

# Appendix E

## TM4 - River Monitoring Program Review



**Region of Waterloo**

**Wastewater Treatment Master Plan Update**

**TM-4: River Monitoring  
Program Review**

**Final**



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## Preparation and Review Log

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## 1. Introduction and Background

The Regional Municipality of Waterloo (the Region) is an upper tier municipal government with a population of approximately 550,000 people. The Region has experienced steady residential and industrial/commercial/institutional growth in previous years and anticipates continued growth in to the future (EarthTech Canada Inc., 2007). On behalf of the Region, CIMA Canada Inc. (CIMA) are currently updating the Region's Wastewater Treatment Master Plan (WWTMP) to reflect the predicted increase in population, wastewater flows and changing regulations. The main goal of the Master Plan update is to develop a current, comprehensive, cost-effective and feasible strategy to address the anticipated wastewater treatment and disposal needs of the Region over the next 35 to 40 years, as consistent with the Region's Strategic Plan.

As part of this Master Plan update, Hutchinson Environmental Sciences Limited (HESL), completed a review of the Region's Surface Water Quality Monitoring Program (SWQMP). The SWQMP focuses on the impacts of ten of the Region's WWTPs on their respective receiving waters. The monitoring program itself was reviewed along with other ongoing river monitoring programs conducted by Grand River Conservation Authority (GRCA) and the Ministry of the Environment and Climate Change (MOECC) within the Region to answer the following questions:

- + Does the data being collected (parameters, locations, seasonal or diurnal timing, frequency, timing with respect to river flow magnitude) adequately address the current and future needs to support Class Environmental Assessments (EA), design of upgrades for WWTPs, and implementation of the Region's long-term Master Plan strategy? (e.g., provides evidence needed to obtain approvals, provides sufficient understanding to effectively evaluate alternatives during future Master Plan updates, provides adequate evidence to demonstrate the degree of receiver improvement resulting from implementation of WWTP upgrades and other projects intended to improve receiver quality);
- + Are there elements of the Region's SWQMP (parameters, locations, timing, frequency) with little or no value to supporting the Region's Master Plan strategy, where cost savings could be achieved by eliminating elements with little risk to the Region's objectives?

- + Is there redundancy between Region and other monitoring programs, where coordinated changes could be mutually beneficial?
- + Are the limitations of the current Region monitoring program (i.e., data/station gaps and/or methodology) hampering any Master Plan objectives, and if so, are there changes in approach that could address these?
- + What, if any, changes are recommended to make the program more effective and/or cost efficient in supporting the Region's Master Plan strategy?

The above questions were answered by:

- + Reviewing the Region's SWQMP, including:
  - SWQMP Annual Reports (2009 through 2014 by LGL Limited) for the Grand River and Nith River,
  - Standard Operating Procedures for the River Monitoring Program (LGL, 2014),
  - Technical Memorandum: Summary of Changes to Grand and Nith Program 2009 to 2013 (LGL, June 2013), and
  - Technical Memorandum: Overview of Changes to Grand and Nith Program for 2014 (LGL, February 2014);
- + Review of the report *Water Quality in the Grand River Watershed* (GRCA, October 2011);
- + Review of the Provincial Water Quality Monitoring Network (PWQMN) program within the Region of Waterloo;
- + Review of GRCA monitoring programs within the Region;
- + Telephone discussions with Mark Anderson, Janet Ivey, and Sandra Cooke at GRCA regarding the Region's river monitoring program, GRCA monitoring programs and the Water Monitoring Review and Optimization Project; and
- + Statistical analyses of water quality data including:
  - The number of samples required to generate statistically significant comparisons (Power Analysis),

- Comparisons between sampling stations at each WWTP (Kruskal-Wallis and/or Mann-Whitney), and
- Trends in upstream water quality at each WWTP (Mann Kendall).

The following sections discuss the current monitoring programs in the Region (Section 2), the results of the review and statistical analyses (Section 3), and opportunities for the Region to consider (Section 4).

## 2. Current River Monitoring Programs within the Region of Waterloo's SWQMP Study Area

### 2.1 Region of Waterloo's SWQMP

The Region of Waterloo's SWQMP monitors water quality upstream and downstream (near and far) of ten WWTPs located on the Grand River (Waterloo WWTP, Kitchener WWTP, Preston WWTP, Galt WWTP), Nith River (Wellesley WWTP, New Hamburg WWTP, and Ayr WWTP), Speed River (Hespeler WWTP), Conestogo River (St. Jacobs WWTP) and Canagagigue Creek (Elmira WWTP). The monitoring program was initiated in summer 2007 as part of the WWTMP completed in 2007 and included monitoring of the receiving water near the Waterloo, Kitchener, Hespeler, Preston, Galt, Wellesley, New Hamburg, and Ayr WWTPs. The St. Jacobs and Elmira WWTPs were added to the program in winter 2012. Sampling was completed by GRCA in 2007 and 2008, and by LGL in 2009 to present.

Since the program's inception, various changes have been made to stations and station locations, including:

- + Adding discrete sampling stations at the downstream near station monitoring points for the Waterloo, Kitchener, Hespeler, Preston and Galt WWTPs in summer 2010;
- + Monitoring the Wellesley downstream (DS) Near station in summer and fall only and the Wellesley DS Far station in winter and spring only beginning in 2014;
- + Removal of the Ayr DS Far station in 2014; and
- + Removal of the Laurel Creek and Schneider Creek monitoring stations in 2014. These stations are already monitored as part of the Province of Ontario's PWQMN program.

Figure 1 presents the current water quality monitoring program. Water quality sampling is conducted six times per season at most stations. The seasons are classified as follows:

- + Winter – January and February – coldest water temperatures, under ice;
- + Spring – March and April – spring melt, rain events;
- + Summer – July and August, but can extend to September – low flow; and

+ Fall – October and November.

Water quality samples collected from all stations (except those labelled “discrete”), are grab samples from near the right bank, center of river, and left bank combined into a single composite. Discrete samples are collected within the plume at the DS near station for the Waterloo, Kitchener, Hespeler, Preston and Galt WWTPs. The quality assurance/quality control (QA/QC) program for the SWQMP includes collecting one blind duplicate sample for every ten samples collected.

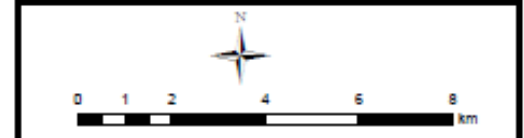
In addition to the water quality monitoring program, fish and benthic community surveys and longitudinal surveys are carried out periodically within the Grand, Nith and Speed Rivers in the vicinity of the WWTPs. Since the river monitoring program’s inception in 2007, a benthic invertebrate community survey and fish survey were conducted in 2009, 2012, and 2015. Longitudinal surveys were carried out in 2010, 2012, 2014 and 2016.

## **2.2 Ontario PWQMN Stations**

There are 14 active PWQMN stations located within the Region’s SWQMP study area, of which eight coincide with the SWQMP stations. All stations are shown in Figure 1. The PWQMN stations are sampled seven to eight times per year, between the spring and fall, by GRCA staff. The samples are collected by taking a single grab sample from the center of the river, and the samples are sent to the MOECC’s laboratory for analysis.

**Figure 1:**  
Region of Waterloo River  
Monitoring Stations and  
PWQMN Stations

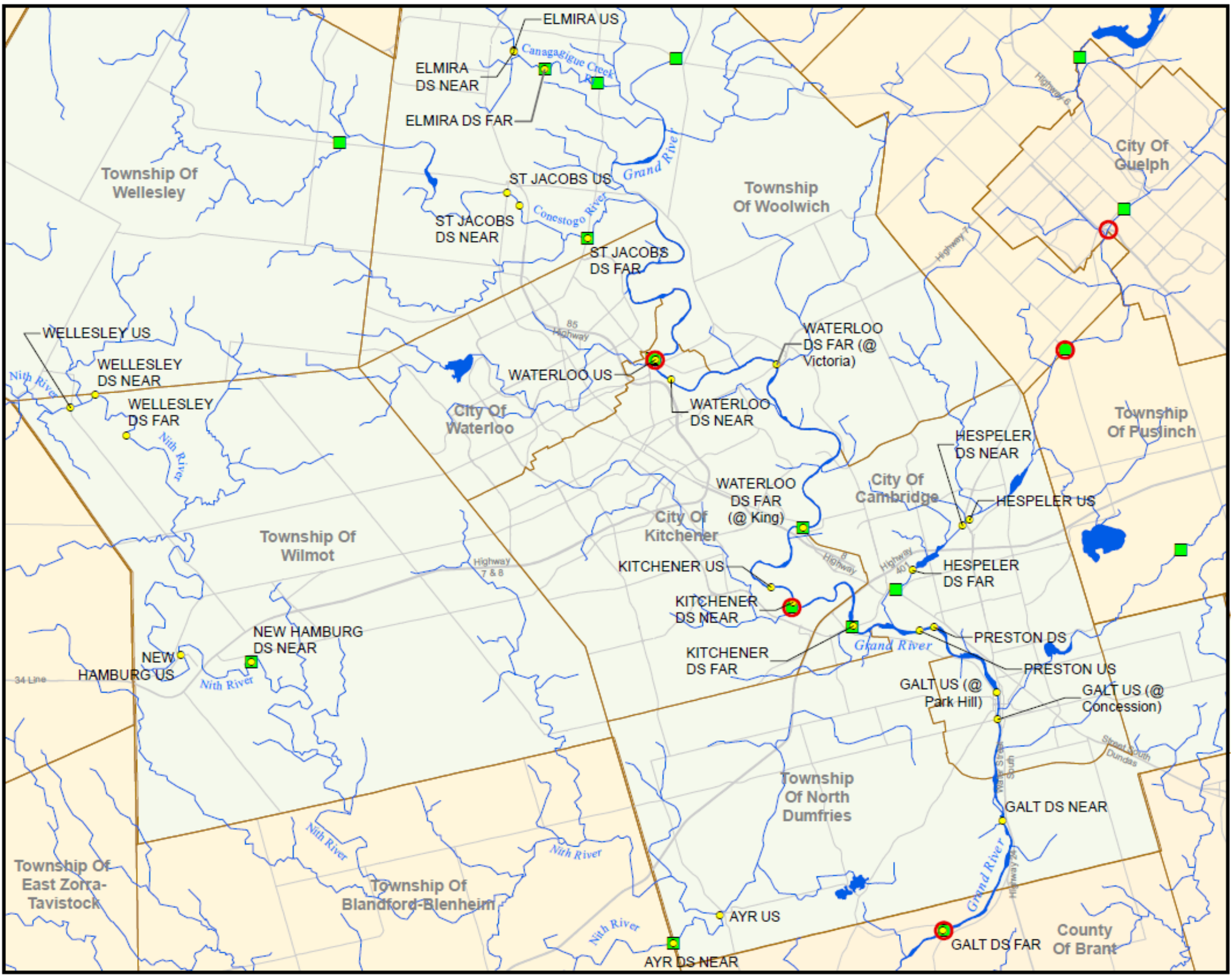
- Region of Waterloo River Monitoring Program Station - Water Quality
- Provincial Water Quality Monitoring Network Station
- GRCA Continuous Monitoring Station
- Arterial
- Highway
- Stream
- Waterbody
- ▭ Regional Municipality of Waterloo
- ▭ Other Municipality



Prepared by: Eric Dilligeard  
Data Source: LIO, PWQMN.  
Coordinate System: NAD 1983 UTM Zone 17N

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Project: Region of Waterloo Wastewater Treatment  
Master Plan Update, River Monitoring Program  
Review  
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**Figure 1** Region of Waterloo River Monitoring Stations and PWQMN Stations

## **2.3 GRCA Monitoring Stations**

The GRCA maintain nine continuous monitoring stations within the Grand River watershed, of which three are located within the Region's SWQMP study area (Figure 1): "Bridgeport" at the Waterloo upstream (US) station; "Blair" at the Kitchener DS Near station; and "Glen Morris" at the Galt DS Far station. The continuous monitoring stations record conductivity, dissolved oxygen, pH, turbidity and water temperature every 15 minutes. In addition, the "Bridgeport" station monitors nitrate. Data is available in near real-time online, at the GRCA website.

The GRCA also have a number of flow gauge stations located within the Region's SWQMP study area (i.e., on the Grand, Nith, Speed, Conestogo Rivers and Canagagigue Creek), which are used when interpreting water quality data for the Region's SWQMP.

## **2.4 Additional Monitoring within the Region's SWQMP Study Area**

Additional monitoring within the Region's river monitoring study area includes monitoring completed by the City of Waterloo, the City of Kitchener and Environment Canada. The monitoring completed by the City of Waterloo and the City of Kitchener were over 1 to 3 year periods. The monitoring completed by Environment Canada focused on the Nith River and was completed as part of the Great Lakes Basin Ecosystem Initiative in 2013.

### 3. Program Review and Statistical Analysis

#### 3.1 Purpose Statement for the SWQMP

As stated in the annual SWQMP reports (LGL, 2010 to 2015), the goals of the SWQMP are to:

- + *“Determine the impact of ten of the Region’s WWTPs on the water quality of the Grand, Nith, Speed and Conestogo Rivers, and Canagagigue Creek; and*
- + *Create a water quality database to track changes in water quality over time and allow the Region to continuously monitor and assess the impacts of planned wastewater treatment plant upgrades on these rivers.”*

The goals of the SWQMP were created in 2007, at the inception of the program. At that time, the program was designed as an “investigative” monitoring program to gain the required data to assess the WWTP impacts on receiver water quality, create a water quality database and track changes in receiver water quality.

At the end of 2015, the water quality database contained over 5,300 water quality monitoring sample entries, with 24 new entries being added for most stations each year (totalling approximately 696 samples per year). The impact of the ten WWTPs on water quality in the Grand, Nith, Speed and Conestogo Rivers, and Canagagigue Creek is now well understood and is discussed in each of the annual SWQMP reports for both the Grand and Nith Rivers (LGL, 2010 to 2015). The extensive database has allowed various statistical analyses on the water quality differences between stations, and between years for the same station. The conclusions from the statistical analyses have been largely unchanged since the first LGL report (2009 Annual SWQMP report), with the exception of improvements in downstream ammonia, un-ionized ammonia, nitrite, and total Kjeldahl nitrogen (TKN) concentrations at the Kitchener WWTP since the Plant 2 upgrades were completed in 2013. (See Section 3.3 for additional statistical analyses). Plant 3 and 4 upgrades are currently in progress.

At this point, nine years into the SWQMP, it is appropriate to re-evaluate and establish new goals for the program. With the now-extensive database and the understanding of the influence of the WWTPs on receiver water quality, the “investigative” monitoring program could be converted in to a “maintenance” monitoring program, where monitoring is conducted in order to 1) continue to monitor trends in water quality; and 2) assess the effect of planned WWTP upgrades (as per the Region’s long term

Master Plan strategy). With this focus in mind, reductions in sampling frequency and number of stations are opportunities for the Region to consider. These changes will continue to meet the goals of the long term Master Plan strategy, while being more cost efficient and providing opportunity to reallocate funds to other watershed-benefitting programs, such as phosphorus offsetting programs and promoting a holistic approach to assessing and improving water quality throughout the Region. These opportunities are detailed throughout the following sections. Any opportunities should be discussed with the MOECC and GRCA to confirm the preferred approach moving forward with the sampling program prior to making changes to ensure the data collected will be sufficient for future assimilative capacity modelling and approvals.

### **3.2 Concurrent Monitoring Programs within the SWQMP Study Area**

There are eight active PWQMN stations located within the Region's SWQMP study area which coincide with SWQMP station locations (Figure 1). The PWQMN stations are sampled typically seven to eight times per year, while the SWQMP stations are sampled typically 24 times per year. Sampling dates in 2014 between the PWQMN and SWQMP stations were compared, and on average, there was only one date at each monitoring station where the two program sampling events coincided.

Optimizing monitoring programs within the Region of Waterloo has been well discussed in the past. In 2015, the Water Monitoring and Optimization Working Group was formed and met on three occasions to discuss a Water Monitoring Review and Optimization Project. The working group was chaired by GRCA staff and included representatives from MOECC, Ontario Ministry of Natural Resources and Forestry (MNR), City of Guelph, City of Waterloo, City of Kitchener, City of Cambridge, City of Brantford, the Region of Waterloo, Agriculture and Agri-food Canada, Environment Canada, Trout Unlimited Canada, and AECOM. One of the main deliverables from the meetings was a summary of current and recent monitoring programs being conducted within the Grand River watershed. The group concluded that one of the largest barriers to merging sampling efforts and/or sharing information are the different monitoring techniques concurrently being used. For example, in the case of the PWQMN and SWQMP water quality sampling collection, PWQMN stations are sampled as a single grab in the middle of the watercourse, whereas the SWQMP stations are a composite of right bank, center and left bank. Furthermore,

depending on the purpose of the monitoring, sample collection and even program design may be completely different. (For example, water quality monitoring of storm runoff versus WWTP effects on downstream water quality).

At this time, it is not appropriate to co-ordinate the sampling efforts between the PWQMN and SWQMP programs due to the discrepancy between sampling techniques, sample timing (the PWQMN has much more flexibility in determining when to monitor, whereas the SWQMP monitoring is completed on specific dates to coincide with WWTP effluent analyses, spring freshet, rain events, and low flows), and laboratories used for sample analysis (PWQMN samples are analyzed at MOECC laboratories while the SWQMP samples are analyzed by Maxxam Analytics). For consistency in QA/QC, it is not recommended that more than one laboratory be used within a single year of SWQMP monitoring.

It is recommended that the Water Monitoring and Optimization Working Group continue to explore the possibilities of data sharing (and data management) between group members and optimizing/ communicating the sampling technique(s) used for sample collection. Additional data from the watershed may be useful when applying for WWTP re-ratings or upgrades in the future and may help to further the understanding of water quality throughout the watershed.

There are three GRCA continuous monitoring stations located within the Region's SWQMP study area which record conductivity, dissolved oxygen, pH, turbidity and water temperature every 15 minutes. In addition, the "Bridgeport" (Waterloo US) station monitors nitrate. Turbidity measurements and total phosphorus concentrations are typically highly relatable; however, it is understood that the GRCA's turbidity probes are highly prone to fouling, producing good quality data when clean but deteriorating in data quality as fouling progresses. If the turbidity probe fouling issues can be resolved, a turbidity to total phosphorus relationship at the Bridgeport, Blair and Glen Morris continuous monitoring stations could provide good insight into phosphorus concentrations with river flow changes (i.e., phosphorus loading on a seasonal basis). This information may be especially beneficial if considering a phosphorus offsetting program.

Nitrate is logged continuously at the Bridgeport station (Waterloo US). It is recommended that the Bridgeport continuous nitrate data be compared to monitoring

results from the Waterloo US station to determine if sampling frequency can be decreased for this parameter.

The Region should consider conducting macrophyte surveys downstream of WWTPs on the Grand and Speed River (i.e., Waterloo, Kitchener, Hespeler, Preston and Galt WWTPs), in the location with the largest diurnal DO swing during summer low flows. Comparison of macrophyte survey results pre- and post- WWTP upgrades could give additional insight into the tangible effects the upgraded plants are having on water quality, beyond chemistry results alone. Macrophyte data is also used to calibrate the Grand River Simulation Model (GRSM), which is used during assimilative capacity studies.

Observed increases in pH levels may be the result of photosynthesis of macrophytes and indicative of increased amounts of macrophyte growth in the rivers. It is recommended that the Region consider developing a pH-DO-macrophyte abundance relationship. If a relationship can be established, the pH levels monitored at the three GRCA continuous monitoring stations would provide real-time evidence of increasing macrophyte growth.

Instrumentation capable of real-time measurement of total phosphorus concentrations in surface water are currently being developed (i.e., the Shimadzu TNPC-4110/4110C Online Total Nitrogen/Phosphorus/TOC Analyzer). When this technology becomes feasible (both economically and performance-wise), real-time total phosphorus monitoring can be considered as part of the SWQMP.

### **3.3 Statistical Analyses**

HESL was provided with the full database containing all monitoring results from the SWQMP collected between 2007 and 2015. In order to examine trends in the data from the point of view of assessing the need for the number of stations and the frequency of sampling, the following statistical analyses were performed:

- ✦ Kruskal-Wallis tests, a non-parametric one-way analysis of variance on ranks, were performed to compare the results at all stations at a given WWTP. The mean concentrations were compared based on seasonal groupings (i.e., spring, summer, winter and fall) of all available data (i.e., 2007 through 2015) for each parameter. For example, the Galt WWTP stations included the US, discrete, DS Near and DS Far. The mean and standard deviation for each station were

computed seasonally for each monitored parameter (i.e., ammonia, biochemical oxygen demand, dissolved chloride, *E. coli*, nitrate+nitrite, nitrate, nitrite, orthophosphate, phosphorus, TKN, total suspended solids [TSS], and chlorophyll a). If the Kruskal-Wallis test indicated a statistically significant difference between at least two of the WWTP stations, post-hoc pair-wise comparisons using the Mann-Whitney test (a non-parametric t-test) were performed, followed by the Benjamini-Hochberg adjustment to account for the multiple t-tests. The probability of Type I error (accepting the false hypothesis as correct) was set to 0.05.

The purpose of executing the Kruskal-Wallis and Mann-Whitney tests was to understand if particular stations were not adding to the water quality interpretation at a given WWTP. For example, if two stations were found to have results that were always statistically similar, there would be good rationale to remove one of the stations from the program.

- + Mann-Kendall trend test, a non-parametric test used to detect trends in date-ordered monitoring data, was performed to analyze long-term upstream water quality at each of the ten WWTPs monitored in the SWQMP. The seasonal data collected was date-ordered for each monitoring parameter and for each upstream monitoring station. For example, at the Waterloo US station, all ammonia data collected in the summer season was ordered from oldest to most recent. A p-value of 0.05 indicated a statistically significant trend, and the positive or negative sign on the trend slope indicated if the concentrations were increasing or decreasing over time, respectively. The purpose of executing the Mann-Kendall trend test was to understand if there have been changes to upstream water quality since monitoring was initiated in 2007.

Results of the statistical analyses are summarized below, and referenced in Section 3.3.2 while discussing recommended station changes. The raw statistical analyses and the box plots are provided in Appendices A through D.

Any suggested changes to the water quality monitoring program should be discussed with the MOECC and GRCA to determine the best approach moving forward.

### **3.3.1 Kruskal-Wallis/Mann-Whitney tests**

The purpose of executing the Kruskal-Wallis and Mann-Whitney tests was to understand if particular stations were not adding to the water quality interpretation at

a given WWTP. This was done by comparison of mean water quality concentrations (divided on a seasonal basis) between each of the monitoring stations at a given WWTP. The results of the Kruskal-Wallis test are presented in Table A.1. The results of the Mann-Whitney post-hoc tests are presented in Table A.2.

- + There were statistically significant differences between upstream and downstream stations at all WWTPs during the summer season.
- + At the Ayr WWTP, there were no statistically significant differences found in any other season (i.e., Fall, Winter and Spring), suggesting that the frequency of water quality monitoring near this WWTP could be reduced and focus mostly on summer months. (Historically, there was an ECA requirement to monitor water quality upstream and downstream of the Ayr WWTP once per quarter).
- + At the Wellesley WWTP, there were statistically significant differences found in summer and winter only, suggesting that the frequency of water quality monitoring near this WWTP could be reduced.
- + At the New Hamburg WWTP, there were no statistically significant differences found in spring, suggesting that the frequency of water quality monitoring near this WWTP could be reduced (i.e. spring high flow sampling offers minimal value). Further, statistically significant differences in fall were for dissolved chloride only, and in winter for dissolved chloride and TSS only.
- + At the Elmira, Galt, Hespeler, Kitchener, St Jacobs and Waterloo WWTPs, statistically significant differences were found for at least one parameter in all seasons.
- + Stations near the Preston WWTP are monitored in summer and fall only. Statistically significant differences were found in both of these seasons for most parameters.
- + The largest plants located on the Grand and Speed Rivers (i.e., Waterloo, Kitchener, Hespeler, Preston and Galt) generally had a greater number of parameters with statistically significant differences.
- + Statistically significant differences in dissolved chloride were noted at all WWTP stations.

- + Statistically significant differences in TSS were noted at all WWTP stations in at least one season.
- + There were no statistically significant differences in Chlorophyll *a* at any station except Hespeler in summer. This suggests that monitoring of Chlorophyll *a* could be removed from the SWQMP,

### 3.3.2 Mann-Kendall Trend tests

The purpose of executing the Mann-Kendall trend test was to understand if there have been changes to upstream water quality at each WWTP, since monitoring was initiated in 2007. This was done by date-ordering seasonal data collected for each monitoring parameter at each upstream monitoring station, and statistically looking for a trend in the data. The results of the Mann-Kendall trend test are presented in Table B.1.

- + Temporal trends in dissolved chloride concentrations at upstream monitoring sites show a statistically significant increasing trend at most WWTPs, and most commonly in the winter season. This suggests the impact of road salt on river water quality.
- + Orthophosphate and total phosphorus concentrations show a statistically significant increasing trend at the upstream station at most WWTPs during the summer and fall seasons. While WWTP effluent is a source of total phosphorus in the watershed, concentrations in WWTP effluent have remained somewhat consistent suggesting that non-point source loadings of phosphorus likely contribute the most to the increasing trend.
- + TKN concentrations show a statistically significant declining trend at all WWTPs during at least one season of the year. At the Waterloo WWTP, this trend was detected in all four seasons. The reason for this declining trend is not apparent.
- + At the Wellesley WWTP, there were statistically significant declining trends for nitrate in all four seasons, and increasing trends for ammonia (summer, winter, spring), phosphorus (summer), and orthophosphate (summer and fall).
- + At the Preston WWTP, there were statistically significant declining trends in nitrate and nitrite concentrations and increasing trends in phosphorus and orthophosphate (summer and fall).

- + Chlorophyll *a* was found to have a statistically significant increase in concentrations during the summer at all plants which are monitored for chlorophyll *a* (i.e., Waterloo, Kitchener, Hespeler, Preston and Galt), indicating the increasing presence of algae and other aquatic plants within the river within the summer. However, as indicated by the Kruskal-Wallis test (Section 3.2.1), there have been no statistically significant changes between stations for each WWTP (except Hespeler in summer), suggesting that monitoring of Chlorophyll *a* may be removed from the SWQMP, and that periodic macrophyte surveys would be a more beneficial means of determining changes in macrophyte types and abundance.
- + Generally speaking, there are no other significant trends currently noted in the data.

### **3.4 Discrete and Downstream Near Station Samples**

At the Waterloo, Kitchener, Hespeler, Preston and Galt WWTPs, discrete grab samples are collected within the effluent plume at their respective DS Near station locations. In addition, a composite sample at the DS Near location (of right bank, centre, and left bank) is also taken concurrently with the discrete sample and sent for separate analysis. Given that the discrete sample is collected within the effluent plume, the act of compositing a sample using water collected from the two banks and the river center effectively dilutes the strength of the plume at that station. When investigating the strength of the plume (for comparison against Provincial Water Quality Objectives, to determine the toxicity of the plume for an investigative monitoring program), only the discrete sample would be appropriate. Therefore, it is recommended that the DS Near composite samples for the Waterloo, Kitchener, Hespeler, Preston and Galt WWTPs be reviewed to confirm the benefit to the SWQMP.

In the case of the Elmira and St. Jacobs WWTP, in-situ chemistry at their respective DS Near stations have both shown a plume signature near the right bank of the receiver. As such, it is recommended that the DS Near composite sample be replaced with a DS Near discrete sample.

The WWTPs located on the Nith River (i.e., Wellesley, New Hamburg and Ayr) only have one upstream and one downstream monitoring station at each monitoring event, and in-situ chemistry at their DS stations (regardless if labelled DS Near or DS Far)

show the effluent plume to be fully mixed at that point. As such, discrete sampling is not appropriate for the Wellesley, New Hamburg and Ayr DS Near/Far stations.

Based on the data analysis, there may be opportunities to adjust the sampling program to reallocate funding to other water quality initiatives. No changes are recommended without consultation with MOECC and GRCA. The potential station changes for consideration are summarized in Table 1.

**Table 1 Opportunities for SWQMP Station Changes**

<b>WWTP</b>	<b>Potential Station Changes</b>
<b>Elmira</b>	<ul style="list-style-type: none"> <li>• Keep US, DS Near and DS Far locations</li> <li>• Review the benefit of the DS Near composite and consider a discrete (right bank) sample               <ul style="list-style-type: none"> <li>➤ Collecting a composite within a transect of the river where the plume is not yet completely mixed dilutes the sample and artificially lowers the sample results. For this reason, the DS Near station sampled as a discrete (right bank) sample may be more beneficial than a composite.</li> </ul> </li> </ul>
<b>St. Jacobs</b>	<ul style="list-style-type: none"> <li>• Keep US, DS Near and DS Far locations</li> <li>• Review the benefit of the DS Near composite and consider a discrete (right bank) sample               <ul style="list-style-type: none"> <li>➤ Collecting a composite within a transect of the river where the plume is not yet completely mixed dilutes the sample and artificially lowers the sample results. For this reason, the DS Near station sampled as a discrete (right bank) sample may be more beneficial than a composite.</li> </ul> </li> </ul>
<b>Waterloo</b>	<ul style="list-style-type: none"> <li>• Keep US and DS Far               <ul style="list-style-type: none"> <li>➤ Mann-Whitney paired tests showed statistical differences between all Waterloo WWTP stations for most parameters and seasons. From the Annual SWQMP reports (LGL, 2010 to 2015), the in-situ monitoring at the Waterloo stations shows the plume to be approximately fully mixed by the DS Far station (at Victoria) but not fully mixed at the DS Near station. Collecting a composite within a transect of the river where the plume is not yet completely mixed dilutes the sample and artificially lowers the sample results. For</li> </ul> </li> </ul>

<b>WWTP</b>	<b>Potential Station Changes</b>
	<p>this reason, the DS Far station is most appropriate to keep in the program.</p> <ul style="list-style-type: none"> <li>• Keep Discrete at DS Near location</li> <li>• Review the benefit of the composite at DS Near location <ul style="list-style-type: none"> <li>➤ The DS Near composite within a transect of the river where the plume is not yet completely mixed dilutes the sample and artificially lowers the sample results.</li> </ul> </li> </ul>
<b>Kitchener</b>	<ul style="list-style-type: none"> <li>• Keep US and DS Far <ul style="list-style-type: none"> <li>➤ Kruskal-Wallis test showed statistical differences between all Kitchener WWTP stations for most parameters and seasons. The Mann-Whitney paired tests found that for many parameters and in many seasons, there was no statistical difference found between the DS Near and DS Far station. However, from the Annual SWQMP reports (LGL, 2010 to 2015), the in-situ monitoring at the Kitchener stations shows the plume to be approximately fully mixed by the DS Far station, but not fully mixed at the DS Near station. Collecting a composite within a transect of the river where the plume is not yet completely mixed dilutes the sample and artificially lowers the sample results. For this reason, the DS Far station is most appropriate to keep in the program.</li> </ul> </li> <li>• Keep Discrete at DS Near location</li> <li>• Review the benefit of the composite at DS Near location <ul style="list-style-type: none"> <li>➤ The DS Near composite within a transect of the river where the plume is not yet completely mixed dilutes the sample and artificially lowers the sample results.</li> </ul> </li> </ul>
<b>Hespeler</b>	<ul style="list-style-type: none"> <li>• Keep US and DS Far <ul style="list-style-type: none"> <li>➤ Kruskal-Wallis test showed statistical differences between Hespeler WWTP stations for most parameters and seasons. The Mann-Whitney test between individual stations generally showed differences between the discrete sample and US, DS Near and DS Far stations. For many parameters and in many seasons, there was no statistical difference found between the DS Near and DS Far station. However, from the Annual SWQMP reports (LGL, 2010 to 2015), the in-situ monitoring at the Hespeler stations shows the</li> </ul> </li> </ul>

<b>WWTP</b>	<b>Potential Station Changes</b>
	<p>plume to be approximately fully mixed by the DS Far station, but not fully mixed at the DS Near station. Collecting a composite within a transect of the river where the plume is not yet completely mixed dilutes the sample and artificially lowers the sample results. For this reason, the DS Far station is most appropriate to keep in the program.</p> <ul style="list-style-type: none"> <li>• Keep Discrete at DS Near location</li> <li>• Review the benefit of the composite at DS Near               <ul style="list-style-type: none"> <li>➤ The DS Near composite within a transect of the river where the plume is not yet completely mixed dilutes the sample and artificially lowers the sample results</li> </ul> </li> </ul>
<b>Preston</b>	<ul style="list-style-type: none"> <li>• Keep US and DS Discrete               <ul style="list-style-type: none"> <li>➤ The Kruskal-Wallis test showed statistical differences between Preston WWTP stations for most parameters in summer and fall. (The Preston WWTP stations are not monitored in winter and spring). The Mann-Whitney test between individual stations generally showed differences between the discrete sample and US and DS stations. Given that a DS Far location does not exist, it is recommended that a discrete sample continue to be collected from the Preston DS location. In addition, during water quality analysis and reporting, the discrete sample results should be compared against Galt US @ Park Hill or Galt US @ Concession stations.</li> </ul> </li> <li>• Review the benefit of the composite at DS Near               <ul style="list-style-type: none"> <li>➤ The DS Near composite within a transect of the river where the plume is not yet completely mixed dilutes the sample and artificially lowers the sample results.</li> </ul> </li> </ul>
<b>Galt</b>	<ul style="list-style-type: none"> <li>• Keep US and DS Far               <ul style="list-style-type: none"> <li>➤ Kruskal-Wallis test showed statistical differences between Galt WWTP stations for most parameters in the summer and for dissolved chloride, nitrate+nitrite and nitrate in the remaining seasons. The Mann-Whitney paired tests showed sometimes conflicting and inconclusive results. However, from the Annual SWQMP reports (LGL, 2010 to 2015), the in-situ monitoring at the Galt stations shows the plume to be approximately fully mixed by the DS Far station, but not quite fully mixed at</li> </ul> </li> </ul>

<b>WWTP</b>	<b>Potential Station Changes</b>
	<p>the DS Near station. Collecting a composite within a transect of the river where the plume is not yet completely mixed dilutes the sample and artificially lowers the sample results. For this reason, the DS Far station is most appropriate to keep in the program</p> <ul style="list-style-type: none"> <li>• Keep Discrete at DS Near location</li> <li>• Review the benefit of the composite at DS Near               <ul style="list-style-type: none"> <li>➤ The DS Near composite within a transect of the river where the plume is not yet completely mixed dilutes the sample and artificially lowers the sample results</li> </ul> </li> </ul>
<b>Wellesley</b>	<ul style="list-style-type: none"> <li>• No change - Keep US and DS Near and DS Far               <ul style="list-style-type: none"> <li>➤ Sampling at the Wellesley WWTP stations occur at the DS Near station in summer and fall only, and at the DS Far station in winter and spring only. For this reason, all stations should remain in the program. Annual SWQMP reports (LGL, 2010 to 2015) indicate that the treated effluent is fully mixed with the Nith River by the time it reaches the DS Near station. Therefore, there are no station changes recommended.</li> </ul> </li> </ul>
<b>New Hamburg</b>	<ul style="list-style-type: none"> <li>• No change - Keep US and DS Near               <ul style="list-style-type: none"> <li>➤ Sampling at the New Hamburg WWTP stations occurs only at one location US and one location DS. Therefore, both stations should remain in the program. Annual SWQMP reports (LGL, 2010 to 2015) indicate that the treated effluent is fully mixed with the Nith River by the time it reaches the DS station. Therefore, there are no station changes recommended.</li> </ul> </li> </ul>
<b>Ayr</b>	<ul style="list-style-type: none"> <li>• No change - Keep US and DS Near               <ul style="list-style-type: none"> <li>➤ Sampling at the Ayr WWTP stations occurs only at one location US and one location DS. Therefore, both stations should remain in the program. Annual SWQMP reports (LGL, 2010 to 2015) indicate that the treated effluent is fully mixed with the Nith River by the time it reaches the DS station. Therefore, there are no station changes recommended.</li> </ul> </li> </ul>

### 3.5 Sampling Frequency

The current SWQMP sampling frequency is six times per season, for a total of 24 samples per station each year. The Region can consider reducing the sampling frequency of the three WWTPs discharging to the Nith River (i.e., Wellesley, New Hamburg, and Ayr) to three times per season, for a total of 12 samples per station per year (or approximately once monthly). For the remaining WWTPs (i.e., Elmira, St. Jacobs, Waterloo, Kitchener, Hespeler, Preston and Galt), the sampling frequency could be reduced during the fall season from six samples to three samples. These opportunities would meet the goals of the SWQMP including: 1) determining the impact of the WWTPs on the water quality of their respective receiving waters; 2) creating a water quality database to track changes in water quality over time; and 3) assessing the impacts of planned WWTP upgrades on the receiving waters.

- + With respect to 1), it has been nine years since the inception of the SWQMP in 2007. The impact of the WWTPs on their receiving waters is very well understood and is presented in the Annual SWQMP reports (LGL, 2010 - 2015).
- + With respect to 2), the Region's SWQMP has built up an extensive database since 2007, thus providing an excellent baseline from which to compare future water quality results. Given this, it is appropriate to consider a reduction in sampling frequency.
- + With respect to 3), assessing the impacts of planned WWTP upgrades would be carried out in order to obtain approvals for upgrades or to evaluate alternatives during future Master Plan updates. As noted in items 1 and 2, the current impact of the WWTPs is well understood and there already exists a large database of water quality data, which can be used to predict the impacts of WWTP upgrades and evaluate alternatives. Under the proposed reduced sampling program, there would continue to be a substantial amount of new water quality data added to the database each year. In our experience, this level of sampling is adequate for approvals of WWTPs. In discussions with the MOECC on the Region's SWQMP, the Ministry indicated that they were most interested in the impacts of the WWTPs on the receiving water in the summer season, followed by the spring and the winter seasons (MOECC, personal communication, January 26, 2017). Water quality impacts during the fall would not be a deciding factor in re-rating and ECA approvals. Further, from the Kruskal-Wallis tests, the fall season had the second

fewest number of significant differences in chemistry results between WWTP sampling stations. (Spring had the fewest due to the proportionally larger influence of runoff from spring freshet on water quality versus WWTP effluent). For this reason, a reduction in sampling frequency at the Elmira, St. Jacobs, Waterloo, Kitchener, Hespeler, Preston and Galt WWTPs in the fall season could be considered.

With respect to the Wellesley, New Hamburg and Ayr WWTPs, there were few significant differences found when comparing upstream to downstream water quality (Kruskal-Wallis and Mann-Whitney tests). This has been a consistent finding at these stations since the inception of the SWQMP. Accordingly, a reduction in sampling frequency at the Wellesley, New Hamburg and Ayr WWTPs in all seasons, from six samples to three samples per season, could also be considered.

### **3.6 Investigative versus Maintenance Monitoring Program**

In discussion with the MOECC on the Region's SWQMP, the Ministry also suggested further reductions to the monitoring program may be appropriate during periods of regular operations (i.e., denoted as "maintenance monitoring"), and that the monitoring program sampling frequency could increase or "ramp up" to an "investigative monitoring" program when upgrades or other changes are planned at a given WWTP and for a short period of time (e.g., 3 years) after the upgrade is completed (MOECC, personal communication, January 26, 2017). There are opportunities to discuss with the MOECC investigative and maintenance monitoring and enhance the current program.

### **3.7 The Region's SWQMP Program – Benthic and Fish Community Monitoring**

Benthic invertebrate community surveying was completed in 2007, 2009, 2012, and 2015 within the SWQMP study area. In 2012, the benthic invertebrates were collected from five study areas following a modified Environmental Effects Monitoring Protocol, which included the collection of three sub-samples at five replicates within each sample site. Up to 300 benthic invertebrates were picked from each sample and identified to the lowest practical taxonomic group. Assemblages were analyzed through a variety of biological metrics including an Index of Biological Integrity.

The benthic invertebrate collection followed standard and accepted methods. The following considerations with respect to data interpretation may allow for a more thorough assessment of the benthic invertebrate survey results:

- + A habitat assessment was completed following the Ohio Environmental Protection Agency Qualitative Habitat Evaluation Index to rank the habitat surveyed at each of the fish community survey reaches and Ontario Benthos Biomonitoring Network (OBBN) Field Sheets provided in the annual report (LGL, 2013) included a description of habitat characteristics at each benthic invertebrate sample location; however, the information from these was not utilized in interpreting the benthic invertebrate community data. All sites were located in riffles so comparison between sites seems suitable. Determination of site comparison using Qualitative Habitat Evaluation Index (QHEI) justifies comparison further but the methodology or results of such calculations were not included in the monitoring report. Habitat characteristics for each sampling location were not presented or used to infer differences in benthic assemblages. Despite comparison between similar (i.e., riffle) habitats and QHEI scores, there could be habitat differences which are stronger determinants of benthic community structure than treated effluent.
- + From the 2012 SWQMP Annual Report (LGL, 2013), statistical differences in benthic invertebrate assemblages at the Waterloo, Kitchener, Preston and Galt study areas were driven by varying abundances of Black Flies (*Simulium vitatum*). It is recommended that literature be reviewed to determine the sensitivity of Black Flies to treated effluent in order to better assess the linkage between effluent and the differences in the abundance of Black Flies between sites.
- + In the 2012 SWQMP Annual Report (LGL, 2013), benthic invertebrate results were compared between 2007, 2009 and 2012. Samples were collected in 2009 following the same protocol as 2012 but samples collected in 2007 by GRCA were collected using the OBBN protocol. OBBN protocol differs substantially from Environmental Effects Monitoring protocol, including the method of collection (i.e. kick and sweep versus surber), so additional justification is recommended during future reporting to show, if appropriate, that data collected in 2007 may be compared to data collected thereafter.

We recommend that benthic invertebrate sampling continue on an approximate five-year frequency, in order to assess potential changes in the communities.

Fish community surveying was completed in 2009 and 2012 within the SWQMP study area. The fish collection methodology was altered between 2009 and 2012 from boat electrofishing to backpack electrofishing for a variety of stated reasons, most importantly to reduce the impacts on Species at Risk (SAR). Backpack electrofishing was completed in riffle habitat within 60 m transects up and downstream of WWTP effluent outfalls at Preston, Galt and Hespeler WWTPs. (No fish were collected near the Waterloo and Kitchener WWTPs in 2012 to avoid conflicts with academic research studies). Fish were measured, weighed and assessed through a variety of biological metrics, including an Index of Biological Integrity, which was altered according to the collection methodology. Forage fish were the focus of monitoring efforts due to the riffle habitat and sampling methodology. Habitat assessment and ranking was also completed during the 2012 fisheries investigation following the Ohio Environmental Protection Agency Qualitative Habitat Evaluation Index.

The following modifications can be considered with respect to fish collection methodology and data interpretation:

- + Backpack electrofishing was used as a collection technique in 2012 to avoid impacts to SAR. Backpack electrofishing is potentially harmful to fish, especially in highly conductive waters. Focusing on only forage fish as opposed to forage and larger fish can limit the assessment and the ability to effectively communicate results to the public, who are often most concerned about larger, sport fish. Passive fish collection techniques exist (e.g., hoop or fyke nets), which are less harmful to fish populations, and can effectively catch both forage fish and larger fish.
- + The habitat assessment provided a qualitative comparison between up and downstream sites. Habitat such as substrate, aquatic vegetation, woody debris, and blockages to fish migration should be considered in terms of the requirements of resident fish species to better inform the evaluation of fish population data and the assessment of treated effluent.
- + Historical data would not be directly comparable to data collected in 2012 because of changes in the collection methodology, but it could be considered as a better comparison of results between sites over multiple years.

It is understood that previous discussions between the Region and representatives from the University of Waterloo, GRCA and LGL have indicated that benthic invertebrate surveys are a better representation of effluent impacts on the receiver

than fish surveys, since fish surveys are a snapshot on a single day and fish are quite mobile. Benthic invertebrates are also a better bioassessment tool than fish to evaluate the impacts of treated effluent. However, fish surveys provide information on the health of the fish community, another layer of information in the multiple lines of evidence approach, and information that is more easily understood by non-scientists (since the public typically care more about fish and sport fishing than other biota). Finally, benthic invertebrates have a stronger seasonal cycle, meaning that the transition through larvae to adult is more difficult to predict than it is for fish, and thus harder to control for this natural temporal change than it is for fish.

Given the above, it is recommended that the fisheries collection continue on an approximate three-year frequency, in order to assess potential changes in the communities.

### **3.8 The Region's SWQMP Program – Longitudinal Surveys**

Longitudinal surveys were carried out in 2010, 2012, 2014, and 2016 in the areas upstream and downstream of the WWTPs. Temperature, DO, pH and conductivity were continuously monitored during the longitudinal surveys. The Region uses these surveys to analyze the effluent impact on the receiver with respect to variations in DO, and these are translated to a visual figure that allows for easy communication of the results to a number of stakeholders.

The survey takes field technicians approximately two hours to boat from the upstream point in the Grand River to the downstream point. As such, the DO measurements collected at the upstream end may not be directly comparable to downstream DO measurements due to the diurnal cycle of DO in response to plant photosynthesis and respiration. To gather additional information on the magnitude of DO swings on the Grand River, the Region could consider continuous DO loggers at selected locations upstream and downstream (DO sag points) of WWTP outfalls.

SWQMP Annual Reports by LGL often reference the longitudinal surveys when discussing plume dimensions. If there is reason to believe that a plume shape has changed (due to reconfiguration of the outfall, a change in the river itself due to erosion or other hydrologic forces, a re-rating of the WWTP, etc.), a dye tracer study could also be considered as an informative, highly visual and measureable means to determine the plume location.

### 3.9 Supplementing the River Monitoring Program

As detailed in Section 1, one of the goals of this SWQMP review was to determine if any changes to the program could make the program more effective and/or cost-efficient while supporting the Region's long-term strategy. One of the items that may become part of the long-term strategy is phosphorus offsetting to benefit the Region's WWTPs. For this reason and in light of the *Great Lakes Water Quality Agreement (GLWQA) Annex 4 - Nutrients* and the resulting Lake Erie nutrient targets, a holistic approach to updating the SWQMP is recommended.

If the changes to the SWQMP suggested in this technical memorandum are implemented, a portion of the budget originally applied to the water quality monitoring program may be re-allocated to items that would support an improved Grand River watershed, including:

- + Continued investigation into developing phosphorus offsetting opportunities, especially in the Nith and Conestogo Rivers and Canagagigue Creek. A water quality program to monitor freshet and storm events may be created as part of this investigation.
- + In addition to water chemistry and benthic invertebrates, the following parameters may also provide an indication of nutrient enrichment in an aquatic water body and should be evaluated for possible inclusion in the SWQMP: zooplankton, periphyton, phytoplankton, and sediment quality.
- + As described in Section 3.2: An evaluation into data obtained from the GRCA's continuous monitoring program including: 1) Determining if a significant relationship exists between turbidity and total phosphorus (if turbidity probe fouling issues can be resolved), and pH and macrophyte growth; and 2) Comparing GRCA continuous monitoring data for nitrate with the Waterloo US station water quality to determine if GRCA's nitrate data may be used as part of the SWQMP.

## 4. Summary of Opportunities for Consideration

This memorandum has been prepared to consider potential future modifications to the SWQMP in 2018. Prior to making any changes, discussion with the MOECC and GRCA is recommended to obtain a consensus on the best approach moving forward.

Based on our review of the Region’s SWQMP, the following opportunities have been identified:

1. The goals of the SWQMP should be re-evaluated every five years to ensure the program is still addressing the needs of the Region and stakeholders.
2. Potential adjustments to the SWQMP are summarized in Table 2 along with the estimated cost savings for each change (utilizing a rate of \$4000/station/year, which equates to \$166/sample).

**Table 2 Potential Changes to the SWQMP and Estimated Annual Cost Savings**

Particulars	SWQMP Details	Estimated Annual Cost Savings
Sampling Frequency	<ul style="list-style-type: none"> <li>• Elmira, St. Jacobs, Waterloo, Kitchener, Hespeler, Preston and Galt WWTP: reduce fall sampling frequency from 6x/season to 3x/season. Spring, summer and winter frequencies remain at 6x/season</li> <li>• Wellesley, New Hamburg and Ayr WWTP: reduce sampling frequency from 6x/season to 3x/season for all seasons</li> </ul>	<ul style="list-style-type: none"> <li>• \$12,450 for Elmira, St. Jacobs, Waterloo, Kitchener, Hespeler, Preston and Galt WWTP reductions</li> <li>• \$11,952 for Wellesley, New Hamburg and Ayr WWTP reductions</li> </ul>
Stations to be sampled (as composite unless otherwise noted)	<ul style="list-style-type: none"> <li>• Elmira: US, DS Near (discrete only), and DS Far</li> <li>• St. Jacobs: US, DS Near (discrete only), and DS Far</li> <li>• Waterloo: US, DS Near (discrete only), and DS Far</li> <li>• Kitchener: US, DS Near (discrete only), and DS Near/Far</li> <li>• Hespeler: US, DS Near (discrete only), and DS Far</li> </ul>	<ul style="list-style-type: none"> <li>• \$20,000 for removal of DS Near composite sample from Waterloo, Kitchener, Hespeler, Preston and Galt WWTPs</li> </ul>

Particulars	SWQMP Details	Estimated Annual Cost Savings
	<ul style="list-style-type: none"> <li>• Preston: US and DS (discrete only)</li> <li>• Galt: US, DS Near (discrete only), and DS Far</li> <li>• Wellesley: US and DS Near/Far</li> <li>• New Hamburg: US and DS Near</li> <li>• Ayr: US and DS Near</li> </ul>	
Water Quality Parameters	<ul style="list-style-type: none"> <li>• Remove Chlorophyll <i>a</i> from parameter suite</li> </ul>	<ul style="list-style-type: none"> <li>• \$3600 (at an analytical cost of \$20/sample)</li> </ul>

From Table 2, the total annual savings to the SWQMP would be \$48,000 and equates to a savings of \$240,000 over a 5-year monitoring period.

3. Discussion with the MOECC to explore the possibility of further reducing the SWQMP during periods of “regular” WWTP operations and increasing monitoring prior to and immediately after upgrades or other changes are planned and carried out at a given WWTP.
4. The installation of continuous DO loggers at selected locations upstream and downstream (DO sag points) of WWTP outfalls to gather additional information on the magnitude of DO swings on the Grand River.
5. Detailed habitat descriptions of each benthic invertebrate sample site should be completed, and interpretation of statistical analyses should be completed in the context of any differences in habitat between sites in order to limit type 1 statistical errors.
6. Literature should be reviewed to determine the sensitivity of Black Flies to treated effluent in order to better assess the linkage between effluent and the differences in the abundance of Black Flies between sites.
7. Consider using passive fish collection techniques (e.g., hoop or fyke nets), which are less harmful to fish populations (including SAR) and can effectively catch both forage fish and larger fish.
8. Habitat such as substrate, aquatic vegetation, woody debris, and blockages to fish migration should be discussed in the Annual SWQMP report in terms of the

requirements of resident fish species to better inform the evaluation of fish population data and the assessment of treated effluent.

9. Historical fisheries data should be presented to allow for a better comparison of results between sites over multiple years.
10. Benthic invertebrate should continue on an approximate five-year frequency.
11. Fisheries collection should continue on an approximate three-year frequency.
12. The Water Monitoring and Optimization Working Group should continue to explore data sharing (and data management) between group members and optimizing/communicating the sampling technique(s) used for sample collection.
13. Evaluate if significant relationships between turbidity and total phosphorus from the GRCA's continuous monitoring program can be established (if turbidity probe fouling issues can be resolved).
14. Compare the GRCA's "Bridgeport" station continuous nitrate data with the monitoring results from the Waterloo US station to determine if sampling frequency can be decreased for this parameter.
15. Conduct macrophyte surveys downstream of WWTPs on the Grand and Speed River (i.e., Waterloo, Kitchener, Hespeler, Preston and Galt WWTPs), in the location with the largest diurnal DO swing during summer low flows to provide additional insight into the tangible effects the upgraded plants are having on water quality and input into future GRSM activities.
16. Evaluate a pH-DO-macrophyte abundance relationship to determine if pH levels monitored at the three stations can provide, in real-time, evidence of increasing macrophyte growth.
17. When real-time total phosphorus analysis technology becomes feasible (both economically and performance-wise), real-time total phosphorus monitoring could be considered as part of the SWQMP.

## **Appendix A – Kruskal-Wallis and Mann-Whitney Tests**

## **Appendix B – Mann Kendall Trend Tests**

## **Appendix C – Temporal Boxplots**

## **Appendix D – Spatial Boxplots**