A Proof-of-Concept Pilot Study of Transboundary Monitoring of Environmental Factors and their Influence on Waterborne Acute Gastrointestinal Illness (AGI) in Cities that Source Water from the Great Lakes

Phase 1: Feasibility Study

Prepared for:
International Joint Commission
by the
Health Professionals Advisory Board
and

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DATA . STRATEGY . RESULTS
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List of Acronyms

AGI	acute gastrointestinal illness
CSO	combined sewer overflow
GLRO	IJC Great Lakes Regional Office
HPAB	Health Professionals Advisory Board
IJC	International Joint Commission
NOAA	US National Oceanic and Atmospheric Administration
PHO	Public Health Ontario
T3W	T3W Business Solutions

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Executive Summary

The International Joint Commission (IJC) Health Professionals Advisory Board (HPAB) conducted a pilot study with the goal of assessing the feasibility of binational surveillance of waterborne acute gastrointestinal illness (AGI) and environmental risk factors. The company T3W Business Solutions (T3W) was contracted to assist with the study. This study collected data on cases of gastrointestinal illness and weather data for four cities within the Great Lakes region of Canada and the United States from 2003 to 2016. Climate change is expected to impact several factors linked to gastrointestinal illness giving some urgency to assessing our capacity to monitor this relationship. The data collected through the pilot study should, in a future project phase, allow examination of challenges specific to source water indicators for four large cities within the Great Lakes basin, Green Bay and Milwaukee, Wisconsin and Hamilton and Toronto, Ontario. This pilot study involved collecting data in a transboundary setting between Canada and the United States that could be used to analyze, interpret and visualize the effects of weather and other risk factors on the incidence of gastrointestinal illness using spatial statistical methods and geographical information systems. Spatiotemporal patterns of waterborne AGI cases around potential exposure sources and weather events may be analyzed in Phase 2 of this pilot.

This pilot study assesses the feasibility of collecting environmental and health data to establish potential associations between variables in these data and to provide recommendations for subsequent analysis regarding relative effects of risk factors on gastrointestinal disease incidence. Risk factor data collected included measures for water quality from source water intakes using the recommended indicators for biological hazards of source water (International Joint Commission Health Professionals Advisory Board 2014). Indicators include turbidity, nitrate, *E. coli*, *Cryptosporidium parvum* and *Giardia lamblia*. Laboratory-confirmed cases of two primary waterborne AGI, giardiasis and cryptosporidiosis, were selected as human health outcomes given the evidence that environmental factors affect the risk of these diseases (Curriero et al. 2001; Thomas et al. 2006). Environmental and meteorological data for extreme rain events, wind direction and air temperatures were obtained to support a statistical time series analysis of the relationship between different event types on both water quality and human illness. In all cases, analytical techniques, sampling frequency and quality control was subject to the processes and parameters in use at each responsible agency.

T3W was directed to obtain comparable data from Hamilton and Toronto on Lake Ontario in Canada, and for Milwaukee and Green Bay on Lake Michigan in the United States. In some cases T3W was successful, while in others, data discovery and analysis by IJC Great Lakes Regional Office (GLRO) staff supplemented the efforts of the contractor. The aim of this study was to develop and evaluate a mechanism for collecting environmental health surveillance data for populations along the shores of all the Great Lakes with these municipalities. Understanding the basinwide origins of potential AGI risk from source water, and mapping AGI occurrences over time, enables consistent binational recommendations and lays a foundation for coordinated testing and potential interventions to address vulnerabilities in drinking water systems. With more related knowledge, jurisdictions may better plan and manage activities to reduce AGI infections caused by drinking water, and plan for climate change and the inevitable associated

weather events which will increasingly test the vulnerability of our drinking water treatment systems.

The HPAB notes that continuation of this work could position IJC as instrumental in harmonizing source water indicators and support real progress on monitoring human health in the Great Lakes. The HPAB evaluated the data collection effort, and the contractor's recommendation to continue analysis, interpretation and visualization of data as part of a second phase of effort. The HPAB evaluation includes a review of resolution, quality, timeframe and metadata for each data set. All four cities provided illness data for giardiasis and cryptosporidiosis between 2009-2014, and that six-year range served as the boundary to assess temporal overlap of all data sets. During those six years, a total of 2993 cases of giardiasis and 577 cases of cryptosporidiosis were reported for all four cities. Based on the health, climate and indicator data retrieved under Phase 1 of this effort, the HPAB also considers it likely that an analysis can be conducted using data in the interval 2009-2014, and therefore recommends moving forward with Phase 2.

1.0 Introduction

The population of the Great Lakes region enjoy widespread ecosystem service from the lakes. For instance, water-based recreation, such as swimming, rafting, canoeing and fishing, are common along the roughly-10,900 miles (7,549 km) of coastline of the Great Lakes. Significant numbers of Canadian and US cities along the Great Lakes also receive drinking water from the Great Lakes. To support continued enjoyment of these services, Great Lakes states and provinces of both countries all adhere to similar, but slightly different, bacterial water quality standards that are based on estimates that ensure a low risk of illness in humans. For example, the US Environmental Protection Agency estimates that, at concentrations of 126 *E. coli* per 100 ml, 8 of every 1,000 swimmers will become ill. Keeping drinking water safe for the 40 million residents of the Great Lakes is one of the most important aspects of the Great Lakes Water Quality Agreement, and the IJC has a responsibility to provide advice to help the Parties (the Canadian and US governments) achieve these human health-related goals.

The Health Professionals Advisory Board (HPAB) previously identified new human health indicators to aid in monitoring the Great Lakes as a drinking water source, which the International Joint Commission (IJC) recommended to the governments of Canada and the United States (International Joint Commission Health Professionals Advisory Board 2014). A source water monitoring approach, and the assessment it supports, requires effort to integrate binational data sets. A related HPAB investigation into the challenges of merging binational environmental and health databases identified limitations of data access, availability and harmonization (Bassil et al. 2015) as barriers. The use of case studies was recommended as a way to further refine and focus binational database integration activities with the aim of examining any relationships between environmental hazards and human illness across the Great Lakes.

This project is a case study to analyze factors contributing to human risk of developing acute gastrointestinal illness (AGI) in the Great Lakes. Phase 1 examines data integration challenges specific to 1) the use of one IJC indicator to assess the Great Lakes as a source of drinking water, and 2) binational data collection and monitoring for source water quality, AGI, and associated environmental information. Data were assembled from four cities in the Great Lakes region: Hamilton, Ontario and Toronto, Ontario in Canada, and Milwaukee, Wisconsin and Green Bay, Wisconsin in the United States. These communities rely heavily on publically-treated and distributed lake water for drinking.

This report details the results of project Phase 1 and the availability and resolution of health, environmental and indicator data. The frequency of reported illness cases for two primarily waterborne AGI, giardiasis and cryptosporidiosis, are summarized. Environmental and meteorological data are detailed for extreme rain events, wind direction, and air and water temperatures were also obtained. The availability of data at drinking water treatment intakes for IJC's biological hazards of source water indicators, (turbidity, nitrate, *E. coli, Cryptosporidium parvum* and *Giardia lamblia*) are also reported.

The data described support the project's Phase 2, a statistical time series analysis of any relationship between different types of extreme rain events on both source water quality and human AGI. Similar studies, including one by Chhetri et al. (2017), have investigated the relationship between cryptosporidiosis and giardiasis, extreme precipitation, drinking water turbidity and changing weather patterns in a drinking water system located in greater Vancouver, British Columbia, Canada. The study was successful at identifying a significant increase in cryptosporidiosis and giardiasis cases nearly four to six weeks after extreme precipitation events.

In some cases, data for this assessment was retrieved by a contractor (T3W), while other data was retrieved by IJC GLRO staff. The HPAB evaluated the data collection effort, and the contractor's recommendation to continue analysis, interpretation and visualization of data as part of a second phase of effort. The HPAB evaluation includes a review of resolution, quality, timeframe and metadata for each data set, as well as the temporal overlap of all data sets, and recommendation for continuing with project Phase 2.

2.0 Methodology

There were two steps accomplished in developing this pilot study: data discovery, and data acquisition and analysis. We have outlined details below.

2.1 Data discovery

The contractor T3W worked to discover, acquire and compile health and environmental data for 10 years (2003-2013) preceding the project approval date for Great Lakes watersheds, though in some cases agencies included data from outside the request period. The actual date ranges for the retrieved data are reported in the sections below. Based on their expertise and contacts, the HPAB shared data providers' contact information as a starting point for T3W queries. The HPAB also identified the required resolution, including frequency of measurement and units (where applicable) for all data in this study. Review of the data received from T3W by IJC GLRO staff indicated that the health data requests were successful in returning the expected number of illness cases, and interpolated weather data for the four cities. Health data were managed in accordance with the data security agreements established with the providing agency and handled in accordance with requirements for health data security of Canada and the United States. IJC GLRO staff collected climate and environmental data, and requested indicator data from source water intakes for each city. All data requested is shown in **Table 1** below on page 4.

2.1.1 Data discovery logistics

Data were available at the state and province level for all regions. IJC GLRO staff found that by using the contacts provided to T3W, the source of indicator, combined sewer overflow (CSO) and weather data could be located fairly quickly, though it was necessary to take the direction of officials to correctly submit the data request. In some cases, the request was redirected to the appropriate point of contact within the agency. Environmental data were usually obtained two weeks to one month after the original request, although invoice processing introduced some delays.

T3W noted additional delay factors for health data discovery, including:

- Slow or no contact response to data requests
- Confusion involving appropriate health data source contact between local and state/provincial agencies
- Lengthy information privacy review process for health data

Table 1: Health, climate and environmental data requested during Phase 1 of this study.

Environmental Data: Weather/Meteorology*	Indicators levels from drinking water intakes**	Health risk factors	Health illness
Precipitation*	Turbidity	Travel history	Reported cases of giardiasis
Extreme rain events	Nitrate	Use of bottled water	Reported cases of cryptosporidiosis
Wind direction and velocity	E. coli	Recreational water exposure	
Temperature: air* and water	Cryptosporidium parvum	Daycare center use	
Lake current	Giardia lamblia		

* Chhetri et al. 2017
** International Joint Commission Health Professionals Advisory Board 2014

For example, the Wisconsin Department of Health Services provided data for Milwaukee and Green Bay. T3W received the data approximately 18 weeks after the initial data request, including agency contact, data and ethics requests processing. Public Health Ontario (PHO) provided health data as requested for Hamilton and Toronto 15 weeks after the initial request. This request may have been processed faster, if not for initial confusion regarding the best provider of data between PHO and individual city public health units. The Communicable Disease Surveillance Unit of Public Health Toronto provided valuable guidance in accessing the data and coordinating communication between the two agencies.

2.1.2 Health data discovery

T3W worked with the IJC HPAB to identify and request data for cases of giardiasis and cryptosporidiosis reported to public health units. Ethics review applications and requirements, with IJC facilitation, were undertaken for data requests for all four cities to secure AGI data at sufficient resolution (e.g., ZIP or postal code, Forward Sortation Area) during the project. Data and ethics review requests were developed and sent on behalf of the IJC HPAB to health data providers including PHO, Ontario Ministry of Health and Long-Term Care, and Wisconsin Department of Health Services. Waterborne AGI variables requested included diagnosed, laboratory confirmed cases for two illnesses and supporting information, with results summarized in **Table 2** (below on page 5).

Initial contact sources for health data often resulted in lengthy callback periods. This delay tended to occur after leaving a message requesting data or when a referral was provided by the initial contact. A contact log was created to document the chain of communication whether by phone or email and the result of the communication, e.g., left a message, referred to another person, etc.

Table 2: Data collected, location and timeframe. The mark represents that data was collected for that type and location, no mark indicates that no data was able to be collected. Health co-factors included travel history, water exposures (municipal water, private well, common well, bottled water, river/lake/pond, ocean, pools, water park, standing water), food exposures (home, restaurant or event), and other contacts or events (pet contact, live/work on farm, animal in environment, manure/compost, diaper wearer).

Data	Green Bay, WI-US	Milwaukee, WI-US	Hamilton, ON-CA	Toronto, ON-CA
Reported cases of giardiasis and cryptosporidiosis	● 2009-2017	● 2009-2017	● 2009-2017	● 2009-2017
Risk factors for infection	●	●		

2.1.3 Environmental data discovery

T3W supplied climate data with the original report. The data was interpolated, however staff were not able to determine if the resolution (e.g., daily rainfall, etc.) was appropriate. Data availability, spatial coverage and date were researched using an internet search engine.

IJC GLRO staff located and obtained most of the requested weather data for each city. At present, the weather data are not interpolated, though a solution for interpolation, either locally or by download of additional agency data sets, could be investigated by staff upon request. **Tables 3** (page 6) and **4** (page 7) list the data collected by IJC GLRO staff from each city, including format, data source, date range, requested resolution and available resolution. All data are geolocated (longitude and latitude). Data for lake temperature and lake currents was obtained from the Great Lakes Observing System and the US National Oceanic and Atmospheric Administration (NOAA). Data for Canadian locations in those downloads were provided to those entities by Environment and Climate Change Canada and the Meteorological Service of Canada as part of a data sharing program. See **Appendix A** for further information.

Table 3: Resolution, source and dates available for climate and environmental data obtained for Ontario cities of Hamilton and Toronto.

City	Data Type	Format	Source	Resolution	Requested Resolution	Date Range
Hamilton, ON	Precipitation	CSV	Meteorological Service of Canada	Daily total (mm)	Daily, aggregated to 7-day cumulative weekly rainfall values	2005-2016
Hamilton, ON	Wind direction/ velocity	CSV	Meteorological Service of Canada	Hourly (degrees, km/h)	Most prevalent wind direction (averaged over the day)	2003-2016
Hamilton, ON	Temperature air	CSV	Meteorological Service of Canada	Daily Max., Min., Mean (°C)	Spatially interpolated historical daily temperature (min., max., and mean)	2005-2016
Hamilton, ON	Temperature water	CSV	NOAA	Hourly	Same as air temperature	2004-2016
Hamilton, ON	Lake Ontario current	CSV	Great Lakes Observing System / NOAA	Daily, every three hours	Averaged over day and taken up to weekly	2006-2016
Toronto, ON	Precipitation	CSV	Meteorological Service of Canada	Daily total (mm)	Daily, aggregated to 7-day cumulative weekly rainfall values	2003-2016
Toronto, ON	Wind direction/ velocity	CSV	Meteorological Service of Canada	Hourly (degrees, km/h)	Most prevalent wind direction (averaged over the day)	2003-2016
Toronto, ON	Temperature air	CSV	Meteorological Service of Canada	Daily Max., Min., Mean (°C)	Spatially interpolated historical daily temperature (min., max., and mean)	2003-2016
Toronto, ON	Temperature water	CSV	NOAA	Hourly	Same as air temperature	2009-2016
Toronto, ON	Lake Ontario current	CSV	Great Lakes Observing System / NOAA	Daily, every three hours	Averaged over day and taken up to weekly	2006-2016

Table 4: Resolution, source and dates available for climate and environmental data obtained for Wisconsin cities of Green Bay and Milwaukee. Data was requested for the years 2003-2016.

City	Data Type	Format	Source	Resolution	Requested Resolution	Date Range
Green Bay, WI	Precipitation	CSV	NOAA	Daily total (mm)	Daily, aggregated to 7-day cumulative weekly rainfall values	2003-2016
Green Bay, WI	Wind direction/ velocity	CSV	NOAA	Average daily speed / Fastest 2 min. direction (m/s, degrees)	Most prevalent wind direction (averaged over the day)	2003-2016
Green Bay, WI	Temperature air	CSV	NOAA	Max., Min., Mean (°C)	Spatially interpolated historical daily temperature (min., max., and mean)	2003-2016
Green Bay, WI	Temperature water (N/A)	N/A	N/A	N/A	Same as air temperature	N/A
Green Bay, WI	Extreme weather events (Brown and Kewaunee County)	CSV	NOAA	Based on NOAA event frequency standard	N/A	2004-2016
Green Bay, WI	Lake Michigan currents	CSV	Great Lakes Observing System	Daily, every three hours	Averaged over day and taken up to weekly	2006-2016
Milwaukee, WI	Precipitation	CSV	NOAA	Daily total (mm)	Daily, aggregated to 7-day cumulative weekly rainfall values	2003-2016
Milwaukee, WI	Wind direction/ velocity	CSV	NOAA	Hourly (degrees, km/h)	Most prevalent wind direction (averaged over the day)	2003-2016
Milwaukee, WI	Temperature air	CSV	NOAA	Max., Min., Mean (°C)	Spatially interpolated historical daily temperature (min., max., and mean)	2003-2016
Milwaukee, WI	Temperature water	CSV	NOAA	Hourly	Same as air temperature	2012-2016
Milwaukee, WI	Extreme weather events (Milwaukee County)	CSV	NOAA	Based on NOAA event frequency standard	N/A	2004-2016
Milwaukee, WI	Lake Michigan surface currents (model)	CSV	Great Lakes Observing System	Daily, every three hours	Averaged over day and taken up to weekly	2006-2016

2.1.4 Indicator and combined sewer overflow data discovery

IJC GLRO staff gathered data on biological hazards of source water indicators from drinking water treatment intakes for three of the four cities. The HPAB assisted with locating entities from which to request indicator measures data and supplemented the contractor's efforts with additional requests. **Tables 5** and **6** below list the available raw water intake data from each city, including the type, resolution and date range of the data. The city of Hamilton, Ontario did not have testing data for *C. Parvum* or *G. Lamblia*; these parameters are not tested for per Mira Bogle of Hamilton Water (Mezzacapo, personal communication). Required annual water reports were also discovered for all cities in PDF format. These reports include data on some of the above indicators. There is wide variation in the collection frequency for these parameters in different locations (e.g., nitrate is collected annually and biannually in the US cities and monthly in Canadian cities).

Table 5: Resolution, source and dates available for indicator data obtained for Ontario cities of Hamilton and Toronto. Data was requested for the years 2003-2016.

City	Indicator	Source	Resolution	Requested Resolution	Date Range
Hamilton, ON	Turbidity NTU	City of Hamilton	Daily average	As granular as possible	2004-2016
Hamilton, ON	Nitrate N (mg/L)	City of Hamilton	2005+ weekly (June-Nov) Monthly (Dec-May)	As granular as possible	2004-2016
Hamilton, ON	E. coli (CFU/ 100mL)	City of Hamilton	Weekly	As granular as possible	2004-2016
Hamilton, ON	*Cryptosporidium parvum*	City of Hamilton	NOT TESTED	As granular as possible	N/A
Hamilton, ON	*Giardia lamblia*	City of Hamilton	NOT TESTED	As granular as possible	N/A
Hamilton, ON	Total coliform	City of Hamilton	Weekly	N/A	2004-2016
Toronto, ON	Turbidity NTU	City of Toronto	Daily average	As granular as possible	11/2004-9/2016
Toronto, ON	Nitrate N (mg/L or ppm)	City of Toronto	Monthly	As granular as possible	9/2003-9/2016
Toronto, ON	E. coli (CFU/ 100mL)	City of Toronto	Daily	As granular as possible	9/2003-9/2016
Toronto, ON	*Cryptosporidium parvum*	City of Toronto	Testing eliminated, previously done ad hoc	As granular as possible	2003-2010
Toronto, ON	*Giardia lamblia*	City of Toronto	Testing eliminated, previously done ad hoc	As granular as possible	2003-2010
Toronto, ON	Total coliform	City of Toronto	Daily	As granular as possible	9/2003-9/2016

Table 6: Resolution, source and dates available for indicator data obtained for Wisconsin cities of Green Bay and Milwaukee. Data was requested for the years 2003-2016.

City	Indicator	Source	Resolution	Requested Resolution	Date Range
Green Bay, WI	Turbidity NTU	Green Bay Water Utility	Daily average	As granular as possible	2004-2015
Green Bay, WI	Nitrate N (mg/L)	Green Bay Water Utility	Annually in April / October	As granular as possible	2003-2017
Green Bay, WI	E. coli (MPN/ 100mL)	Green Bay Water Utility	Monthly	As granular as possible	2015-2016
Green Bay, WI	*Cryptosporidium parvum*	Green Bay Water Utility	Monthly	As granular as possible	2004-2016
Green Bay, WI	*Giardia lamblia*	Green Bay Water Utility	Monthly	As granular as possible	2004-2016
Green Bay, WI	Total coliform	Green Bay Water Utility	Daily pass or fail	As granular as possible	2004-2015
Milwaukee, WI	Turbidity NTU	Milwaukee Water Works	Daily average	As granular as possible	2004-2016
Milwaukee, WI	Nitrate N (mg/L)	Milwaukee Water Works	Once, annually	As granular as possible	2004-2016
Milwaukee, WI	E. coli (CFU/ 100mL)	Milwaukee Water Works	Daily	As granular as possible	2004-2016
Milwaukee, WI	*Cryptosporidium parvum*	Milwaukee Water Works	Every 2 weeks, 2004-2012, then monthly	As granular as possible	2004-2016
Milwaukee, WI	*Giardia lamblia*	Milwaukee Water Works	Every 2 weeks, 2004-2012, then monthly	As granular as possible	2004-2016
Milwaukee, WI	Total coliform	Milwaukee Water Works	Daily	As granular as possible	2004-2016

T3W provided CSO data for the City of Milwaukee, Wisconsin along with its original report. IJC GLRO staff discovered some form of CSO data is available for three cities in the study, and the data retrieved are summarized in **Table 7** below. Locations (X,Y coordinates) of Milwaukee CSO outfalls were provided along with an aggregate of all outfall locations during a CSO event based upon modeling and some flow-meter data. Individual flow-meter outfall data for specific pipes are not available. CSO data were not available for the City of Green Bay, Wisconsin. Per Jeff Smutty of NEW Water (Green Bay Sewer), the city does not have combined sewer systems (Mezzacapo, personal communication). Modeling data was available for all of Hamilton, Ontario outfall locations from the years of 2013-2016, and actual flow-metered monthly totals were available from CSO holding tanks between 2005-2016. Spatial resolution of these data varies greatly. The City of Toronto, Water Treatment and Supply Department was able to supply

modeling data on CSO outfall locations between the years of 2013-2016. The table below illustrates the acquired CSO data for each city. Environment and Climate Change Canada supplied an excel spreadsheet with the reported CSO outfall locations (X,Y coordinates) in the cities of Hamilton and Toronto.

Table 7: Source and dates available for indicator data obtained for Ontario and Wisconsin cities. Data was requested for the years 2003-2016.

CSO City	Format	Data Received	Date Range	Summary
Toronto, ON	.SHP / Excel	TBD	2013-2016*	Model data for CSO outfalls/ reported outfalls to Environment and Climate Change Canada
Hamilton, ON	PDF / Excel	CSO outfall locations, model data, monthly actual outfall data	2006-2016 (some gaps)	Do not have monthly summary numbers for non-tank outfall locations
Milwaukee, WI	.SHP / Excel / PDF	CSO outfall locations, reported events	2003-2016	Events do not list locations
Green Bay, WI	N/A	N/A	N/A	No CSO sewers

* Environment and Climate Change Canada may have 2003-2012

2.2 Data acquisition

Once the data were identified, they were acquired and data quality was examined in terms of resolution, completeness and time frame of the individual data set. In all cases, analytical techniques, sampling frequency and quality control was subject to the processes and parameters in use at each responsible agency. Metadata and contact information for these data sets are included in **Appendix A**.

Most acquired data were freely available. To date, Wisconsin Department of Health Services data cost US$224 (illnesses and co-factors), the City of Green Bay costs US$107 (indicators) and the City of Milwaukee costs US$142 (indicators), for staff to pull the data. All other data were provided at no cost. The wind data requested from Environment and Climate Change Canada did normally incur a charge, but they accepted nonpayment because the request was small.

2.2.1 Health data acquisition summary

Illness data were received by T3W from PHO and the Wisconsin Department of Health Services Bureau of Communicable Diseases, Division of Public Health. Collecting data through public

health organizations took approximately three months from the time of initial contact. For illness and risk factor information, data are discrete and reported as individual cases.

Health data was available, acquired and reported by T3W for all four cities, though risk factor data is more limited. Public Health Toronto noted that risk factor data for cases were not available in digital format and indicated to T3W that data were also not currently digitized in the Institute for Clinical Evaluative Sciences database. Risk factor data are often kept only on paper in the questionnaire file at the local public health unit or are not collected at all. Access to paper records was considered highly unlikely by the PHO contact. As a result, any risk factor analysis in a subsequent project phase would be limited to Wisconsin cities.

One factor limiting data completeness was observed for the Ontario health data set. Roughly 75 percent of the health data from Ontario included a geographical identifier (Forward Sortation Area) while the remaining 25 percent of data delivered did not include Forward Sortation Areas. The data missing a Forward Sortation Area were generally for cases prior to 2006.

Data limitations based on timeframe were reported by T3W and can be observed in **Figures 1** and **2** below (pages 12 and 13, respectively). Continuous year-to-year data sets are available from 2009 to 2014, a shorter time frame than originally anticipated. Illness data from Wisconsin was only available starting in 2009, and for Toronto in 2004 as data prior to this year has not been digitized. In both cases, the agencies' point of contact deemed access to written records highly unlikely

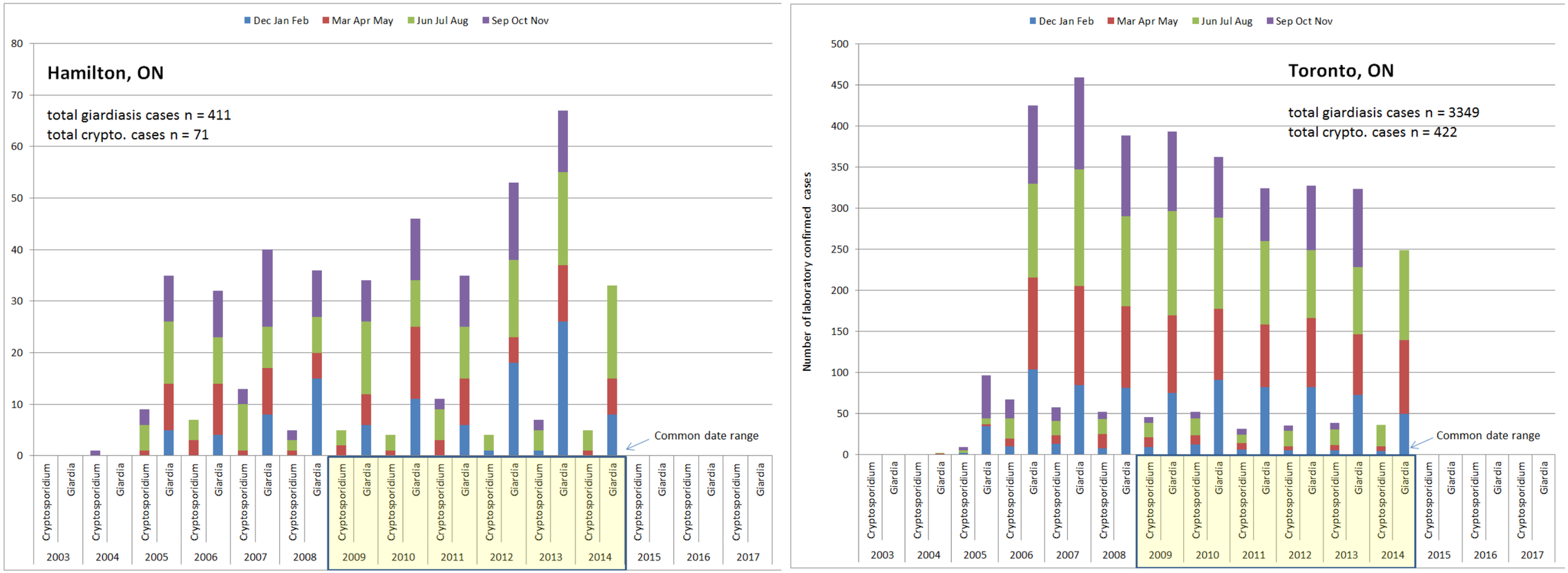
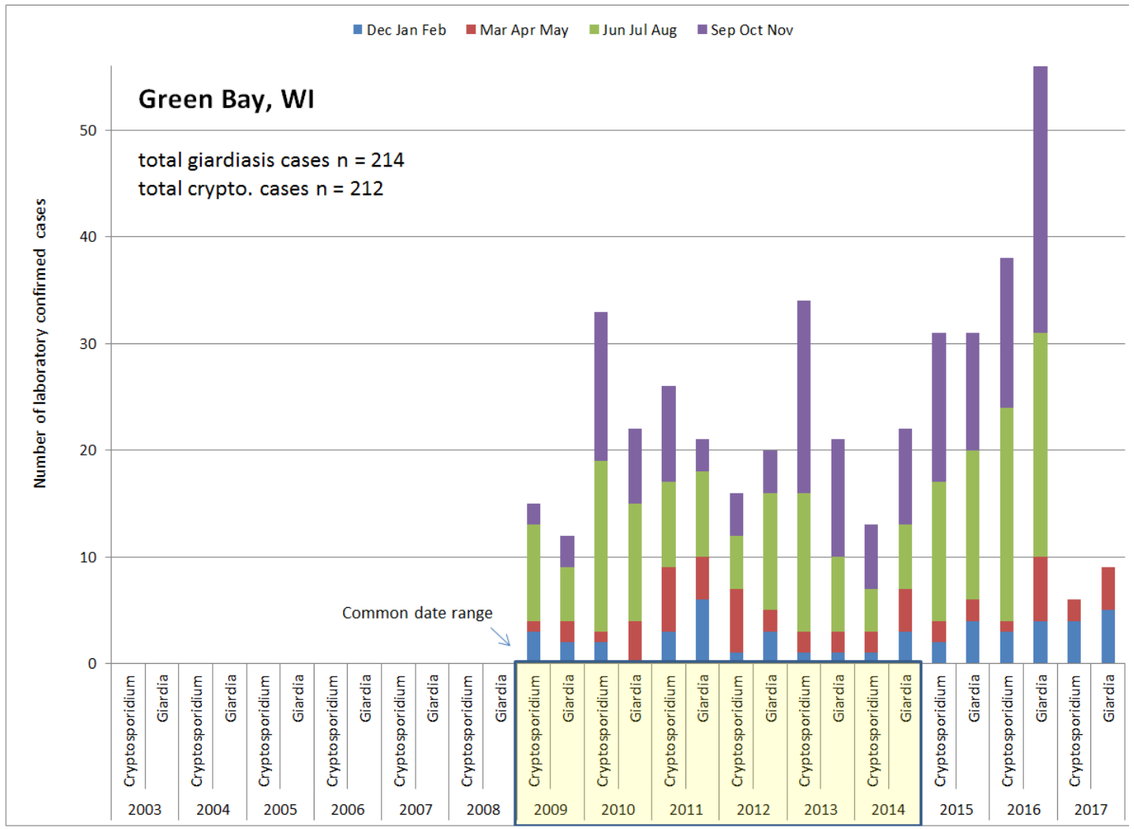


Figure 1: Cases of Giardia and Cryptosporidium for two Ontario cities. Colors refer to season as defined by the legend at the top of each bar graph.



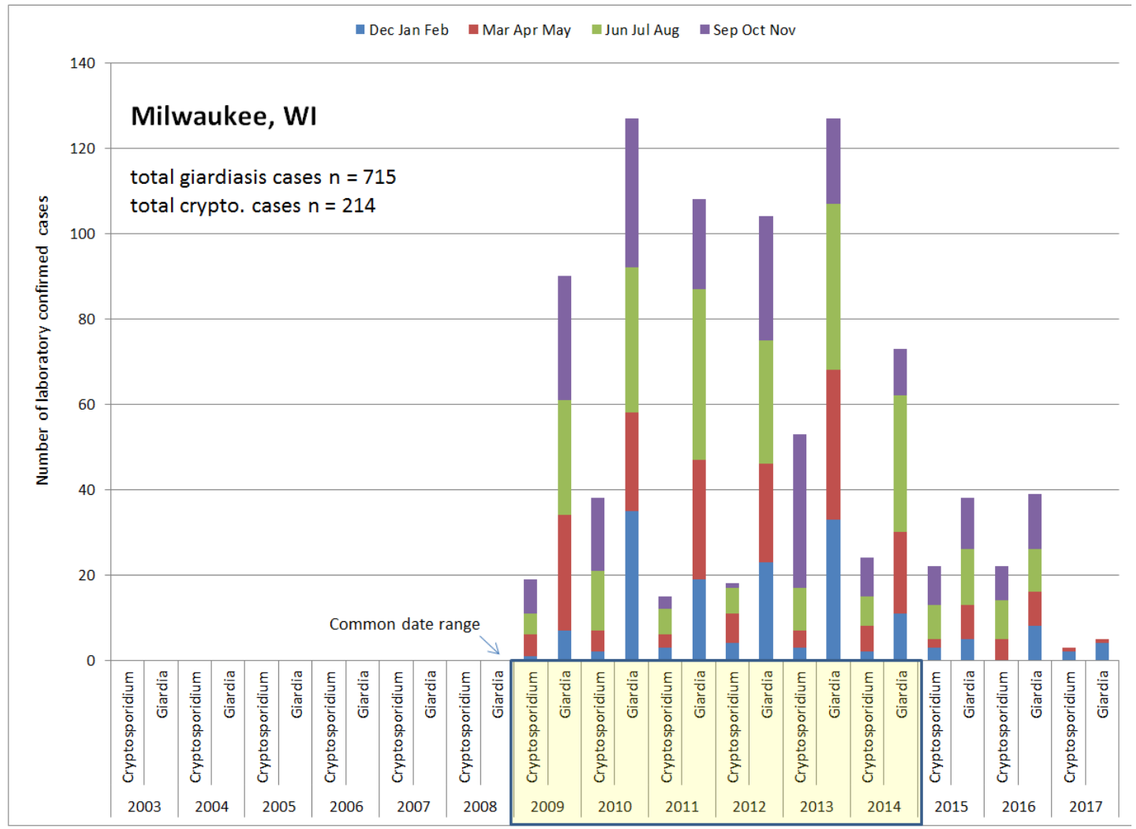


Figure 2: Cases of Giardia and Cryptosporidium for two Wisconsin cities. Colors refer to season as defined by the legend at the top of each bar graph.

2.2.2 Environmental data acquisition summary

IJC GLRO staff obtained nearly all the requested weather data for each city at the requested resolution (**Tables 3** and **4** above). Weather data are available and directly accessible for the region from Environment and Climate Change Canada and NOAA in the United States. Data set completeness was assessed as acceptable for the purposes of the study, in that all data sets requested were retrieved, and for the required timeframe in that no major gaps were detected over time (e.g., none that standard interpolation methods could not be used for missing data). In addition to air temperature and lake current data, corresponding water temperature data were also available for Toronto, Hamilton, and Milwaukee. NOAA reports extreme events based on its own criteria, though the designation of extreme events for this project will be based on the criteria in Chhetri et al. 2017.

2.2.3 Indicator data acquisition summary

GLRO staff were able to obtain indicator data from source water intakes by contacting water agencies in each city to obtain measurements collected at the raw water intake for drinking water treatment plants. A summary of drinking water treatment plant intakes for the four cities in this study is presented in **Table 8**.

Table 8: Great Lakes drinking water treatment plant intakes and their respective plants for the four cities in this study.

City	Water treatment plant	Distance from shore (m)	Intake depth (m)	Lake
Toronto, ON*	R.L. Clark	1600	11	Ontario
	Island (shallow)	*Not in active use*		*Ontario*
	Island (deep)	5400	83	Ontario
	R.C. Harris	2000	15	Ontario
	F.J. Horgan	3200	18	Ontario
Hamilton, ON**	Woodward-Pipe 1	945	8.5	Ontario
	Woodward-Pipe 2	*Not in active use*		*Ontario*
	Woodward-Pipe 3	*Not in active use*		*Ontario*
Green Bay, WI†	Green Bay Water Utility (primary)	1610	15	Michigan
	Green Bay Water Utility (peak depand supplement)	914	9.1	Michigan
Milwaukee, WI‡	Howard Avenue	3285	17	Michigan
	Linnwood	2000	19	Michigan

* CTC Source Protection Committee 2015
** Halton-Hamilton Source Protection Committee 2015
† NSF International and P. C. Carolla Engineers, 2003
‡ Milwaukee Water Works 2017

Tables 5 and **6** describe the requested indicators, their measurement, frequency and availability. Metadata for these data sets are included in **Appendix A**. The timeframe of the individual data sets was deemed compliant in that no major gaps in collection between years were found over the proposed study timeframe.

The completeness of the indicators data set is challenged by the fact that not all cities collect the same measures to monitor the quality of source water at the plant intake, and testing methods and reported units also vary. This impacts whether seasonal trends in indicator levels could be evaluated over time. Turbidity is the only parameter that is collected at intakes for all four cities at the same frequency using the same units, reported as a daily average of Nephelometric Turbidity Units (NTU).

For example, total coliform is collected at all four cities (Hamilton, Toronto, Milwaukee and Green Bay), though Green Bay and Milwaukee collect measurements daily while Hamilton and Toronto collect them weekly.

Nitrate data is collected by all four cities and reported in similar units as mg/L, although the testing frequency of the data varied widely, from annually (Milwaukee) to weekly during the summer season (Hamilton).

E. coli data is collected in all four cities in similar units of Most Probable Number (MPN) per 100mL and Colony Forming Units (CFU) per 100mL, ranging in frequency of daily for Milwaukee and Toronto, weekly for Hamilton and monthly for Green Bay.

Significant variation in the data set resolution for *C. Parvum* or *G.Lamblia* at drinking water intakes were found between the four cities, which should be accounted for at the analysis stage. Milwaukee and Green Bay test for these indicators at least monthly. However, Hamilton does not test for these indicators. Toronto tested for both indicators on an *ad hoc* basis for several years, but this testing ceased in 2010. We have not explored differences in laboratory methods, equipment or training that could affect these measurements, nor are we aware of any 'round-robin' laboratory comparisons between countries.

2.2.4 Sewerage overflow acquisition summary

Sewerage overflow events were collected through Milwaukee Metro Sewer District. City of Hamilton Water Systems stated that data will be made available, though T3W did not receive the data by the close of the contract period. Toronto Sewer asked for T3W to submit a FOIA request, which was submitted on January 9, 2017. As of July 19, 2017, T3W had not received data from Toronto or Green Bay. IJC GLRO staff were able to obtain indicator data by contacting the water agencies in each city, and a FOIA request was not requested from any city. Metadata and contact information for these data sets are included in **Appendix A**. The resolution of this data set is impacted by the combination of measure and modeled inputs, though both methods aim to identify individual CSO events. Milwaukee and Hamilton report the total volume and duration of CSO events from multiple outfall locations provided by a mix of modeling data and flow meters. Toronto models the hydrologic and hydraulic behavior and responsiveness of the city's sewer systems. In Ontario, modelling provides CSO estimates for the nonwinter period (April to

October). Therefore, the CSO reporting to Environment and Climate Change Canada only includes these months.

Data completeness and timeframe for this CSO data set is impacted by the relatively short span of data available from the City of Toronto, which is available starting in 2013. Since 2013, the City of Toronto has provided an annual online report on CSOs to Environment and Climate Change Canada under the Federal Wastewater Systems Effluent Regulations of 2012. CSO data for Hamilton is available from 2009-2016, and for Milwaukee from 2003-2016. Green Bay does not have a combined sewer system and so no data was available. Weekly estimates of CSO events across all cities with combined sewers would be difficult to achieve given the current data available.

3.0 Results

During the course of this pilot, it was discovered that an advocate, such as those found in the City of Hamilton and PHO, was helpful to identify and acquire data. Further familiarity with data collectors and disseminators would be helpful to refine data requests. For example, how data are collected, specific variables collected and codes used to specify data attributes (e.g., International Classification of Diseases). Indicator and CSO data are likewise accessible once agency contacts are established. Weather and lake data are publicly accessible for download. Not all cities require a fee to access their data, but for those that do, to date the cost encountered has been relatively nominal.

During Phase 2 of this pilot project, data would be consolidated into a geographically indexed database to facilitate linking attributed data to geographic data where applicable. This process will allow the HPAB to integrate or link data by geography so that they can compare, analyze, interpret and present the relationships between the various sets of environmental, human health and spatial data in temporal univariate and multivariate analysis. All data collection must be approved by local research ethics boards, and the anonymity of citizens protected.

Data collected with a geographic feature (point, line, polygon, or grid [raster]), or which contains an attribute that may link to a geographic feature, can be mapped in Phase 2 using geographical information systems software. Weather and lake data can be linked to a location, such as sampling station. The same holds true for the health data; there is an attribute that may be directly linked to a Forward Sortation Area (FSA) for Canada and ZIP code for the United States. Geographic attributes for all mapped CSO locations can be established. Locations of indicator data collection may not be directly attributable to drinking water plant intakes for all cities in this study, as cities decline to give coordinates due to security concerns (**Appendix A**). However, general locations can be determined based on supplied pumping station locations and the reported distance offshore for intake pipes.

The number of reported cases of disease from each city will influence the feasibility of Phase 2. **Figures 1** and **2** show the distribution of illness cases received for Ontario and Wisconsin by season and year. The data are color coded by season, and some initial trends can be seen. Overall, the number of giardiasis cases tends to be higher than the number of cryptosporidiosis cases for all cities for any given year. However, the number of cryptosporidiosis cases in Green Bay (**Figure 2**) were particularly high and will warrant additional analysis as to whether reasons for this variation can be determined. All four cities provided illness data for giardiasis and cryptosporidiosis between 2009-2014. During those six years, a total of 2993 cases of giardiasis and 577 cases of cryptosporidiosis were reported for all four cities.

One possible next step is to expand the analysis to include other cities. Health data were provided through central databases at the state and provincial levels, therefore the same contacts could be used for additional cities and the process should be similar for the rest of the Great Lakes region. Similar challenges as noted above will likely persist until an advocate at each targeted agency is discovered. In addition, the digitization of health data limited the availability

of data over time for this study, and this limitation may be encountered for other jurisdictions and may pose challenges for larger-scale analyses in the future.

A timeline of all data received as part of this study is shown in **Tables 9** and **10** (below), and data available during the 2009-2014 timeframe are highlighted per the availability of illness cases described above. Weather and associated environmental data are available during this time interval, though indicator and CSO data are more limited. Part of the purpose of this study was to examine the components monitored by source water intakes for drinking water treatment plants using these four cities as examples and compare results with the measures recommended for the biological hazards of source water indicator (International Joint Commission Health Professionals Advisory Board 2014). Of the suite of indicators requested for this study, all four cities provided and consistently monitor three measures described for the indicator biological hazards of source water: turbidity, total coliform, and *E. coli* levels. This data set should allow analysis of trends for weekly measurements of total coliform, and daily measurements of turbidity. *E. coli* data were provided at a resolution sufficient for monthly/seasonal comparisons and analysis of trends over time. These analysis options can be considered for inclusion during Phase 2. The other measures requested are collected by some cities, but at varying frequencies of measurement, and this variation will need to be considered in Phase 2. These differences in monitoring activity may reflect awareness of local risk factors, and differences in monitoring required for compliance with jurisdictional (national to municipal) water quality requirements.

CSO data are available for three of the four cities. While not critical to the statistical modeling proposed as part of Phase 2, CSO data are valuable for corroborating the occurrence of extreme events identified by precipitation patterns and highlighting temporal intervals where special attention is required during the analysis. In Green Bay, there is no combined sewer system, so identification of extreme events will need to rely on precipitation and weather information. A similar approach will be needed for Toronto for any analyses before 2013, as the current CSO data set begins in that year.

Table 9: Timeline and availability for illness, weather and environmental data acquired for this study. Fields highlighted in teal denote common data available over time for all locations. nd means no data.

Data	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Green Bay, WI-US															
Illnesses	nd	nd	nd	nd	nd	nd	●	●	●	●	●	●	●	●	●
Illness co-factor	nd	nd	nd	nd	nd	nd	●	●	●	●	●	●	●	●	●
Precipitation	●	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
Wind direction/velocity	●	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
Lake currents	nd	nd	nd	●	●	●	●	●	●	●	●	●	●	●	nd
Temperature (air)	●	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
Milwaukee, WI-US															
Illnesses	nd	nd	nd	nd	nd	nd	●	●	●	●	●	●	●	●	●
Illness co-factors	nd	nd	nd	nd	nd	nd	●	●	●	●	●	●	●	●	●
Precipitation	●	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
Wind direction/velocity	●	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
Lake currents	nd	nd	nd	●	●	●	●	●	●	●	●	●	●	●	nd
Temperature (air)	●	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
Hamilton, ON-CA															
Illnesses	●	●	●	●	●	●	●	●	●	●	●	●	nd	nd	nd
Illness co-factors	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Precipitation	nd	nd	●	●	●	●	●	●	●	●	●	●	●	●	nd
Wind direction/velocity	●	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
Lake currents	nd	nd	nd	●	●	●	●	●	●	●	●	●	●	●	nd
Temperature (air)	nd	nd	●	●	●	●	●	●	●	●	●	●	●	●	nd
Toronto, ON-CA															
Illnesses	●	●	●	●	●	●	●	●	●	●	●	●	nd	nd	nd
Illness co-factors	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Precipitation	●	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
Wind direction/velocity	●	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
Lake currents	nd	nd	nd	●	●	●	●	●	●	●	●	●	●	●	nd
Temperature (air)	●	●	●	●	●	●	●	●	●	●	●	●	●	●	nd

Table 10: Timeline and availability for indicators and CSO data acquired for this study. Fields highlighted in teal denote common data available over time for all locations. nd means no data.

Data	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Green Bay, WI-US															
Turbidity	nd	●	●	●	●	●	●	●	●	●	●	●	●	nd	nd
Nitrate	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
E. coli	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	●	●	nd
Total coliform	nd	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
C. parvum	nd	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
Giardia lamblia	nd	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
Sewerage overflow events – city does not use combined sewer															
Milwaukee, WI-US															
Turbidity	nd	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
Nitrate	nd	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
E. coli	nd	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
Total coliform	nd	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
C. parvum	nd	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
Giardia lamblia	nd	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
Sewerage overflow events	●	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
Hamilton, ON-CA															
Turbidity	nd	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
Nitrate	nd	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
E. coli	nd	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
Total coliform	nd	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
C. parvum – not tested	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Giardia lamblia – not tested	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Sewerage overflow events	nd	nd	nd	●	●	●	●	●	●	●	●	●	●	●	nd
Toronto, ON-CA															
Turbidity	nd	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
Nitrate	●	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
E. coli	●	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
Total coliform	●	●	●	●	●	●	●	●	●	●	●	●	●	●	nd
C. parvum	●	●	●	●	●	●	●	●	nd	nd	nd	nd	●	●	nd
Giardia lamblia	●	●	●	●	●	●	●	●	nd	nd	nd	nd	●	●	nd
Sewerage overflow events	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	●	●	●	●	nd

4.0 Conclusions and Recommendations

This project aims to determine if there are sufficient data available for four cities, in terms of quantity and quality, to estimate the relationship in space and time of extreme weather events and cases of acute gastrointestinal illness, namely giardiasis and cryptosporidiosis. Data were identified, acquired and formatted to develop space-time series that can be used for analysis in Phase 2 of this pilot project.

The HPAB notes that this work could position the IJC as instrumental in harmonizing source water indicators between both countries and support real progress on monitoring human health in the Great Lakes. Based on the collected data described in Section 3, T3W concluded that the data are sufficient in quantity and quality to proceed with an analysis to estimate the association between weather events and gastrointestinal illness, using health data over six years (2009-2014) linked geographically and temporally with climate data. The additional CSO and turbidity indicators obtained by IJC staff strengthen the basis for this conclusion and expand the breadth of the possible analyses. Despite the availability of health data from all cities for an interval of only six years, based on the frequency of reported AGI cases in all four cities, the HPAB also considers it likely that an analysis can be conducted using data in the interval 2009-2014, and therefore recommends moving forward with Phase 2.

5.0 References

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6.0 Appendix A. Metadata for Collected Health, Environmental and Weather Data

Climate Data:

Lake Currents: Lake current data was obtained through NOAA/Great Lakes Observing System via a website query. The NOAA Great Lakes Coastal Forecasting System is a numerical model that calculates waves, currents and temperatures for each of the Great Lakes. The "GLCFS Nowcast" model is run four times per day and provides estimates of conditions near the point query. Data is collected in cooperation with various agencies, such as Environment and Climate Change Canada for locations along Lake Ontario.

Website: data.glos.us/glcfs/

Data includes: Eastward water velocity (knots), Northward water velocity (knots), water velocity (knots), water velocity direction (degrees) and geographic X and Y coordinates. A total of seven locations were obtained, one location each for Green Bay, Hamilton and Milwaukee and three locations for Toronto. Three locations were chosen for Toronto because of the multiple locations of the raw water intake pipes.

Lake Temperature: The NOAA National Data Buoy Center provided water temperature data for three buoys. Data was obtained through a website query. Data for Canadian locations is managed and collected in cooperation with Environment and Climate Change Canada. The locations chosen are closest to each cities raw water intakes. No buoys were in close proximity to the Green Bay raw water intake near Kewaunee, Wisconsin. Data includes: air temperature (°C), dew point (°C), wind direction (degrees), wind speed (m/s), cloud cover (percentage), solar radiation (W/m2), barometric pressures (mb), water temperature (°C) and geographic X and Y coordinates of buoys.

Website: coastwatch.glerl.noaa.gov/marobs/marobs.html

Toronto Weather: The climate data was obtained from the Meteorological Service of Environment and Climate Change Canada. Data was obtained through a website query and an email query for data unavailable on the website. The data is derived from two different stations due to the fact that average daily values for wind data was not available at a single location. The next closest station to the precipitation station with appropriate wind data was chosen, however, wind data was measured on an hourly basis. Geographical X and Y coordinates are listed for each station. Precipitation station data includes maximum, minimum and mean temperature (°C), total rainfall (mm) and total snowfall (mm). Wind station data includes wind speed (km/h) and wind direction (degrees).

Website: climate.weather.gc.ca/contactus/climate_services_e.html#nat

Hamilton Weather: The climate data was obtained from the Meteorological Service of Environment and Climate Change Canada. The data is derived from two different stations due to the fact that average daily values for wind data was not available at a single location. The next closest station to the to the precipitation station with appropriate wind data was chosen, however, wind data was measured on an hourly basis. Geographical X and Y coordinates are listed for each station. Station data includes maximum, minimum and mean temperature (°C), total rainfall (mm) and total snowfall (mm). Wind station data includes wind speed (km/h) and wind direction (degrees).

Website: climate.weather.gc.ca/contactus/climate_services_e.html#nat

Milwaukee/Green Bay Weather: Climate data was obtained from NOAA. Data was obtained through a website query. Individual daily station data was obtained for one location in each US city. Data includes daily averages of wind speed (m/s), wind gust direction (degrees) sustained for a minimum of two minutes, maximum, minimum and mean temperatures (°C), and daily totals of rain (mm) and snowfall (mm). Geographical X and Y coordinates are listed for each station.

Website: ncdc.noaa.gov/cdo-web/search

CSO Data:

CSO Milwaukee: Data was obtained through the Milwaukee Metropolitan Sewer District via an email inquiry. The event table displays total volume (MG) and event duration (days) from multiple outfall locations provided by a mix of modeling data and flow meters. Per Sharon Mertins of Milwaukee Metropolitan Sewer District, it is possible to obtain specific volumes (MG) from individual CSO pipes if needed. Though not all outfall locations have data. In addition, a large number of locations and many outfalls may be impacted by SSO events from other communities.

CSO Toronto: Data was obtained through an email inquiry to Grace Lin of the Toronto Sewer Department. The CSO events are modeled events and not measured through flow metering. Since 2013, the City of Toronto has provided an annual online report on CSOs events to Environment and Climate Change Canada under the Federal Wastewater Systems Effluent Regulations, 2012. The report data includes CSO location (geographical X and Y coordinates), number of days of overflow and total volume (m^3) every month at each CSO point based on a modelling approach with monitored rainfall data.

The “InfoWorks CS” computer model has been used by Toronto to determine the hydrologic and hydraulic behavior and responsiveness of the city’s sewer systems. The model has been calibrated and validated to estimate CSO events, volumes and duration under dry weather and wet weather flow conditions. The modelling provides CSO estimates for the nonwinter period (April to October). Therefore, the CSO reporting to Environment and Climate Change Canada

only includes these months. According to Toronto Sewer, the model generally overestimated the results when comparing with flow monitoring data where/when available. The City has identified 312 CSO outfalls, which would potentially discharge to watercourses through 84 outfalls in the combined area. The city does not have a system-wide flow monitoring for all CSO outfall locations on a year-round basis.

CSO Hamilton: Data was obtained through an email inquiry to Llynda Lukasik of Environment Hamilton and Winston Wang of the City of Hamilton. Two different datasets were obtained. One dataset highlights monthly flow meter totals (m^3) of annual (January to December) events for CSO storage tanks from the years 2006-2015. Another dataset of CSO volume (m^3) modelling data was obtained for the nonwinter periods (April 15 to November 14) for outfall locations between 2013-2016. Included in the data is receiving waterbody, geographic X and Y coordinates for outfall locations and estimated CSO volumes (m^3). The modeling data is part of the required reporting on CSOs to Environment and Climate Change Canada under the Federal Wastewater Systems Effluent Regulations, 2012. Some data in the modeling estimates were based on actual measurements of overflows provided by City's "SCADA" system, this distinction is indicated in the data table. Modeling data is based on estimates provided by computer simulations using updated "MIKE URBAN" integrated urban water modeling of combined and sanitary sewer system. For information, see: mikepoweredbydhi.com/products/mike-urban.

CSO Locations Hamilton/Toronto: A phone inquiry was placed to Michael Maier of Environment and Climate Change Canada to request clarification on CSO reporting requirements for the study cities in Canada. Environment and Climate Change Canada had available the geographic X and Y coordinates of CSO outfalls reported by the Cities of Toronto and Hamilton. Environment and Climate Change Canada has not verified the accuracy of the coordinates provided by the cities. For the Wastewater Systems Effluent Regulations, 2012 the location of the CSOs is based on the point in a wastewater system where excess wastewater may be deposited in water or a place and beyond which the owner/operator no longer exercises control over the quality of wastewater. This is usually the point where the effluent exits the sewer trunk line, not the point where the effluent enters the receiving waterbody.

CSO Green Bay: A phone inquiry was placed to Jeff Smutty of New Water in Green Bay. According to personal communication with Jeff Smutty, the city does not have any combined sewer systems. Therefore, no data was available.

Raw Water Intake Data:

Green Bay: A phone inquiry was placed with Russ Hardwick of Green Bay Water. Data was obtained from the years of 2004-2015. Data includes daily average measurements of turbidity (NTU), total coliform (pass or fail) and monthly cryptosporidium testing. Cryptosporidium testing was not in an electronic format and therefore required payment to process the request. An invoice of 106.90 was obtained on September 21, 2017, and data was provided on September 21,

2017. Requested data for *E.coli*, nitrates and giardia was unavailable because the department does not test these indicators at the raw water intake. Exact coordinates could not be obtained due to security reasons.

Toronto: An email inquiry was placed with William Fernandes of Toronto Water. Raw water intake data was obtained from the years of 2003-2016. Data includes testing of *E.coli*, total coliform, turbidity, nitrates, and Cryptosporidium and Giardia measurements. A second follow-up request for metadata on the water quality indicators data was sent to William Fernandes in September 2017 and was received in September 2017. Exact coordinates could not be obtained due to security reasons.

Hamilton: An email inquiry was placed to Lien Dang and Scott Gardin of the City of Hamilton. Data for the single raw water intake was obtained from the years of 2004-2016. Data includes testing of: *E.coli*, turbidity, nitrates and total coliform. Hamilton does not test raw water for Cryptosporidium and Giardia. According to personal communication with Scott Gardin, Hamilton is required to maintain CT values (concentration of a disinfectant and the contact time with the water being disinfected) capable of inactivating Giardia and Cryptosporidium and therefore the city does not currently test for those organisms. Exact coordinates could not be obtained due to security reasons.

Milwaukee: A request was sent to Sandra Rusch Walton, Communications Manager, City of Milwaukee Department of Public Works for the requested water quality indicators. An invoice in the amount of US$149.28 was received, payment was processed and the data was received on October 6, 2017. Data includes turbidity, nitrate, E.coli, total coliform, and Cryptosporidium and Giardia. Exact coordinates could not be obtained due to security reasons.