2022 Watershed Overview of Wastewater Treatment Plant Performance

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Acronyms and Abbreviations

ADF	Average daily flow
cBOD	Carbonaceous 5 day biochemical oxygen demand
CCP	Composite Correction Program
ECA	Environmental Compliance Approval (formerly called Certificate of Approval)
EPA	US Environmental Protection Agency
GRCA	Grand River Conservation Authority
I/I	Inflow/Infiltration
MECP	Ontario Ministry of the Environment, Conservation and Parks
NDF	Nominal Design Flow (listed in plant's ECA)
OCWA	Ontario Clean Water Agency
TAN	Total ammonia nitrogen
TBOD	Total 5 day biochemical oxygen demand
TKN	Total Kjeldahl nitrogen
TP	Total phosphorus
TSS	Total suspended solids
UIA	Un-ionized ammonia
WMP	Water Management Plan
WWOP	Watershed-wide Wastewater Optimization Program
WWTP	Wastewater treatment plant

EXECUTIVE SUMMARY

Since 2010, the Grand River Conservation Authority (GRCA) has been working collaboratively with municipal partners and the Ministry of the Environment, Conservation and Parks (MECP) to develop a Watershed-wide Wastewater Optimization Program (WWOP). A key program activity is the preparation of an annual report on effluent quality and plant loading for treatment facilities discharging in the Grand River watershed. The first annual report was produced for data collected in 2012. Year-to-year variations are used to evaluate the success of the program and track WWTP impacts on the Grand River. Available performance and loading data for 28 of 30 municipal wastewater treatment plants were voluntarily reported in 2022. These results were summarized in terms of treatment performance, data integrity, impacts on the Grand River, plant loading and bypasses and overflows and compared to results from previous years.

Treatment Performance

Figure 1 shows the total average day flow for all the reporting plants from 2012 to 2022. Additionally, the reported serviced population for each year is included on the secondary axis in orange. From 2012-2022 the reported population increased by 13% (or 1.2% per year) from about 805,200 people in 2012 to 921,700 in 2022 while the flows increased by 2%. Variations in total plant flow reflects the impact of variations in precipitation.

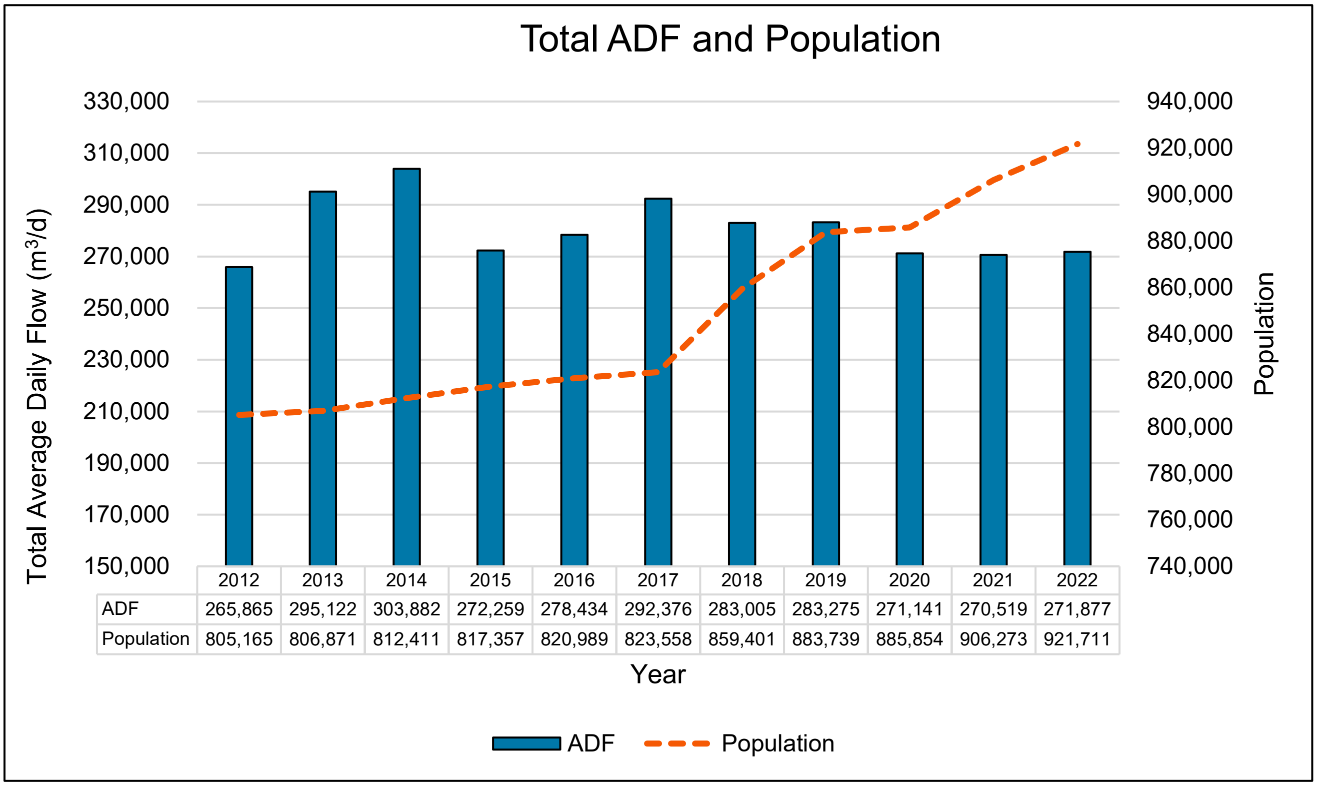
Despite the increase in population, flow-weighted concentrations and loadings of effluent TP and TAN discharged from the plants have steadily decreased over the years. Figure 2 and Figure 3 shows the final effluent TP and TAN flow-weighted average concentrations and the total loading from 2012 to 2022. The dashed line in Figure 2 represents the watershed-wide flow-weighted concentration target for TP, which is calculated based on each plant's ADF multiplied by the corresponding TP target and the sum of these values is divided by the total ADF. This target can change year over year as the annual average daily flow changes. The TAN targets in Figure 3 are calculated using the same method.

With respect to the TP concentrations and loads in Figure 2, the following observations can be made:

- From 2021 to 2022, the TP flow-weighted concentration decreased by 5% and the TP load also decreased by 5% (from 22.2 to 21.1 tonnes); and
- From 2012 to 2021, the TP flow-weighted concentration decreased by 42% and the TP load by 41% (from 36.0 to 21.1 tonnes);

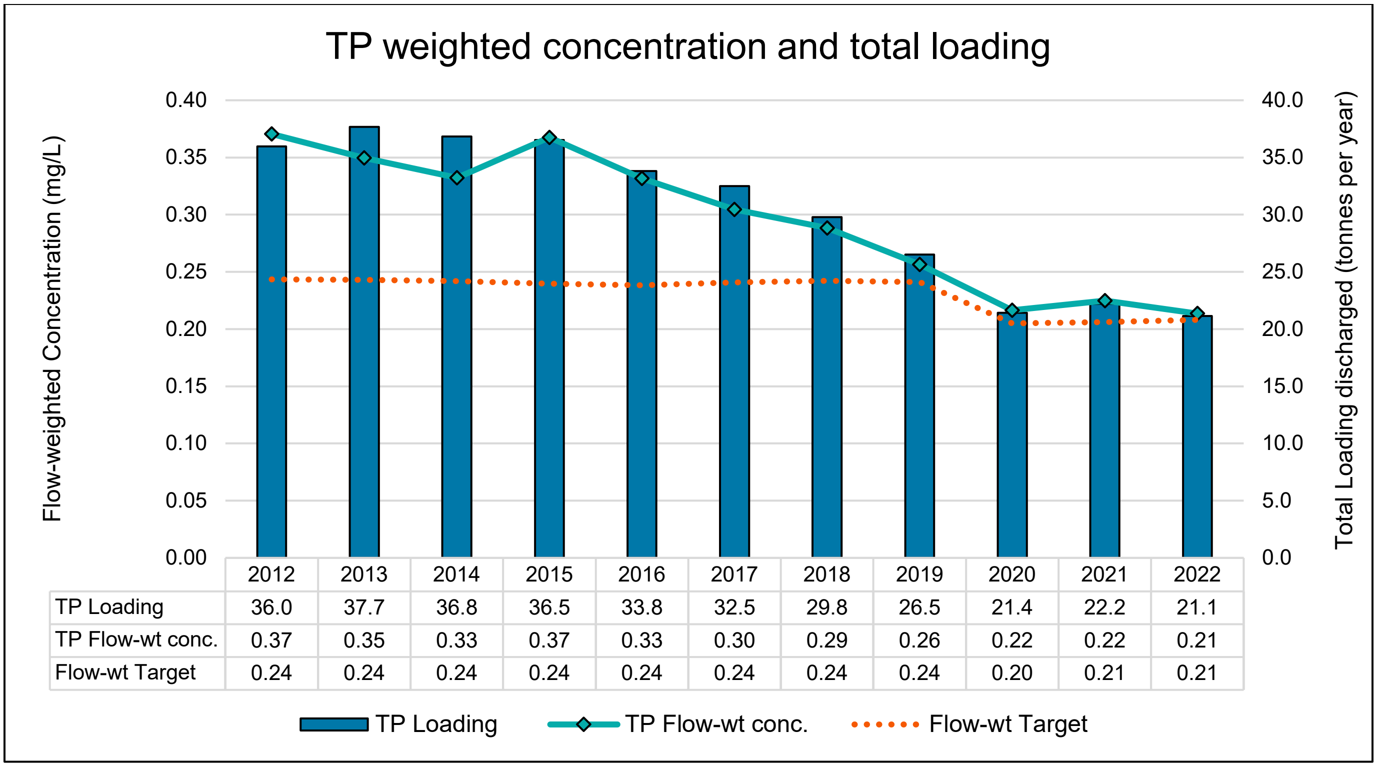
With respect to Figure 3 showing the TAN loads and concentrations, the following comments are applicable:

- From 2021 to 2022 the summer TAN decreased by 40% and winter TAN decreased by 3%. TAN total loading decreased 14% (68 to 58 tonnes) compared to the previous year.
- From 2012 to 2022, the overall total TAN flow-weighted concentration decreased by 94% and the total loading by 94% (954 to 58 tonnes).



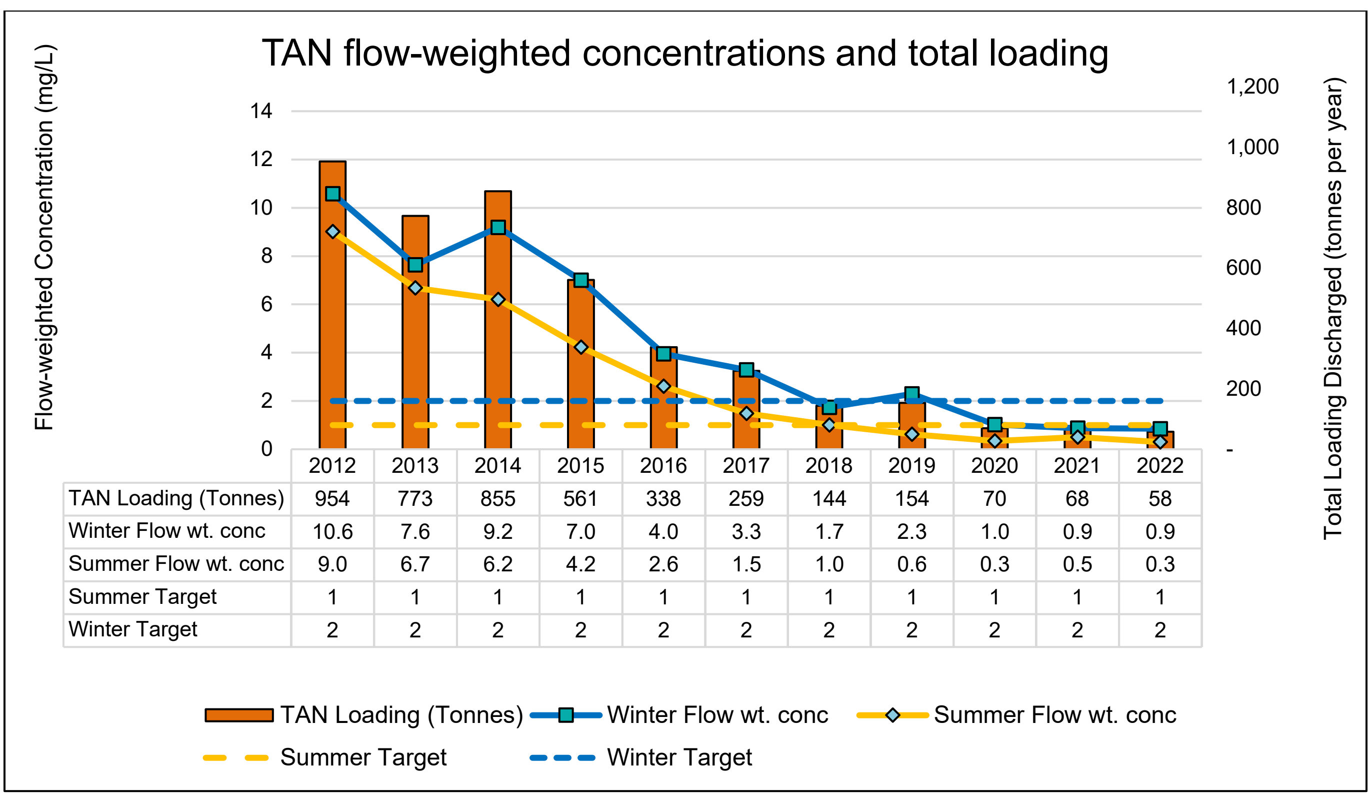
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
ADF	265,865	295,122	303,882	272,259	278,434	292,376	283,005	283,275	271,141	270,519	271,877
Population	805,165	806,871	812,411	817,357	820,989	823,558	859,401	883,739	885,854	906,273	921,711

Figure 1: Total reported WWTP average daily flow and population from 2012-2022



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
TP Loading	36.0	37.7	36.8	36.5	33.8	32.5	29.8	26.5	21.4	22.2	21.1
TP Flow-wt conc.	0.37	0.35	0.33	0.37	0.33	0.30	0.29	0.26	0.22	0.22	0.21
Flow-wt Target	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.20	0.21	0.21

Figure 2: Flow-weighted TP concentrations and total loading



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
TAN Loading (Tonnes)	954	773	855	561	338	259	144	154	70	68	58
Winter Flow wt. conc	10.6	7.6	9.2	7.0	4.0	3.3	1.7	2.3	1.0	0.9	0.9
Summer Flow wt. conc	9.0	6.7	6.2	4.2	2.6	1.5	1.0	0.6	0.3	0.5	0.3
Summer Target	1	1	1	1	1	1	1	1	1	1	1
Winter Target	2	2	2	2	2	2	2	2	2	2	2

Figure 3: Flow-weighted summer and winter TAN concentrations and total loading

Despite the overall reductions in TP and TAN loading to the Grand River, the optimization program has work to do to ensure that all plants achieve the voluntary targets in all months. For instance, in 2022, three plants did not achieve the TP target in any month of discharge and one plant did not achieve the TAN target in any month of discharge.

Data Integrity Checks

A sludge accountability analysis compares the annual amount of sludge reported by a mechanical plant to the amount of sludge projected based on plant loadings and removal. Conducting this analysis can help to determine if monitoring is truly representative. In 2021, sludge accountabilities were reported for 22 plants in the watershed. For ten of the plants, the accountability "closed" within ± 15%. In 2022, 22 plants reported sludge accountability and 13 plants "closed" within ± 15%.

A water balance analysis compares the annual amount of measured net precipitation on the surface area of a lagoon system to the annual amount of projected net precipitation using lagoon level measurements, total influent and total effluent flows of a lagoon system. This analysis can help to determine if the flow measurement devices at a lagoon are accurate. In 2022, water balances were reported for 3 lagoon systems in the watershed. One of these analyses closed within ±15%.

Grand River Impacts

Table ES-1 summarizes the impact of total annual average discharge of effluent from wastewater treatment plants to the total flow in the Grand River.

Table ES-1: WWTP Effluent flow as a percentage of Grand River total flow

Parameter	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
% Annual Average Flow	6.8%	3.1%	2.6%	5.0%	4.7%	3.5%	3.6%	3.7%	4.5%	5.1%	5.5%
% August Average Flow	13.9%	5.4%	9.5%	11.5%	9.0%	7.3%	8.7%	10.3%	10.2%	12.6%	14.5%

The year to year variations in Table ES-1 are largely a function of precipitation and weather in the watershed in any given year. The percent of flows in August is also shown, as August is typically the month when flows in the river are the lowest and treated wastewater makes up a larger portion of river flow. In 2017 and 2019, precipitation was above average. In 2014, 2018, 2020 and 2021 precipitation was close to the long-term average. In 2012, 2015, 2016 and 2022 precipitation was near the lower end of typical. 2022 was characterized by extended periods of no rain interspersed with small shots of light rain, as a result, streams flows dropped and augmentation from the reservoirs was increased to ensure the minimum flow in the Grand River. The watershed was moved to a Level 1 low water condition at the end of June and a Level 2 condition by mid-July and remained in Level 2 for the remainder of the year (Shifflett S. , 2022).

Some improvements in the water quality of the Grand River have been noted due to recent WWTP upgrades and optimization efforts. For example, optimization activities at the Hespeler WWTP resulted in lower concentrations of TAN in the lower Speed River in the summer and winter of 2018 (LGL Limited, 2019). Additionally, upgrades at the Kitchener and Waterloo WWTPs have allowed the plants to nitrify, resulting in lower concentrations of TAN, UIA and nitrite in the Grand River. Data from 2022 show That TP concentrations at Waterloo WWTP were elevated at discrete station in winter and at all downstream stations in summer and fall (Limited, LGL, 2023)

Plant Loading

Table ES-2 summarizes the 2022 median and 2012-2021 ranges for raw influent concentrations for TBOD, TSS, TP and TKN. This data is helpful to give a rough idea of typical concentrations for the plants in Grand River watershed as sometimes poor estimates of population play into the per capita loadings. Table ES-3 summarizes key process loading metrics for 2022 as well as typical values and the range of median reported values from 2012 to 2021. The results in the tables enable municipalities to compare loadings at their facilities to those at other plants in the watershed, which can be used to determine the impact of industrial discharges and may highlight concerns with unrepresentative sampling of raw influent.

Table ES-2: Summary of 2012 to 2022 watershed WWTP raw influent concentrations

Raw Influent concentrations	**Watershed Median** 2012-2021 (min-max)	**Watershed Median 2022**
TBOD (mg/L)	183-224	**251**
TSS (mg/L)	204-255	**258**
TP (mg/L)	5-6	**6**
TKN (mg/L)	38-45	**47**

Table ES-3: Summary of 2012 to 2022 watershed WWTP loading metrics

Loading Measure	**Watershed Median** 2012-2021 (min-max)	**Watershed Median** 2022	**Typical Value**
Per capita flow (L/person/day)	294 - 351	**280**	350 - 500
ADF as % of Nominal Design	51% - 66%	**55%**	N/A
Peak day: Annual average flow	2.25 – 3.54	**2.62**	2.5 – 4.0
Per capita TBOD[1] loading (g/person/day)	63 - 77	**66.9**	80
Per capita TSS loading (g/person/day)	69 - 93	**74.2**	90
Per capita TKN loading (g/person/day)	13 - 14	**13.0**	13
Per Capita TP loading (g/person/day)	1.6 – 2.0	**1.6**	2.1
Raw TSS:TBOD ratio	1.01 - 1.25	**1.06**	0.8 - 1.2
Raw TKN:TBOD ratio	0.17 - 0.23	**0.20**	0.1 - 0.2

Year-to-year variations in per capita flow, the average day flow as a percentage of the design flow and the ratio of the peak day to average day flow from Table ES-3 are largely due to differences in inflow and infiltration (I&I) related to precipitation.

[1] Three of the reporting plants do not measure total BOD_5 in the raw influent because their ECAs require measurement of carbonaceous BOD_5. Research indicates that $cBOD_5$ measurements of raw wastewater underestimate organic loading by 20 to 40%. For this summary $TBOD_5$ values were assumed to be 20% higher than $cBOD_5$. This assumption may be impacting the metrics related to TBOD in Table ES-3

Bypasses and Overflows

Bypasses and overflows are terms used to describe events that result in untreated or partially treated sewage reaching natural water bodies (Grand River Municipal Water Managers Working Group, 2009). Bypasses occur when parts of a treatment process are bypassed and partially treated wastewater discharges to the environment via the WWTP effluent outfall. Overflows occur when sewage enters the environment at a location other than the effluent outfall. Bypasses/overflows can be classified as low, moderate or high according to the level of risk to downstream users. Overall, the total number of bypasses has decreased by 68% from 66 in 2013 to 21 in 2022. The total volume of bypasses has decreased 98% from 1,156,707 m^3 in 2013 to 27,195 m^3 in 2022. A number of low and high-risk bypass in 2022 occurred in February and December and were related to weather conditions generating high peak day flows to the WWTP.

INTRODUCTION

The Grand River watershed has a population of about 994,000 that is expected to reach 1.44 million by 2041 (Irvine, 2018). Based on data reported to the GRCA, wastewater from a total population of about 921,000 is treated by municipal facilities in the watershed while the remainder of the population is serviced by other means such as private septic systems. Significant population growth will result in more wastewater treatment plant (WWTP) effluent being discharged into the Grand River and its tributaries. There are 30 municipal WWTPs that discharge their treated effluent into rivers in the watershed as shown in Figure 4. The organizations listed below are responsible for their operation:

- Township of Southgate
- Town of Grand Valley
- Township of Mapleton
- Township of Wellington North
- Township of Centre Wellington
- Region of Waterloo
- City of Guelph
- Oxford County
- County of Brant
- City of Brantford
- Haldimand County
- Six Nations of the Grand River
- Mississaugas of the Credit First Nation

The following report describes the background and objectives of the Grand River Watershed-wide Wastewater Optimization Program (WWOP) and provides a summary of performance data from 2012 to 2022 voluntarily reported by the program participants.

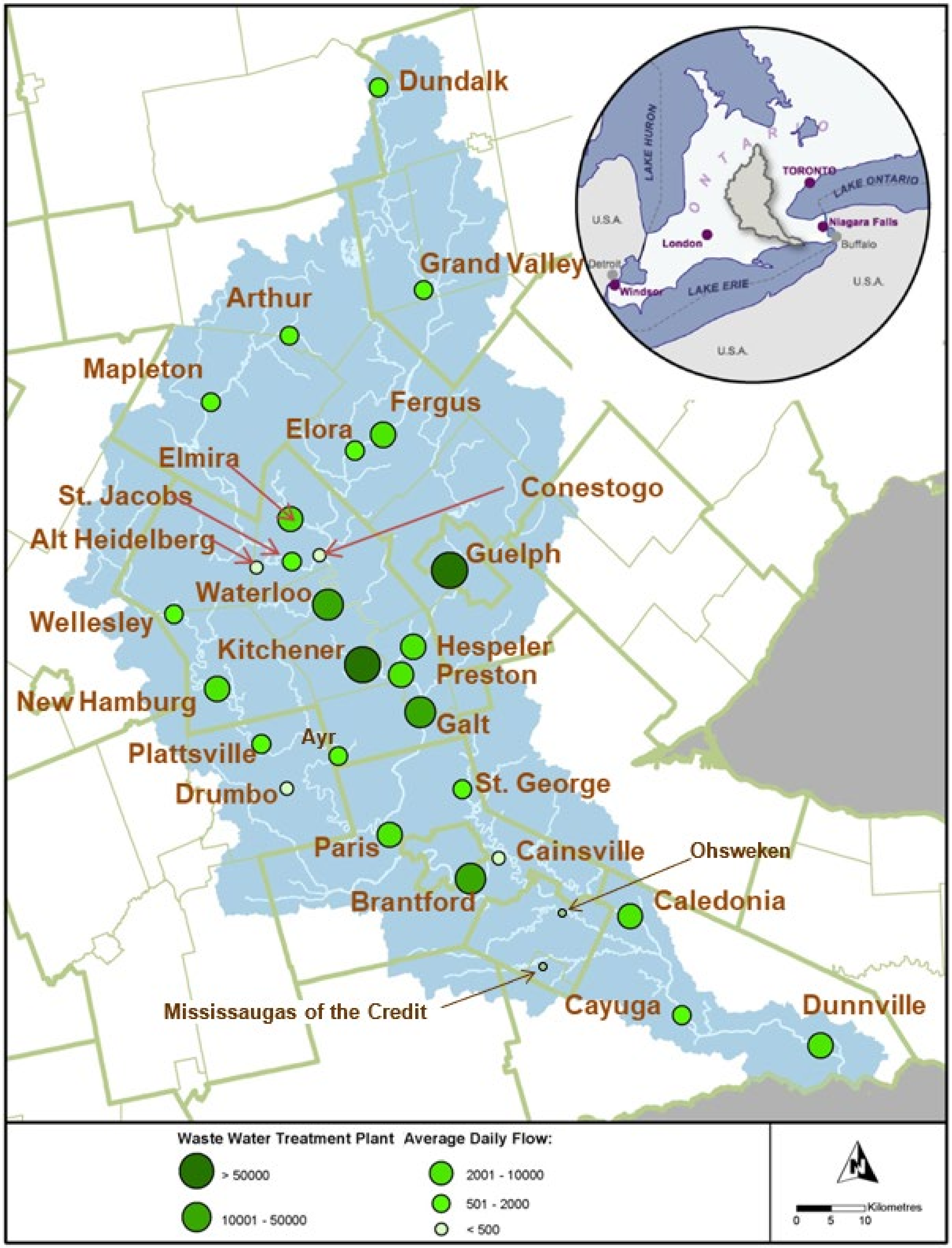


Figure 4: Map showing locations of WWTPs in the watershed

Background

The Grand River, located in southwestern Ontario, traverses a distance of approximately 310 km from its source near Dundalk to its point of discharge into Lake Erie at Port Maitland. The River serves as drinking water supply for four communities in the watershed in addition to providing other uses including a world-renowned brown trout tail-water fishery, active and passive recreation opportunities and productive agricultural lands (Anderson et al., 2011). Because of its cultural heritage and outstanding recreational opportunities, the Grand River and its major tributaries (Nith, Conestogo, Speed and Eramosa) were designated as a Canadian Heritage River in 1994 (Canadian Heritage Rivers System, 2017). Thirty municipal WWTPs discharge treated effluent to the Grand or its tributaries.

Since 2010, the Grand River Conservation Authority (GRCA) has been working collaboratively with municipal and First Nations partners and the Ministry of the Environment, Conservation and Parks (MECP) to develop a Watershed-wide Wastewater Optimization Program (WWOP). The WWOP supports maintaining and improving water quality in the Grand River, as identified in the Grand River Water Management Plan (WMP) (Project Team, 2014). The WWOP is a voluntary program focused on skills development, knowledge transfer and capacity building within the watershed. The objectives of the program are to:

- Improve water quality in the Grand River and its tributaries as a direct result of improving wastewater treatment plant performance,
- Improve the quality of Lake Erie,
- Tap the full potential of existing wastewater infrastructure and promote excellence in infrastructure management,
- Reduce vulnerability to climate change,
- Build and strengthen partnerships for wastewater optimization,
- Enhance partner capability and motivation,
- Leverage and learn from existing area-wide optimization programs in the United States (US), and
- Demonstrate strategies that can serve as a model for other areas of Ontario.

The WWOP promotes optimization across the watershed by encouraging the adoption of the Composite Correction Program (CCP). The US Environmental Protection Agency (EPA) developed the CCP as a structured approach to identify and systematically address performance limitations to achieve a desired effluent quality (EPA, 1989). The CCP was adapted for Ontario and documented in the handbook, “The Ontario Composite Correction Program Manual for Optimization of Sewage Treatment Plants” (PAI & WTC, 1996). Additionally, the WMP suggests that adopting the CCP will help to reduce the overall loading of total phosphorus to the Grand River and, ultimately, to Lake Erie.

The CCP is based on the model shown in Figure 5. Good administration, design, and maintenance establish a “capable plant” and, by applying good process control, operators achieve a “good, economical” effluent.

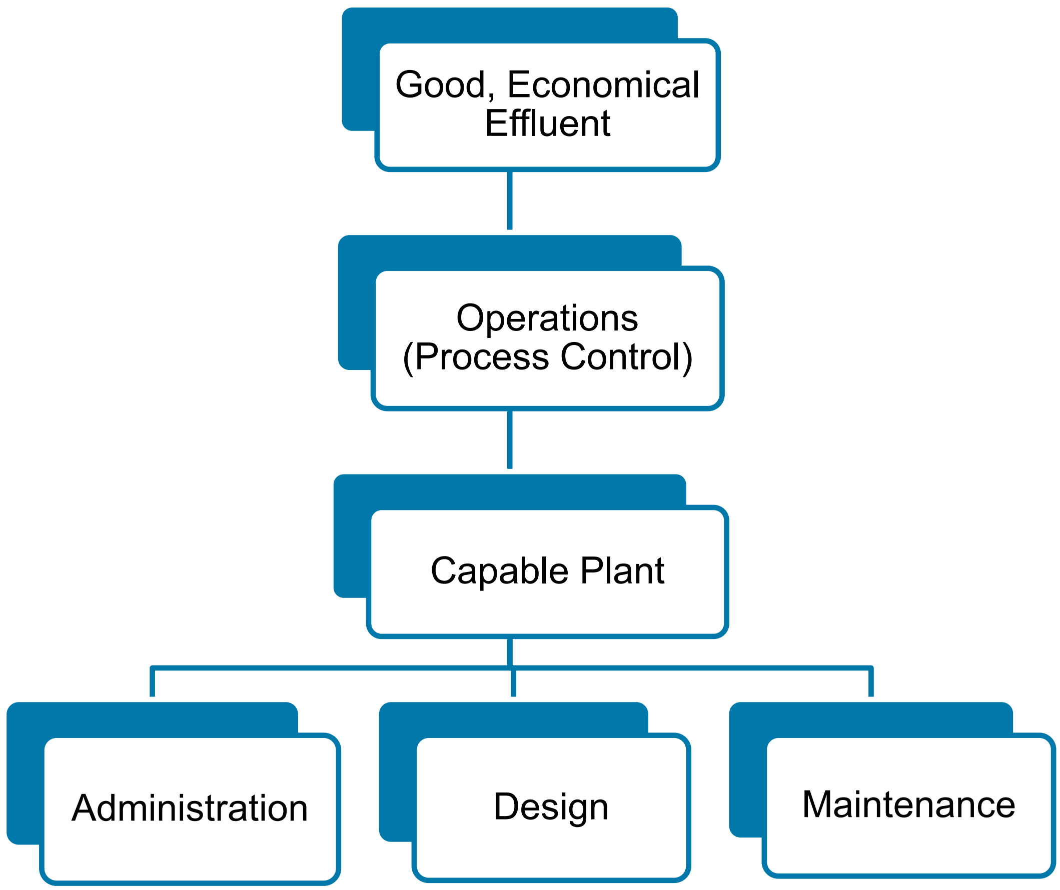


Figure 5: Composite Correction Program Performance Pyramid

The CCP is a two-step approach. The first step, a Comprehensive Performance Evaluation, evaluates and identifies performance limiting factors in the areas of administration, design, maintenance and operations of a wastewater treatment plant. If applicable, in Step 2 (Comprehensive Technical Assistance) a facilitator works with plant operators and managers to address and resolve any factors identified in Step 1. The watershed municipalities of Guelph, Haldimand County and Brantford have applied the CCP approach and have demonstrated its benefits, including improved effluent quality and re-rated capacity.

This approach has proven to be successful but is resource intensive when applied on a plant-by-plant basis. To address this challenge, an area-wide approach (as shown in Figure 6) was adopted based on the successful strategy for optimizing drinking water treatment systems in the United States. Major components include: Status, Targeted Performance Improvement, and Maintenance. The model utilizes a proactive, continuous improvement approach to improve effluent quality.

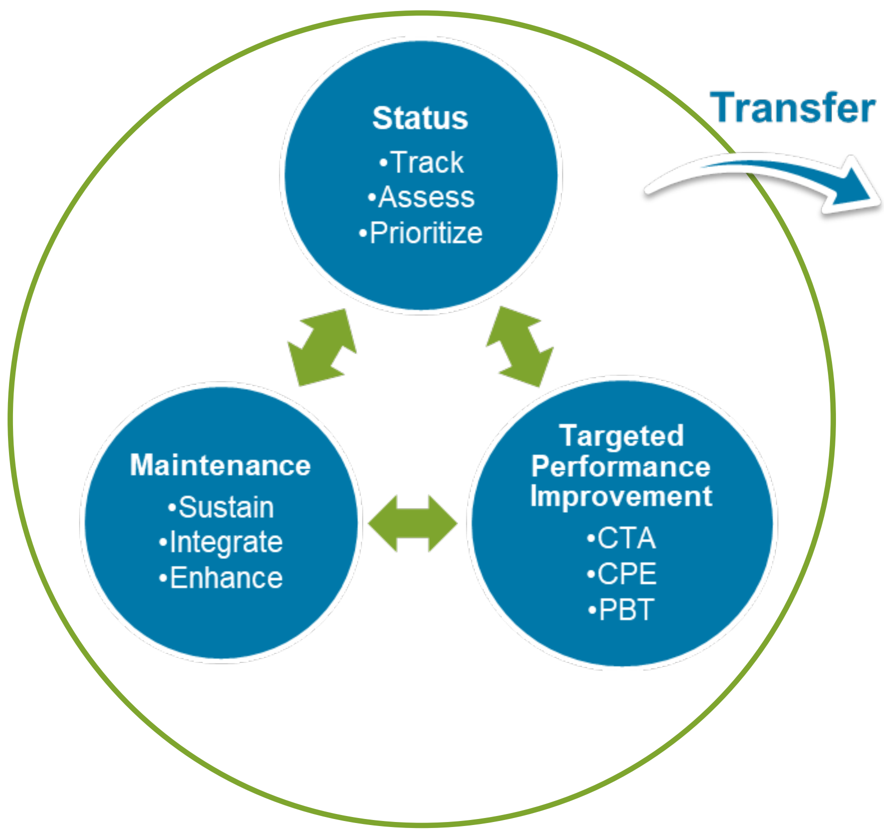


Figure 6: Area-Wide Optimization Model

Lake Erie Action Plan

Wastewater treatment plant optimization and area-wide optimization programs are highlighted as actions in the Canada-Ontario Lake Erie Action plan as a means to reduce phosphorous loadings. (Canada-Ontario Agreement Partners, 2018)

A key activity under the Status Component is plant performance monitoring, used to demonstrate the success of the program, track changes over time and identify plants for further optimization work. Targeted Performance Improvement establishes voluntary performance targets and applies tools for achieving them. This component can include performance-based training, technical assistance, and other activities to develop and transfer skills. The purpose of the Maintenance component is to sustain and grow the program. As part of the maintenance component, a recognition program was developed to encourage participation and to acknowledge plants that:

- Participate in the WWOP,
- Apply CCP concepts,
- Meet all of the effluent compliance limits stated in their Environmental Compliance Approval (ECA),
- Adopt and achieve voluntary effluent quality performance targets,
- Participate in enhanced annual reporting (per capita loading, sludge accountability, etc.) and,
- Conduct annual sludge accountability analysis or water balance for lagoon systems.

The recognition awards based on 2022 plant data will be presented in the fall 2023.

Additionally, the WWOP area-wide model includes a Transfer element to share and encourage other jurisdictions to adopt this approach.

Data Collection Methodology

Voluntary performance reporting across the watershed was initiated through several workshops that were held in 2010 and 2011 that brought wastewater operators, supervisors and managers together from communities within the watershed. These workshops provided information on optimization using the CCP and training on some of the tools used to evaluate WWTP performance. Workshop participants, with the assistance of peer facilitators, were encouraged to carry out the following performance calculations using their own plant data for 2012:

- Annual Average Daily Flow (ADF) as a percentage of Nominal Design Flow (NDF),
- Per capita influent flow,
- Ratio of peak day flow to ADF,
- Per capita TBOD, TSS and TKN loading to the plant, and
- The ratios of TSS to TBOD and TKN to TBOD in the raw influent.

Additional workshops were held throughout 2012-2022 to review these performance metrics. Participants across the watershed were encouraged to calculate these metrics on an annual basis, report the information back to the GRCA as well as include them in performance reports to the MECP.

In addition to the metrics listed above, plant staff voluntarily submitted plant performance data including effluent total phosphorous (TP) and Total Ammonia Nitrogen (TAN) concentrations. An Excel spreadsheet template was provided to plant owners and operators for data submission.

This report summarizes 2022 plant data and compares it to 2012 - 2021 data.

WASTEWATER TREATMENT PLANT REPORTING AND PERFORMANCE

Data Reporting

For 2022, 28 of the 30 municipal WWTPs voluntarily reported their performance to the GRCA. All of these treatment plants reported their data using an Excel spreadsheet template. In presenting summaries of the data in the following sections, the plants are ranked from largest to smallest in terms of flow treated.

Final Effluent Quality

Total Phosphorus (TP)

TP is being targeted for improvement in the WWOP since "a high concentration of phosphorus in most rivers and streams in the Grand River watershed has long been recognized as an issue as it is the primary nutrient that promotes nuisance growth of aquatic plants and algae in the rivers" (Project Team, 2014). Over the past decade, zones of low oxygen, as a result of excessive algal growth, have been increasing in Lake Erie causing significant impact on the lake's environment and Canadian economy (Canada-Ontario Agreement Partners, 2018). In early 2018, the Canada-Ontario Lake Erie Action Plan on achieving phosphorus loading reductions in Lake Erie from Canadian sources was finalized. According to 2003-2013 data, "Canadian sources contribute 54 percent of the total phosphorus load to the eastern basin, with the majority of this coming from one tributary - the Grand River" (Canada-Ontario Agreement Partners, 2018). This is another important reason to reduce phosphorous levels in the Grand River and its tributaries.

Total Ammonia Nitrogen (TAN)

Nitrate and ammonia can have direct toxic effects on aquatic life at high concentrations and total ammonia nitrogen (TAN) acts as an oxygen scavenger that reduces the DO concentration in water. TAN is being targeted under the WWOP since "high levels of un-ionized ammonia occur in the Grand River watershed in reaches downstream of wastewater treatment plants" (Project Team, 2014).

Voluntary Effluent Quality Performance Targets

The Grand River Water Management Plan recommends that "watershed municipalities who own WWTPs adopt voluntary effluent quality performance targets that go beyond the compliance objectives as stated in ECAs" to achieve the goal of improved water quality in the watershed. (Project Team, 2014). The proposed voluntary effluent targets are set out in Table 3. The total phosphorous targets were established based on demonstrated performance across the province and within the watershed for various levels of treatment (e.g. separate targets were established for secondary and tertiary treatment). Because nitrification is less effective in colder temperatures, there are different targets for TAN in "summer" and "winter" periods.

Table 3: Voluntary effluent quality performance targets for TP and TAN

Treatment Type	TP Target (monthly average mg/L)	Summer[1] TAN Target (monthly average mg-N/L)	Winter[1] TAN Target (monthly average mg-N/L)
Lagoon	0.30	Meet ECA objectives, if any	Meet ECA objectives, if any
Tertiary Lagoon	0.15	Meet ECA objectives, if any	Meet ECA objectives, if any
Secondary	0.30	1.0	2.0
Tertiary	0.15	1.0	2.0

Notes: [1] "summer" is May to October, "winter" is November to April

Figure 7 shows the number of plants meeting the TP and TAN targets in all months of discharge, from 2012 to 2022. In 2022, 28 plants reported their monthly final effluent TP and TAN and of those plants, 7 met the TP target in each month and 15 met the TAN target in each month. Table 4 shows the percentage of months the TP and TAN targets were achieved in 2022 for each plant. The Table 4 cells are color coded, green cells show the targets were achieved in more than 90% of the months of discharge, light yellow cells the targets achieved from 50% to 90% and the red cells shows the targets were met in less than 50% of the months of discharge. Blank cells are plants with no TAN target. Achieving the targets can vary from year to year, due to changing factors such as staffing, weather conditions, equipment maintenance or operating costs. This shows the need for ongoing engagement of WWOP to support plants.

Figure 8 shows the proportion of months that all plants combined met the TP and TAN targets from 2012 to 2022. A percentage is used because some plants do not discharge year round. Additionally, there are two plants that do not have a target for TAN. As presented in Figure 8, the TP targets were achieved 62% in 2012 and 73% in 2022 respectively, a 15% improvement. Overall, the achievement of TAN targets has improved 15% since the start of the program in 2012, from 75% to 88% in 2022. The ultimate goal is to meet the voluntary targets 100% of the time.

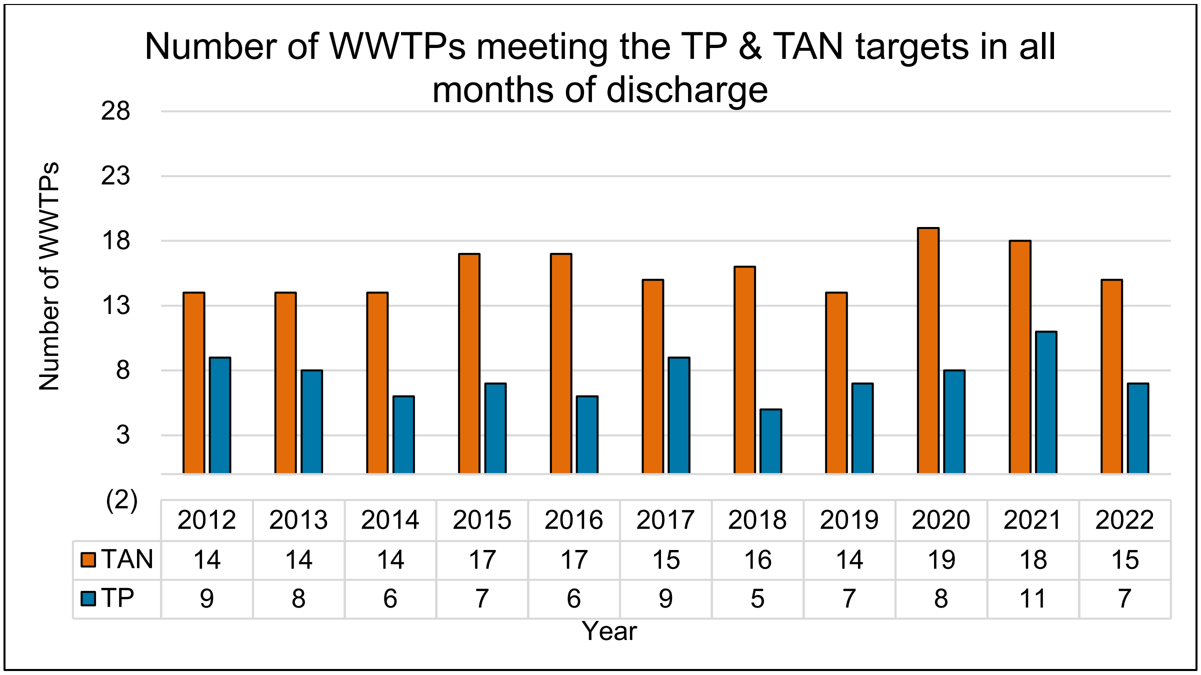


Figure 7: Number of plants meeting TP and TAN targets in all months of discharge (2012-2022)

Table 5 shows the annual average effluent TP loadings from all WWTPs combined for the years 2012 to 2022, as well as flow-weighted TP concentrations. For a majority of plants, the TP loading was calculated based on the product of each plant's monthly average flow and its corresponding effluent TP concentration. For plants that did not report monthly data, the TP loading was based on the annual average flow and TP concentration. The flow-weighted concentrations were calculated by dividing the total combined loading by the total average flow. There was a 5% decrease in TP loading in 2022 from 2021, largely as a result of decreased loadings from the, Brantford, Galt, Hespeler, and Paris WWTPs. The flow-weighted concentrations in 2022 are also lower than the previous year. From 2012 to 2022 the TP loadings and flow-weighted concentrations have dropped by 41 and 42%, respectively.

Voluntary Targets

A study modelling future river water quality conditions suggests that water quality will incrementally improve with the adoption of effluent quality performance targets achieved through enhanced process control techniques as set out in the CCP." (Project Team, 2014)

Table 4: Percentage of months plants meeting TP and TAN targets in 2022

WWTP	TP	TAN
Kitchener	83%	100%
Guelph	92%	92%
Waterloo	58%	100%
Brantford	75%	100%
Galt	0%	75%
Preston	100%	100%
Hespeler	0%	58%
Dunnville	100%	58%
Paris	83%	100%
Fergus	0%	83%
Elmira	67%	83%
New Hamburg	83%	100%
Caledonia	67%	83%
Elora	92%	100%
Ayr	100%	100%
Arthur	50%	88%
Dundalk	64%	No Target
Wellesley	67%	92%
Grand Valley	100%	100%
Cayuga	92%	100%
St. George	83%	100%
St. Jacobs	92%	100%
Mapleton	80%	80%
Plattsville	100%	100%
Drumbo	33%	0%
Cainsville	100%	No Target
Heidelberg	100%	100%
Conestogo	83%	100%

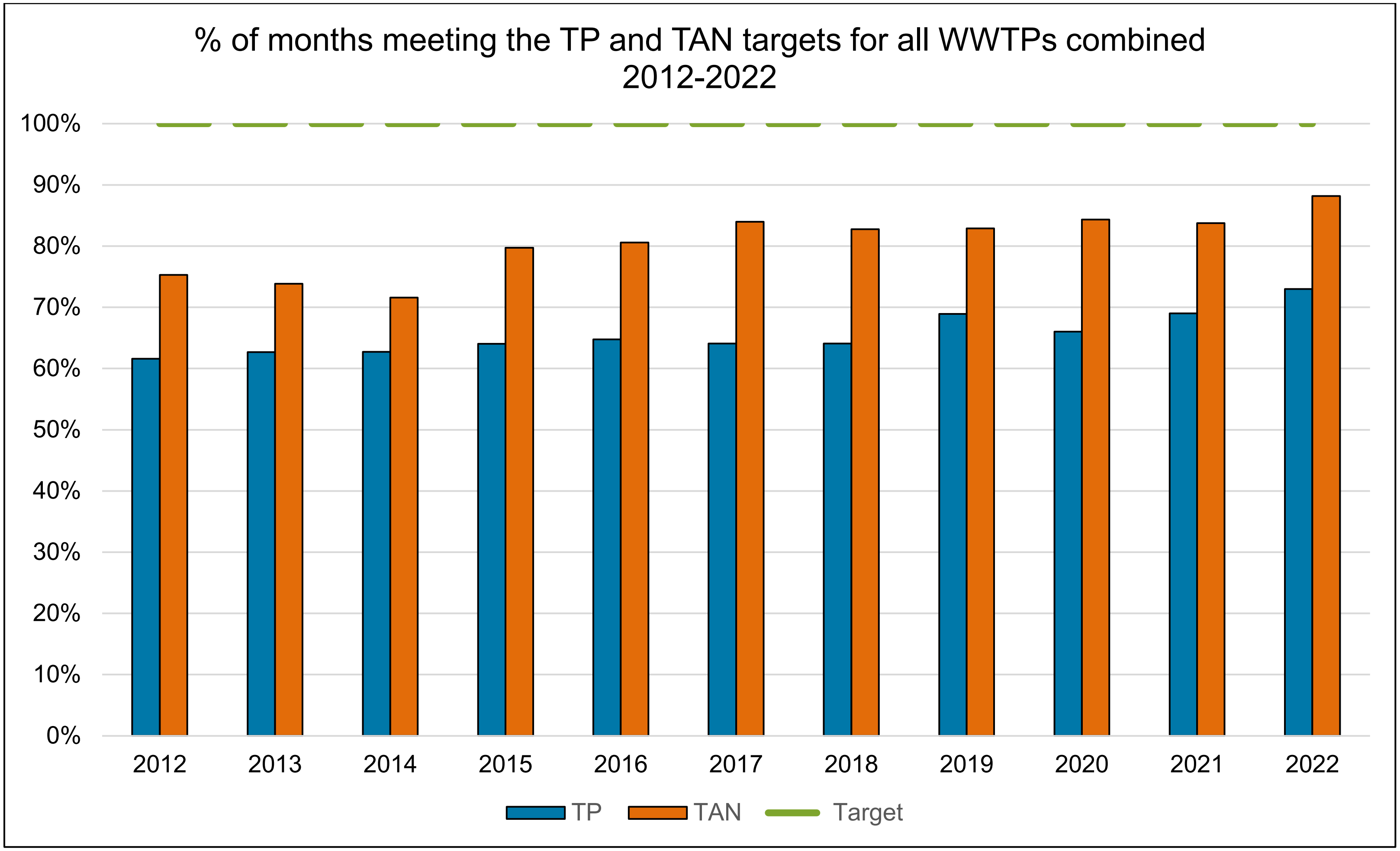


Figure 8: Percentage of months meeting the voluntary targets for all plants combined from 2012-2022

Table 5: Wastewater effluent TP loading and flow-weighted concentration to the Grand River

	Loading (tonne)	Flow-Weighted Concentration (mg/L)
2012	36.	0.37
2013	37.7	0.35
2014	36.8	0.33
2015	36.5	0.37
2016	33.8	0.33
2017	32.5	0.30
2018	29.8	0.29
2019	26.5	0.26
2020	21.4	0.22
2021	22.2	0.22
2022	21.1	0.21

The total annual loading of wastewater effluent TAN discharged to surface water and corresponding flow-weighted concentrations are documented in Table 6 , which shows the TAN loadings separated into summer and winter periods. There was a 43% decrease in summer TAN loadings from 2021 to 2022, which can be attributed to loading reductions from , Hespeler, Galt, Elora, Brantford, Paris, and Dundalk WWTPs. There was a 1% increase in winter TAN loadings from 2021 to 2022. Since 2012, total TAN annual loading and flow-weighted concentrations both decreased by 94%.

Table 6: Wastewater effluent TAN loading and flow-weighted concentrations to the Grand River

Year	TAN summer Loading (tonne)	TAN summer Conc.* (mg/L)	TAN winter Loading (tonne)	TAN winter Conc.* (mg/L)	TAN Annual Loading (tonne)	TAN Annual Conc.* (mg/L)
2012	417	9.0	534	10.6	**951**	**9.8**
2013	346	6.7	426	7.6	**773**	**7.2**
2014	343	6.2	512	9.2	**855**	**7.7**
2015	206	4.2	353	7.0	**560**	**5.6**
2016	124	2.6	223	4.0	**347**	**3.3**
2017	77	1.5	182	3.3	**259**	**2.4**
2018	49	1.0	97	1.7	**146**	**1.4**

Year	TAN summer Loading (tonne)	TAN summer Conc.* (mg/L)	TAN winter Loading (tonne)	TAN winter Conc.* (mg/L)	TAN Annual Loading (tonne)	TAN Annual Conc.* (mg/L)
2019	31	0.6	118	2.3	**149**	**1.5**
2020	15	0.3	54	1.0	**70**	**0.7**
2021	24	0.5	44	0.9	**68**	**0.7**
2022	14	0.3	44	0.9	**58**	**0.6**

*all concentrations are flow-weighted average concentrations

Influence of WWTPs on the Grand River

TP Loading to Lake Erie from Grand River

Figure 9 shows the estimated TP loading to Lake Erie from the Grand River at York[2] (shown in blue) and the annual TP load from WWTPs (shown in orange) in the Grand River Watershed, from 2012 to 2022. The annual load from the Grand River to Lake Erie is highly variable because of high flows and agricultural non-point sources of phosphorus in the spring which are closely linked to climate factors such as precipitation, the timing/volume of snow melt, etc.

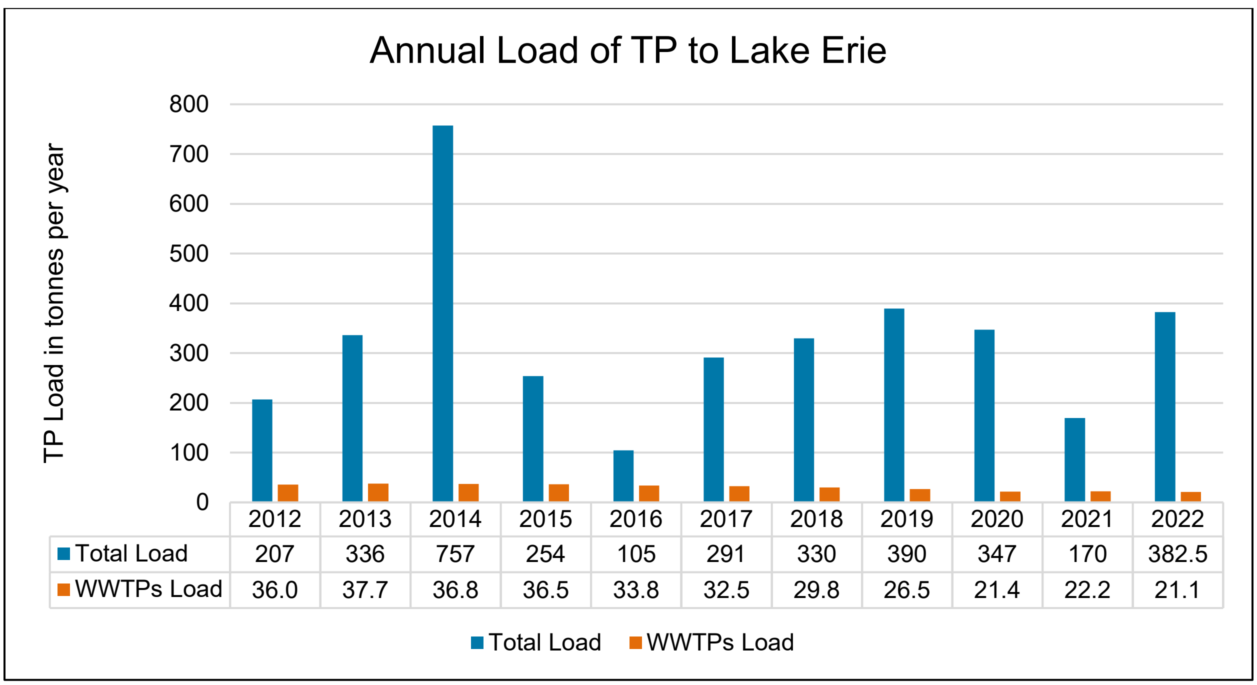


Figure 9: Annual TP Load to Lake Erie at York

[2] York, in Haldimand County, is the location of GRCA's southern-most flow monitoring station on the Grand River. Annual loadings from the Grand River to Lake Erie are calculated by Environment and Climate Change Canada and made available on-line through the Environment Canada Data Catalogue

Over the 11-year period from 2012 to 2022, TP loading from York averaged 324 tonnes per year and ranged between 105 tonnes per year (in 2016) to 757 tonnes per year (in 2014). The TP load from WWTPs in the watershed ranged from 21.1 to 37.7 tonnes per year and averaged 30 tonnes per year or roughly 12% of the TP load to Lake Erie from the Grand River.

Precipitation

Figure 10 shows total precipitation (i.e. snow and rain) at selected sites in the watershed. 2022 was one of the driest years on record for most of the watershed. The driest months of the year were July and September. In February, about a month's worth of precipitation was recorded during a single large storm event on February 16 and 17. In August, most of the rain was recorded in the first few days of the month with very dry extended periods before and after. (Shifflett S. , 2022). Table 7 shows the relative influence of wastewater effluent on the Grand River by comparing the total volume of treated effluent in each of the years from 2012 to 2022 to the annual average river flow at York for the same years. In addition, the table also contains a statement characterizing the precipitation in each year with respect to the long-term average precipitation in the watershed.

Table 7: WWTP effluent flow as a percentage of Grand River total flow over 2012-2022 period.

Year	Precipitation Characterization*	% Annual Average Flow	% August Average Flow
2012	Low end of typical	6.8%	13.9%
2013	Higher than typical in some areas	3.1%	5.4%
2014	Long-term average	2.6%	9.5%
2015	Low end of typical	5.0%	11.5%
2016	Long-term average	4.7%	9.0%
2017	Higher than typical	3.5%	7.3%
2018	Long-term average	3.6%	8.7%
2019	Higher than typical	3.6%	10.3%
2020	Long-term average	4.7%	11.7%
2021	Long-term average	5.1%	12.6%
2022	Low end of typical	5.5%	14.5%
	Overall Average	**4.4%**	**10.3%**

* (Shifflett, 2012) (Shifflett, 2013) (Shifflett, 2014) (Shifflett, 2016) (Shifflett, 2017) (Shifflett, 2018) (Shifflett, 2019) (Shifflett, 2020) (Shifflett, 2021) (Shifflet, 2022)

The volume of treated effluent ranges from 2.6% to 6.8% of the total river flow on an annual average basis. By comparison, based on low flow conditions observed in the month of August, under summer low flow, the proportion of treated effluent ranges more widely from 5.4% to 14.5%

of the river flow. The influence of WWTP flow on the river varies from year to year depending on precipitation.

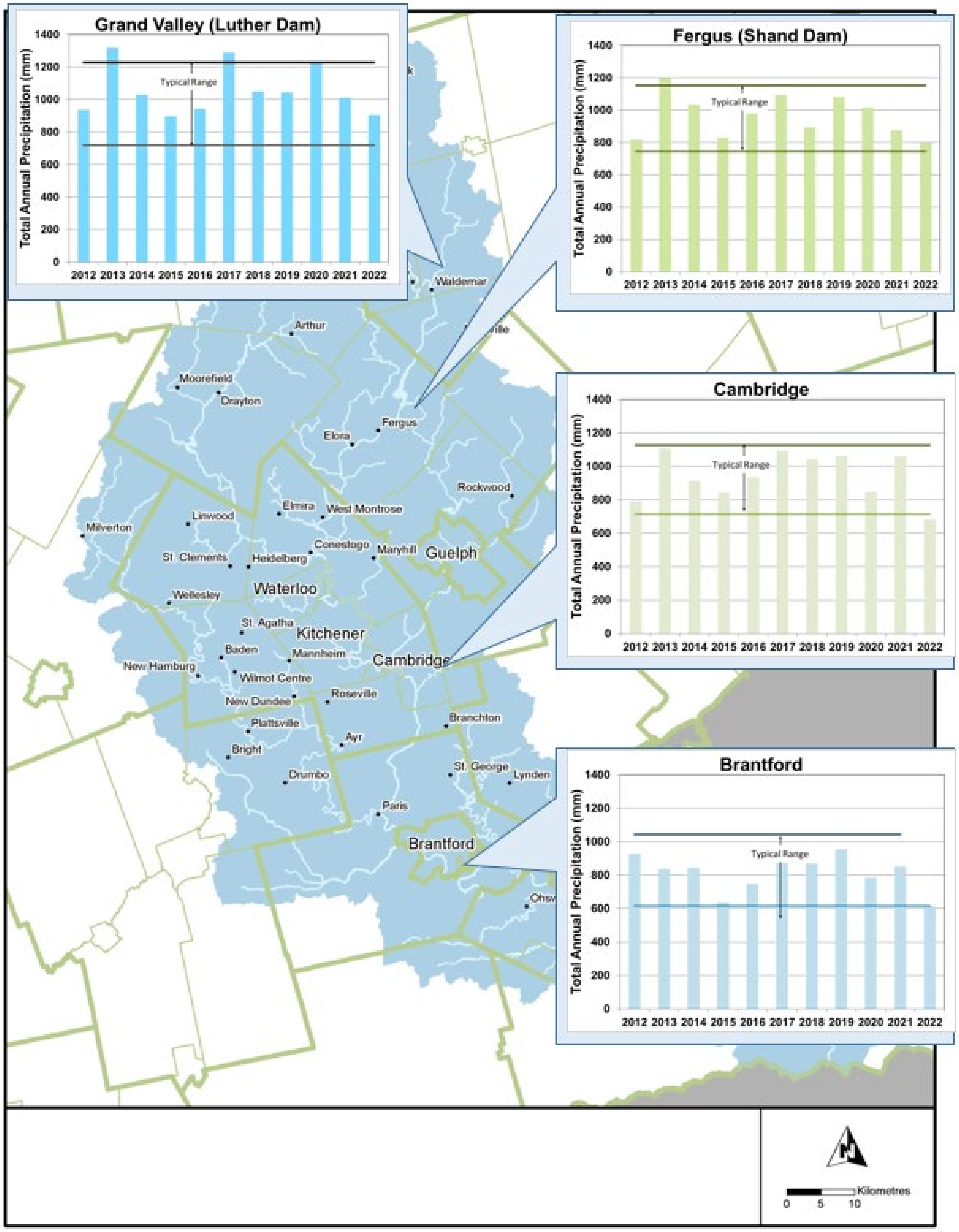


Figure 10: Total annual precipitation (in mm) at selected locations across the watershed. Typical range is based on 5th and 95th percentile of historical observations over the past 50 years.

Recent studies

Since 2007, the Region of Waterloo has carried out a comprehensive surface water quality monitoring program upstream and downstream of its WWTPs. The purpose of the program is to determine what impacts, if any, effluent discharges are having on the Grand River and its tributaries and to document how those impacts may be changing with time. This monitoring program has shown that some Regional WWTPs, especially the larger ones, can have observable impacts on water quality, particularly in the summer and fall seasons when river flows are low. The Kitchener and Waterloo WWTPs experienced reduced TAN concentrations downstream compared to previous years, which was a result of the recent upgrades completed at the plants (LGL Limited, 2022). Waterloo and Kitchener WWTPs experienced higher concentrations of TP at the discrete station in winter, and all downstream stations in summer and fall in comparison to upstream sites in 2022. Downstream of Kitchener WWTP, TAN concentrations were elevated for summer only compared to upstream stations, no statistically significant difference observed from Waterloo WWTP. On the other hand, the Hespeler plant saw increased TP concentrations downstream in the summer and fall due to ongoing upgrades/construction. (Limited, LGL, 2023).

Table 8 below summarizes some of the observed impacts.

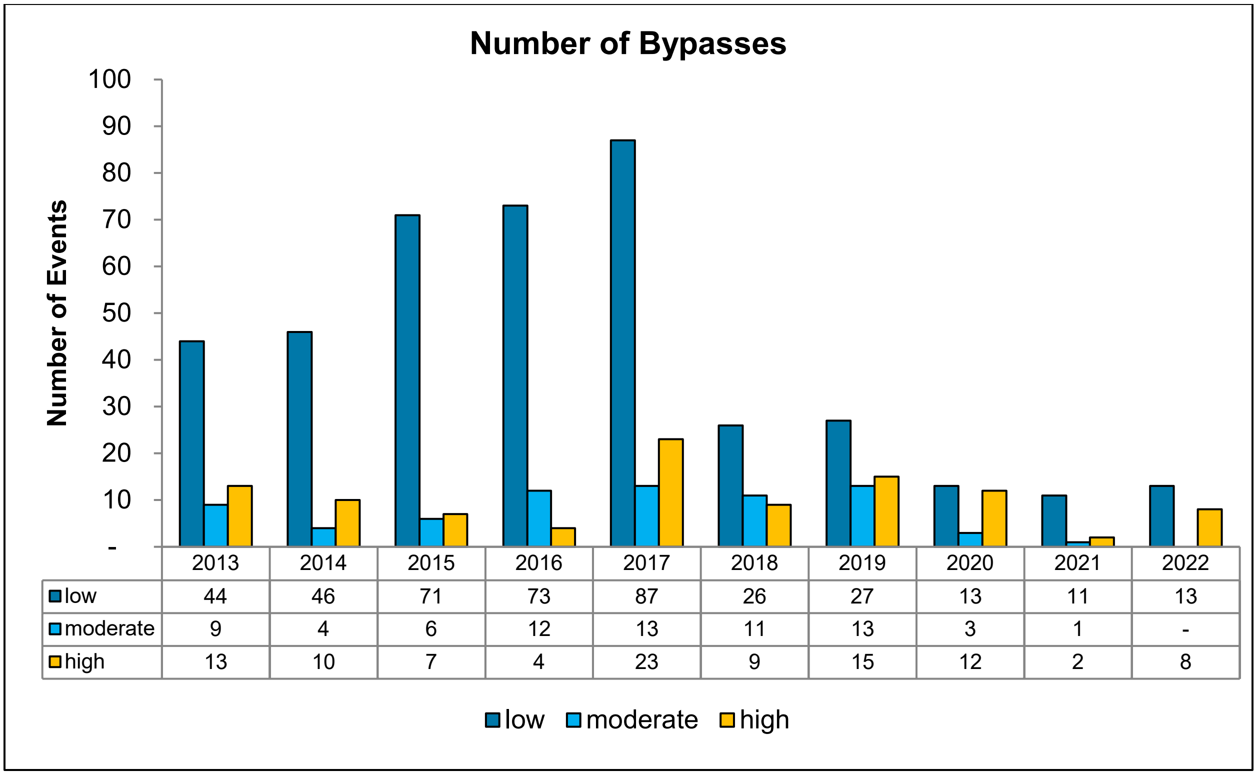
Table 8: Summary of 2022 River Water Quality Monitoring Upstream and Downstream of Select WWTPs

WWTP	TP	TAN
Waterloo	Winter: ↑ Spring: ↔ **Summer:** ↑ **Fall**: ↑	Winter: ↔ Spring: ↔ Summer: ↔ Fall: ↔
Kitchener	Winter: ↑ Spring: ↔ Summer: ↑ **Fall:** ↑	Winter: ↔ Spring: ↔ Summer: ↑ Fall: ↔
Galt	Winter: ↑ Spring: ↔ Summer: ↓ Fall: ↑	Winter: ↔ Spring: ↔ Summer: ↑ Fall: ↔
Hespeler	**Winter:** ↑ Spring: ↔ **Summer:** ↑ **Fall:** ↑	**Winter:** ↑ **Spring:** ↔ Summer: ↓ **Fall:** ↓

Note: ↔ indicates there is no statistically significant difference between upstream and downstream concentration, ↑ indicates statistically significant increase downstream compared to upstream and ↓ indicates a statistically significant decrease in concentration downstream of the plant

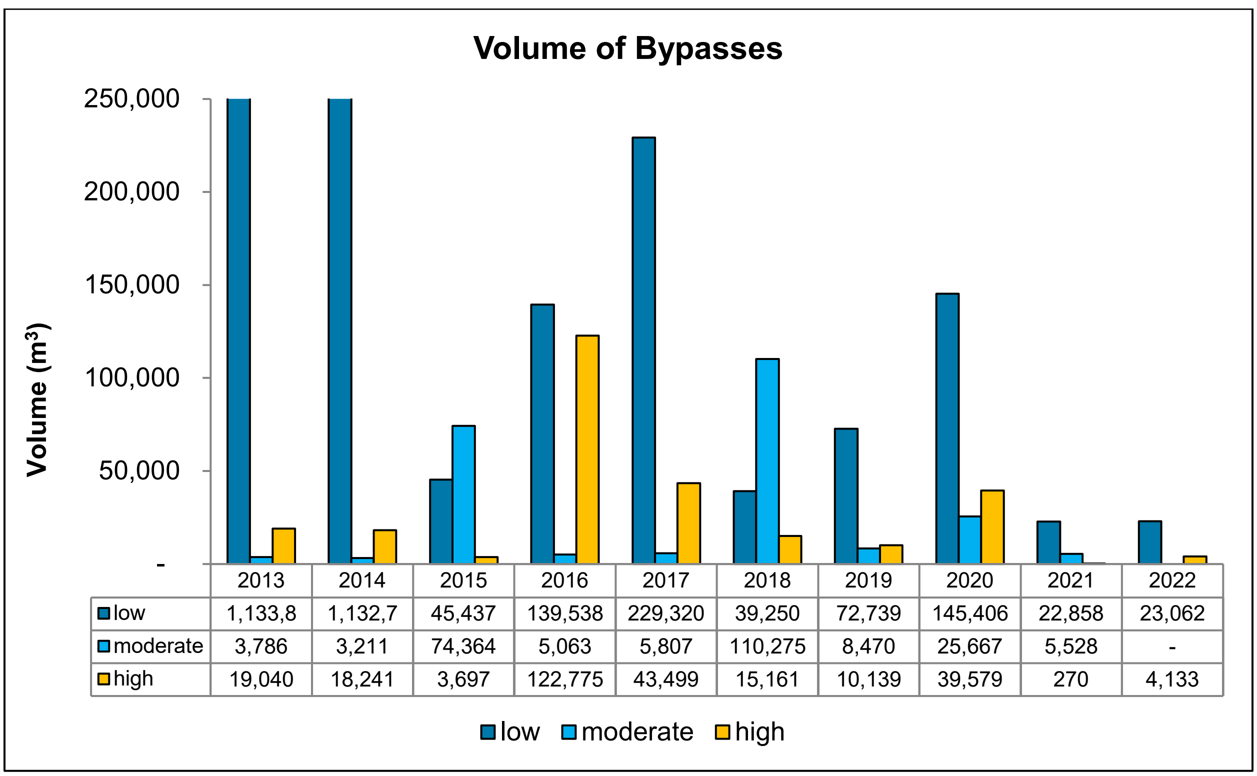
Bypasses and Overflows

Bypasses are a diversion of sewage around one or more treatment processes. The diverted sewage is combined with treated effluent at the point of discharge. Overflows are discharges to the environment from the WWTP at a location other than the effluent discharge point. Bypasses and overflows can be caused by equipment failure, power outage, weather-related events, etc. Bypasses/overflows can be classified as low, moderate, or high according to the level of risk to downstream users. In the Grand River watershed, one of the most sensitive downstream uses is the abstraction of river water as a source for drinking water. The risk categories were developed based on the professional judgment of the Grand River Municipal Water Managers Working Group (Grand River Municipal Water Managers Working Group, 2009). For example, a bypass that has received secondary treatment and disinfection is considered low risk, whereas a bypass that has received secondary treatment without disinfection is classed as moderate risk. A high-risk bypass or overflow, for example, occurs when raw sewage is discharged to the environment without disinfection. Figure 11 shows the number of low, moderate and high-risk bypasses from WWTPs in the Grand River watershed from 2013-2022. The number of low risk bypasses increased from 11 in 2021 to 13 in 2022. There were no moderate risk bypasses recorded in 2022. The number of high risk bypasses increased from 2 in 2021 to 8 in 2022. Figure 12 shows the total volume of bypasses in 2022. Most of the bypasses in 2022 were related to weather conditions generating high peak day flows to the WWTP.



	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
low	44	46	71	73	87	26	27	13	11	13
moderate	9	4	6	12	13	11	13	3	1	-
high	13	10	7	4	23	9	15	12	2	8

Figure 11: Number of low, moderate and high-risk bypasses from 2013-2022



	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
low	1,133,8	1,132,7	45,437	139,538	229,320	39,250	72,739	145,406	22,858	23,062
moderate	3,786	3,211	74,364	5,063	5,807	110,275	8,470	25,667	5,528	-
high	19,040	18,241	3,697	122,775	43,499	15,161	10,139	39,579	270	4,133

Figure 12: Volume of low, moderate and high-risk bypasses from 2013-2022

Data Integrity Checks

Several data integrity checks were used to determine if the monitoring conducted at the WWTP is truly representative of plant performance. A sludge accountability analysis for mechanical activated sludge plants compares the amount of sludge reported to the amount of sludge projected based on plant loadings and removals, on an annual basis. The reported sludge includes sludge intentionally wasted by the operator to control the biological process and unintentional wasting (i.e. solids lost from the plant in effluent TSS). Projected sludge can include an estimate of primary sludge, biological sludge generated by the conversion of organics to biomass, and chemical sludge (i.e. solids produced as a result of coagulant addition). The formula to calculate sludge accountability is as follows:

$$\frac{projected\ sludge - reported\ sludge}{projected\ sludge} * 100\%$$

If the result is within a range of ± 15% the sludge accountability is considered to "close". If the value is outside of this range, then the monitoring may not be truly representative of plant loading or performance. In the case of sludge accountability that does not close, further investigation is warranted to review sample frequency, sampling techniques, analytical methods, flow measurement accuracy, etc.

Common sources of sludge accountability analysis discrepancy include:

- Non-representative sampling (poor sampling techniques or analytical procedures, inadequate sampling frequency, a sampling location which is not representative, etc.),
- Lack of flow measurement on some streams or inaccurate flow measurement, and
- Neglecting to take into account all inputs and outputs (e.g. no measurements on return streams such as filter backwash or digester decant, etc.).

Table 9 shows the results for 22 plants in the watershed that conducted sludge accountability for 2022. For 2022, Kitchener, Brantford, Guelph, Galt, Waterloo, Preston, Hespeler, Caledonia, Paris, St. Jacobs, Grand Valley, Wellesley, Drumbo, and Conestogo WWTPs have a sludge accountability analysis that closed within ±15%., Sludge accountability results for all plants, including reported and projected sludge values can be found in Appendix 1: Sludge Accountability and Water Balance Summary.

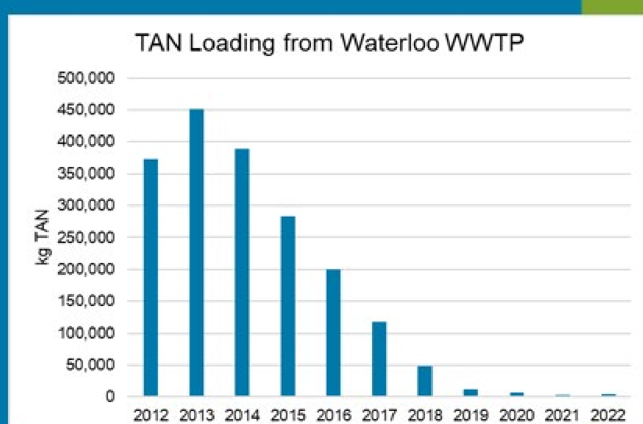
Table 9: Summary of 2018 - 2022 Sludge Accountability analyses

WWTP	2018	2019	2020	2021	2022
Kitchener	-24.6%	-8.3%	-14.2%	8.3%	-3.1%
Brantford	9.6%	-8.3%	6.3%	-3.8%	13.5%
Guelph	5.6%	-6.9%	-13.9%	-6.3%	9.6%
Galt	-5.9%	-3.1%	14.8%	25.7%	4.7%
Waterloo	45.4%	18.9%	7.5%	14.9%	-3.6%
Preston	6.5%	8.2%	-10.7%	7.8%	-7.3%
Hespeler	-21.6%	-1.9%	-24.4%	1.7%	9.9%
Fergus	19.7%	Not Reported	Not Reported	-21.6%	Not Reported
Elmira	-16.4%	-8.0%	-27.7%	-19.1%	-35.3%
Dunnville	10.9%	-16.7%	15.7%	0.6%	-32.2%
Caledonia	30.8%	31.1%	7.6%	21.6%	10.5%
Paris	35.3%	-36.2%	-10.3%	-23.1%	13.5%
New Hamburg	19.0%	-167.6%	-100.0%	-47.6%	-17.0%
Elora	-97.8%	Not Reported	Not Reported	-43.1%	Not Reported
Ayr	6.7%	-7.7%	-3.4%	-9.9%	19.6%
Arthur	-25.0%	Not Reported	Not Reported	Not Reported	-27.3%
St. Jacobs	-0.1%	1.2%	-5.4%	26.3%	12.2%
St. George	-44.6%	-410.9%	Not Reported	-36.0%	-48.3%
Grand Valley	Not Reported	Not Reported	Not Reported	Not Reported	-4.0%
Wellesley	-75.3%	9.1%	15.4%	15.9%	12.2%
Cayuga	-31.1%	-31.5%	-32.2%	-32.2%	-42.1%
Drumbo	11.5%	7.3%	-11.0%	-4.3%	11.6%
Conestogo	22.1%	19.9%	53.2%	11.0%	14.7%
Alt Heidelberg	-82.6%	-125.0%	-119.3%	-51.5%	-83.0%

Load Reductions at Waterloo WWTP

Upgrades at the Kitchener and Waterloo WWTPs have allowed the plants to nitrify, resulting in lower concentrations of TAN, UIA and nitrite in the Grand River. In addition, loadings to the plant were managed with a new sewer-use by-law. As a result, effluent loadings of TP and TAN were reduced.

The figure to the right shows the effluent TAN loading from the Waterloo WWTP and indicates the 2022 TAN load is 4,829 kg which is a 99% decrease from the 2012 loading of 373,088 kg



Under the Grand River program, a water balance analysis was developed for lagoon systems as a performance check since sludge accountability cannot be performed. A water balance analysis compares the difference between the measured net precipitation and the projected net precipitation and is reported as a percentage of influent flow. The measured net precipitation is based on the net precipitation and the lagoon surface area. Projected net precipitation is determined using lagoon level measurements, total influent sewage and effluent volume on an annual basis. The formula to calculate a water balance is as follows:

$$\frac{reported\ net\ precipitation - projected\ net\ precipitation}{influent\ flow} * 100\%$$

If the result is within a range of ± 15%, the water balance is considered to “close”. If the value is outside of this range, then the flow measuring devices or lagoon level measurements may not be accurate. Further investigation is warranted to review all flow measuring devices and confirm their accuracy.

Table 10 shows the results for the lagoons that conducted a water balance analysis for 2018 - 2022. A detailed summary of water balance results is located in Appendix 1: Sludge Accountability and Water Balance Summary. Sources of discrepancy in the calculation may include the following: inaccurate flow measurement, inaccurate surface area information, uncertainties in precipitation and/or evaporation data and error in storage lagoon measurements.

Table 10: Summary of 2018-2022 Water Balance analyses of lagoons

Lagoon	2018	2019	2020	2021	2022
Dundalk	14.6%	13.8%	10.4%	6.4%	15.6%
Drayton	16.2%	Not Reported	Not Reported	Not Reported	Not Reported
Plattsville	-4.2%	2.6%	-6.5%	13.8%	11.2%
Cainsville	Not Reported	77.0%	66.9%	25.9%	85.2%

WASTEWATER TREATMENT PLANT LOADING SUMMARY

Influent flow

Figure 13 shows a summary of the average daily flow (ADF) to each plant for 2019 to 2022 compared to the Nominal Design Flow (NDF) of the plant as stated in the plant’s ECA (shown in grey). Figure 13 shows three vertical scales since the nominal design of the WWTPs in the watershed range from 130 m^3/d to 122,745 m^3/d. Figure 14 shows the ADF as a percentage of the NDF. In 2022, all plants experienced an ADF that was less than the NDF. Since 2012 four plants experienced ADFs higher than their NDF: Arthur (2012 to 2014 and 2017), Drumbo (2013 and 2014), Cainsville (2014) and Wellesley (2019). The NDF for the Drumbo plant was rerated in 2015 from 273 to 300 m^3/d. The NDF for the Arthur plant was rerated in 2020 from 1,465 to 1,860 m^3/d.

Another way to look at influent flow is to normalize it based on the serviced population and express it as per capita flow. Per capita wastewater flows vary from location to location, but typical values used in the CCP are from 350 to 500 L/person/d. Figure 15 shows per capita flows for WWTPs in the watershed for 2018 to 2022. From this figure, plants in the Grand River watershed were generally at or below the low end of the typical range. The watershed median for 2022 was 280 L/person/day, a 5% decrease from the 2021 median of 294 L/person/day and 10% decrease from the 2012 median of 310 L/person/day.

Plants experience higher than typical per capita flows for various reasons. For example, the Cainsville WWTP services primarily industrial users and therefore has a higher per capita flow than a typical domestic sewage system. Others WWTPs, such as Arthur, St. Jacobs, and Dundalk, appear to be subject to high inflow/infiltration (I/I).

Load Reductions at Kitchener WWTP

The Kitchener WWTP has undergone upgrades in the recent years which included upgrades to the aeration system and filters. These upgrades at the treatment plant have led to loading reductions in both TP and TAN in the final effluent. 2020 represents the first full year of flow through the upgraded facility which is reflected in the figure to the right.

The figure shows a TP loading of 3,779 kg in 2022, which is a 76% reduction from 15,844 kg in 2012.

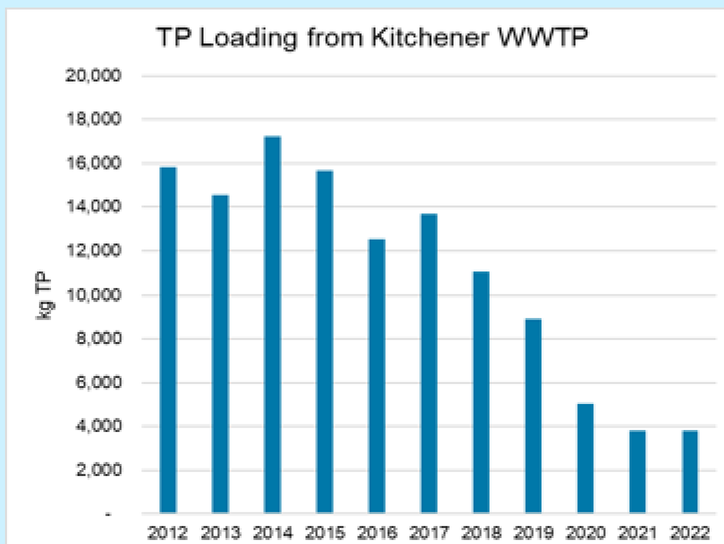


Figure 16 shows the ratio of peak day flow to ADF, which is another indicator of I/I or large inflows. The ratio or peak day flow to ADF varies from year to year depending on climate factors such as heavy rainfall or snowmelt events. The median ratio for plants across the watershed was 2.6 in 2022. Most plants were within the typical range or less. Several plants are known to experience I/I (such as the Dundalk, Mapleton or Caledonia WWTP) and this is reflected in Figure 16.

Year-to-year variability in per capita flow is largely due to differences in inflow and infiltration related to precipitation. The highest per capita flows were 351 L/d per person in 2013 which was a “wet” year. The smallest per capita flows were 294 L/d per person in 2014 which was a “dry” year (Shifflett S. , 2017).

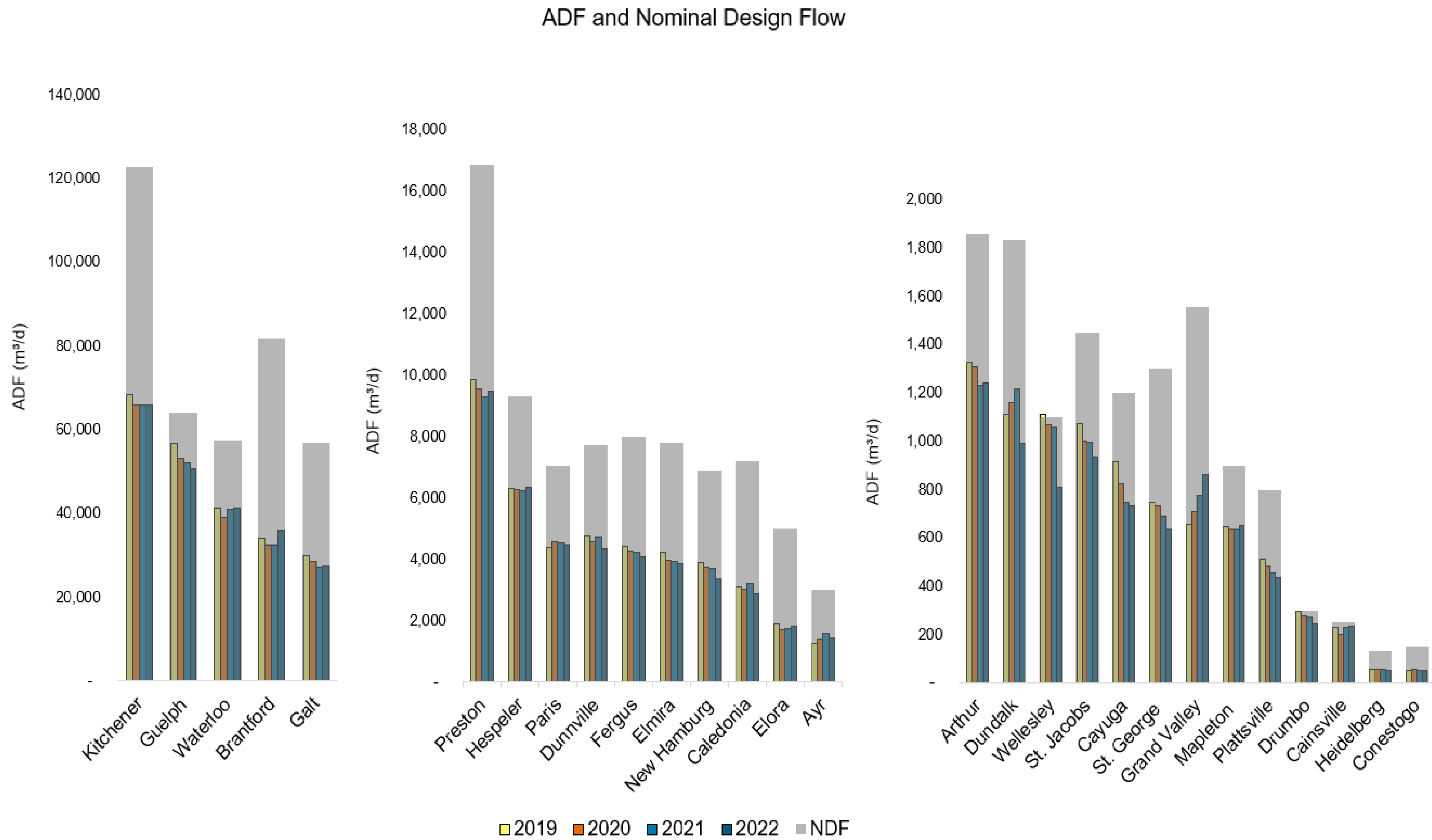


Figure 13: ADF and Nominal Design Flow of watershed WWTPs

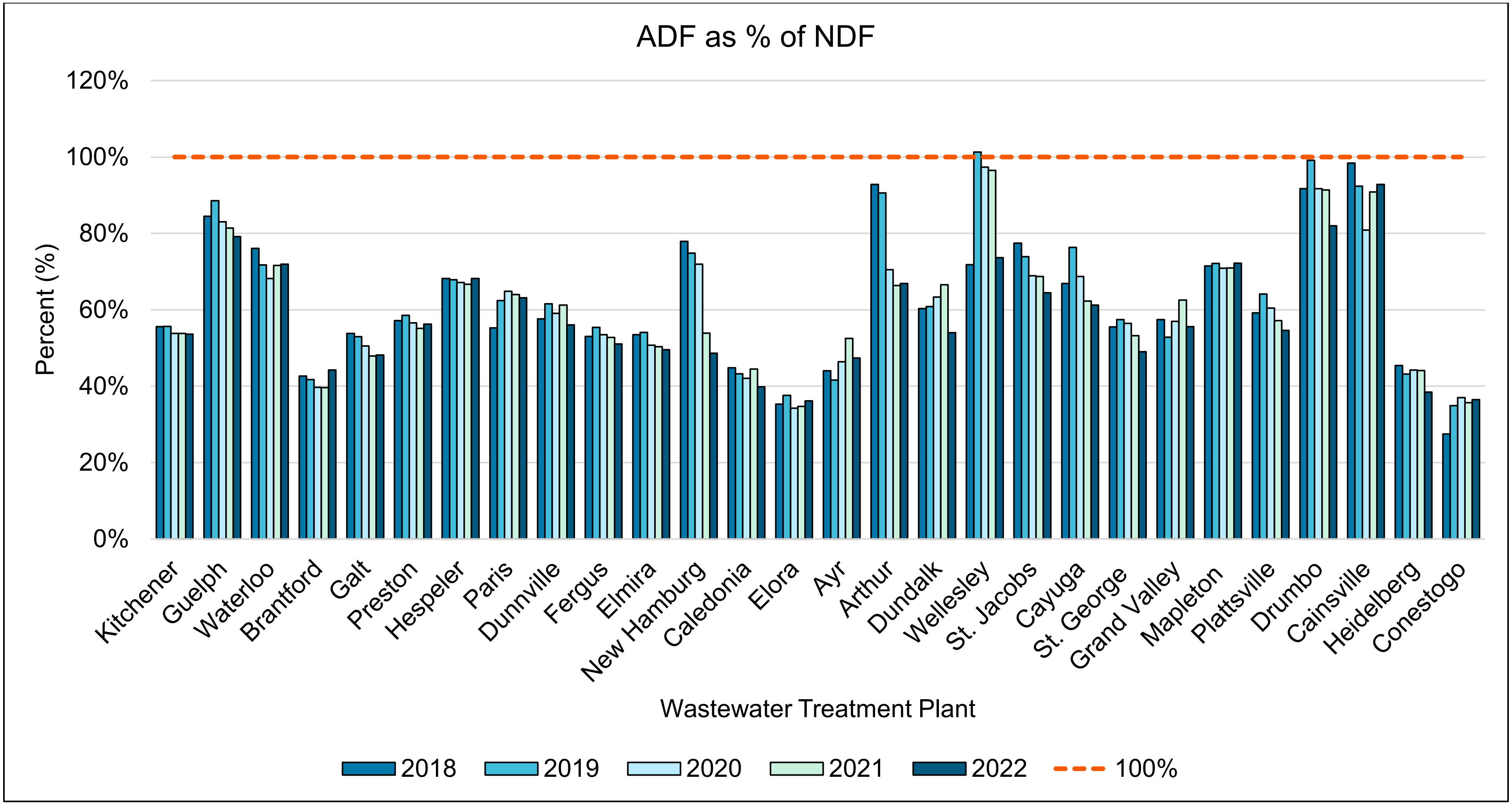


Figure 14: Annual average flow as a percentage of rated plant capacity

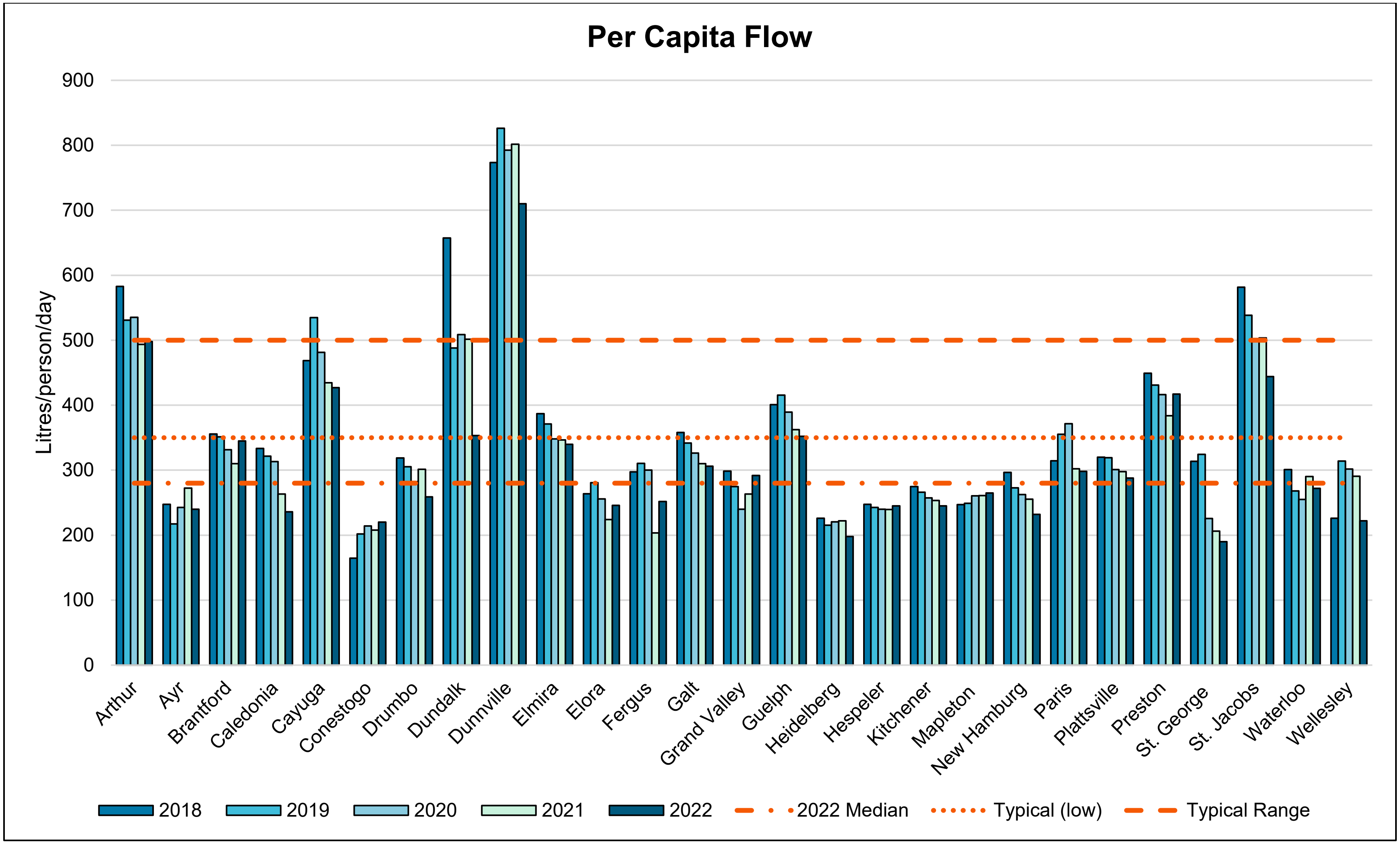


Figure 15: Per capita influent flow

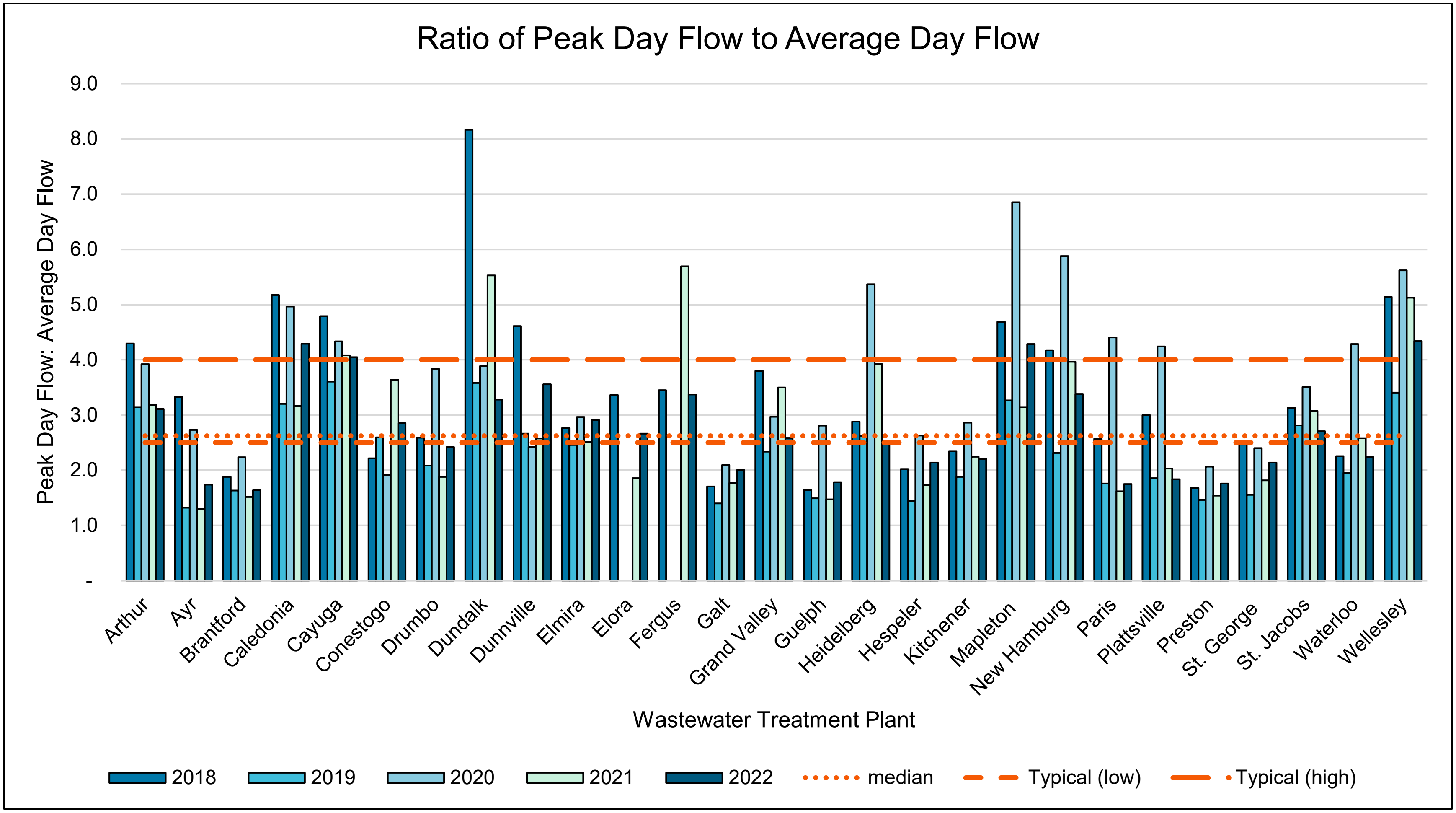


Figure 16: Ratio of peak day flow to annual average flow

Raw Influent Loads

Characterization of raw wastewater is important to ensure effective wastewater treatment, assist with future planning, and identify any issues or changes occurring in the collection system. Loading of raw influent TBOD, TSS and TKN can be calculated by multiplying raw influent concentrations by flow. These loads can be expressed on a per capita basis and compared to values typical of domestic sewage.

TBOD Loading

In 2022, all of the 28 plants that reported data measured raw influent TBOD. Table 11 summarizes the results of both cBOD and TBOD as reported by plants in the Grand River watershed between 2016 and 2022:

Table 11: Annual average raw influent cBOD and TBOD concentrations reported by Grand River watershed plants in 2016 - 2022.

Year	No. of plants reporting cBOD	No. of plants reporting TBOD	No. of plants reporting Both cBOD & TBOD	Median (mg/L) cBOD	Median (mg/L) TBOD	Range (mg/L) cBOD	Range (mg/L) TBOD
2016	18	21	11	195	208	127-389	142-411
2017	18	26	16	177	194	98-411	108-421
2018	18	26	16	182	197	94-296	112-304
2019	18	24	16	177	211	92-269	107-311
2020	17	23	14	192	203	81-322	88-396
2021	21	28	18	199	208	89-360	134-378
2022	19	28	19	214	251	113-366	134-393

Albertson has documented that the cBOD test underestimates the strength of raw wastewater by 20-40% (Albertson, 1995). In 2022, 19 of 28 reporting plants in the watershed measured both cBOD and TBOD. The average TBOD:cBOD ratio among these plants is 1.18 which is similar to the 1.2 factor which was used for estimation in previous years. .

Figure 17 shows estimated per capita TBOD loads for plants in the Grand River watershed. A typical value for domestic wastewater is 80 g/person/d. The reported 2022 median is 66.9 g/person/d, which is a slightly higher value compared to 2021.

Per capita TBOD loads that are much higher or much lower than the typical value should be further investigated to see if there is a reasonable explanation for the discrepancy. In some cases, industrial contributions may result in elevated per capita TBOD loads. However, atypical TBOD loads may also be related to inadequate sampling frequency, non-representative sampling, errors in flow metering or population estimates, etc.

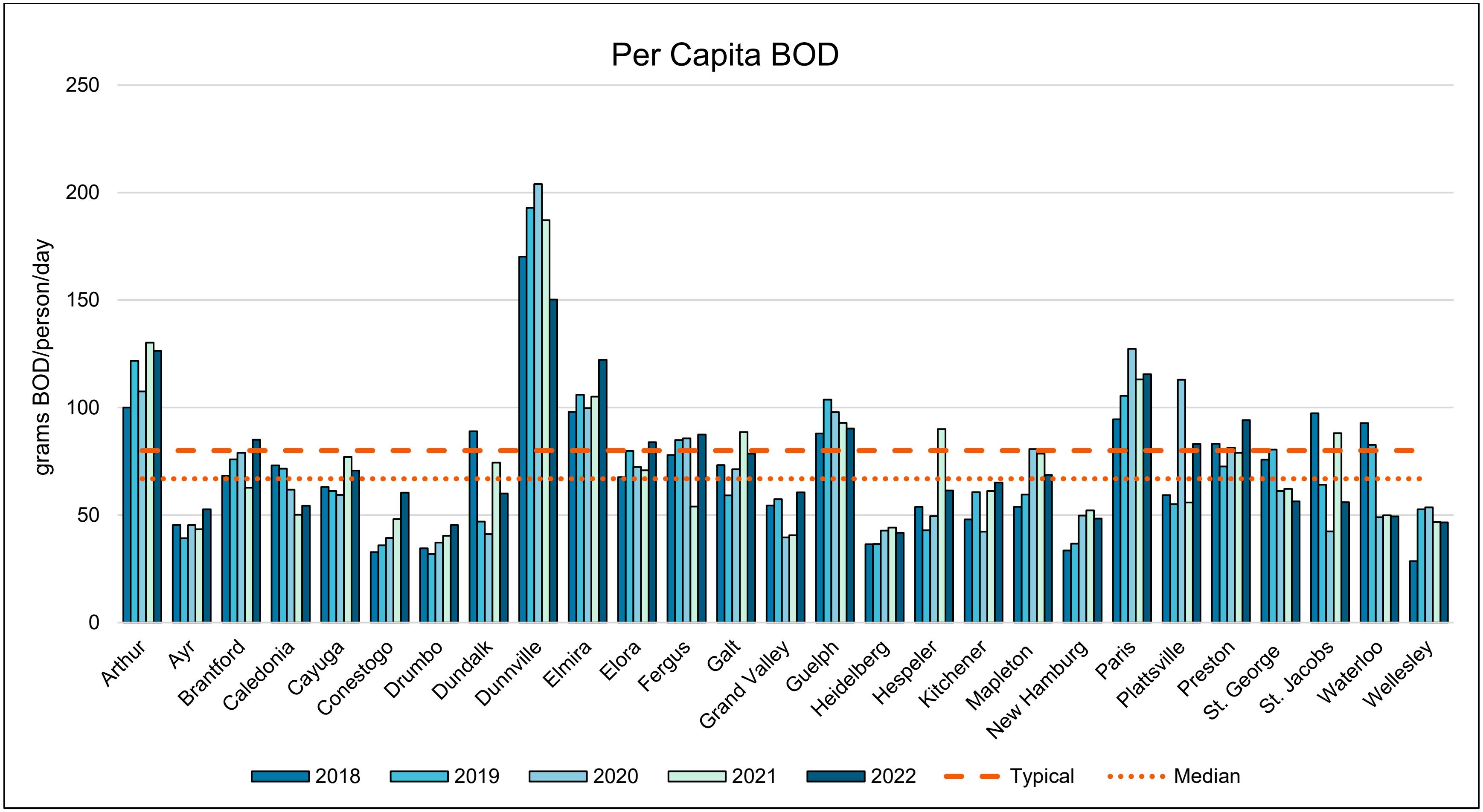


Figure 17: Per Capita TBOD Load

TSS Loading

TSS loads in raw influent for 2018 to 2022 are summarized in Figure 18. The 2022 watershed median was 74 g/person/d, which is less than the typical value of 90 g/person/d. This value was 82 g/person/d in 2018. Where the loads are significantly less than typical, it brings into question the adequacy of raw influent sampling to accurately characterize the influent. Higher than expected loads may be attributed to industrial inputs and/or internal recycle streams.

TKN Loading

Figure 19 shows per capita TKN loads to plants in the watershed. The watershed median was 13 g/person/d for 2022 which is the same as the typical value. Several plants (such as Preston, Elmira and Dunnville) reported TKN loads that are higher than expected and in most cases the per capita TSS and/or estimated TBOD loads were also high. A small number of plants had TKN, TSS and TBOD loads that were less than typical. Further investigation, such as characterization of raw influent and recycle streams and review of population estimates, may be helpful when per capita loadings are outside the typical range.

TP Loading

Figure 20 shows the TP loads in the raw influent for 2018 to 2022. The watershed median for 2022 was 1.6 g/person/d. This is less than the typical value of 2.1 g/person/d.

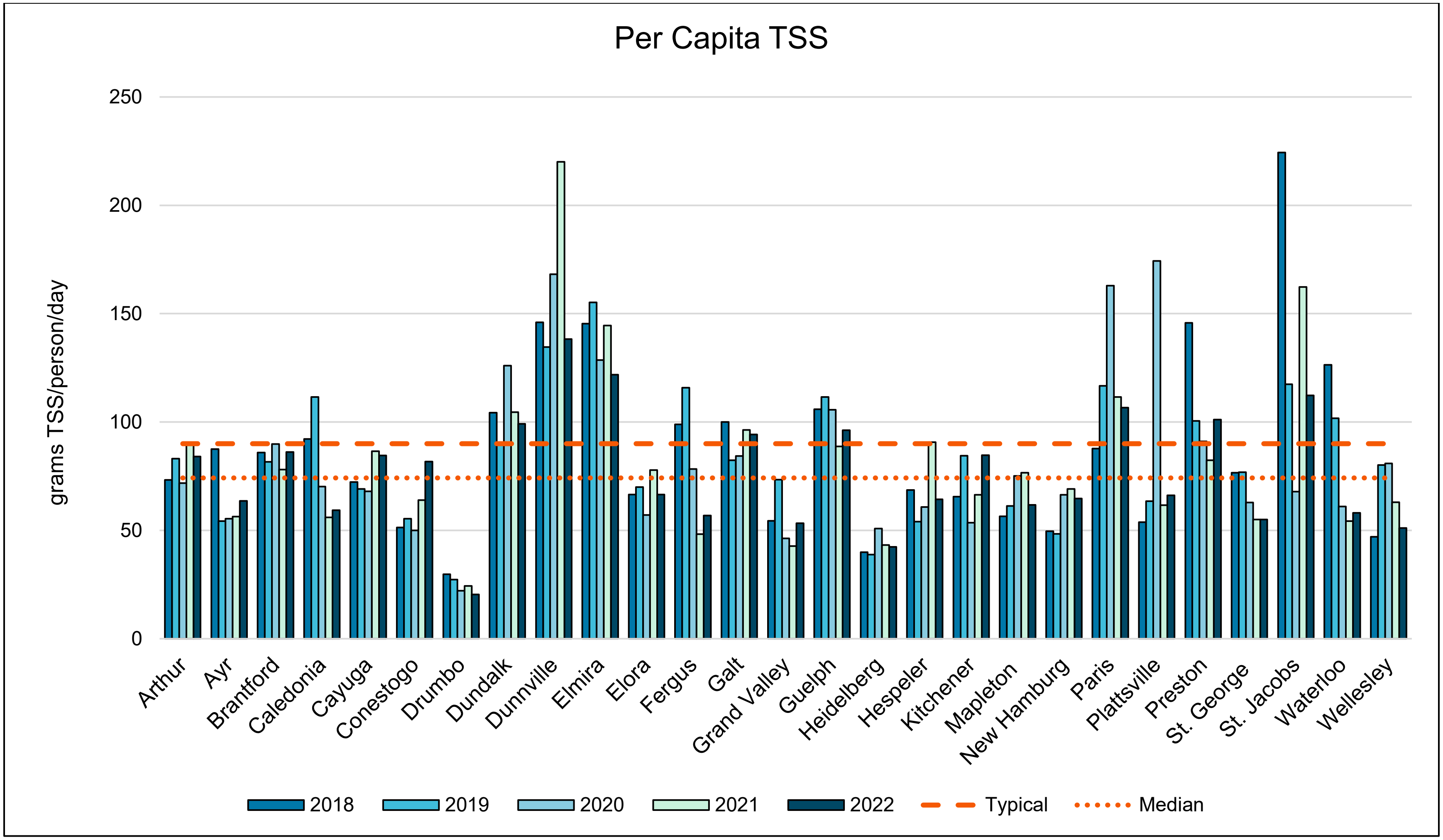


Figure 18: Per Capita TSS Load

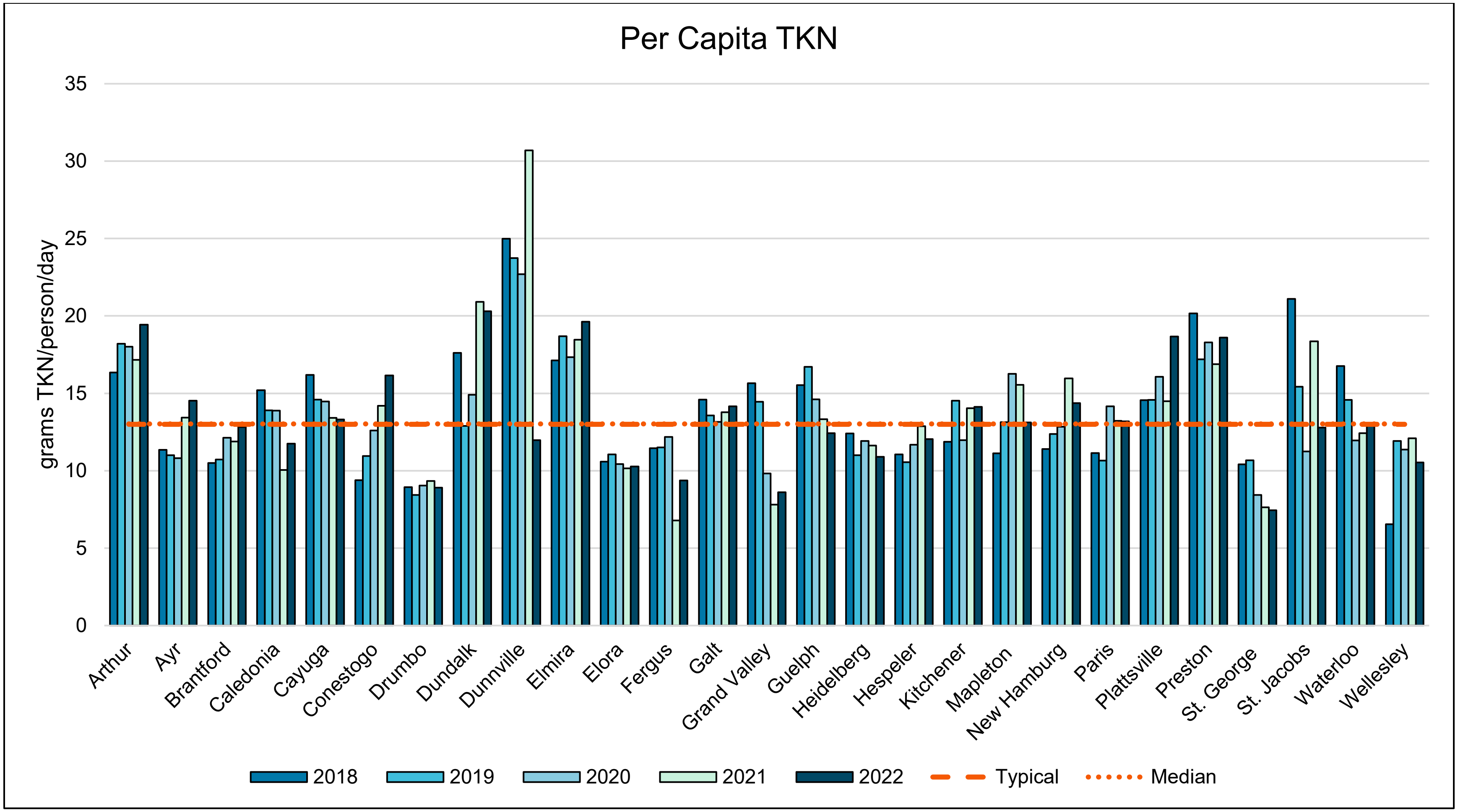


Figure 19: Per Capita TKN Load

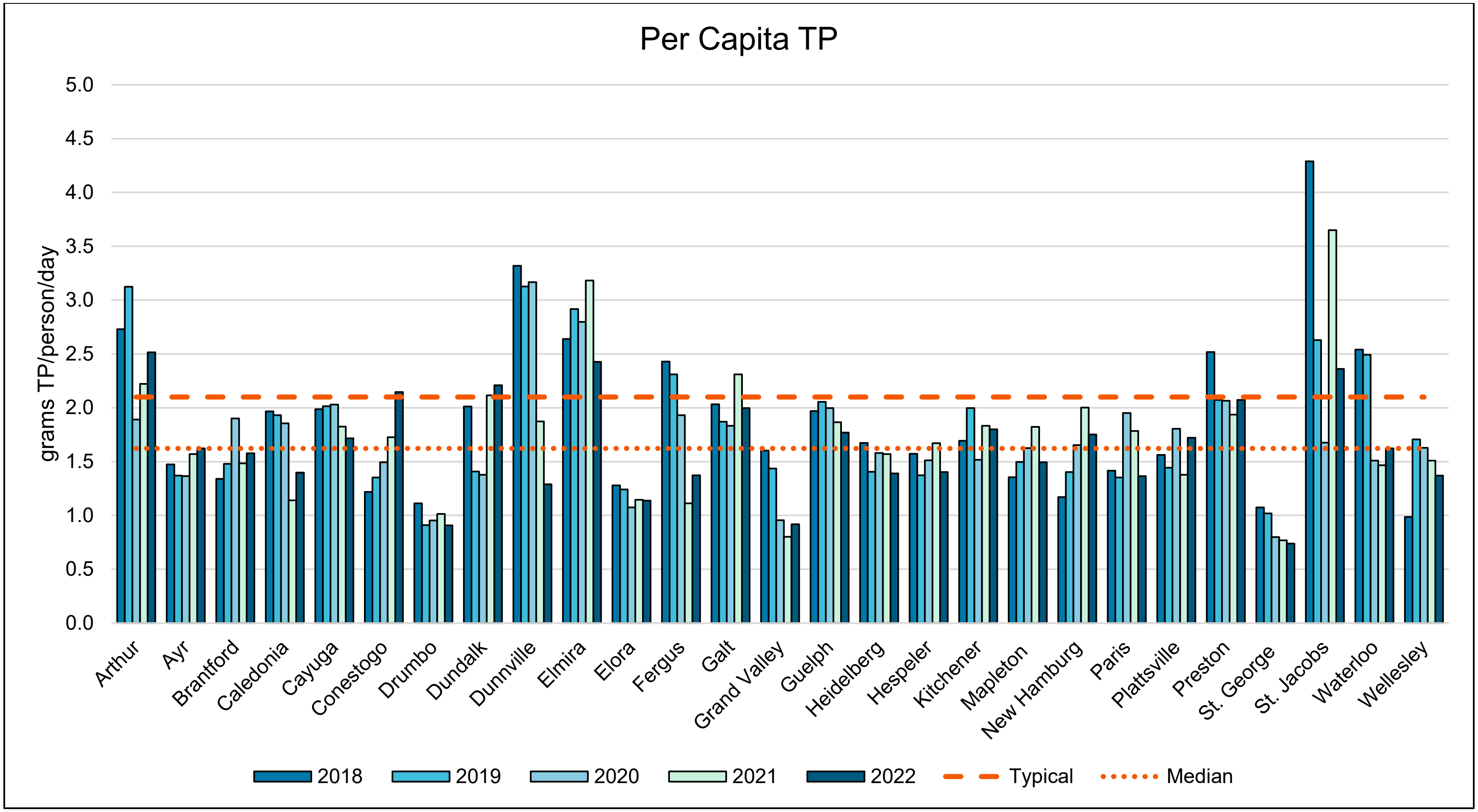


Figure 20: Per Capita TP Load

Ratios

Calculating raw influent ratios for TSS:TBOD and TKN:TBOD can be used to provide insight on what is entering the plant from the collection system as well as any potential sampling problems. Figure 21 shows the ratio of raw influent TSS to TBOD concentrations. For a typical domestic sewage system, this value ranges between 0.8 and 1.2. The median for watershed plants in 2022 was 1.06, which is the high end of the typical range, slightly less compared to previous years.

Figure 22 shows a graph for the ratio of raw TKN to TBOD, with a range of 0.1 to 0.2 considered typical. The 2022 watershed median was 0.2, which is at the higher end of the typical range but similar to previous years. Higher ratios could be attributed to recycle streams, an industrial influence in the collection system, or the fact that most plants are now reporting TBOD, which may have been overestimated in previous years.

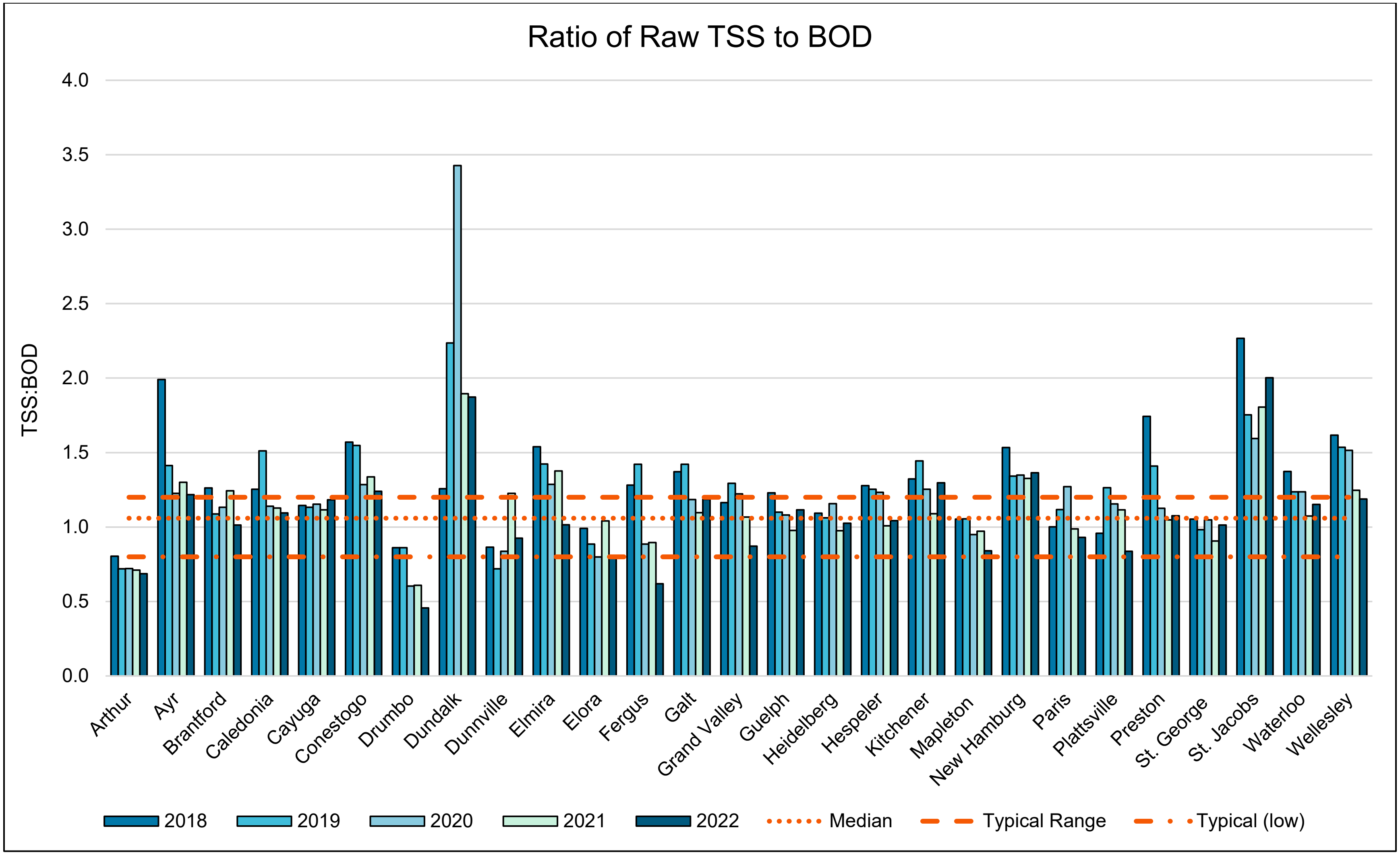


Figure 21: Ratio of Raw TSS to Raw TBOD

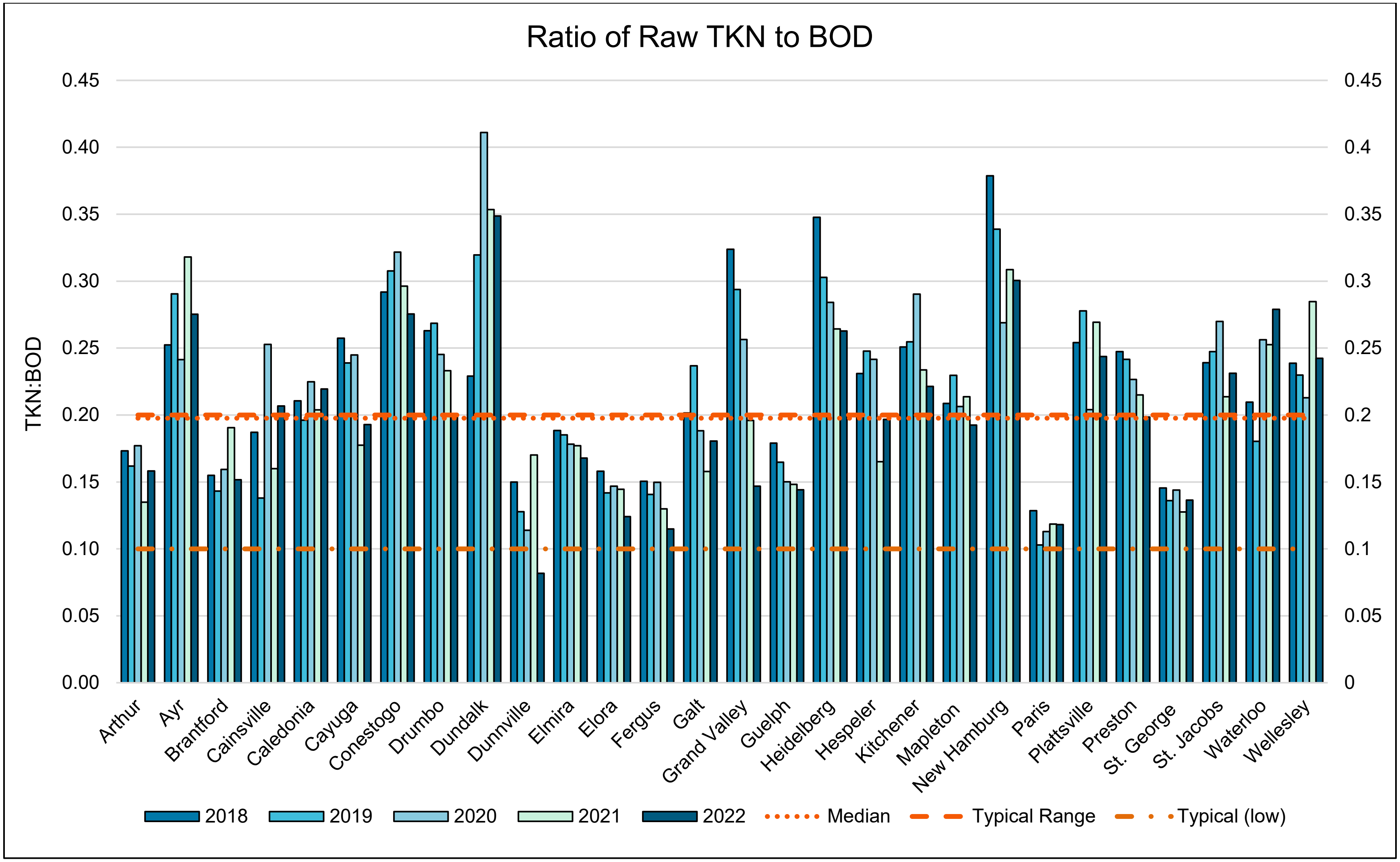


Figure 22: Ratio of Raw TKN to Raw TBOD

Final Comments

The information presented in this report documents that effluent quality has improved since 2012 as a result of upgrades and optimization. These improvements have led to significant reductions in total phosphorus and total ammonia nitrogen discharged to the Grand River.

As part of the ongoing watershed-wide wastewater optimization program, the GRCA will continue to encourage and support municipalities to report on this performance and loading metrics on an annual basis. Tracking these metrics over time will document the effectiveness of the program and help to identify candidates that may benefit from further optimization activities.

The authors thank Ministry of Environment, Conservation and Parks (MECP) for financial contribution, and WWOP participants for their efforts at voluntary reporting and encourage them to consider adopting and reporting against the Water Management Plan voluntary effluent quality performance targets for TP and TAN. By embracing an optimization approach to reduce these nutrients in wastewater effluent, municipalities can help to ensure a healthy and sustainable watershed that supports prosperous and growing communities into the future.

Further information on the Grand River Watershed-wide Optimization Program can be obtained from the Grand River wastewater optimization web page, or by contacting Simion Tolnai, the Optimization Extension Specialist at 519-621-2761 Ext. 2295 or Mark Anderson at 519-621-2761 Ext. 2226.

Bibliography

Albertson, O. (1995). Is the cBOD5 Test Viable for Raw and Settled Wastewater? *Journal of Environmental Engineering*, 515-520.

Anderson et al., 2. (2011). Watershed-wide Wastewater Optimization Pilot Project for the Grand River Watershed. *WEAO 2011 Technical Conference.* Toronto, ON.

Canada-Ontario Agreement Partners. (2018). *Partnering on Achieving Phosphorus Loading Reductions to Lake Erie from Canadian Sources.* Environment and Climate Change Canada and the Ontario Ministry of the Environment and Climate Change.

Canadian Heritage Rivers System. (2017). *Grand River Designation*. Retrieved January 15, 2019, from Canada's National River Conservation Program: http://chrs.ca/the-rivers/grand/designation/

EPA, U. (1989). *Handbook: Retrofitting POTWs.* Cincinnati OH: Center for Environmental Research Information.

Grand River Municipal Water Managers Working Group. (2009). *Best Practices: Municipal Wastewater Treatment Plant Bypass and Spill Prevention & Reporting in the Grand River Watershed.*

Irvine, C. (2018). *Summary of Population Statistics for the Grand River Watershed.* Cambridge Ontario: Grand River Authority.

LGL Limited. (2019). *Surface Water Quality Monitoring Program for the Grand and Nith Rivers.* Cambridge, Ontario.

LGL Limited. (2020). *Surface Water Quality Monitoring Program for the Grand and Nith Rivers.* Cambridge, Ontario.

LGL Limited. (2022). *Grand River Surface Water Quality Monitoring Program - 2021 Annual Report DRAFT.*

Limited, LGL. (2023). *Grand River Surface Water Quality Monitoring Program - 2022 Annual Report DRAFT.*

Maccoux, M. J., Dove, A., Backus, S. M., & Dolan, D. M. (2016). Total and soluble reactive phosphorus loadings to Lake Erie A detailed accouting by year, basin, country and tributary. *Journal of Great Lakes Research*.

Muirhead, W. F. (2006). Study of Raw Wastewater BOD5 and cBOD5 Relationship Yields Surprising Results. *WEFTEC 2006*, (pp. 840-853). Dallas TX.

PAI & WTC. (1996). *The Ontario Composite Correction Program Manual for Optimization of Sewage Treatment Plants.* Prepared for Ontario Ministry of Environment and Energy, Environment Canada and The Municipal Engineers Association.

Project Team. (2014). *Grand River Watershed Water Management Plan.* Cambridge ON: Grand River Conservation Authority.

Shifflett, S. (2012). *Current Watershed Conditions as of December 11, 2012.* Cambridge ON: Report GM-12-12-90 to GRCA Board of Directors.

Shifflett, S. (2013). *Current Watershed Conditions as of December 10, 2013.* Cambridge ON: Report GM-12-13-149 to GRCA Board of Directors.

Shifflett, S. (2014). *Current Watershed Conditions as of December 9, 2014.* Cambridge ON: Report 12-14-139 to GRCA Board of Directors.

Shifflett, S. (2016). *Current Watershed Conditions as of January 20, 2016.* Cambridge ON: Report GM-01-16-10 to GRCA Board of Directors.

Shifflett, S. (2017). *Current Watershed Conditions as of December 6, 2017.* Cambridge, ON: Report GM-12-17-136 to Members of the GRCA.

Shifflett, S. (2017). *Current Watershed Conditions as of January 27, 2017.* Cambridge ON: Report GM-01-17-15 to GRCA Board of Directors.

Shifflett, S. (2018). *Current Watershed Conditions as of December 5, 2018.* Cambridge: GM-12-18-124 Report to Members of the GRCA.

Shifflett, S. (2019). *Current Watershed Conditions as of December 4, 2019.* Report GM-12-19-125 To Members of the GRCA.

Shifflett, S. (2021). *Current Watershed Conditions as of December 8, 2021.* Report GM-12-21-99 to Members of the GRCA.

Shifflett, S. (2022). *Current Watershed Conditions as of December 7, 2022. Report GM-12-22-106 to Members of the GRCA.* Cambridge: Grand River Conservation Authority.

APPENDIX 1: SLUDGE ACCOUNTABILITY AND WATER BALANCE SUMMARY

Table 12: Summary of sludge accountability analysis results

Year	2018			2019			2020			2021			2022		
WWTP	Projected	Reported	Analysis	Projected	Reported	Analysis	Projected	Reported	Analysis	Projected	Reported	Analysis	Projected	Reported	Analysis
Kitchener	17,057	17,591	**-3.1%**	23,076	24,992	**-8%**	12,111	13,837	**-14%**	15,524	14,234	**8.3%**	17,057	17,591	**-3.1%**
Brantford	10,105	8,737	**13.5%**	9,034	9,781	**-8%**	10,135	9,499	**6%**	8,553	8,877	**-3.8%**	10,105	8,737	**13.5%**
Guelph	14,029	12,689	**9.6%**	10,465	11,191	**-7%**	13,602	15,492	**-14%**	12,736	13,534	**-6.3%**	14,029	12,689	**9.6%**
Galt	7,632	7,274	**4.7%**	8,500	8,763	**-3%**	9,071	7,727	**15%**	10,030	7,455	**25.7%**	7,632	7,274	**4.7%**
Waterloo	10,419	10,798	**-3.6%**	17,412	14,123	**19%**	9,662	8,937	**8%**	8,630	7,343	**14.9%**	10,419	10,798	**-3.6%**
Preston	2,880	3,091	**-7.3%**	2,669	2,449	**8%**	2,624	2,905	**-11%**	2,363	2,178	**7.8%**	2,880	3,091	**-7.3%**
Hespeler	1,633	1,471	**9.9%**	1,210	1,233	**-2%**	1,343	1,671	**-24%**	2,239	2,201	**1.7%**	1,633	1,471	**9.9%**
Fergus	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	1,251	1,521	**-21.6**	NA	NA	**NA**
Elmira	1600	2164	**-35.3%**	1,856	2,005	**-8%**	1,559	1,990	**-28%**	1,712	2,039	**-19.1%**	1600	2164	**-35.3%**
Dunnville	643	851	**-32.2%**	845	985	**-17%**	869	732	**16%**	793	788	**0.6%**	643	851	**-32.2%**
Caledonia	1000	895	**10.5%**	1,242	856	**31%**	974	900	**8%**	944	740	**21.6%**	1000	895	**10.5%**
Paris	1142	987	**13.5%**	816	1,112	**-36%**	932	1,028	**-10%**	1,060	1,305	**-23.1%**	1142	987	**13.5%**
New Hamburg	698	816	**-17.0%**	575	1,540	**-168%**	717	1,435	**-100%**	734	1,083	**-47.6%**	698	816	**-17.0%**
Elora	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	566	810.2	**-43.1**	NA	NA	**NA**
Ayr	**306**	**246**	**19.6%**	247	266	**-8%**	271	280	**-3%**	268	294	**-9.9%**	306	246	**19.6%**
Arthur	209	266	**-27.3%**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	209	266	**-27.3%**
St. Jacobs	155	136	**12.2%**	170	167	**1%**	146	154	**-5%**	203	149	**26.3%**	155	136	**12.2%**
St. George	139	206	**-48.3%**	66	335	**-411%**	NR	NR	**NA**	189.7	257.9	**-36.0%**	139	206	**-48.3%**
Grand Valley	101	105	**-4.0%**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	101	105	**-4.0%**
Wellesley	166	146	**12.2%**	171	156	**9%**	152	128	**15%**	139	117	**15.9%**	166	146	**12.2%**
Cayuga	102	145	**-42.1%**	93	123	**-32%**	95	126	**-32%**	95.4	126.1	**-32.2%**	102	145	**-42.1%**
Drumbo	98	87	**11.6%**	80	74	**7%**	91	101	**-11.0%**	91	95	**-4.3%**	98	87	**11.6%**
Conestogo	18	0	**99.4%**	14	11	**20%**	15	7	**53%**	16	14	**11%**	18	0	**14.7**
Heidelberg	9	17	**-83.0%**	8	19	**-125%**	9	21	**-119%**	10	15	**-51.5%**	9	17	**-83.0%**

Table 13: Summary of Water Balance results from plants that report on it

Year	Plant	Dundalk	Mapleton	Plattsville	Cainsville
2016	Reported Projected Influent Flow **Water Balance (%)**	28,101 -17,969 380,883 **-12.1%**	48,910 -9,672 215158 **-27.2%**	Not Reported	Not Reported
2017	Reported Projected Influent Flow **Water Balance (%)**	60,260 7,475 404,642 **-13.0%**	Not Reported	17,107 27,493 196,483 **5%**	Not Reported
2018	Reported Projected Influent Flow **Water Balance (%)**	38,875 -16,532 380,477 **14.6%**	47,700 9,835 233,250 **16.2%**	8,237.24 15,497 172,542 **-4.2%**	Not Reported
2019	Reported Projected Influent Flow **Water Balance (%)**	23,292 -33,731 413,461 **13.8%**	Not Reported	20,381 15,522 187,078 **2.6%**	1,968.2 -62,908 84,205 **77%**
2020	Reported Projected Influent Flow **Water Balance (%)**	31,952 -8,490 388,091 **10.4%**	Not Reported	19,995 31,550 176,723 **-6.5%**	-6,547 -62,908 84,205 **67%**
2021	Reported Projected Influent Flow **Water Balance (%)**	34,984 7,451 431,240 **6.4%**	Not Reported	7,102 -19,290 81,139.6 **26%**	1,725.7 -19,290 81,139.6 **26%**
2022	Reported Projected Influent Flow **Water Balance (%)**	3,772 -52,415 360,770 **15.6%**	Not Reported	-15,208 -32,987 159,301 **11.2%**	-4,343 -76,494 84,642 **85.2%**