg/L for streams discharging into reservoirs and a maximum level of 0.1 mg/L for rivers and streams (USEPA 1986). Project results were compared to state standards and USEPA recommendations.

89 of 150 samples (59%) exceeded the state established regulations for total phosphorus. Appendix G shows total phosphorus results against the state standard maximum. 78 of 150 samples (52%) had total orthophosphate results above 0.05 mg/L. 13 of 150 samples (9%) exceeded the USEPA recommendations for maximum levels of orthophosphate which included locations L2 (N. Branch Milwaukee River near terminus), L3 (Milwaukee River upstream of River Road Creek), L4 (Milwaukee River downstream of Fredonia Wastewater Plant Discharge), L7 (Hawthorne Drive Creek near terminus), L9 (Riverside Drive Creek near terminus), and L23 (Ulao Creek near terminus) (Table7). L7 (Hawthorne Drive Creek near terminus) exceeded recommended levels in 4 of 5 samples and L9 (Riverside Drive Creek near terminus) exceeded recommended levels in 3 of 5 samples. Appendix G shows total orthophosphate results against the USEPA recommended maximum.

Table 7 Orthophosphate results higher than USEPA recommended maximum levels

Laboratory Description	Location Description From Upstream to Downstream	Collected	Sampling Location Condition Dry=low flow Wet=high flow	Total Orthophosphate (mg/L)
SW-L1-R3	Milwaukee River at Newburg Dam tailwater	10/7/2013	Wet	0.13
SW-L2-R3	N. Branch Milwaukee River near terminus	10/7/2013	Wet	0.11
SW-L3-R3	Milwaukee River upstream of River Road Creek	10/7/2013	Wet	0.12
SW-L4-R3	Milwaukee River downstream of Fredonia Wastewater Plant Discharge	10/7/2013	Wet	0.13
SW-L7-R1-12	Hawthorne Drive Creek near terminus	5/31/2012	Dry	0.11
SW-L7-R2-13	Hawthorne Drive Creek near terminus	8/6/2013	Dry	0.13
SW-L7-R3	Hawthorne Drive Creek near terminus	10/7/2013	Wet	0.12
SW-L7-R5-13	Hawthorne Drive Creek near terminus	4/29/2014	Wet	0.28
SW-L9-R1-12	Riverside Drive Creek near terminus	5/31/2012	Dry	0.15
SW-L9-R2-13	Riverside Drive Creek near terminus	8/6/2013	Dry	0.14
SW-L9-R5-13	Riverside Drive Creek near terminus	4/29/2014	Wet	0.37
SW-L23-R2-13	Ulao Creek near terminus	8/6/2013	Dry	0.18
SW-L23-R3	Ulao Creek near terminus	10/7/2013	Wet	0.14

Parameter: Total Suspended Solids

There is not yet any state or federal standard for total suspended solids (TSS), but the Milwaukee River Basin TMDL currently in development is using 12 mg/L as the allowable load and target concentration. Studies show that TSS can be harmful to organisms at acute and chronic levels and the target may need to be adjusted in the future, but our results were compared to the current limit set in the TMDL for a baseline comparison. 42 of 150 (28%) samples were above the limit for TSS. Appendix G shows total TSS results against the Milwaukee River Basin TMDL target concentration.

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

Normalized Data Comparisons

As noted above, results of data collected for the Project were compared to state and federal standards or recommendations for each parameter (as available) in an initial effort to highlight sampling locations with results that may warrant further examination. However, these standards are often generalized for larger water bodies or systems and thus are not always directly applicable in all systems (e.g., the Milwaukee River and its tributary stream in Ozaukee County). As such, discrete monitoring data was normalized using mass balance calculations based on estimated discharge rates to facilitate location comparisons. The mass of each parameter was calculated for each sample and wet (two samples at each location taken under low flow conditions) and dry samples (three samples each at location taken under high flow conditions) were averaged for comparison between sampling locations. Appendix H includes a series of tables showing the mass balance results for the average wet and dry mass balance calculations for each location, and comparisons between a selection of grouped locations to show up and downstream conditions.

The most notable patterns shown from the mass balance calculations are that larger main stem Milwaukee River sampling locations hold the most volume (e.g. largest discharge area) and account for the highest mass input to the system and the masses calculated during high flow sampling events are much higher than masses calculated under dry sampling events. A comparison of grouped sampling locations showed uniform results from location to location, but wet conditions showed elevations at certain locations. Across all parameters there is a general pattern of lower masses to higher masses from upstream to downstream in the system with elevated results at a few locations. Comparing the most upstream sampling location (L1, Milwaukee River at Newburg Dam tailwater) to the most downstream sampling location (L30, Milwaukee River downstream of Trinity Creek) indicates a similar pattern of lower results across all parameters upstream compared to higher results downstream under high flow conditions; however, under dry conditions the results were very similar from upstream to downstream.

Results tend to be higher just downstream of the Fredonia wastewater treatment plant (L4) under high flows for all parameters, but drastically lower at the near-by downstream sampling point (L6). Results downstream of the treatment plant and the next downstream sampling point are very similar to each other under dry conditions. Alternatively, results are generally higher upstream of the Saukville wastewater treatment plant (L11) than downstream. Again, upstream and downstream results are similar to each other under dry conditions.

The location downstream of Hawthorne Drive Creek (L8) resulted in small to moderate elevations in nutrient and pollutant loads indicating that Hawthorne Drive Creek could be an important contributor to the mainstem Milwaukee River.

Under high flows, results show an elevation downstream of Mole Creek (L15) for all parameters. The results of the two sampling locations on Mole Creek (L13, L14) were low compared to the mainstem sampling location (L15), but results from the location at the terminus (L14) were consistently higher than the upstream location (L13). Under low flows, L13 and L14 had lower and more uniform results. Appendix I shows maps with subwatersheds ranked from lowest to highest and includes an example comparing orthophosphate results on the two portions of Cedar Creek and Mole Creek. Under high flows, the results of the two portions of Cedar Creek tend to be more uniform (an equal contribution) whereas the downstream portion of Mole Creek consistently had higher results than the upstream portion (unequal contribution). The high results downstream of Mole Creek could be a function of Mole Creek contributions or from a contribution further upstream.

In general, results surrounding the Bridge Street Dam (L16, L17) are higher than locations upstream, but results from the tailwater location (L17) tended to be much higher than in the impoundment. An exception was an elevation in TSS in the impoundment under high-flow conditions. Further downstream

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

surrounding the Mequon-Thiensville Dam, results were generally high in this stretch of the river up and downstream of the dam, but there were higher elevations in the impoundment (L25) than in the tailwater (L26) during high flows, opposite of the results from the Bridge Street Dam. Results were similar to each other during low flows.

Under high flows, results show a significant elevation downstream of the Grafton wastewater treatment plant discharge area (L18) for all parameters. Results from upstream of the wastewater treatment plant (L17) tended to be similar to those downstream during dry conditions.

Results for each parameter tended to drop at the location upstream of Cedar Creek (L19) and elevate again downstream of Cedar Creek (L22) under high flow conditions. Under low flow conditions, results upstream (L19) and downstream (L22) of Cedar Creek for each parameter were mixed. Some results were similar to each other upstream to downstream and some results the downstream location remained higher. The consistent elevations downstream of Cedar Creek under high flows and in some cases low flows could indicate the creek is an important contributor to the main stem Milwaukee River.

Results were generally higher for the locations in the downstream portion of the mainstem Milwaukee River as compared to locations sampled in the upstream portions. Following this pattern, results from locations downstream of Pigeon (L28) and Trinity Creeks (L30) were high, but often even higher than nearby locations upstream under wet and dry conditions, indicating that Pigeon and Trinity Creeks may be contributing to the high loads and/or there is a build-up of nutrients and pollutants from upstream.

The results of the mass balance calculations showed strong and consistent patterns across most or all parameters (depending on the sampling location) giving insight into potential point source or tributary source pollution and nutrient hotspots. It is important to note, however, that some of the flow calculations used to determine the mass were estimated based on available data and the results from the two dry samples were averaged against the results of the three wet samples. In addition, larger main stem Milwaukee River sampling locations hold the most volume (e.g. largest discharge area) accounting for the highest mass input to the system and mass is not normalized by area contribution (Rice and Izuno 2001). Furthermore, additional sampling and land-use research is warranted to gain a greater understanding of long-term water quality conditions at each sampled location under various flow events.

Subwatershed (Tributary) Influence on Mainstem Milwaukee River Quality

As noted above, larger main stem Milwaukee River sampling locations hold the most volume thus accounting for the highest mass of input to the system. The area of each tributary watershed was calculated to compare the relative load contributions of each parameter per unit of area to account for the differences in masses due to the varying flow volume (discharge area) (Rice and Izuno 2001). This calculation was not done for samples taken on the mainstem Milwaukee River as the area influence in the mainstem is not clearly defined. Appendix I includes a table for each parameter comparing the unit or mass per acre of each tributary (subwatershed) contributing to the Milwaukee River. Also included in Appendix I is a series of maps showing the same information with a color gradient showing the lowest to highest mass (or unit for fecal coliform) per acre among those subwatersheds.

Observations: Subwatershed Results under Dry Conditions

The results of each parameter at each subwatershed sampling location were sorted from least to greatest mass (unit) per acre (Appendix I) under dry sampling conditions to compare relative influences to the Milwaukee River. The Mole Creek watershed was divided into two sections as one sampling location (L14) was located just upstream of the confluence with the Milwaukee River and the other further upstream (L13). L14 had the highest unit/mass per acre for each parameter among all the locations (aside from chlorophyll a) where L13 ranked much lower, indicating a greater land-use influence between L13

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

and L14 on Mole Creek. Cedar Creek also had two sampling locations and results tended to be ranked lower or in the middle among other subwatersheds. The two Cedar Crek sampling sites also ranked close together, indicating the two portions of Cedar Creek are contributing at a similar rate. Fredonia Creek, North Branch Milwaukee, Riverside Drive Creek, and Ulao Creek also tended to rank higher in comparison with the other sites. Hawthorne Drive Creek consistently ranked lowest across all the parameters.

Observations: Subwatershed Results under Wet Conditions

The results of each parameter at each subwatershed sampling location was sorted from least to greatest mass (unit) per acre (Appendix I) under wet sampling conditions to compare relative influences to the Milwaukee River. Overall, the total mass (unit) per acre under wet conditions was higher than dry conditions confirming higher nutrient and contaminant output under higher flows. Under wet conditions, the two Mole Creek sampling locations ranked more in the middle among other subwatersheds. Higher results came from the upstream sampling site (L13) under wet conditions; however opposite results were noted under dry sampling conditions. The Cedar Creek sampling locations again ranked lower and close together. Fredonia Creek ranked highest for the majority of the parameters followed by the North Branch Milwaukee, Riverside Drive Creek, and Ulao Creek sampling sites ranking higher in comparison with the other sites under both wet and dry conditions. Pigeon Creek consistently ranked lowest across all the parameters.

Continuous Water Quality Sampling Results

Daily and monthly maximum, average and minimum graphs for each parameter and year can be found in appendices J, K and L.

Parameter: Water temperature

The WDNR Chapter NR102 Water Quality Standards for Wisconsin Surface Waters (WDNR 1973) sets a water temperature maximum for a Warm Water Sport Fishery (Milwaukee River) of 31.7°C. Daily maximums were measured against this standard.

At all three sites in 2011 water temperatures averaged mid to high 20's during the hottest part of the year, but stayed below the state standard maximum except for one day in July at site 1, which reached a high of 32°C. All three sites showed similar temperatures and fluctuation patterns for the entire set of data.

In 2012, water temperatures consistently averaged low to mid 30's from late-June to mid-August, reaching above the maximum state standard water temperature. 2012 was a severe drought year and the hottest year on record, which likely contributed to the extremely high water temperatures (NOAA 2012). All three sites showed similar temperature and fluctuation patterns for the entire set of data.

In 2013, water temperatures peaked at 30.5 °C at site 1, but averaged low to mid-20's during the hottest part of the year. Site 3 water temperatures peaked at 30.9 but averaged low- to mid-20's during the hottest part of the year. Data was not recorded until late September at site 2, but all three sites showed similar temperatures fluctuation patterns for the entire set of data.

In 2011 and 2013 when yearly weather was more typical, water temperatures were mostly below the state standard water temperature maximum aside from a few days in the year, with 2013 results slightly higher than 2011. In 2012, a severely dry and hot year, daily maximum temperatures were above the standard maximum for most of the summer months. All three locations followed similar temperatures and fluctuation patterns during periods of monitoring.

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

Parameter: Water depth

The continuous water monitoring systems measured water depth to illustrate the changes throughout the seasons as well as upstream to downstream. Depth results were not intended to be analyzed alone, but in comparison with other parameters in further or future analysis. Overall, site 1 had the highest average depth and site 2 the lowest average depth.

Parameter: Dissolved Oxygen (DO) Concentration

WDNR Administrative Rule 102.04 (4a) states: "the dissolved oxygen content in many surface waters (including waters designated as a Warm Water Sport Fishery) may not be lowered to less than 5 mg/L at any time (WDNR 1973)". Dissolved oxygen was measured as a percent concentration where 80-120% concentration is considered "good" and below 60% is considered "poor".

In 2011 daily maximum, minimum and average results consistently stayed within the ideal range for site 1, but the daily minimum and average dipped below the 60% threshold for the majority of July, during the hottest part of the year as well as a few isolated days in August and September. Daily minimum and average results consistently stayed within the high range of an ideal dissolved oxygen concentration throughout the monitoring period, but maximum daily concentrations were often higher than 120%, reaching 140% at a maximum. Daily maximum, minimum and average results consistently stayed within an ideal range for site 3, but the daily minimum dipped below the 60% threshold for parts of July and August.

In 2012, the majority of the daily minimum and average results for site 1 were below the 60% threshold during the sampling period with daily minimum results nearing dangerously low results. The daily maximum results were above 60%, and generally above 100% saturation. Dissolved oxygen readings were only recorded in July and a portion of June and August, due to probe malfunction, but monthly averages were all below the 60% threshold. At site 2, daily minimum, maximum and average dissolved oxygen results fluctuated greatly from above 100% saturation to lower than 20%. Again, readings were only recorded during the months of June, July and August due to probe malfunction with June averaging above 60% saturation and July and August below. At site 3, dissolved oxygen was recorded from June until November with each month averaging over 60% saturation. Daily minimums fluctuated throughout the season with undesirable low readings during the summer months. Daily maximums were generally above 100% saturation and daily averages were consistently around 70% saturation during the summer months and fluctuating more in the fall.

In 2013, daily maximum, minimum and average results consistently stayed within the ideal range for site 1 throughout the monitoring season, but daily minimums dipped below 60% from late July through mid-September. The monitoring system used at site 2 was not deployed until September due to equipment malfunction and need for repair thus dissolved oxygen concentration was not recorded during the hottest part of the year when dissolved oxygen is typically lower, but daily maximum, minimum and average results consistently stayed within the ideal range for the remainder of the monitoring period. The dissolved oxygen probe at site 3 also malfunctioned and data was not recorded at this site during 2013.

All three years showed lower dissolved saturation during the hotter, drier summer months (June, July and August). Due to multiple probe malfunctions and partial data sets site to site comparisons may not elucidate true conditions from the data collected and further analysis may be warranted.

Parameter: Hydrogen Ion Concentration (pH)

WDNR Administrative Rule 102.04 (4c) (WDNR 1973) states that the pH shall be within the range 6.0 to 9.0, with no change greater than 0.5 units outside the estimated natural seasonal maximum and minimum. A pH of 7.5 is considered ideal.

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

In 2011, daily minimum, maximum and average results were all within the state standard range for site 1, but tended to be on the high end of the range. Site 2 had daily minimum and average results within the State standard range, but had a few readings above the standard, and in general readings were high. The pH probe at site 3 was giving erroneous readings throughout the monitoring season even after multiple recalibrations and needed to be replaced, thus there is not enough data to compare with the other sites.

In 2012, daily minimum, maximum and average results were generally within the state standard range for sites 1 and 2, but were consistently on the high end of the range, with a few maximum daily averages surpassing the State standard range. Site 3 showed a similar pattern with the majority of the readings on the high end of the range, but had more variation with some results closer to the ideal pH range.

In 2013, daily minimum, maximum and average results were within the state Standard range for all three sites and stayed closer to ideal pH of 7.5 to the lower end of the State standard range.

2011 and 2012 pH results were generally within the state standard range, but had multiple readings above a pH of 9, with 2012 showing the most frequent high results. 2013 showed significantly lower pH levels, much closer to the ideal pH range. Site 3, the furthest upstream location, consistently had lower pH levels in comparison to sites 1 and 2.

Parameter: Conductivity

Conductivity in streams is naturally affected by geology and can be higher or lower depending on the bedrock, soils and water passing through. It can also be affected by discharges to streams such as chlorides, heavy metals, sewage, and nutrients (phosphates and nitrates). A conductivity reading of 150-500 umhos/cm can provide for a healthy aquatic ecosystem and conductivity outside of this range could indicate the waterbody is not suitable for certain aquatic species (water.epa.gov). Our data was compared to this range. In 2011, 2012, and 2013 daily maximum and average conductivity readings were significantly above the maximum recommended by USEPA at all three continuous monitoring stations. Daily minimum readings were closer to the maximum conductivity recommended by USEPA, but the lowest readings were still above 500 uhmos. The high readings could be the result of many variables and needs to be investigated further, but could indicate high levels of chlorides and nutrients or other pollutants in the water.

Discussion

Comparisons to Other Data

In 2013 and 2014 the Ozaukee County Land and Water Management Department and River Alliance of Wisconsin took grab samples for total phosphorus and orthophosphate at multiple points along Ulao Creek, including at the same Ulao Creek location sampled for this project (L 23). In 2013, under low flow conditions, their L23 samples averaged 0.175 mg/L total phosphorus, with a minimum of 0.0651 mg/L and a maximum of 0.315. In 2014, under low and high flow conditions, an average of 0.529 mg/L was calculated for all samples at all sites along Ulao Creek, with a minimum of 0.125 mg/L and maximum of 0.821 mg/L. 2014 results for the L23 sampling location was 0.464, with a minimum of 0.229 and maximum of 0.821. 2013 Project results are comparable and similar to the Land and Water Management/River Alliance of Wisconsin results and samples were taken during similar time periods and flows at the same location. This project did not take as many samples, but the trends in the results indicate high phosphorus loads in Ulao Creek under low and high flow conditions.

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

Ongoing and Relevant Work

Continuous Water Quality Monitoring

Department staff continued continuous water quality monitoring activities in 2014 under procedures and protocols outlined in the Project QAPP as staff time and field conditions allowed, though formal continuous water quality monitoring activities under this grant were completed in 2013. This data will be added to the overall continuous water quality monitoring database, vetted for quality control, and formatted for inclusion into the SWIMS database.

Ulao Creek Watershed Water Quality Monitoring

In 2013 and 2014 the Ozaukee County Land and Water Management Department and River Alliance of Wisconsin took grab samples for total phosphorus and orthophosphate at multiple points along Ulao Creek, including the same Ulao Creek location sampled for this Project (Location 23).

Milwaukee Riverkeeper Monitoring

The local water quality non-profit organization, Milwaukee Riverkeeper, has been collecting water quality data within the Milwaukee River Basin since 2010 in an effort to summarize the conditions of watersheds within the basin as well as the changes occurring from year to year. Several of Milwaukee Riverkeeper's monitoring stations are located near the Project's discrete and continuous sampling locations allowing for comparison of results. In their annual report card (Appendix M), Milwaukee Riverkeeper divides the Milwaukee River by larger subwatersheds to give an overall grade to each section and includes data on specific monitoring stations. The northern two-thirds of the Milwaukee River South subwatershed and the most downstream portion of the Cedar Creek and East and West Branches subwatersheds make up most of the Milwaukee River Basin located in Ozaukee County. From 2010 to 2012, the Milwaukee River South subwatersehed was given an overall "A" grade for dissolved oxygen, pH, instantaneous and continuous water temperature data collected. On the contrary, a failing grade was given for turbidity, phosphorus, conductivity, chlorides, and bacteria for all three years. Cedar Creek and the East & West Branches subwatersheds had similar "high grade" results for dissolved oxygen, pH, instantaneous and continuous water temperature data collected as well as turbidity. Phosphorus and conductivity were again given failing grades. Without completing a formal statistical analysis, we noted consistencies with Milwaukee Riverkeeper data for pH, temperature, suspended solids, conductivity, and nutrient loads, indicating where water quality is meeting standards and where further studies and/or improvements are needed. A combination of the Milwaukee Riverkeeper monitoring data, Ozaukee County data, and other sources will be useful for future water quality improvement planning by providing baseline and highlighting potential pollution hotspots, significant load contributions and trends overtime.

Milwaukee Metropolitan Sewerage District Data Sharing

Portions of Ozaukee County receive sanitary sewerage treatment services from the Milwaukee Metropolitan Sewerage District (MMSD). After Ozaukee County was awarded the USEPA/GLRI funding to complete Project activities, MMSD expressed interest in acquiring Project data to assist with ongoing studies and initiatives in the Milwaukee River Watershed. On June 12, 2012, MMSD and Ozaukee County entered into an Intergovernmental Cooperation Agreement (ICA) (Appendix N) for the purposes of sharing water quality information and other environmental data for the development of joint projects, such as addressing ecological productivity through fish passage techniques (i.e., specially designed culverts, fishways), addressing beneficial use impairments in the Milwaukee Estuary Area of Concern, and development of scientifically supported and sustainable total maximum daily loads for various pollutants and other substances. The ICA states that the shared Ozaukee County and MMSD data would reside in the MMSD/United States Geological Survey Corridor Study Database. As such, all Project data will be uploaded to this Database. Furthermore, the Department is currently coordinating with MMSD on installing a continuous water quality monitoring system in Cedar Creek at Covered Bridge County Park as well as collaborating on efforts to take a full suite of grab samples for up to 43

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

water quality variables that MMSD currently analyzes within the Milwaukee River Watershed over a longer term under the ICA.

Lessons Learned

While the data collected during discrete water quality sampling is most useful as a set of baseline data with the potential to guide future water quality management decisions, continuous sampling for a longer period would give the ability to compare to state and federal standards that use long term averages rather than discrete points of data. Streams and rivers are constantly changing. Thus, the data collected only reflects the stream conditions at one location in one point in time and the parameters being analyzed are analyzed on a microscopic scale. Further long-term testing using the same procedures and protocols is recommended for a more comprehensive data set. In addition, collecting the same parameters taken at each continuous water quality monitoring station (e.g., water temperature, conductivity, dissolved oxygen, pH, depth) would have been useful for data analysis at each discrete location.

Results of data collected for the Project were compared to state and federal standards or recommendations for each parameter (as available) in an initial effort to highlight sampling locations with results that may warrant further examination. However, these standards are often generalized for larger water bodies or systems and thus are not always directly applicable in all systems (e.g., the Milwaukee River and its tributary streams) in Ozaukee County. As such, discrete monitoring data was normalized using mass balance calculations based on estimated discharge rates to facilitate location comparisons. Discharge estimates for each discrete sampling site were calculated using stream profile and flow data acquired by the Consultant during the initial low flow and final high flow sampling event. Per the QAPP, flow was measured by using either the float method or with a hand-held flow meter. At some sites the flow was too low to get an accurate reading with the hand held flow meter, as the low flow cutoff was .5 feet per second. Per consultant recommendations, flows of .1 feet per second were used at these locations. In addition, the consultant was not able to take accurate stream profile measurements due to safety or access concerns (e.g., in the Bridge Street and M-T Dam impoundments). As such, the discharge rates at the nearest USGS stream gauging station (station 04086600 near Cedarburg) were used for these locations.

The Project budget provided for the purchase of three Global Water continuous monitoring systems. These systems required yearly factory calibration and replacement of miscellaneous failing parts, resulting in unanticipated costs, extra staff time to manage and coordinate, and loss of data. More reliable systems with less required maintenance would have been preferred, but the proposed budget did not allow for higher end units.

WDNR recommended retesting at discrete sampling sites with fecal coliform results higher than 400 CFU/100 mL. Sites with high fecal analysis results in the first round discrete sampling were retested and results were significantly lower, not warranting further E.coli testing. It is possible that the lag time and changing conditions between the initial and retest resulted in a lower result. In addition, the holding time for testing a sample for E. coli is 24 hours and initial results were not provided by the lab for several days after testing. As such, retesting for fecal coliform and E. coli did not occur subsequent to the remaining four sampling events due to the timeframe lag between the field sampling and lab analysis and results delivery. Ideally, laboratory results would be provided immediately after sampling, so field retesting could be completed in similar water conditions. However, receiving immediate results would have likely required significantly higher consultant and laboratory costs to manage the quick turnaround time, which would have reduced the overall remaining sampling budget. In addition, budgeting for an unknown number of re-tests (theoretically, fecal coliform and e-coli retesting at each sampling site after each event) required a large contingency to be built into consultant contracts, which also impacted the overall remaining budget for remaining required sampling.

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

Recognition and Awards

The County and its partners have received numerous awards and recognition for efforts supported by the GLRI and USEPA. In 2011, the Ozaukee County Planning and Parks Department received a National Association of Counties (NACO) award for its “Fish Passage for the Milwaukee River Watershed” Program, noting the promotion of quality, efficient, and responsive management and administration. In 2012, Andrew Struck received the Treasures of Oz “Wizard of Oz” for environmental leadership and organization. Also in 2013, Andrew received the Gathering Waters “Conservationists of the Year” award for aquatic connectivity efforts, and Andrew received the Ozaukee Washington Land Trust “Timothy Kaul Leadership Award” for outstanding leadership in conservation. In addition, the Ozaukee County Fish Passage Program received a 2013 Wisconsin Department of Natural Resources “Wisconsin Citizen Based Monitoring Program of the Year” award, and Rick Frye, a Program volunteer, received the Wisconsin Department of Natural Resources “Wisconsin Citizen Volunteer of the Year” award.

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

References Cited

Bain, M. B. and Stevenson, N. J., editors. 1999. Aquatic habitat assessment: common methods. American Fisheries Society, Bethesda, Maryland.

Ohio EPA (Ohio Environmental Protection Agency). 2006. Level 2 data requirements and reporting. 3745-4-05. http://www.epa.state.oh.us/portals/35/rules/04-05.pdf. May 16, 2011.

NOAA (National Oceanic and Atmospheric Administration). 2012 Wisconsin Yearly Weather Summary. Online: (http://www.crh.noaa.gov/images/mkx/climate/2012/2012_WI_Yrly_Wx_Summary.pdf).

Rice, R.W. and Izuno, F.T. 2001. Calculating Nutrient Loads. University of Florida Cooperative Extension Service, Institute of Food and Agriculture Sciences, EDIS, Gainesville, Florida.

SEH and ECT (Short Elliot Hendrickson and Environmental Consulting and Technology Inc). 2008. Delisting targets for the Milwaukee Estuary area of concern: final report. Submitted to the Wisconsin Department of Natural Resources, Madison, Wisconsin.

USEPA (United States Environmental Protection Agency). 5.9 Conductivity. Last updated March 2012. Online: (http://water.epa.gov/type/rsl/monitoring/vms59.cfm).

USEPA (United States Environmental Protection Agency). 1986. Agency Quality Criteria for Water. EPA-440/5-86-001. Washington, DC.

USEPA (United States Environmental Protection Agency). 2000. Ambient Water Quality Criteria Recommendations − Information supporting development of state and tribal nutrient criteria: Rivers and streams in nutrient ecoregion VII. EPA 822-B-00-018. Washington, DC.

USEPA (United States Environmental Protection Agency). 2013. Aquatic Life Ambient Water Quality Criteria for Ammonia – Freshwater 2013. EPA-822-R-13-001. Washington, DC.

WDNR (Wisconsin Department of Natural Resources). 1973. Chapter NR 102 Water quality Standards for Wisconsin Surface Waters. Published under s. 35.93, Wisconsin Statutes, by the the Legislative Reference Bureau. Wisconsin Department of Natural Resources, Madison, Wisconsin.

WDNR (Wisconsin Department of Natural Resources). 2014. Remedial Action Plan Update for the Milwaukee Estuary Area of Concern.

WDNR (Wisconsin Department of Natural Resources). 2010. Wisconsin 2010 consolidated assessment and listing methodology (WisCALM). PUB WT-913 2009. Wisconsin Department of Natural Resources, Madison, Wisconsin.

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0

Appendices

Appendix A: No Cost Time Extension Letters and Approvals

Appendix B: QAPP Revision 4

Appendix C: Water Quality Sampling Locations and Continuous Monitoring Stations

Appendix D: Subwatershed Map of Water Quality Sampling Locations and Continuous Monitoring Stations

Appendix E: Data Quality Review

Appendix F: Summary of Continuous Water Quality Monitoring Systems Checks and Maintenance

Appendix G: Discrete Water Quality Sampling Results – All Inclusive Graphs

Appendix H: Calculated Mass Balance Tables

Appendix I: Calculated Mass (Unit) per Area Tables and Maps

Appendix J: 2011 Daily and Monthly Minimum, Maximum and Average Continuous Water Quality Graphs

Appendix K: 2012 Daily and Monthly Minimum, Maximum and Average Continuous Water Quality Graphs

Appendix L: 2013 Daily and Monthly Minimum, Maximum and Average Continuous Water Quality Graphs

Appendix M: Milwaukee Riverkeeper 2011 and 2012 River Report Cards

Appendix N: MMSD and Ozaukee County Intergovernmental Cooperation Agreement

Funded by the United States Environmental Protection Agency and the Great Lakes Restoration Initiative, Grant #GL-00E00607.0