2017 Watershed Overview of Wastewater Treatment Plant Performance

July 2018

Report Prepared by:
Kelly Hagan and Mark Anderson,
Grand River Conservation Authority
400 Clyde Road, Cambridge, ON N1R 5W6

TABLE OF CONTENTS

List of Tables

List of Figures

Acronyms and Abbreviations

ADF	Average daily flow
TBOD	5 day biochemical oxygen demand
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
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 monitoring performance and plant loading, which are used to evaluate the success of the program and track WWTP impacts on the Grand River over time. Available performance and loading data for 28 of 30 municipal wastewater treatment plants were voluntarily reported in 2017. These results were summarized and compared to results from 2012 to 2016.

Treatment Performance

Figure 1 and Figure 2 shows the final effluent TP and TAN flow-weighted average concentrations from 2012 to 2017. The TP flow-weighted concentrations decreased by 9% in 2017 compared to 2016. The summer TAN flow-weighted concentration decreased by 42% in 2017 compared to 2016. The winter TAN flow-weighted concentration decreased by 22% from 2016 to 2017. The overall TAN flow-weighted concentrations decreased by 31% in 2017 compared to 2016. The TP and TAN flow-weighted concentrations decreased by 19% and 76%, respectively, in 2017 compared to 2012.

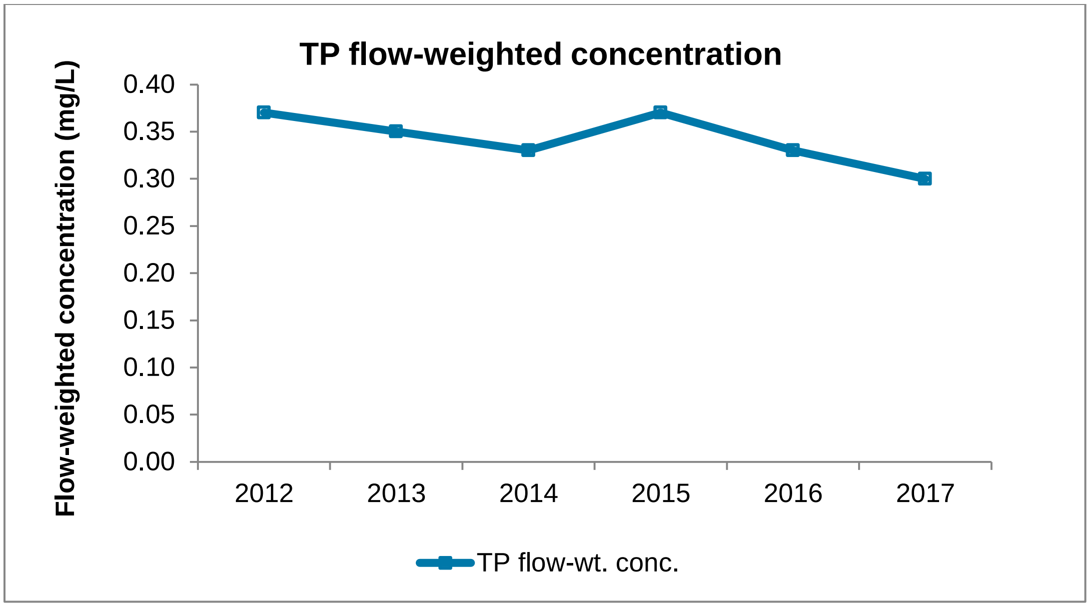


Figure 1: Flow-weighted TP concentrations

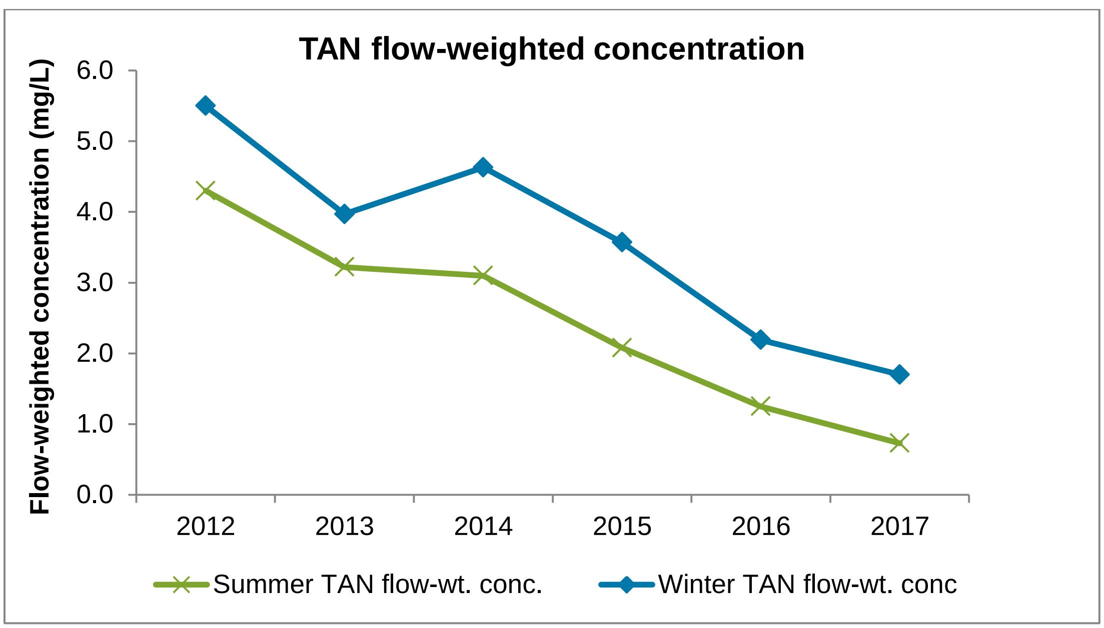


Figure 2: Flow-weighted summer and winter TAN concentrations

Sludge Accountability and Water Balance

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 2017, sludge accountabilities were reported for 22 plants in the watershed. For ten of the plants, the accountability “closed” within ± 15%. In 2016, 23 plants reported sludge accountability and 11 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 2017, water balances were reported for 2 lagoon systems in the watershed. Both of these analyses did close within ±15%.

Grand River Impacts

Table ES-1 summarizes the impact of wastewater effluent discharges on the Grand River.

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

Parameter	2012	2013	2014	2015	2016	2017
% Annual Average Flow	7%	3%	3%	5%	5%	4%
% August Average Flow	14%	5%	9%	12%	9%	8%

The values in Table ES-1 are largely a function of precipitation and weather in any given year. In 2017, precipitation was above average. In 2016, precipitation was close to (but lower than) the long-term average. In 2015, precipitation was near the lower end of typical. In 2014, precipitation was close to the long-term average. In 2013, the watershed generally experienced higher than normal precipitation across its central and northern portions. Precipitation in 2012 was near the low end of typical.

Plant Loading

Table ES-2 summarizes key process loading metrics for 2017 as well as typical values and the minimum and maximum median reported values from 2012 to 2016. The results in the table 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 2017 watershed WWTP performance measures

Performance Measure	Watershed Median 2012-2016 (min-max)	Watershed Median 2017	Typical Value
Per capita flow (L/person/day)	294 - 351	**332**	350 - 500
ADF as % of Nominal Design	51% - 66%	**61%**	N/A
Peak day: Annual average flow	2.25 - 2.75	**2.49**	2.5 - 4
Per capita TBOD[1] loading (g/person/day)	65 - 77	**75**	80
Per capita TSS loading (g/person/day)	69 - 93	**78**	90
Per capita TKN loading (g/person/day)	13 - 14	**14**	13
Per Capita TP loading (g/person/day)	1.7 – 2.0	**1.6**	2.1
Raw TSS:TBOD ratio	1.01 - 1.17	**1.08**	0.8 - 1.2
Raw TKN:TBOD ratio	0.17 - 0.22	**0.22**	0.1 - 0.2

Year-to-year variations in many of the flow metrics in Table ES-2 are largely due to differences in inflow and infiltration (I&I) related to precipitation.

By embracing an optimization approach to reduce the impacts of wastewater effluents on the Grand River, including nutrients, municipal wastewater managers and operators can help to ensure a healthy and sustainable watershed that supports prosperous and growing communities into the future.

[1] A number of 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-2.

INTRODUCTION

The Grand River watershed has a population of about 986,000 that is expected to reach 1.53 million by 2051 (Project Team, 2014). The population currently serviced by 28 of the municipal WWTPs in the watershed is almost 845,000 people, based on the data reported to the GRCA. Significant population growth will result in more wastewater being discharged into these rivers. There are 30 municipal wastewater treatment plants (WWTPs) that discharge their treated effluent into rivers in the watershed as shown in Figure 3. 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 New Credit First Nation.

Wastewater effluent of high quality will help to ensure that river health continues to improve and watershed communities will continue to prosper.

The following report describes the background and objectives of the Grand River Watershed-wide Wastewater Optimization Program (WWOP) and provides a 6 year summary of 2012-2017 performance data voluntarily reported by the program participants.

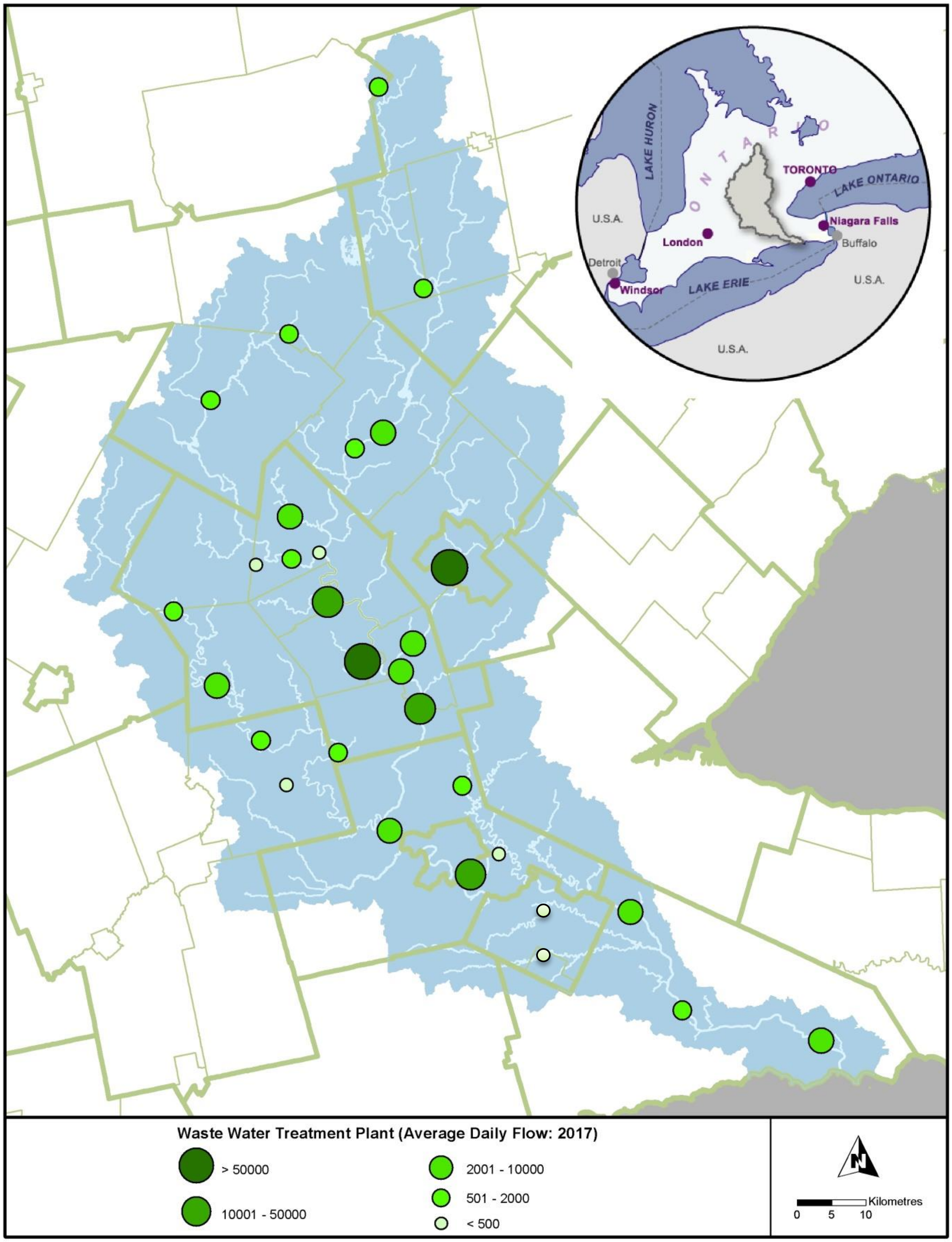


Figure 3: Map of Grand River Watershed showing locations of municipal WWTPs

Background

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). The WWOP supports maintaining and improving water quality in the Grand River, as identified in the Grand River Water Management Plant (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 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 U.S. Environmental Protection Agency (EPA) developed the CCP as a structured approach to identify and systematically address performance limitations to achieve a desired effluent quality (U.S. 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 4. Good administration, design, and maintenance establish a “capable plant” and, by applying good process control, operators achieve a “good, economical” effluent.

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)

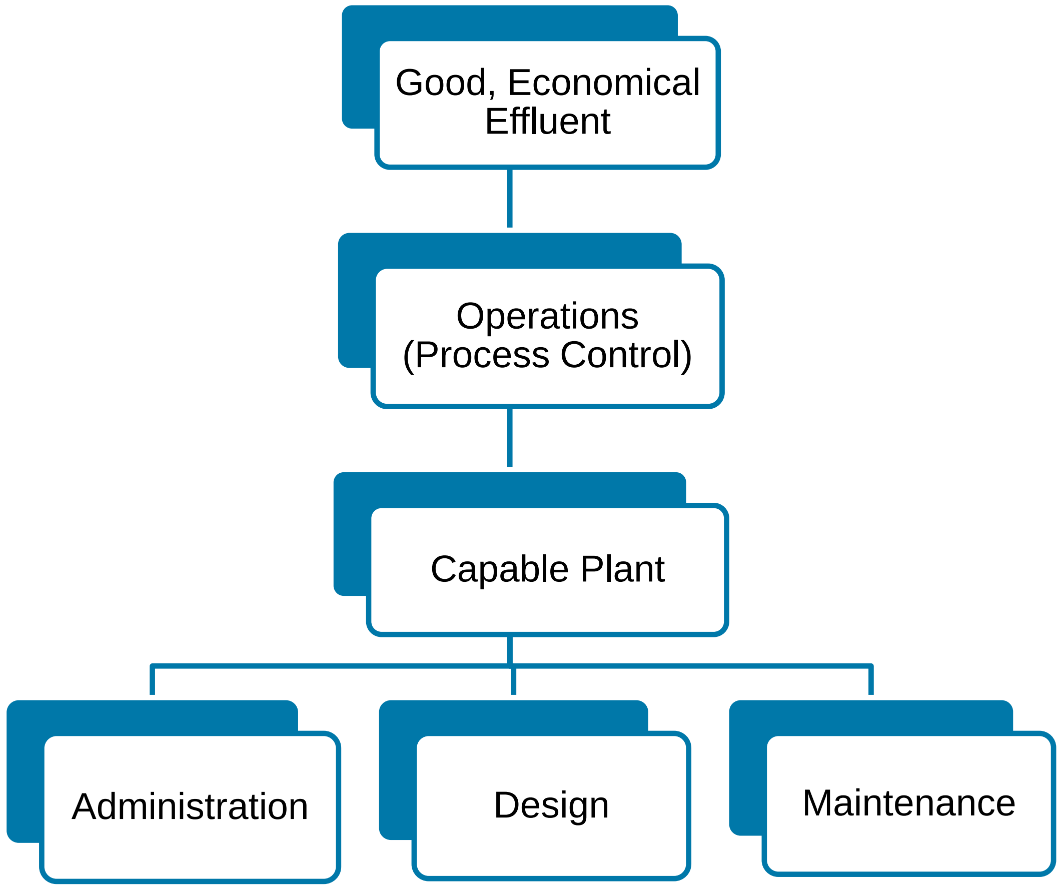


Figure 4: Composite Correction Program Performance Pyramid

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 also very resource intensive, as it used on a plant-by-plant basis. To address this challenge, an area-wide approach (as shown in Figure 5) was adopted based on the successful strategy for optimizing drinking water treatment systems in the United States (US). Major components include: Status, Targeted Performance Improvement, and Maintenance. The model utilizes a proactive, continuous improvement approach to improve effluent quality.

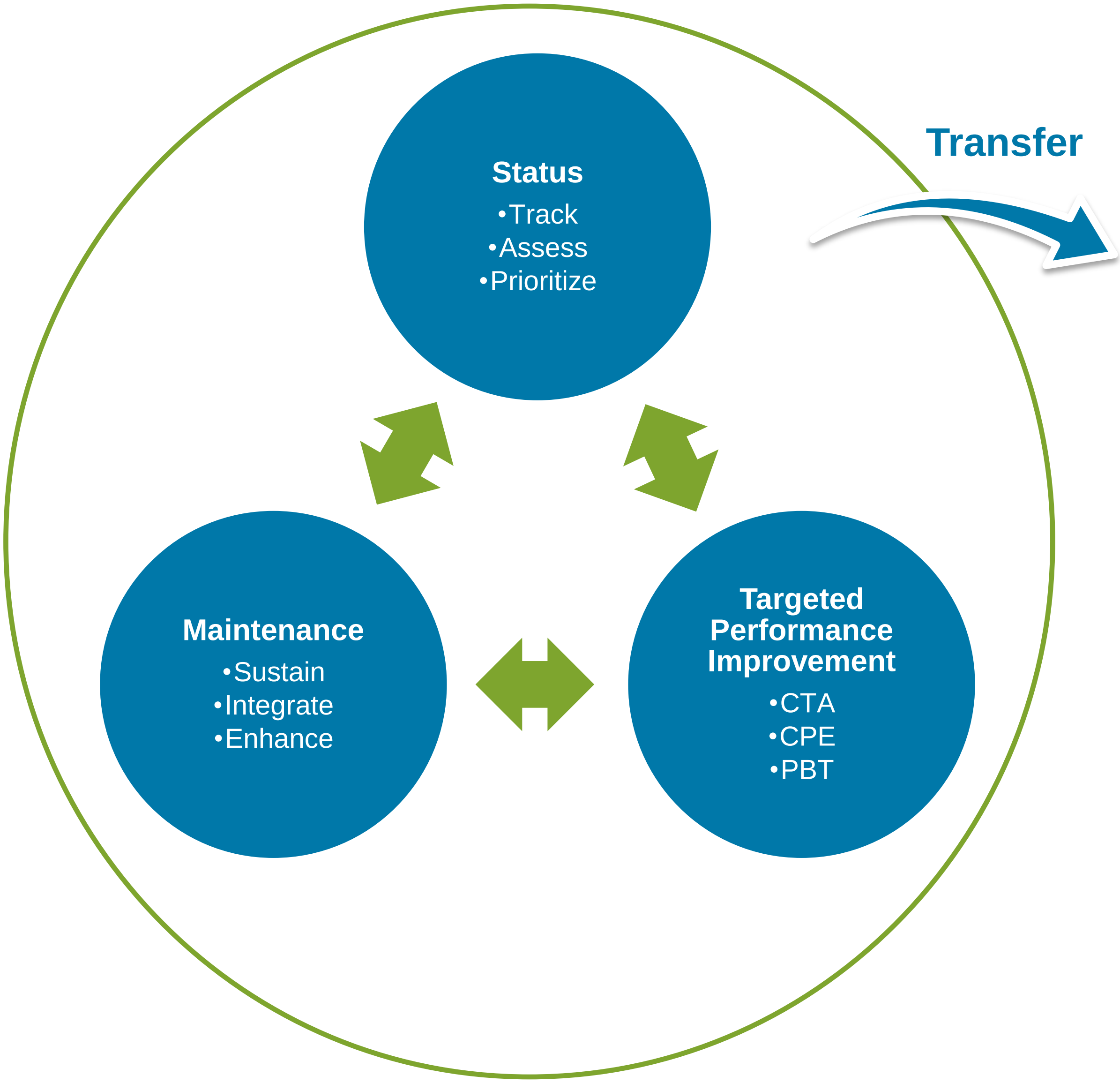


Figure 5: Area-Wide Optimization Model

A key activity under the Status Component is plant performance monitoring, which can be 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 and includes a recognition program to encourage participation. Additionally, the WWOP area-wide model includes a Transfer element to share and encourage other jurisdictions to adopt this approach.

Recognition 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 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 2017 plant data will be presented at the November 2018 WWOP workshop.

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 2012-2017 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 MOECC.

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 data spreadsheet was provided to plant owners and operators for data submission.

This report summarizes 2017 plant data and compares it to 2012-2016 data.

WASTEWATER TREATMENT PLANT REPORTING AND PERFORMANCE

Data Reporting

For 2017, 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. Data was not available for two facilities.

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)

A body of water requires a proper amount of nutrients to stay healthy; however, excessive quantities of these elements can have negative impacts on an aquatic ecosystem. An excessive amount of phosphorous in water leads to algal growth which ultimately consumes dissolved oxygen (DO) in the water. 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 lakes 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 shows 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 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 suggests 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 final targets are set out in Table 3. Previous reports focused on the interim targets whereas this report and moving forward the final targets will be used. 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 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 6 shows the percentage of the number of months in 2017 that the targets for TP and TAN were met for each plant. In 2017, nine plants met the TP target in all months and 16 plants met the TAN target in all months.

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)

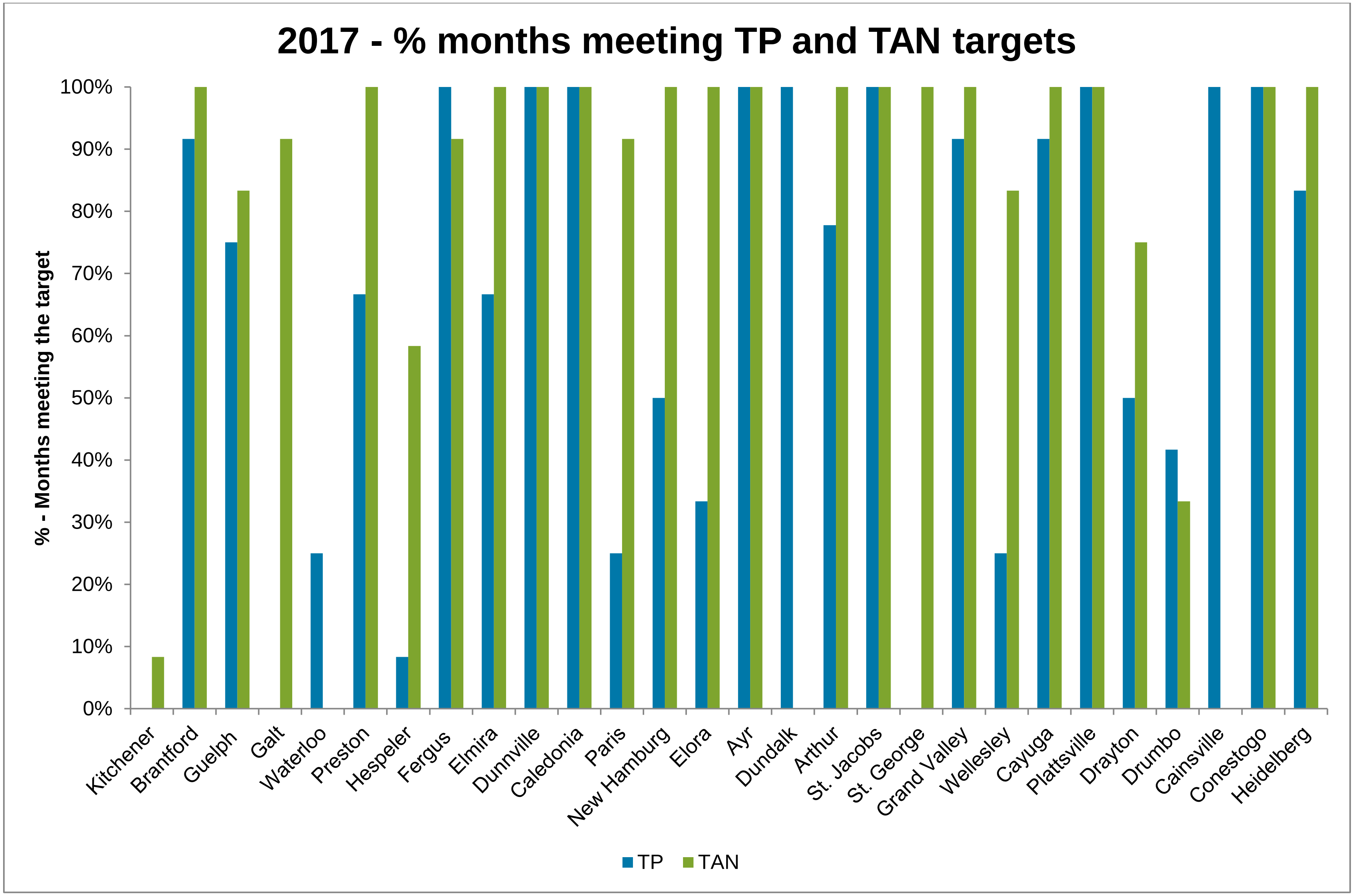


Figure 6: Percentage of months the voluntary targets are met in 2017

Sludge Accountability and Water Balance

A sludge accountability analysis is a key component of the CCP evaluation and is used to determine if monitoring 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. effluent TSS). Projected sludge can include an estimate of primary sludge, biological sludge generated by the conversion of organics to biomass, and chemical sludge (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. 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 4 shows the results for 22 plants in the watershed that conducted sludge accountability for 2017. The number of plants that conducted the analysis increased from 9 in 2015 to 23 in 2016. For 2017, Kitchener, Guelph, Galt, Preston, Fergus, Elmira, Caledonia, New Hamburg, Paris and Drumbo WWTPs have a sludge accountability analysis that closed (i.e. within ±15%). Appendix 1 – Sludge accountability Summary, contains the sludge accountability results containing reported and projected sludge values.

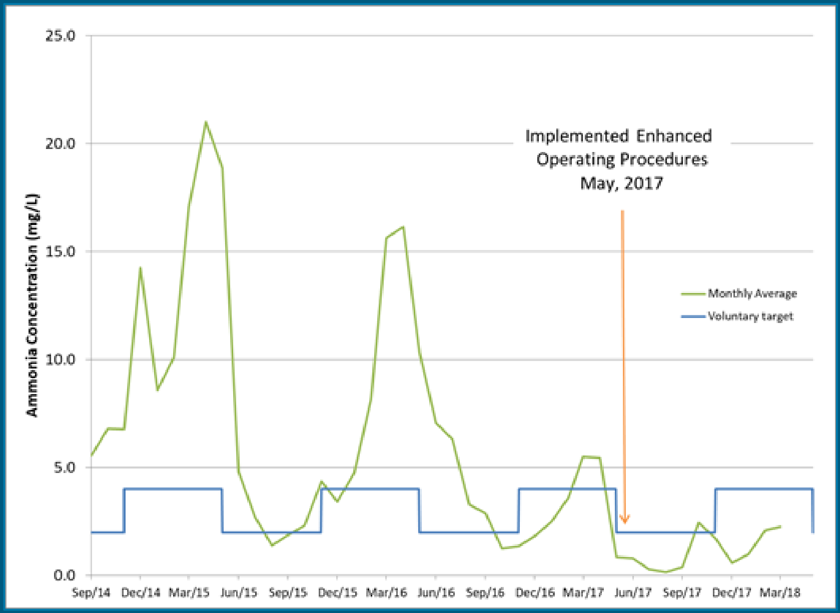
Table 4: Summary of 2014 - 2017 Sludge Accountability analyses of plants that report on it

WWTP	2014	2015	2016	2017
Kitchener			-12.9%	-14%
Brantford	12.8%	10.1%	8.0%	17%
Guelph	8.7%	10.2%	-7.6%	4%
Galt			-12.3%	4%
Waterloo			-40.6%	21%
Preston			3.3%	1%
Hespeler		-60.6%	-59.2%	-40%
Fergus		-30.9%	6.1%	11%
Elmira			1.8%	-6%
Dunnville	4.2%	19.4%	33.5%	22%
Caledonia	22.7%	8.2%	13.9%	14%
Paris		24.7%	-15.3%	1%
New Hamburg			43.7%	12%
Elora		-252.9%	-198.9%	-154%
Ayr			-6.2%	-19%
Arthur			32.6%	Not Reported
St. Jacobs			7.9%	-21%
St. George			-55.9%	-82%
Grand Valley			-68.1%	Not Reported
Wellesley			-57.0%	-61%
Cayuga	-17.7%	-20.8%	-18.7%	25%
Drumbo			Not Reported	-9%
Conestogo			-64.6%	18%
Alt Heidelberg			-9.2%	25%

Improved Performance - Hespeler WWTP

Recently, GR WWOP staff have been working with the Hespeler WWTP staff from OCWA and the Region of Waterloo to implement a total mass control program. Since starting the program in May 2017 the Hespeler WWTP has seen a dramatic decrease in effluent TAN concentrations. The following figure shows the plant has begun to meet the voluntary effluent interim target, based on monthly average effluent TAN concentrations.

Note: Total Mass Control is a process control approach where wasting is controlled to achieve a target total mass in the system. The total mass is comprised of mass in both the aeration basin and the secondary clarifier.



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 5 shows the results for the lagoons that conducted a water balance analysis for 2016 and 2017. Sources of discrepancy in the calculation may include the following; inaccurate flow measurement, inaccurate surface area information, uncertainties in precipitation data and error in storage lagoon measurements.

Table 5 - Summary of 2016-2017 Water Balance analyses of plants that report on it

	2016				2017			
Plant	Reported	Projected	Influent Flow	Water Balance (%)	Reported	Projected	Influent Flow	Water Balance (%)
Dundalk	28,101	-17,969	380,883	**12**	60,260	7,475	404,642	**13**
Drayton	49,142	-9,518	215,158	**18**	**Not Reported**			
Plattsville	**Not Reported**				17,107	27,493	196,483	**5**

Work is continuing as part of the WWOP to develop the water balance methodology for lagoons as part of voluntary reporting in the Grand River watershed.

Influence of WWTPs on the Grand River

Figure 7 shows total precipitation (i.e. snow and rain) at selected sites in the watershed. 2017 observed precipitation was above the long-term average across the watershed (Shifflett, 2017). 2016 observed precipitation was close to the long-term average (Shifflett, 2017) and although the annual total was close to the long-term average, much of the precipitation fell in the winter and spring (January to April) with an extended dry period from May to November. 2015 experienced precipitation near the low end of typical (Shifflett, 2016). 2014 saw precipitation close to the long term average (Shifflett, 2014), whereas 2013 generally experienced higher than normal precipitation across the central and northern portions of the watershed (Shifflett, 2013). Precipitation in 2012 was at the low end of typical (Shifflett, 2012). Table 6 shows characterization of precipitation in the Grand River watershed according to GRCA precipitation data over the period 2012-2017.

Table 6 - Characterization of precipitation in Grand River watershed over 2012-2017 period

Year	Precipitation Characterization
2012	Low end of typical
2013	Higher than typical in some areas
2014	Long-term average
2015	Low end of typical
2016	Long-term average
2017	Higher than typical

Figure 8 shows the relative influence of wastewater effluent on the Grand River by comparing the total volume of treated effluent in each of the years 2012 to 2017 to the annual average river flow at York for the same years. York, in Haldimand County, is the location of GRCA's southern-most flow monitoring station on the Grand River. Figure 8 shows that the volume of treated effluent ranges from 3% to 7% of the total river flow on an annual average basis.

Figure 9 shows a similar comparison based on low flow conditions observed in the month of August. Under summer low flow, the proportion of treated effluent ranges from 5% to 14% of the river flow. The influence of WWTP flow on the river varies from year to year depending on precipitation.

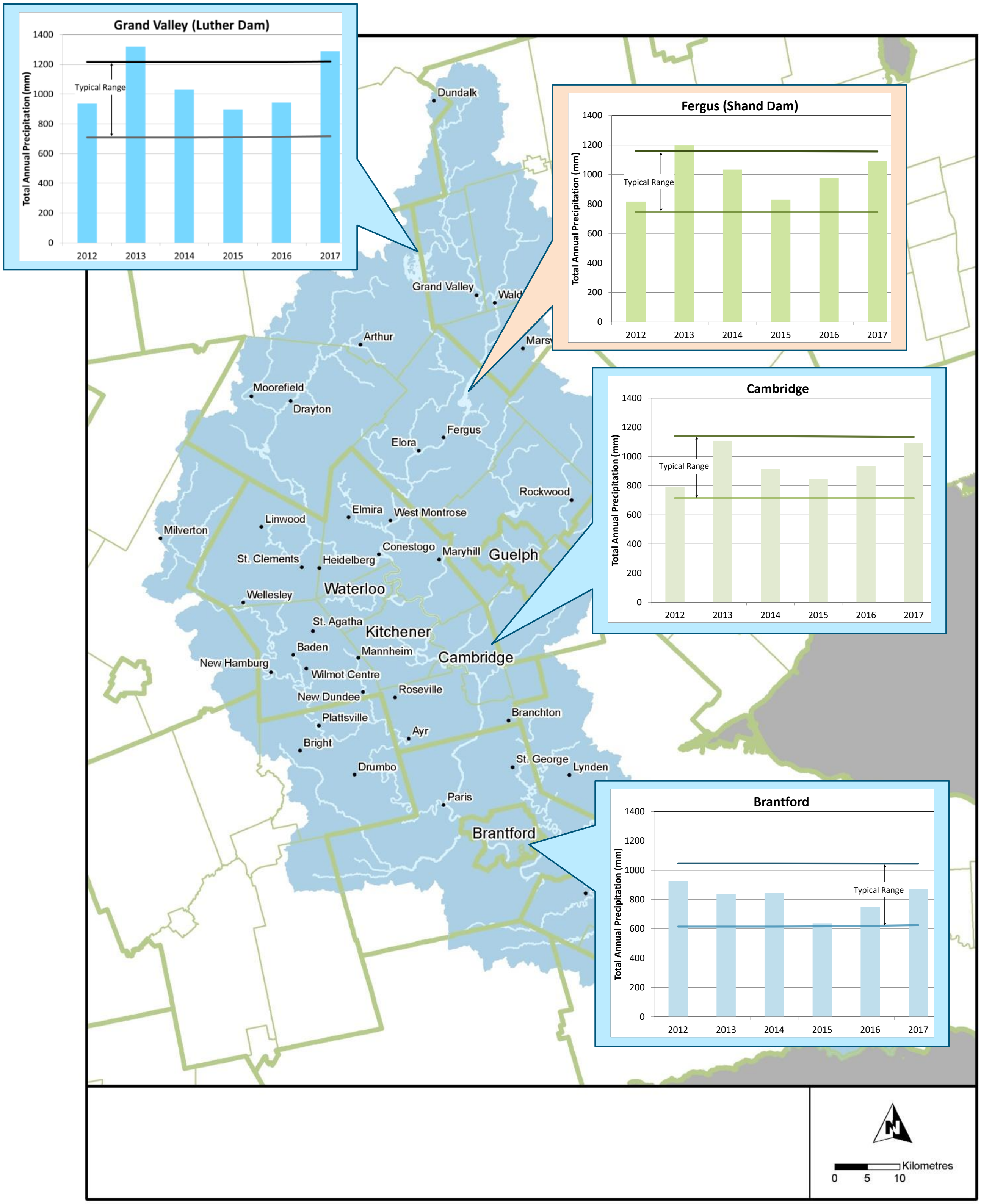


Figure 7: Total annual precipitation (in mm) at selected locations across the watershed. Typical range is based on 5th and 95th percentile of historical observations over the past 50 years.

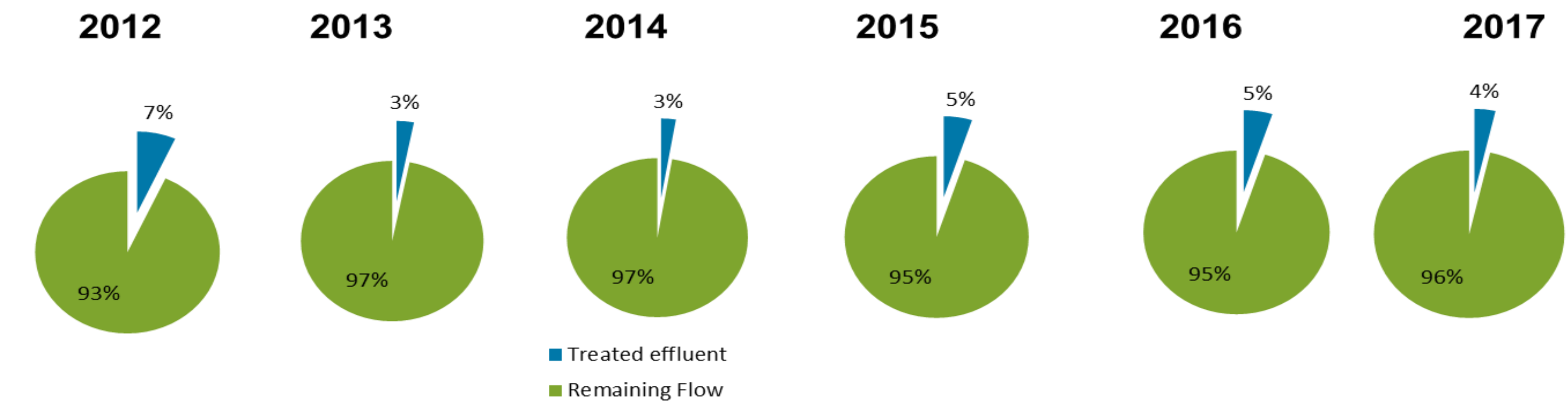


Figure 8: Annual Average Effluent Flow compared to Grand River Flow at York from 2012 to 2017

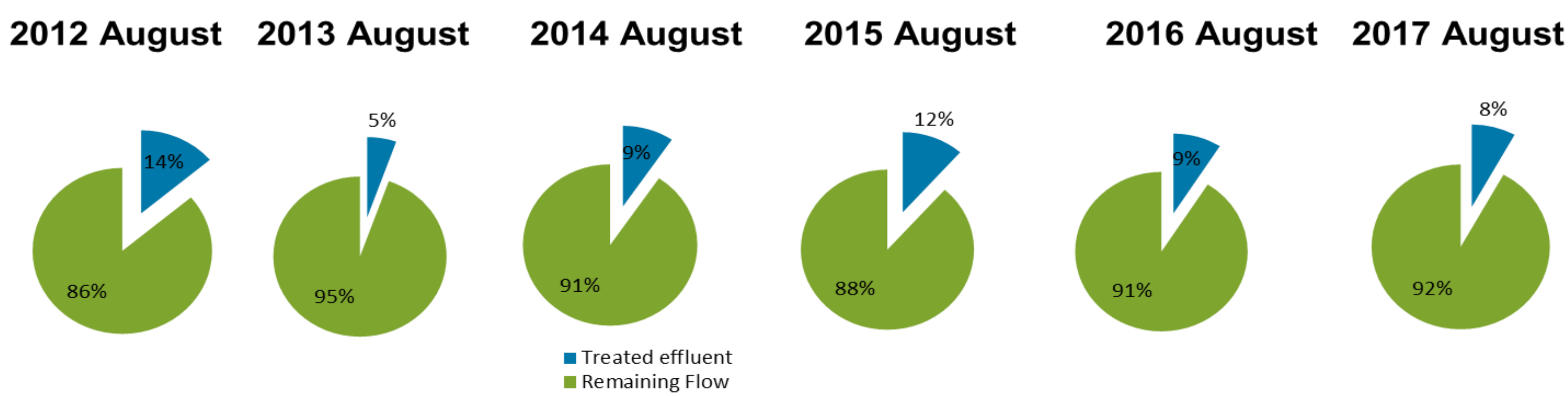


Figure 9: Average Effluent Flow compared to Grand River Flow at York in August from 2012 to 2017

Table 7 shows the annual average effluent TP loadings from WWTPs for the years 2012 to 2017, as well as flow-weighted TP concentrations. The TP loading was calculated based on the product of each plant's monthly average flow and its corresponding effluent TP concentration. The flow-weighted concentrations were calculated by dividing the loading by the total average flow. There was a 4% decrease in TP loading in 2017 from 2016, largely as a result of reduced loadings from the Brantford, Guelph and Galt WWTPs. There was a corresponding 9% decrease in the flow-weighted concentrations from 2016 to 2017. From 2012 to 2017 the TP loadings and flow-weighted concentration have dropped by 9 and 19%, respectively.

Table 7 - Wastewater effluent TP loading and flow-weighted concentration to the Grand River

	Loading (tonne)	Flow-Weighted Concentration (mg/L)
2012	35.9	0.37
2013	37.6	0.35
2014	36.8	0.33
2015	36.5	0.37
2016	33.8	0.33
2017	32.5	0.30

The total annual loading of wastewater effluent TAN discharged to surface water and corresponding flow-weighted concentrations are documented in Table 8, which shows the TAN loadings separated into summer and winter periods. There was a 38% decrease in summer TAN loadings from 2016 to 2017, which can be attributed to large loading decreases from Kitchener, Brantford and Waterloo WWTPs. There was an 18% decrease in winter TAN loadings from 2016 to 2017, which can be attributed to large loading decreases from the same plants as well as from Hespeler, Dunnville and St. Jacobs WWTPs. Overall, there was a 25% decrease in wastewater effluent TAN loading from 2016 to 2017. Since 2012, total TAN loading and flow-weighted concentrations decreased by 73% and 75%, respectively.

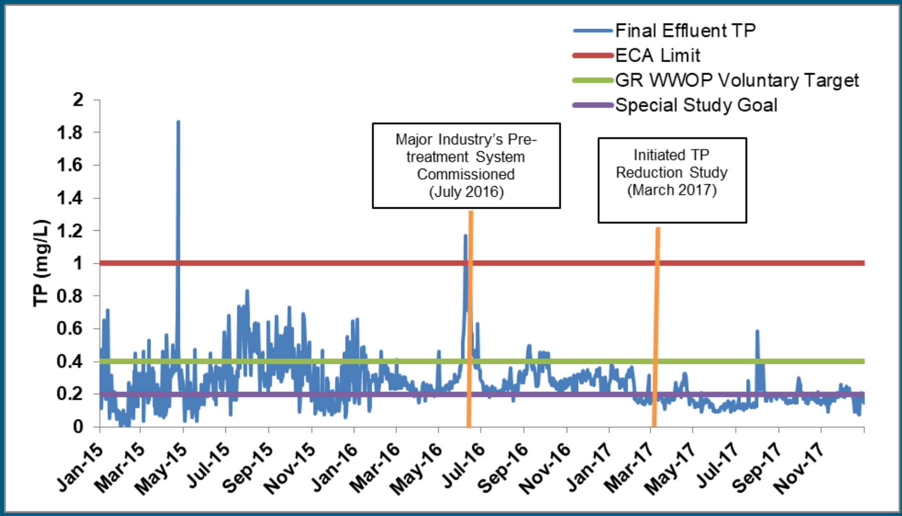
Table 8 - Wastewater effluent TAN loading and flow-weighted concentrations to the Grand River

	TAN summer		TAN winter		Total	
Year	Loading (tonne)	Conc. (mg/L)	Loading (tonne)	Conc. (mg/L)	Loading (tonne)	Conc. (mg/L)
2012	417	4.3	534	5.5	**951**	**4.9**
2013	346	3.2	426	4.0	**773**	**3.6**
2014	343	3.1	512	4.6	**855**	**3.9**
2015	206	2.1	353	3.6	**560**	**2.8**
2016	124	1.3	223	2.2	**347**	**1.8**
2017	77	0.7	182	1.7	**259**	**1.2**
*all concentrations are flow-weighted average concentrations						

Improved Performance - Brantford WWTP

The City of Brantford initiated an optimization program at their treatment plant in 2012, using the Composite Correction Program as a basis. As a result of their rigorous process control strategy and revised sewer-use bylaw, the plant achieved more stable TP control.

To further reduce effluent TP concentrations, a special study was completed under the MOECC's Draw the Graph funding. As shown in the figure to right the facility is achieving tertiary effluent TP levels with a secondary treatment plant. (Howarth, 2018)



WASTEWATER TREATMENT PLANT LOADING SUMMARY

Influent flow

Figure 10 shows a summary of the average daily flow (ADF) to each plant for 2012 to 2017 compared to the Nominal Design Flow (NDF) of the plant as stated in the plant's ECA (shown in light grey). Figure 10 shows three vertical scales since the nominal design of the WWTPs in the watershed range from 130 m^3/d to 81,000 m^3/d. Figure 11 shows the ADF as a percentage of the NDF. In 2017, all but one plant experienced an ADF that was less than the NDF. Since 2012 three plants experienced ADFs higher than their NDF: Arthur (2012 to 2014 and 2017), Drumbo (2013 and 2014) and Cainsville (2014).

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 12 shows per capita flows for WWTPs in the watershed for 2012-2017. 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 2017 was 332 L/person/day, a 10% increase from the 2016 median of 298 L/person/day and 6% increase from 2012 median of 313 L/person/day.

Some plants experience higher than typical per capita flows and this may be attributed to a variety of reasons. For example, the Cainsville WWTP services primarily industrial users and is therefore expected to have higher per capita flow than a typical domestic sewage system. Others WWTPs, such as Arthur and Dundalk, appear to be subject to inflow/infiltration (I/I).

Figure 13 shows the ratio of peak day flow to ADF, which is another indicator of I/I or periodic industrial flows. The 2012 median was 2.25 and increased to 2.49 in 2017, which is at the lower end of the typical range (2.5 to 4.0). Most plants were within the typical range or less. Several plants are known to experience I/I (such as the Arthur WWTP) and this is reflected in Figure 13.

Year-to-year variability in per capita flow is assumed to be 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, 2017).

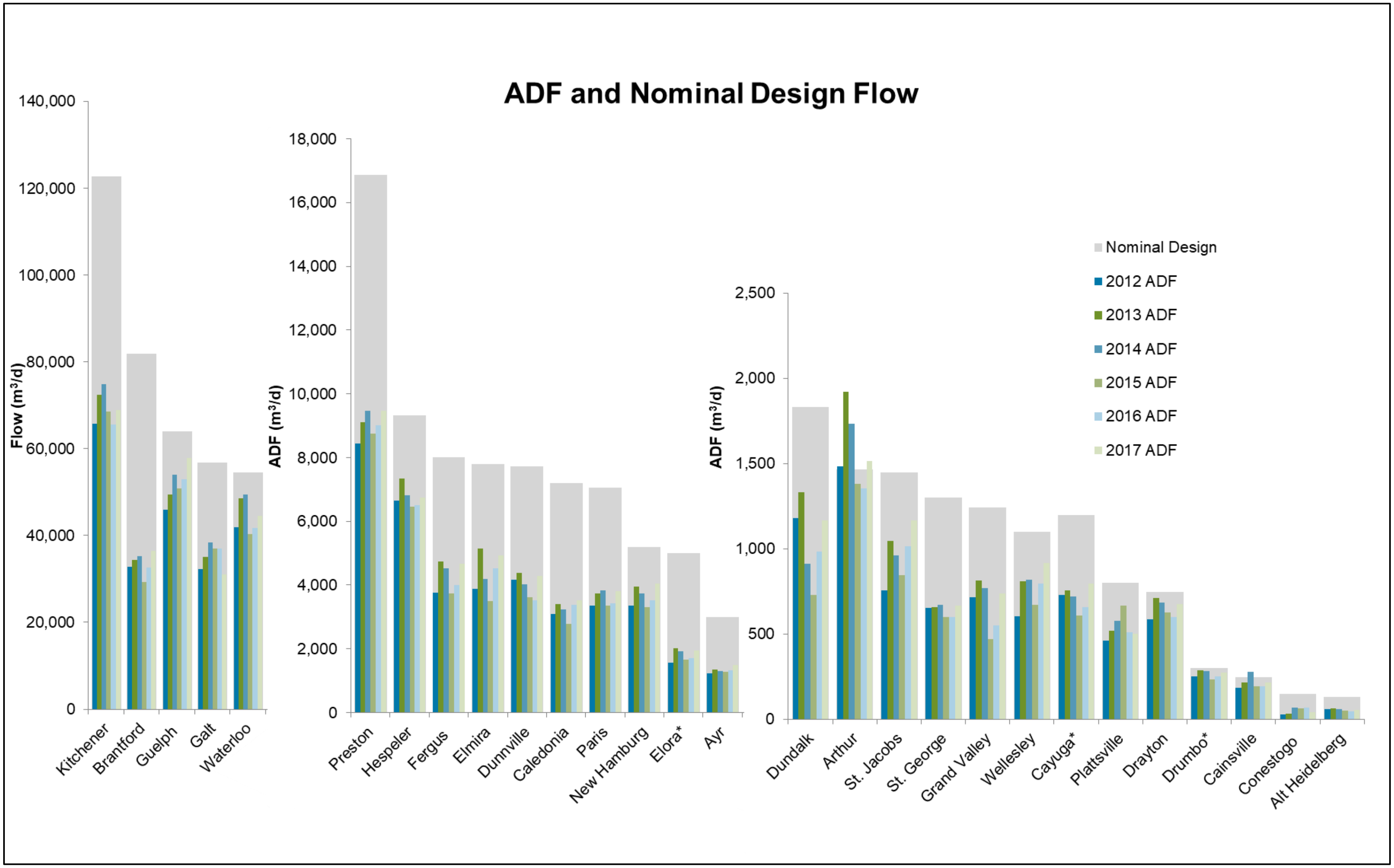


Figure 10: ADF and Nominal Design Flow of 28 WWTPs in the watershed

***NDF of Elora WWTP was increased from 3,066 to 5,000 m^3/d in 2015 and NDF of Drumbo WWTP was increased from 272 to 300 m^3/d in 2015 and NDF of Cayuga WWTP was increased from 873 to 1,200 m^3/d in 2015**

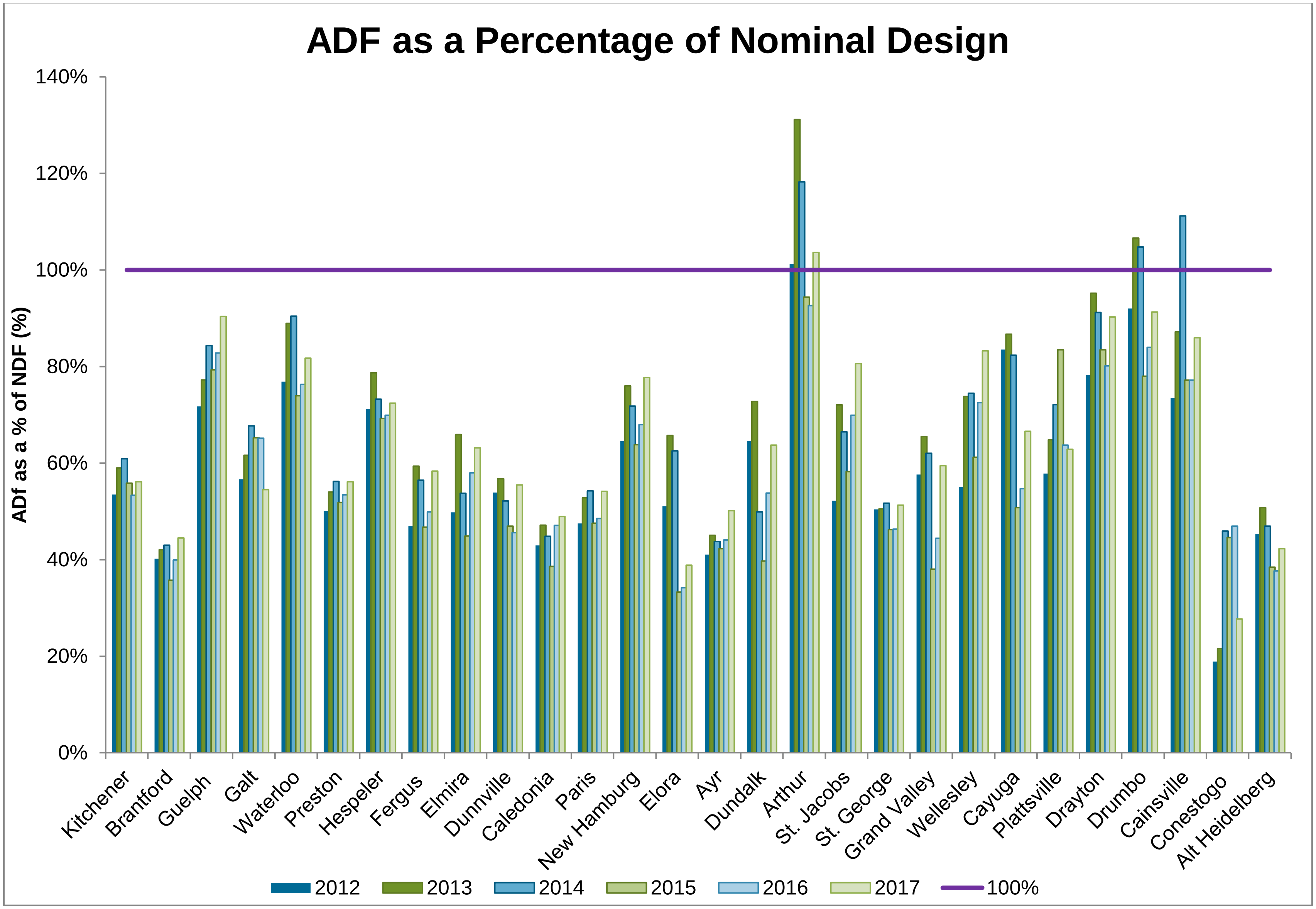


Figure 11: Annual average flow as a percentage of rated plant capacity

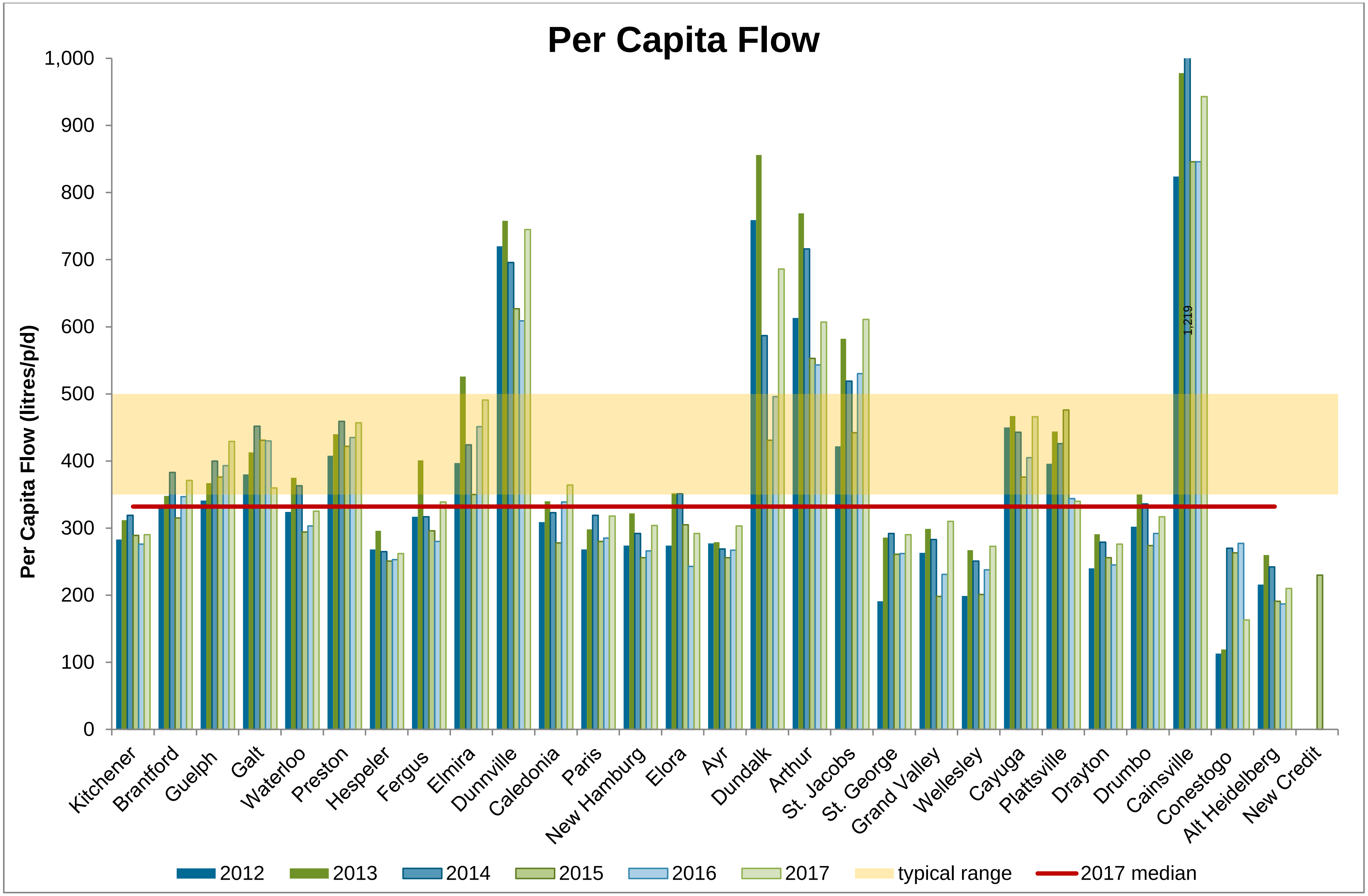


Figure 12: Per capita influent flow

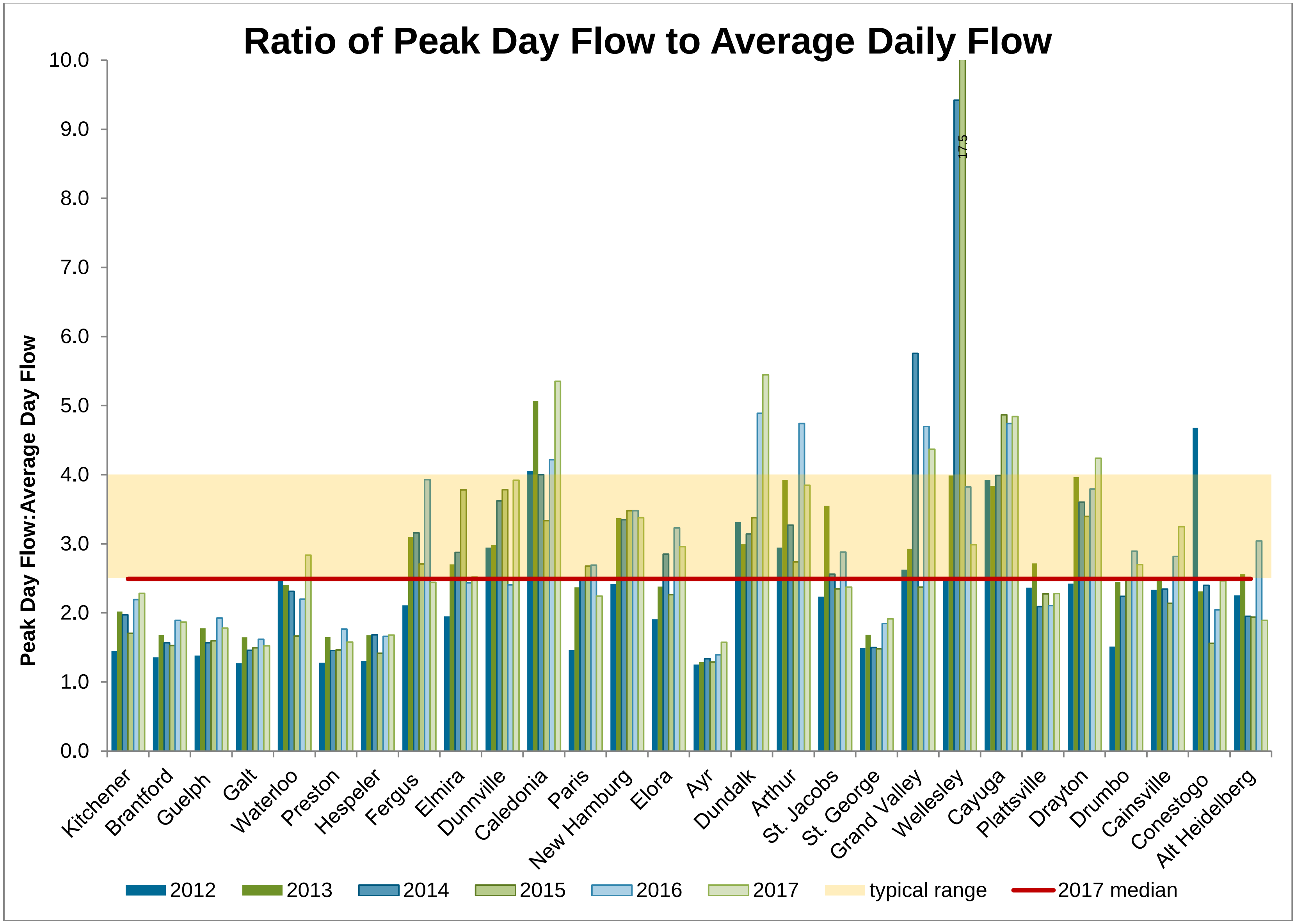


Figure 13: Ratio of peak day flow to annual average flow

Raw Influent Loads

Characterization of raw wastewater is important to ensure effective wastewater treatment, assist with future planning, and identify any issues 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 2015, 16 of 28 plants in the watershed did not measure TBOD in the raw influent on a routine basis because their ECAs required cBOD measurements of the raw influent. In 2017, this number decreased to two, in part due to new ECAs that were adopted for Fergus and Elora WWTPs requiring measurement of TBOD in raw sewage and Region of Waterloo WWTPs measured both cBOD and TBOD under the Region's enhanced monitoring program in Kitchener, Galt, Waterloo, Preston, Hespeler, Wellesley and Alt Heidelberg plants for potential expansion purposes. Table 9 summarizes the results of both cBOD and TBOD as reported by plants in the Grand River watershed in 2016 and 2017:

Table 9 - Annual average raw influent BOD concentrations reported by Grand River watershed plants in 2016 and 2017

	No. of plants reporting		Median (mg/L)		Range (mg/L)	
	cBOD	TBOD	cBOD	TBOD	cBOD	TBOD
2016	18	21	195	208	127-389	142-411
2017	18	26	177	194	98-411	108-421

Albertson (Albertson, 1995) has documented that the cBOD test underestimates the strength of raw wastewater by 20-40%. In the absence of measured TBOD data, TBOD loads were estimated based on cBOD concentrations multiplied by a factor of 1.2. The assumed scaling factor of 1.2 introduces significant uncertainty in the estimate of TBOD loads. In 2017, 16 of 28 plants in the watershed measured both cBOD and TBOD. The average TBOD:cBOD ratio among these plants is 1.16 which is slightly lower than the 1.2 factor used in estimations.

Figure 14 shows estimated per capita TBOD loads for plants in the Grand River watershed; plants with estimated TBOD values are represented by hatched bars and plants with actual TBOD data are represented by solid bars. A typical value for domestic wastewater is 80 g/person/d. The reported 2017 median is 75 g/person/d, which is higher than the 2016 median value of 69 g/person/d and the 2012 value of 65 g/person/d.

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 very high per capita TBOD loads; for instance, the Cainsville lagoon system services mainly commercial/industrial users, which has led to very high per capita concentrations (for TBOD, TSS, TKN, TP, etc). However, atypical TBOD loads may also be related to inadequate sampling frequency, non-representative sampling, errors in flow metering or population estimates, etc.

Measuring $cBOD_5$ in the raw influent?

"Use of raw wastewater $cBOD_5$ possibly **underestimates the organic load** for some facilities and might result in inadequate designs." (Muirhead, 2006)

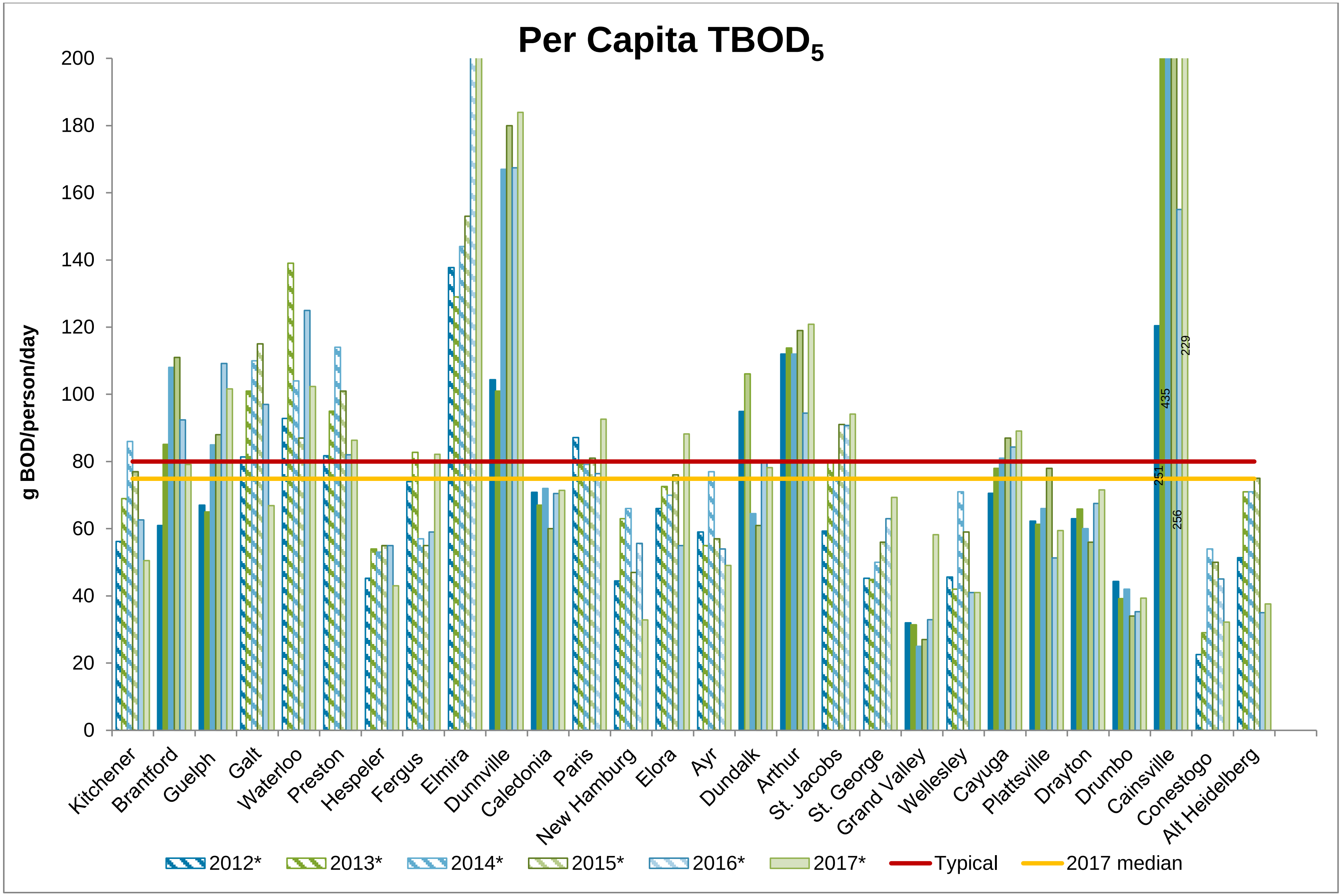


Figure 14: Per Capita TBOD Load

TSS Loading

TSS loads in raw influent for 2012 to 2017 are summarized in Figure 15. The 2017 watershed median was 78 g/person/d, which is less than the typical value of 90 g/person/d. This value was 82 g/person/d in 2012. 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 16 shows per capita TKN loads to plants in the watershed. The watershed median was 14 g/person/d for 2017 which is slightly higher than the typical value of 13 g/person/d and the same as 2012 per capita TKN load. Several plants (such as Waterloo, Preston, Fergus, Elmira, Dunnville, Caledonia, Dundalk, Arthur, Cayuga, Plattsville, and Cainsville) 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 17 shows the TP loads in the raw influent for 2012 to 2017. The watershed median for 2017 was 1.6 g/person/d. This is slightly less than the typical value of 2.1 g/person/d. TP per capita has not changed significantly since 2012 (1.8 g/person/d).

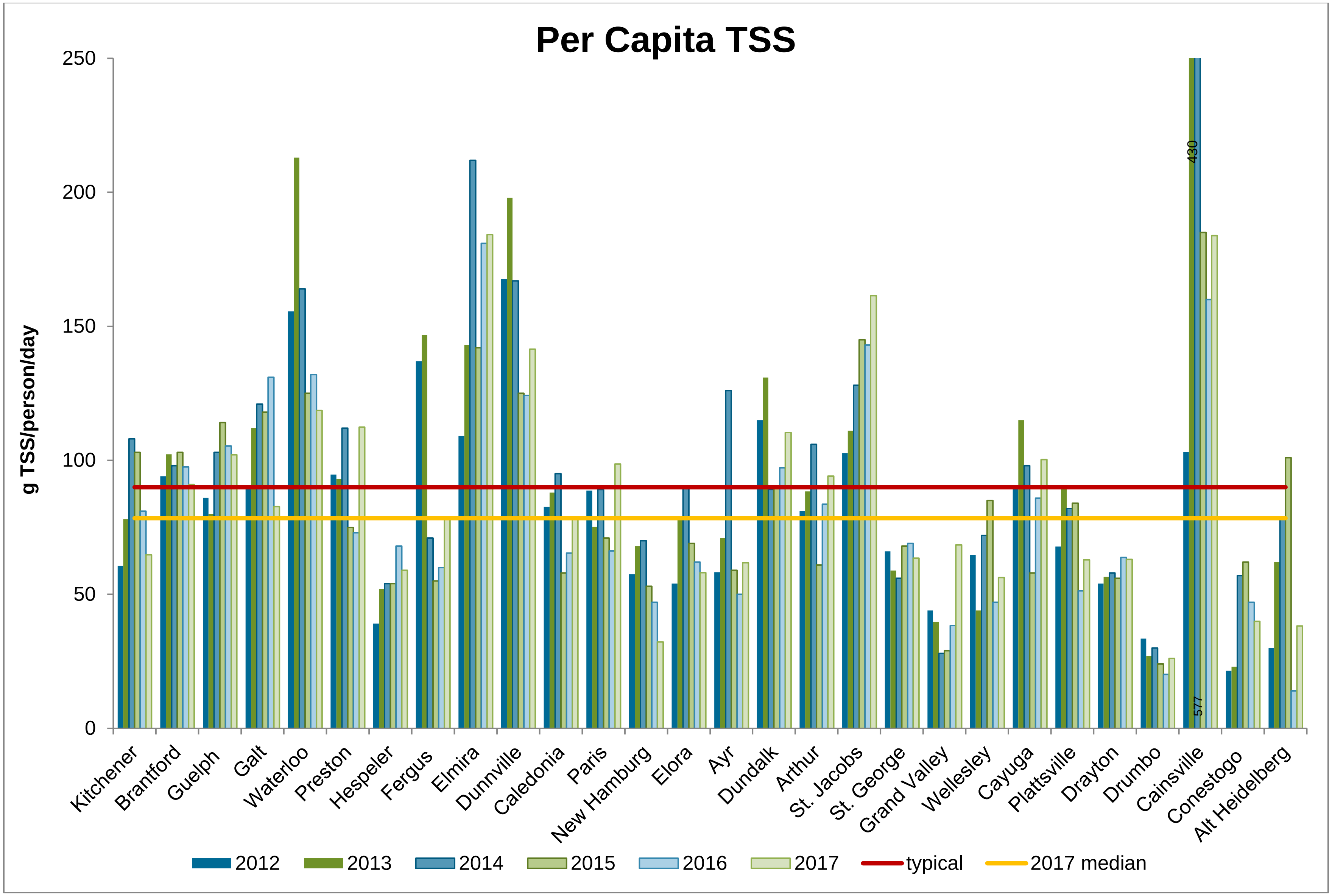


Figure 15: Per Capita TSS Load

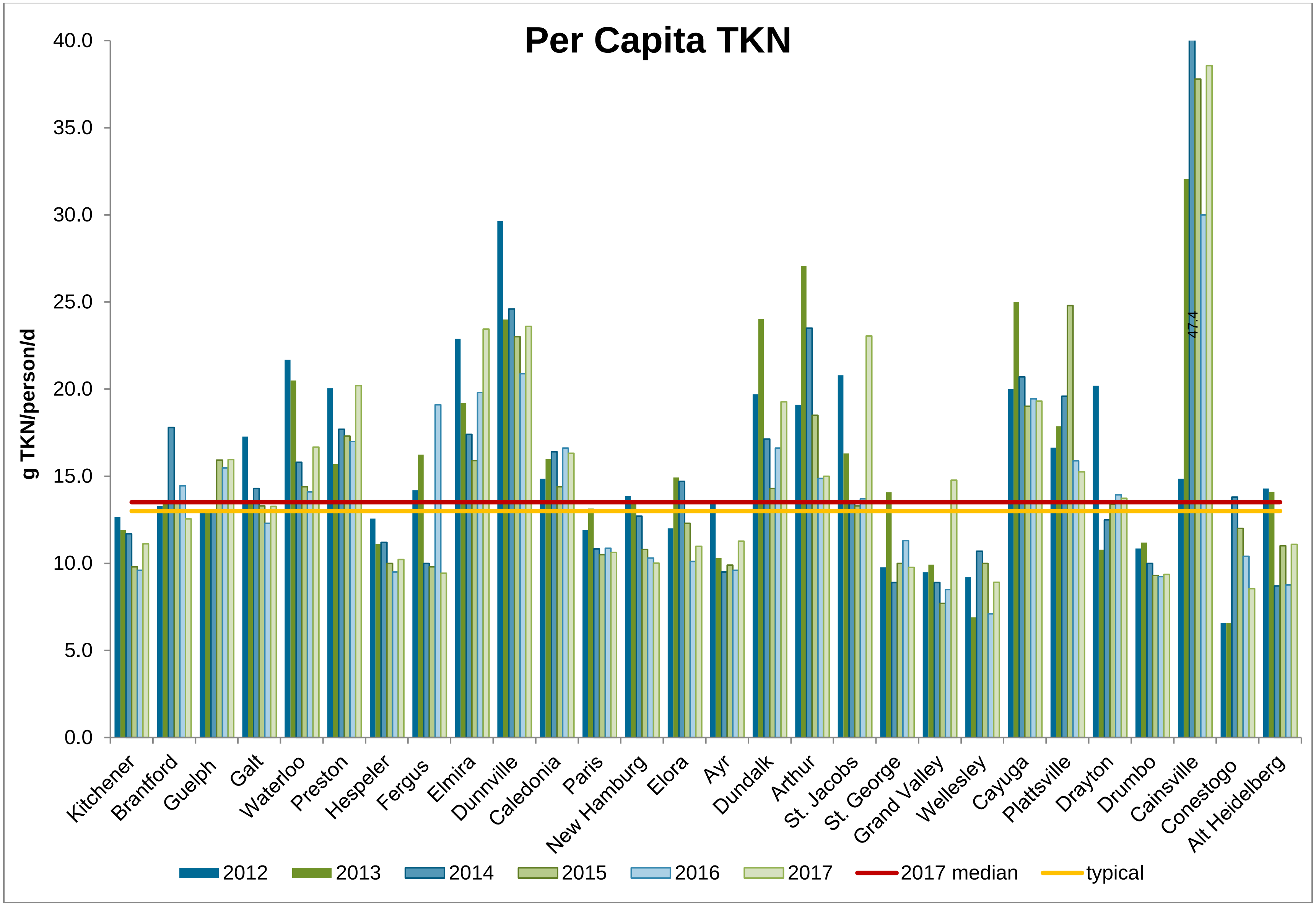


Figure 16: Per Capita TKN Load

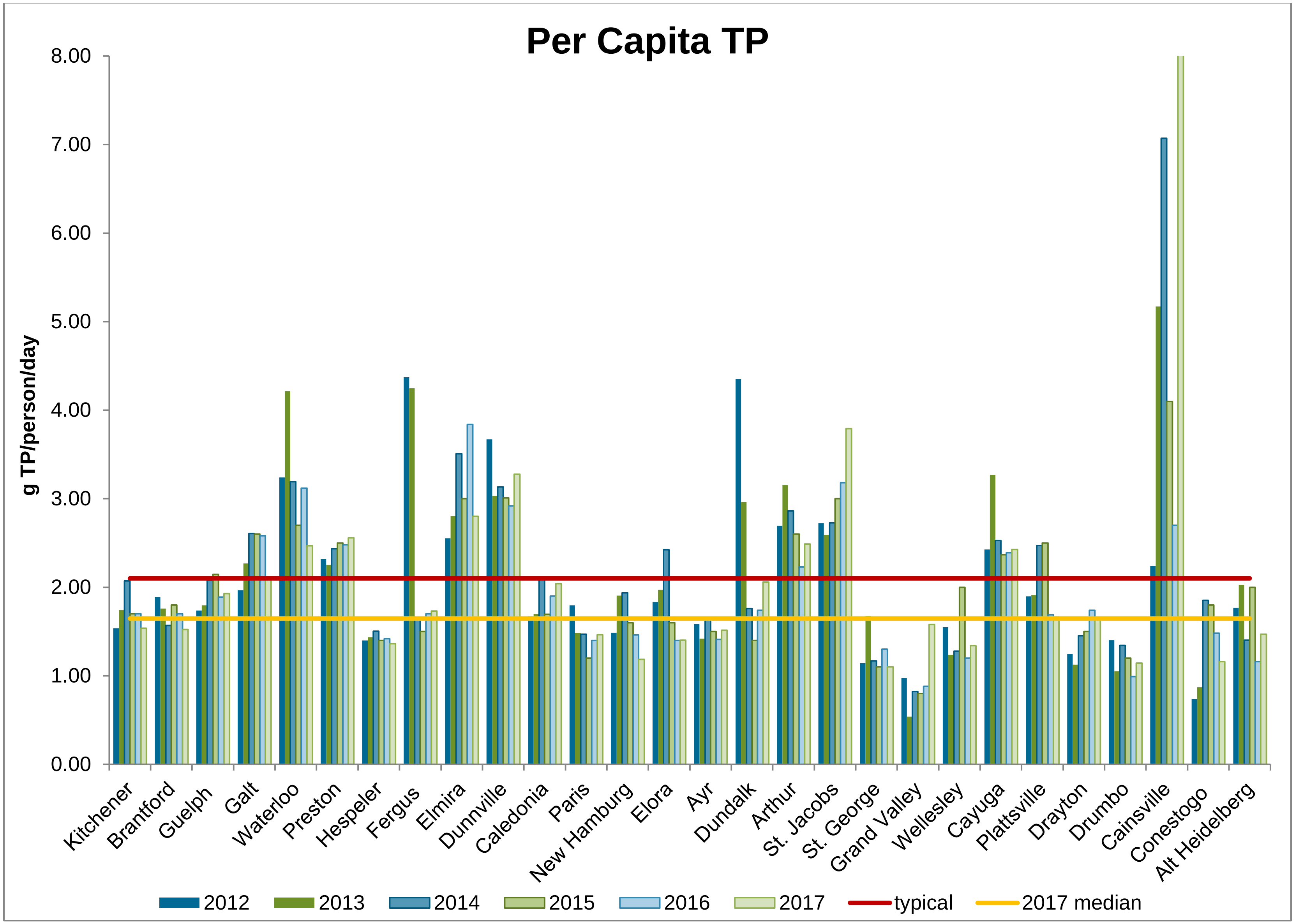


Figure 17: Per Capita TP Load

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 18 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 2017 was 1.08. The 2017 median was lower than 2012 value of 1.14.

Figure 19 shows a graph for the ratio of raw TKN to TBOD, with a range of 0.1 to 0.2 considered typical. The 2017 watershed median was 0.22, which is slightly higher than typical. 2012 data showed slightly higher median of 0.23. Higher ratios could be attributed to recycle streams, an industrial influence in the collection system, or estimated TBOD values that are lower than actual.

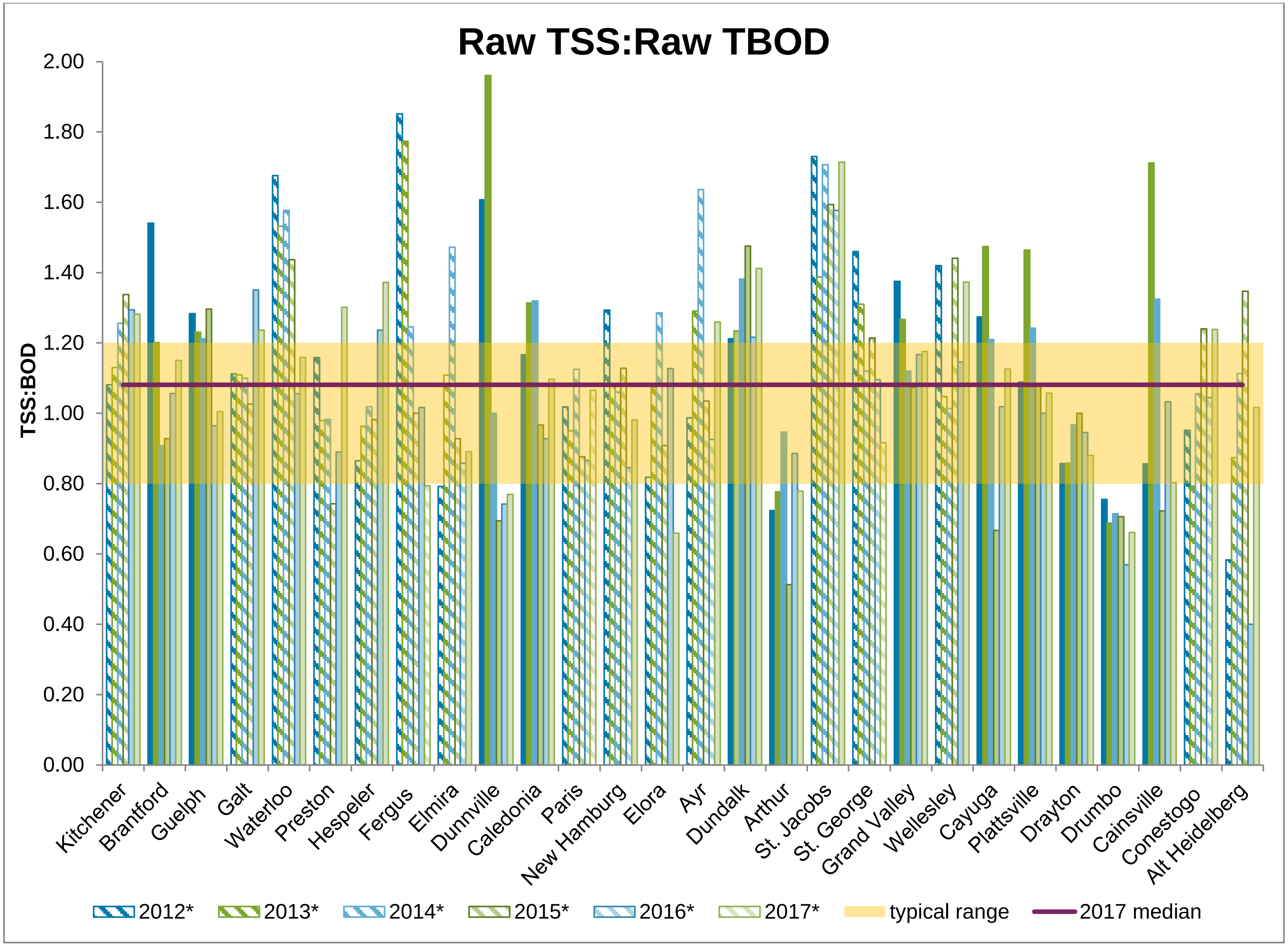


Figure 18: Ratio of Raw TSS to Raw TBOD

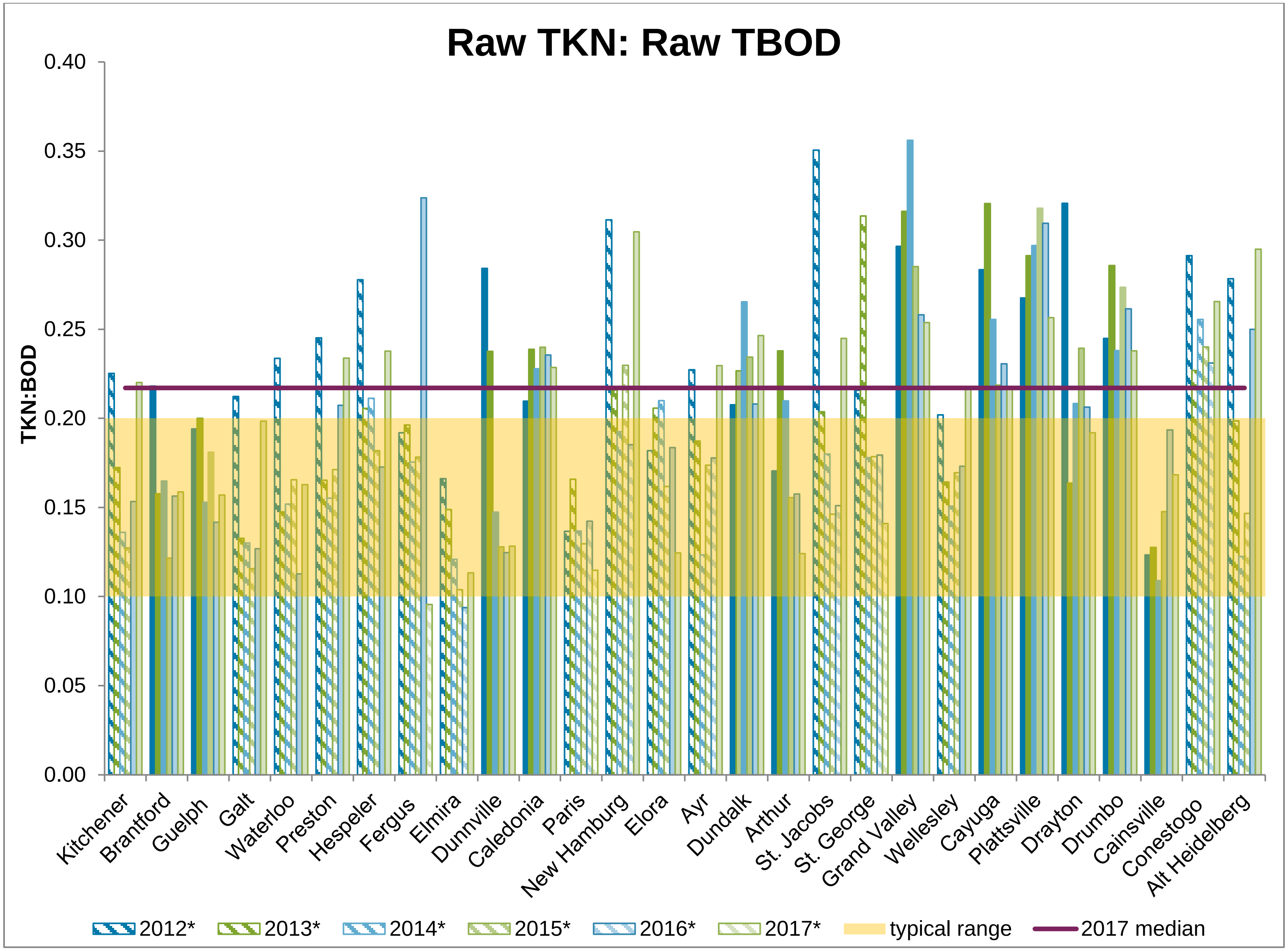


Figure 19: Ratio of Raw TKN to Raw TBOD

Final Comments

For this report, monthly average effluent concentrations for TP and TAN were compared to the final voluntary effluent quality performance targets. In 2017, nine plants met the effluent quality performance target for TP in all 12 months. Sixteen plants met the effluent quality performance target for TAN in all 12 months.

As part of the ongoing watershed-wide optimization program, the GRCA will continue to encourage and support municipalities to report on these 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 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 Kelly Hagan, 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.

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.

Howarth, T. (2018). Maximizing Phosphorus Removal from a Secondary Treatment System. *WEAO 47th ANNUAL TECHNICAL SYMPOSIUM AND OPCEA EXHIBITION*, (p. XXX). London ON.

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.

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

APPENDIX 1 – SLUDGE ACCOUNTABILITY SUMMARY

Table 10 – Summary of sludge accountability analysis results

WWTP	2014			2015			2016			2017		
	Projected	Reported	Analysis	Projected	Reported	Analysis	Projected	Reported	Analysis	Projected	Reported	Analysis
Kitchener							12,672	14,303	**-12.9%**	19,561	22,317	**-14%**
Brantford	8,056	7,024	**12.8%**	10,491	9,427	**10.1%**	10,202	9,387	**8.0%**	8,931	7,386	**17%**
Guelph	14,079	12,855	**8.7%**	15,952	14,320	**10.2%**	13,655	14,690	**-7.6%**	12,964	12,405	**4%**
Galt							8,052	9,045	**-12.3%**	9,822	9,456	**4%**
Waterloo							10,645	14,970	**-40.6%**	19,845	15,623	**21%**
Preston							1,642	1,587	**3.3%**	2,693	2,672	**1%**
Hespeler				1,021	1,640	**-60.6%**	968	1,541	**-59.2%**	1,177	1,643	**-40%**
Fergus				350	458	**-30.9%**	554	520	**6.1%**	1,415	1,258	**11%**
Elmira							1,173	1,152	**1.8%**	2,255	2,383	**-6%**
Dunnville	646	619	**4.2%**	682	550	**19.4%**	798	531	**33.5%**	902	700	**22%**
Caledonia	1,044	807	**22.7%**	1,232	1,131	**8.2%**	844	727	**13.9%**	876	750	**14%**
Paris				438	330	**24.7%**	661	762	**-15.3%**	177,045	175,078	**1%**
New Hamburg							471	265	**43.7%**	363	321	**12%**
Elora				263	928	**-252.9%**	374	1,118	**-198.9%**	432	1,099	**-154%**
Ayr							162	172	**-6.2%**	267	317	**-19%**
Arthur							193	130	**32.6%**	**Not Reported**		
St. Jacobs							216	199	**7.9%**	210	254	**-21%**
St. George							149	232	**-55.9%**	77	140	**-82%**
Grand Valley							59	100	**-68.1%**	**Not Reported**		
Wellesley							122	192	**-57.0%**	132	213	**-61%**
Cayuga	96	113	**-17.7%**	101	122	**-20.8%**	99	118	**-18.7%**	114	86	**25%**
Drumbo							**Not Reported**			79	86	**-9%**
Conestogo							13	21.4	**-64.6%**	12	10	**18%**
Alt Heidelberg							12	13	**-9.2%**	9	6	**25%**