RAW WATER ASSESSMENT: TAY AREA AND ROPE SUBDIVISION INTAKES

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Severn Sound Environmental Association
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Purpose

This report provides a general water quality assessment that included trends, current conditions, and a discussion on algae compounds and abundance for surface water sources for both Township of Tay intakes, at the Rope Subdivision and Tay Area Water Treatment Plants. This information will be used by the Township of Tay to assess and demonstrate that:

1. The source water has not substantively deteriorated or varied since the issuance of the renewed Licence [in 2015], and;
2. Existing unit processes of the treatment system continue to be appropriate and effective for the treatment of the source water [to be assessed by the Township].

This report serves as an update to the last raw water assessment which was completed in 2015.

Knowing the quality of the raw source water for municipal drinking water is critical in the multi-barrier approach to protecting municipal source water drinking water. This includes having a good understanding of current conditions and variability, and recent trends. This information will help water treatment plant operators make important decisions regarding treatment processes to ensure safe and high quality municipal drinking water.

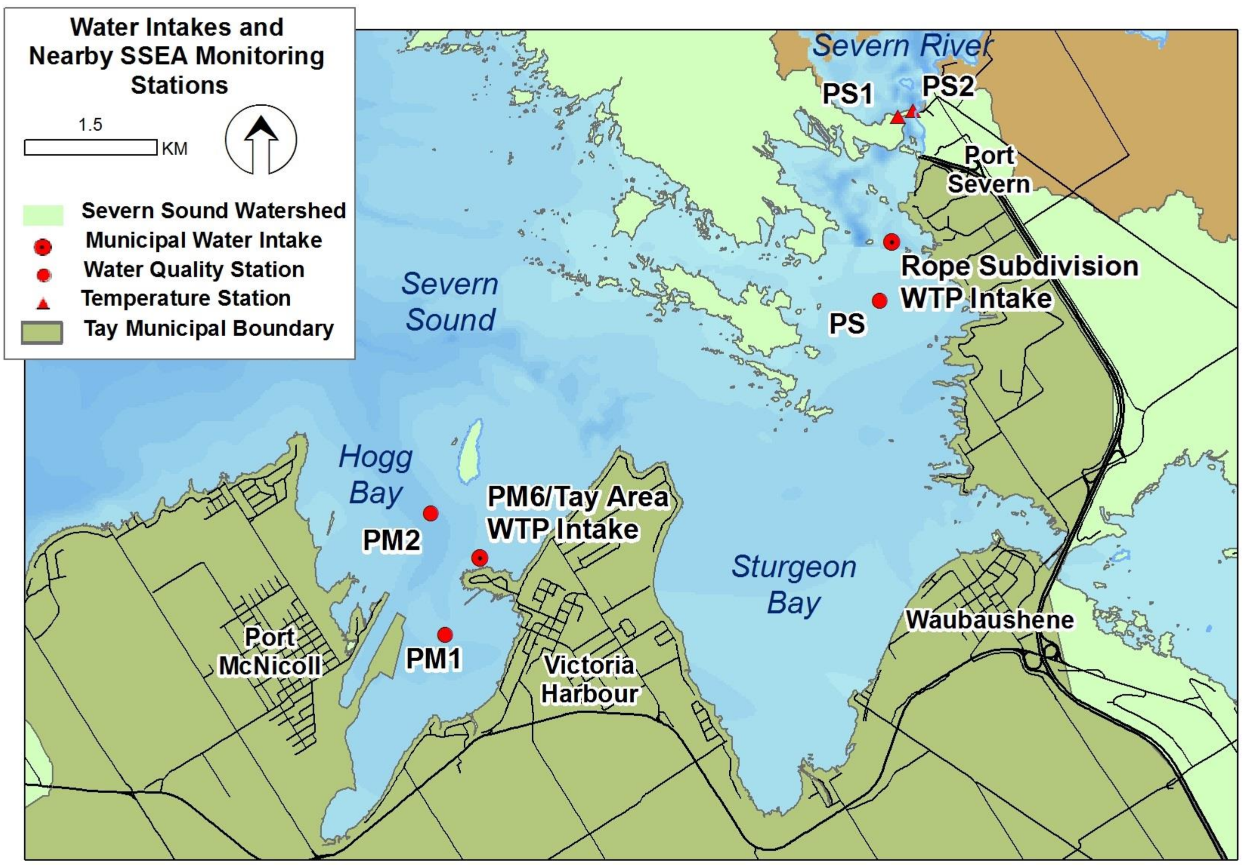
Background

The source of water for the Tay Area Water Treatment Plant (TAWTP) intake is Hogg Bay of Severn Sound, Georgian Bay. This water treatment system serves approximately 8063 people and 141 non-residential users. The inlet to the drinking water system is at an elevation of 171.9 m above sea level and is approximately 100 m off shore, with the intake riser extending 1.23 m above the lakebed. The depth range for the intake opening based on the overall daily minimum and maximum water levels at the Midland gauge from 2015-2019 is 3.1-4.3 m. The area in the vicinity of the intake is relatively shallow, but has good circulation with particularly open exposure to predominating north-west winds.

The source of water for the Rope Subdivision Water Treatment Plant (RSWTP) intake is also from Severn Sound, immediately downstream of the main outlet of the Severn River. This water treatment system serves approximately 70 people. The inlet to the drinking water system is at an elevation of 174.1 m above sea level and is approximately 315 m off shore, with the intake riser extending 0.4 m above the lakebed. The depth range for the intake opening based on the overall daily minimum and maximum water levels at the Midland gauge from 2015-2019 is 1.7-2.9 m. The navigational chart and engineering drawings show that depths in the vicinity are shallower than 2 m throughout most of the area. This and the relatively protected aspect of the area result in slow moving currents, aquatic plant growth and warm water temperatures. The operator of this treatment plant notes that bottom sediments are drawn in following storms (South Georgian Bay-Lake Simcoe Source Protection Committee, 2015).

Sampling Methods

The Severn Sound Environmental Association (SSEA) monitors water quality at open water locations near both intakes (stations PM2, PM1 near the TAWTP and PS near the RSWTP), at the TAWTP (station PM6) (Figure 1). Data from these locations can be used to describe the raw water characteristics for both intakes.



Produced by the Severn Sound Environmental Association with Data supplied in part from the County of Simcoe, the Ontario Ministry of Natural Resources (© Queen's Printer 2015) and under License with Members of the Ontario Geospatial Data Exchange, 2015. Bathymetry for Georgian Bay generated from contour and depth data sourced from Geogratis (Natural Resource Canada) and the National Hydrographic Service of Canada

Figure 1. Tay water intakes and nearest SSEA water quality monitoring stations.

Intake Sampling

Raw water quality from the low lift station has been sampled by SSEA staff since 2011. Sampling occurs on a biweekly basis from May to early October to coincide with open water sampling, and on a monthly basis from November to April. Samples are collected as grab samples, and analyzed for general water chemistry, nutrients, chlorophyll *a* and heavy metals by Ministry of Environment Conservation and Parks (MECP) labs, and algae identification and biomass by independent taxonomists. Testing through the summer months for the taste and odour compounds geosmin and 2-methyl isoborneol (MIB), as well as the blue-green algae toxin microcystin, began in 2016. These analyses were carried out by SGS Ltd. Coinciding with sample collection, field measurements of water temperature, conductivity and pH are also recorded using a Hanna meter. SSEA does not sample the Rope Subdivision intake, however data is available at the nearby open water location PS.

In addition to sampling by SSEA, Township of Tay staff also conduct weekly monitoring and sample both intakes for the following: alkalinity, colour, hardness, temperature, total organic carbon, total suspended solids, turbidity, coliform, and *E. coli*. Geosmin, MIB, and microcystin were also sampled from 2017-2019. Quarterly sampling also includes a suite of heavy metals, pesticides and organic contaminants, which will not be discussed here.

Open Waters – Hogg Bay and Severn River Mouth

Two open water sites in Hogg Bay (PM1, started in 1997 and PM2, started in 1969) and one at the Severn River mouth (PS, started in 1999) are sampled on a biweekly basis from May to early October. Samples are collected as composites from surface down to twice the Secchi depth or 1m off bottom, whichever is less, which approximates the sunlit portion of the water column. Samples are analyzed for general water chemistry, nutrients, chlorophyll *a* and heavy metals by Ministry of Environment Conservation and Parks (MECP) labs, and algae identification and biomass by independent taxonomists. Note that metals and chlorophyll *a* are only analyzed for PM2 and PM6 samples. Coinciding with sample collection, field measurements of water clarity (Secchi depth), water temperature, conductivity and turbidity are also recorded using a Hanna meter.

For algae samples collected at PM2 and PM6, each individual sample was analyzed, while individual samples from PM1 and PS were pooled into a single annual composite sample. Thus, data from PM2 and PM6 can be used to examine seasonal patterns while data from PM1 and PS can be used to examine year to year changes.

Results

Temperature

The annual maximum recorded temperature as measured by municipal staff at the TAWTP from 2015- 2018 ranged from 20 to 24°C. These temperatures were slightly lower than those of the RSWTP raw water, likely due to the more sheltered location of the RSWTP intake. Between 2015-2018, temperatures ranged from 22 to 24°C at the RSWTP. 2019 data were not yet compiled at the time of writing.

Between 2015-2019, temperatures at PM2 at 3-4 m depth and PS at 2-3 m depth have been above the Ontario Drinking Water Standard (ODWS) drinking water aesthetic objective (AO) of 15°C 35% and 36% of the time, respectively (OMOE 2006). These values were obtained by standardizing the portion of the sampling season above the AO to the portion of the year the sampling season makes up.

Long term temperature analyses using Mann Kendall trend tests show that water temperatures across Severn Sound are increasing (Figure 2). At station PM2, the rate of increase in surface water temperature based on data going back to 1969 is 0.4°C per decade. Continued increases in water temperature are expected as regional air temperatures rise.

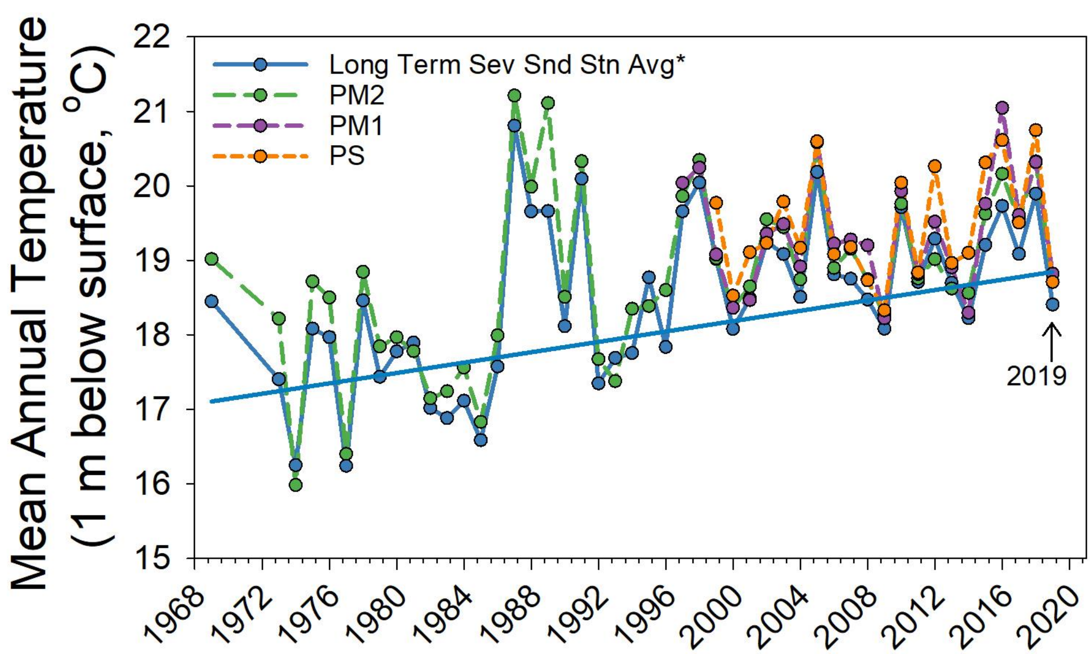


Figure 2. Long term temperature trends based on annual mean temperature at 1m below surface.

General Chemistry

Based on water samples from stations PM1, PM2, PM6 and PS, general water chemistry in the vicinity of the TAWTP and RSWTP intakes was typical of the open waters of Severn Sound (see Table 1). Alkalinity measurements indicated moderately hard water, and were within operational guidelines (OGs), as was pH. Colour was consistently above AOs. Sulphate and chloride both met AOs. While sodium concentrations met the AO, maximum concentrations at all locations exceeded 20 mg/L. The Township is required to report sodium levels exceeding 20 mg/L to the local Medical Officer of Health (MOH) so that this information may be passed on to local medical physicians who can advise individuals on sodium-restricted diets. Biweekly ice-free season turbidity data collected by SSEA does not show exceedances of the AO, however weekly year round data collected by the Township does show exceedances of this objective, indicating that high turbidity events are better captured by higher frequency monitoring. High turbidity events tended to happen during the winter months, and less often in spring and fall. These may increase as climate change results in less ice cover and more frequent storms.

Table 1. General chemistry variables sampled at or in the vicinity of the TAWTP and RSWTP from 2015-2019. Ontario Drinking Water Standards (ODWS) are shown, where applicable, as operational guidelines (OG) or aesthetic objectives (AO). Exceedances are shown in red boldface. Turbidity values from the Township's weekly sampling up to 2018 are also included.

Variable (units)	Location	Minimum	Median	Maximum	Standard Deviation	ODWS
Total Alkalinity (mg/L $CaCO_3$)	PM1	63.5	76.3	86.3	4.9	30-500 (OG)
	PM2	49.3	74.4	79.7	6.1	
	PM6	56.0	75.5	94.2	7.5	
	PS	34.0	72.6	82.8	11.6	
Chloride (mg/L)	PM1	13.4	19.6	27.2	3.4	250 (AO)
	PM2	13.4	19.5	28.1	3.8	
	PM6	13.4	20.1	39.2	4.8	
	PS	10.5	31.4	40.7	8.9	
True Colour (TCU)	PM1	**8.2**	**16.4**	**37.9**	6.9	5 (AO)
	PM2	**7.5**	**15.5**	**46.6**	8.0	
	PM6	**4.8**	**16.8**	**52.9**	10.7	
	PS	**10.3**	**16.4**	**48.6**	8.8	
pH	PM1	7.57	7.96	8.36	0.16	6.5-8.5 (OG)
	PM2	7.49	7.94	8.26	0.15	
	PM6	6.64	7.84	8.19	0.25	
	PS	7.46	7.93	8.43	0.24	
Sodium (mg/L)	PM1	0.70	11.90	**65.40**	7.36	200 (AO)[a]
	PM2	8.20	12.05	**39.60**	4.28	20 (Med.
	PM6	2.01	12.20	**22.40**	3.04	Officer
	PS	5.27	18.05	**26.20**	5.14	notified)
Sulphate (mg/L)	PM1	7.0	9.1	11.4	1.0	500 (AO)
	PM2	6.0	9.4	11.6	1.1	
	PM6	6.4	9.6	13.4	1.5	
	PS	4.9	10.7	12.8	2.2	

Variable (units)	Location	Minimum	Median	Maximum	Standard Deviation	ODWS
Turbidity (NTU)	PM1	0.69	1.48	4.42	0.71	5 (AO)[b]
	PM2	0.78	1.73	3.25	0.53	
	PS	0.44	1.15	1.58	0.31	
	TAWTP	0.13	0.76	**27.70**	2.28	
	RSWTP	0.18	1.37	**28.40**	2.37	

[a] Although the ODWS guideline is 200mg/L, the Medical Officer of Health is notified if surface water to be used for drinking is above 20mg/L.

[b] To ensure sufficient disinfection and filtration, turbidity in filter effluent water should be less than 1 NTU.

In terms of long term trends, sodium and chloride levels across Severn Sound are steadily increasing at each location. This trend that has been observed across the province, and is likely linked to road salt usage. There was no trend in colour, and a slight decrease in pH at both Hogg Bay sites. There has also been a decrease in water clarity since the mid 90’s at both Hogg Bay sites.

Nutrient Chemistry

Nutrients directly relevant to drinking water quality include nitrate, organic nitrogen and dissolved organic carbon (DOC) (Table 2). Between 2015-2019, nitrate+nitrite concentrations were well below the maximum acceptable concentration (MAC). Organic nitrogen (total Kjeldahl nitrogen minus ammonia) was consistently above the OG, and DOC was often above the AO near both intakes.

Table 2. Nutrients relevant for drinking water standards at or in the vicinity of the TAWTP and RSWTP from 2015-2019. Ontario Drinking Water Standards (ODWS) are shown, where applicable, as operational guidelines (OG), aesthetic objectives (AO), or maximum acceptable concentrations (MACs). Exceedances are shown in red boldface.

Variable (units)	Location	Minimum	Median	Maximum	Standard Deviation	ODWS
Nitrate+nitrite (mg/L)	PM1	0.001	0.010	0.254	0.057	10 (MAC)
	PM2	0.001	0.014	0.160	0.043	
	PM6	0.001	0.056	0.442	0.095	
	PS	0.001	0.007	0.100	0.022	
Organic nitrogen (mg/L)	PM1	**0.233**	**0.290**	**0.357**	0.029	0.15 (OG)
	PM2	**0.198**	**0.286**	**0.356**	0.033	
	PM6	**0.181**	**0.283**	**0.375**	0.041	
	PS	**0.242**	**0.340**	**0.401**	0.032	
DOC (mg/L)	PM1	3	4.6	**6.7**	0.7	5 (AO)
	PM2	2.8	4.6	**6.6**	0.7	
	PM6	0.5	4.5	**8.2**	1.1	
	PS	3.9	**5.1**	**6.4**	0.5	

Severn Sound is considered a mesotrophic, or moderately enriched, water body. Following completion of the Severn Sound Remedial Action Plan (Sherman 2002) and substantial completion of actions to satisfy the phosphorus control strategy (accepted by the federal and provincial governments in 2003), the quality of the open water near both intakes has been meeting most of the RAP targets for trophic indicators. Since 2015, mean annual ice-free values of total phosphorus concentration (TP) have been less than 15 µg/L. Chlorophyll *a* concentrations have been less than 5 µg/L, however water clarity values at PM1 and PM2 have not met the target of 3 m. The clarity target has been met at station PS.

Over the long term, there has been a decrease in organic nitrogen at PM2 since 1969 and PS since 1992, and a decrease in DOC at PS since 2010.

Heavy Metals

Concentrations of trace metals that have associated ODWS showed no exceedances of MACs, and values were generally an order of magnitude or more below the MACs for waters near the TAWTP (Table 3). Maximum concentrations of aluminum and iron occasionally exceeded the ODWS, although median values are well below the standards. Metals were not analyzed for samples from station PS.

Table 3. Trace metal concentrations at or in the vicinity of the TAWTP from 2015-2019. Ontario Drinking Water Standards (ODWS) are shown, as operational guidelines (OG), aesthetic objectives (AO), maximum acceptable concentrations (MACs), or interim maximum acceptable concentrations (IMACs). Exceedances are shown in red boldface. SSEA collected ice-free season biweekly samples at PM2 and PM6 (TAWTP), and monthly samples at PM6 during the winter.

Variable (units)	Location	Minimum	Median	Maximum	ODWS
Aluminum (µg/L)	PM2	4.4	15.75	82.3	100 (OG)
	PM6	4.8	14.95	**192**	
Antimony (µg/L)	PM2	0*	0.1*	0.4	6 (IMAC)
	PM6	0*	0.1*	0.1*	
Arsenic (µg/L)	PM2	0.2*	0.4	0.7	25 (IMAC)
	PM6	0.2*	0.4	0.6	
Barium (µg/L)	PM2	18.2	21.75	27.3	1000 (MAC)
	PM6	19.4	22.75	28.7	
Boron (µg/L)	PM2	8	12	16	5000 (IMAC)
	PM6	8	12	16	
Cadmium (µg/L)	PM2	0*	0*	0*	5 (MAC)
	PM6	0*	0*	0*	
Chromium (µg/L)	PM2	0*	0.2*	0.9	50 (MAC)
	PM6	0*	0.2*	0.9	
Copper (µg/L)	PM2	0*	0.65	29.9	1000 (AO)
	PM6	0.8	1	9.8	
Iron (µg/L)	PM2	0*	30	180	300 (AO)
	PM6	20	60	**440**	
Lead (µg/L)	PM2	0*	0.1*	0.3	10 (MAC)
	PM6	0*	0.1*	1.4	
Manganese	PM2	2.9	11.3	30.2	50 (AO)

(µg/L)	PM6	1.1	8.9	38.9	
Selenium	PM2	0*	0.1*	0.5	10 (MAC)
(µg/L)	PM6	0*	0.1*	0.5	
Uranium	PM2	0.1*	0.2*	0.2*	20 (MAC)
(µg/L)	PM6	0.1*	0.2*	0.3	
Zinc	PM2	0.5*	0.9	13.2	5000 (MAC)
(µg/L)	PM6	1.0	2.0	15.4	

* Less than or equal to the value of the uncertainty level for the analysis.

There have been no appreciable trends in the metals highlighted in the above table.

Bacteria

Weekly raw water *E. coli* data collected between 2015-2019 by municipal staff at the TAWTP and RSWTP showed that all raw water samples had densities less than 100 colony forming units (CFU)/100 mL on any given sampling day, and geometric annual mean *E. coli* of less than 1 (Table 4). For each year from 2015-2019, between 29-56% of samples at the TAWTP and 33-60% of samples at the RSWTP had densities greater than zero. Overall, the bacteria load, as determined by *E. coli* as an indicator, at both intakes is relatively low, and is similar at both intakes.

Table 4. *E. coli* densities in raw water at the TAWTP and RSWTP from 2015-19. Geomean calculations cannot include values of zero, so where *E. coli* densities were zero, a value of 0.001 was substituted. Also shown are annual maximum densities and the percentage of samples with densities greater than zero. *n* = number of samples taken, *E. coli* density units in CFU/100 ml.

Plant	Year	Geomean *E. coli*	Maximum *E. coli*	% of Samples >0	*n*
TAWTP	2015	0.05	71	47	53
	2016	0.03	96	44	52
	2017	0.09	20	56	52
	2018	0.05	46	48	50
	2019	0.01	7	29	48
RSWTP	2015	0.09	24	56	52
	2016	0.03	31	44	52
	2017	0.01	20	33	52
	2018	0.10	9	60	43
	2019	0.03	20	44	45

Nuisance Algae and Algal Compounds

Algae are a natural and essential part of all lake ecosystems, and a balanced algal community includes species from a variety of groups. When triggered by conditions related to water temperature, wind and light conditions and nutrients, individual species can dominate the community and form a bloom. When blooms of algal species that produce taste and odour compounds or toxins like microcystin occur, this can have negative impacts on drinking water in terms of aesthetic quality and safety.

Data from 2012-2016 were used in this analysis since all algae samples were processed by the same taxonomist. Beginning in 2017, a different taxonomist was used, and work is ongoing to standardize the data so that it is comparable to the previous taxonomist. Overall, the total biovolume of algae (a measure of biomass in units of mm^3 of algal cell volume per m^3 of water) at PM1, PM2, PM6 and PS from 2012-2016 was considered low to moderate, depending on the time of year. Peaks in the total amount of algae occur in mid to late summer. In terms of composition, the community was generally well balanced, although data from PM2 and PM6 showed that certain groups dominated at different times of the year (Figure 3).

Open water samples were compared with samples collected at the TAWTP taken on the same date and approximately the same time. Generally, total biovolume of algae was higher in the open waters than from the intake. The maximum biovolume for individual samples between 2012-2016 at PM2 was 1,191 mm^3/m^3 compared to 554 mm^3/m^3 at PM6. On average, intake samples contain 41% less algae biomass compared to open water samples. This is likely due to the fact that open water samples are collected as composites from the entire sunlit portion of the water, compared to the intake which draws water from a lower depth and a narrow portion of the water column.

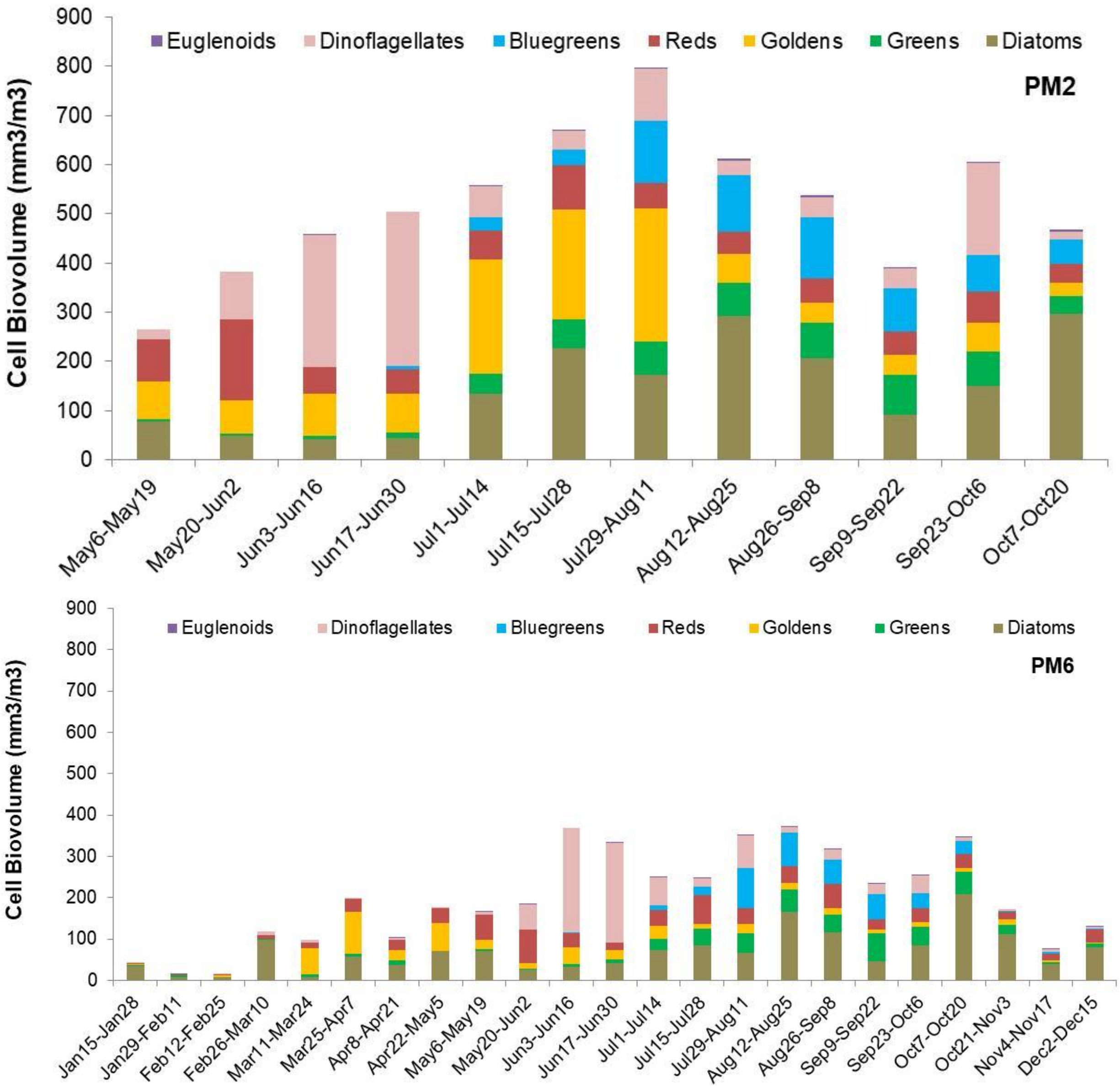


Figure 3. Seasonal algae biovolume by major algal classes from 2012-2016 for PM2 and PM6. Seasonal values were averaged over each biweekly period.

In the vicinity of the RSWTP, the maximum annual total biovolume was 323 mm^3/m^3 at PS (pooled annual count) between 2012-2016 (Appendix D). Biovolume is less at this location compared to PM2, possibly due to increased water currents.

Algae taxa known to cause adverse taste and odours in drinking water were noted such as the diatoms *Stephanodiscus* and *Fragilaria*, the chrysophytes *Chrysosphaerella,* and *Dinobryon*, and the blue-green algae *Mirocystis and Dolichospermum (Anabaena)*. Relatively high biovolumes (>100 mm^3/m^3) of *Stephanodiscus, Dinobryon* and *Mirocystis* occurred in TAWTP intake samples. A sum of all taste and odour causing taxa from each sampling date from 2012-2016 showed a maximum of 528 mm^3/m^3 and

292 mm^3/m^3 or 79% and 94% of the total biovolume at PM2 and PM6, respectively. In terms of seasonality, peaks in taste and odour causing taxa can vary widely, and can occur during the winter months as seen in 2012 (Figure 4). More often, peaks anywhere from July to September, which corresponds to peaks seen in geosmin and MIB.

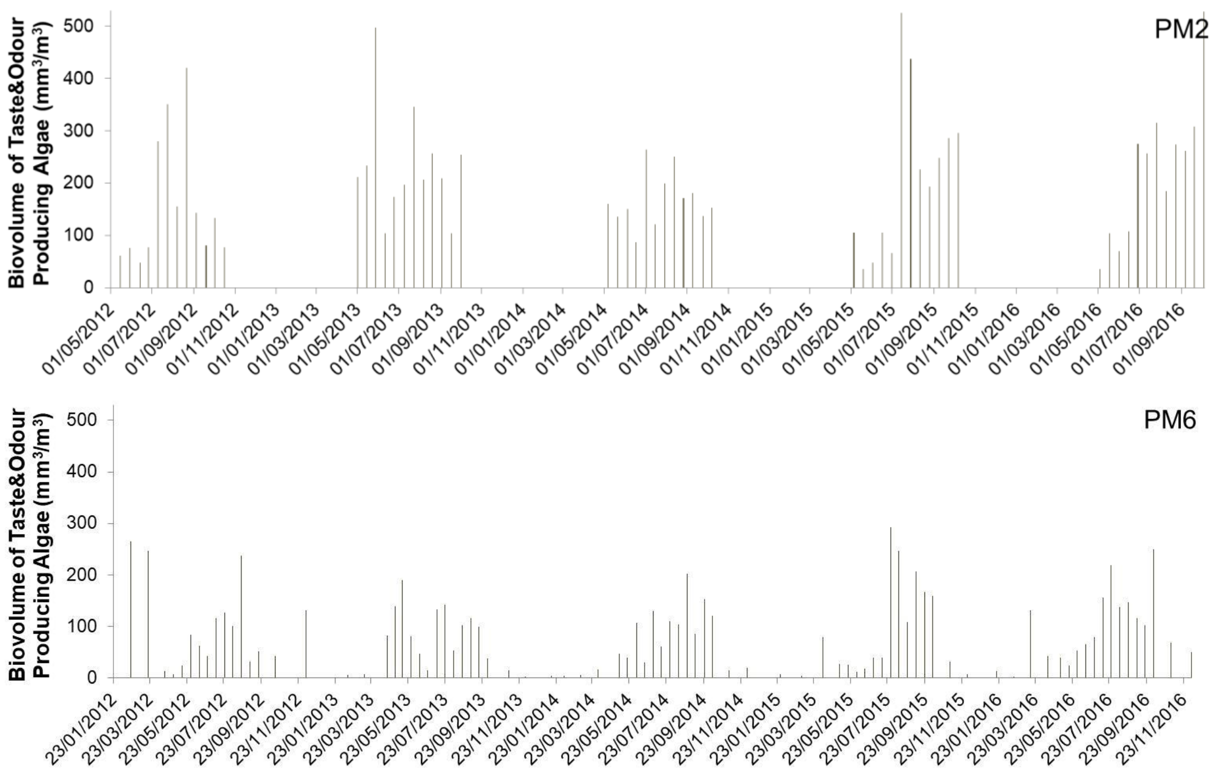


Figure 4. Biovolume of common taste and odour causing algae for PM2 and PM6 from 2012-2016.

Algae that have the potential to produce toxins were also noted, namely blue-green algae that produce microcystins including: *Aphanizomenon, Dolichospermum, Planktothrix, Pseudanabaena,* and *Microcystis* (Health Canada, 2018). Biovolume of these genera were generally low based on data from each sampling date from 2012-2016, but did collectively reach a maximum of 226 mm^3/m^3 and 191 mm^3/m^3 or 27% and 39% of the total biovolume at PM2 and PM6, respectively (Figure 5). Peaks in biovolume occurred anywhere from late July to early September, which corresponds to when microcystin concentrations were detectable.

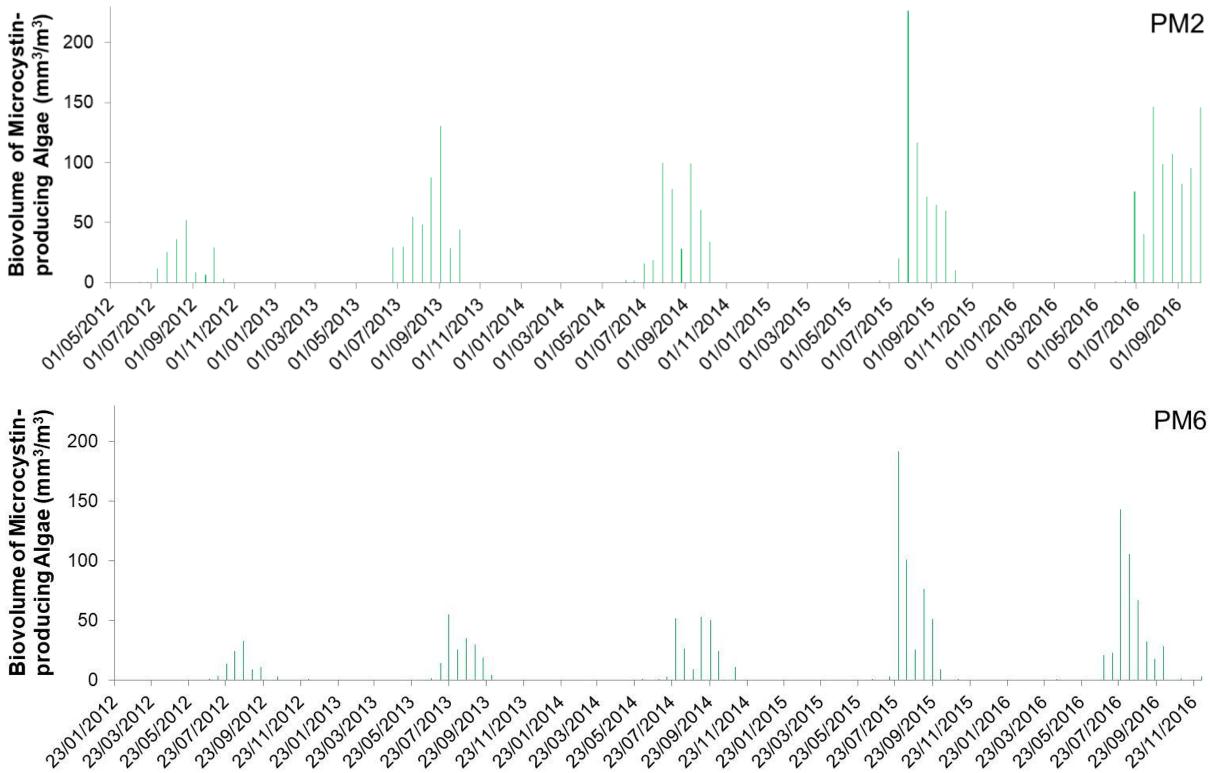


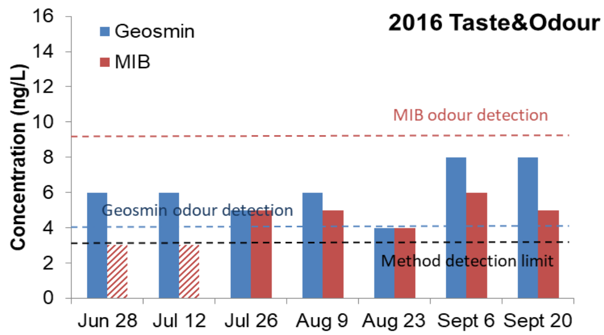
Figure 5. Biovolume of common microcystin-producing blue-green algae, including *Aphanizomenon*, *Dolichospermum, Planktothrix, Pseudanabaena*, and *Microcystis* for PM2 and PM6 from 2012-2016.

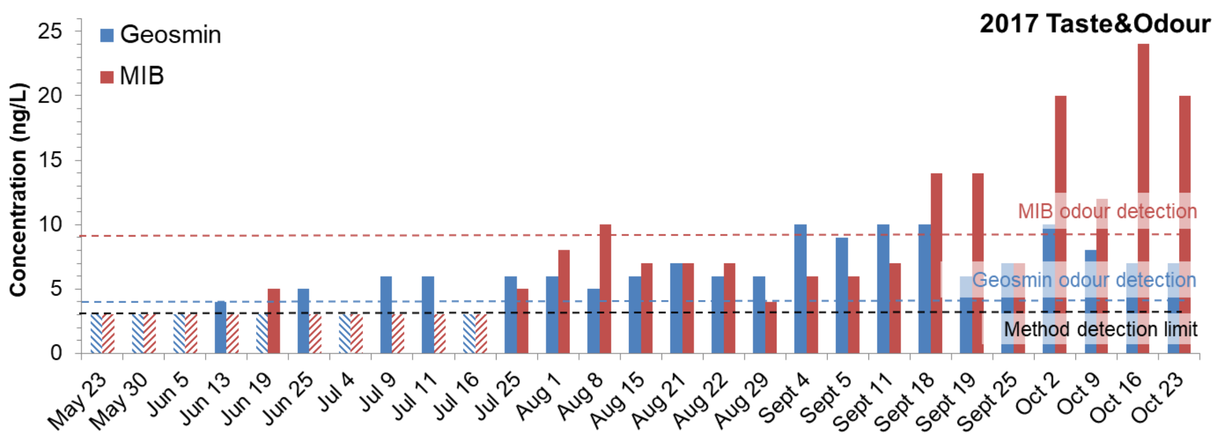
Analysis of long term trends in algae biovolume using a Mann Kendall trend test shows that the amount of algae at PM1, PM2 and PS has increased since the mid 90's (Appendix E). The proportion of golden algae, which includes many taxa that can cause taste and odour issues, has increased at all locations, and the proportion of dinoflagellates which also includes taxa that can cause taste and odour issues, has increased at PM1 and PS. The proportion of blue-green algae has also increased at PM2, but not the other two stations. Changes in the algal community may have implications for the severity and nature of taste and odour events.

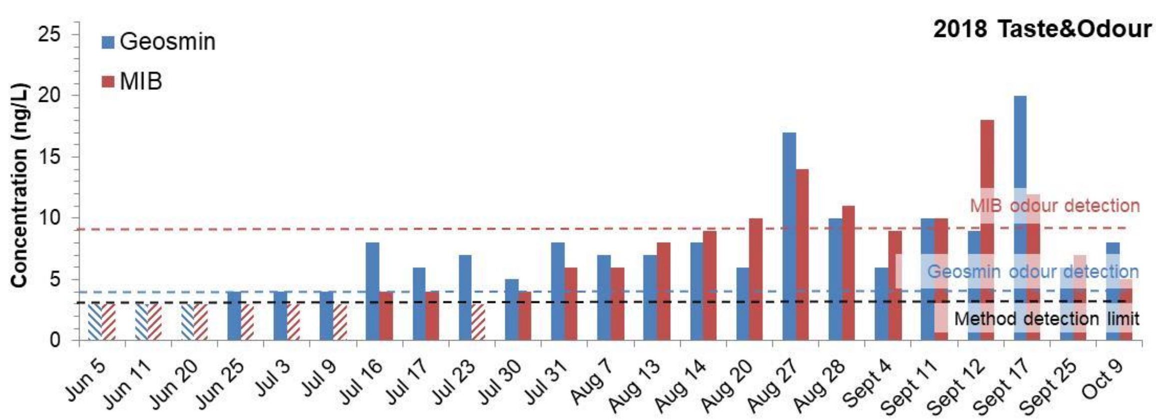
Taste and Odour

Many species of algae produce compounds that impart an objectionable taste or odour to drinking water. Two of these compounds are geosmin and MIB, which are detected as an earthy taste and odour, and are typically produced by blue-green algae and actinomycetes (Watson et al., 2000). While there are no specific ODWSs for these compounds, they are detectable by the average person at thresholds of 4 ng/L and 9 ng/L, respectively, and the ODWS states that "water provided for public consumption should have an inoffensive taste."

Results from 2016-2019 show that geosmin is often above 4 ng/L beginning in mid-June, and MIB is often above 9 ng/L beginning in mid-July at the TAWTP (Figure 6) and the RSWTP (Figure 7). Geosmin concentrations remain above the odour threshold longer than MIB, and persisted as late as November in 2019. It should be noted that in 2019, the Township undertook a study to investigate water treatment options for removing geosmin and MIB, the results of which are being considered for implementation.







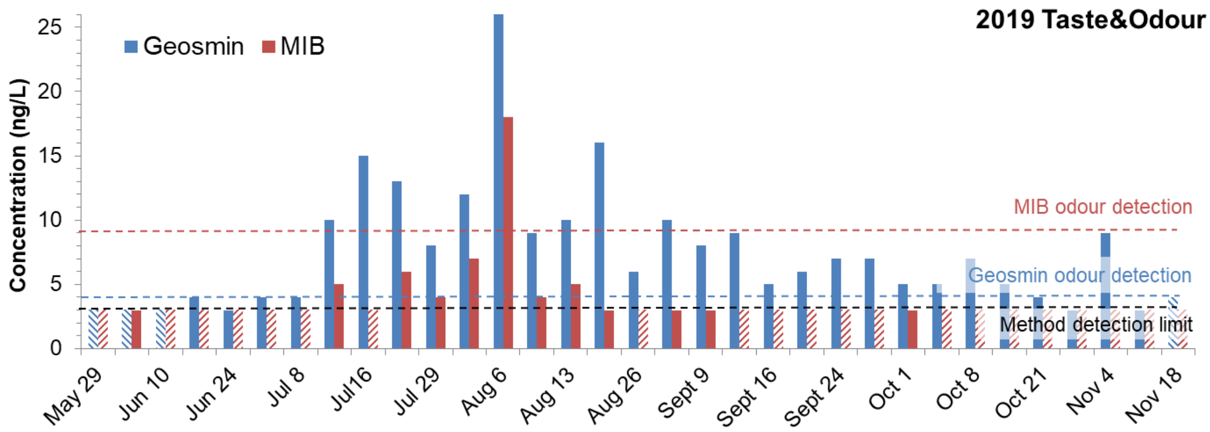
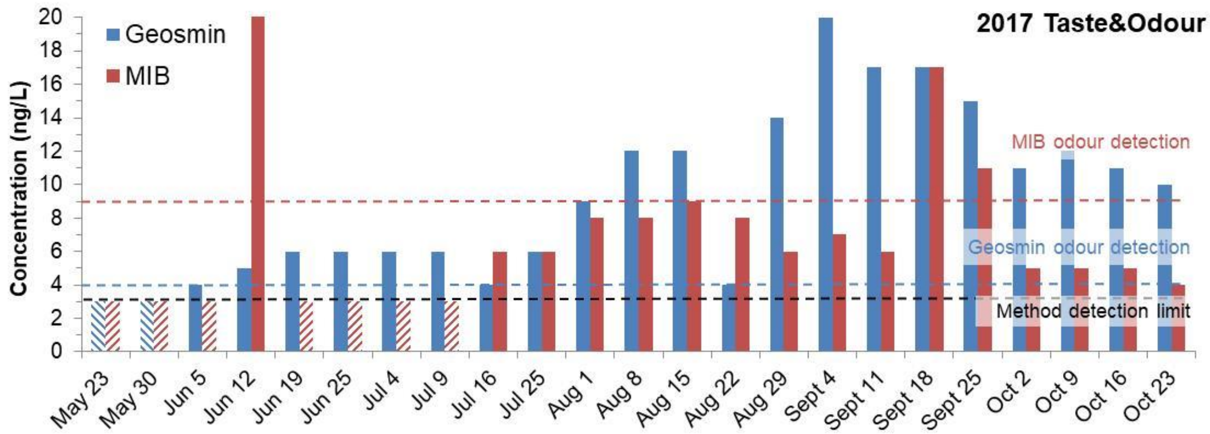
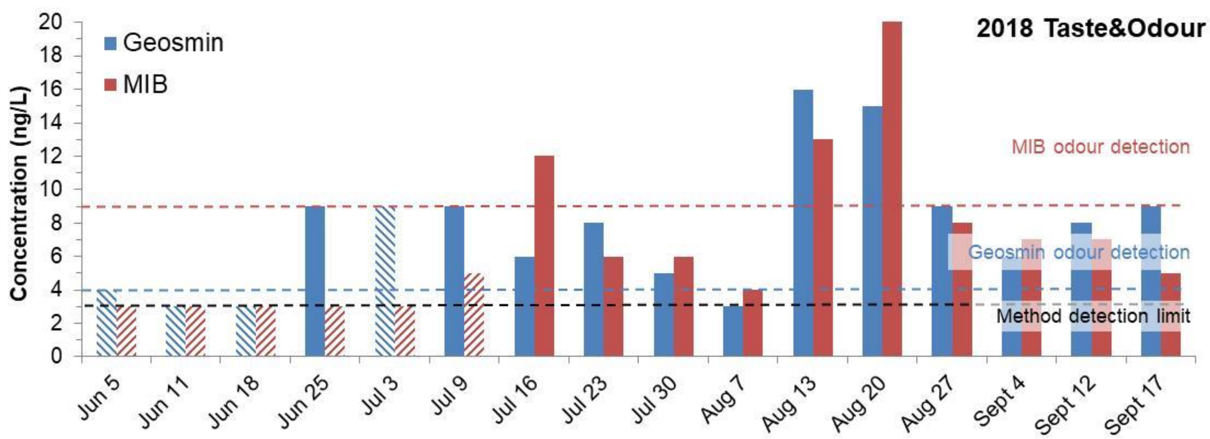


Figure 6. Taste and odour concentrations at the TAWTP raw water intake from 2016-2019. The 2017-2019 graphs includes results from Township as well as SSEA sampling.





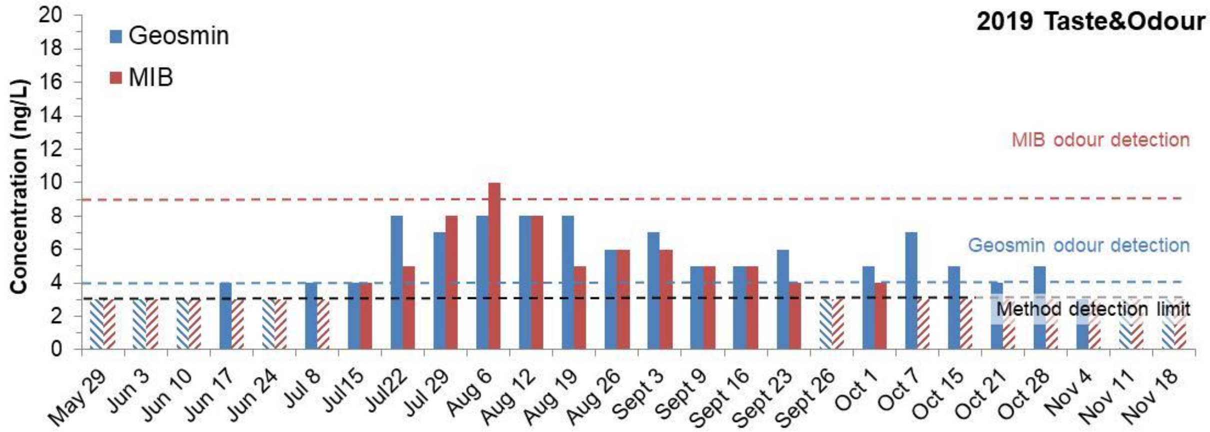
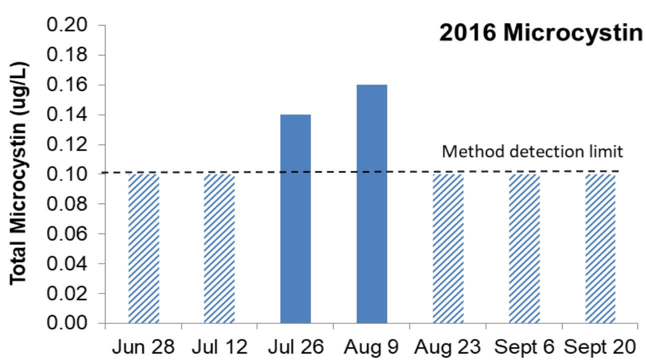


Figure 7. Taste and odour concentrations at the RSWTP raw water intake from 2017-2019 based on Township sampling.

Microcystin

Microcystins are a class of algal toxins produced by numerous species of blue-green algae. In high enough concentrations, they can have negative effects on human health. Fortunately, concentrations of total microcystin at both intakes were very low. At the TAWTP from 2016-2019, levels were generally below method detection limit (Figure 8). On occasions where concentrations were detectable, they did not exceeded 0.2 µg/L. Throughout 2019 at the RSWTP, levels were below method detection limit. The ODWS is for a specific type of microcystin called microcystin-LR, and the standard is 1.5 µg/L. Thus, all results for total microcystin at both intakes meet this standard.



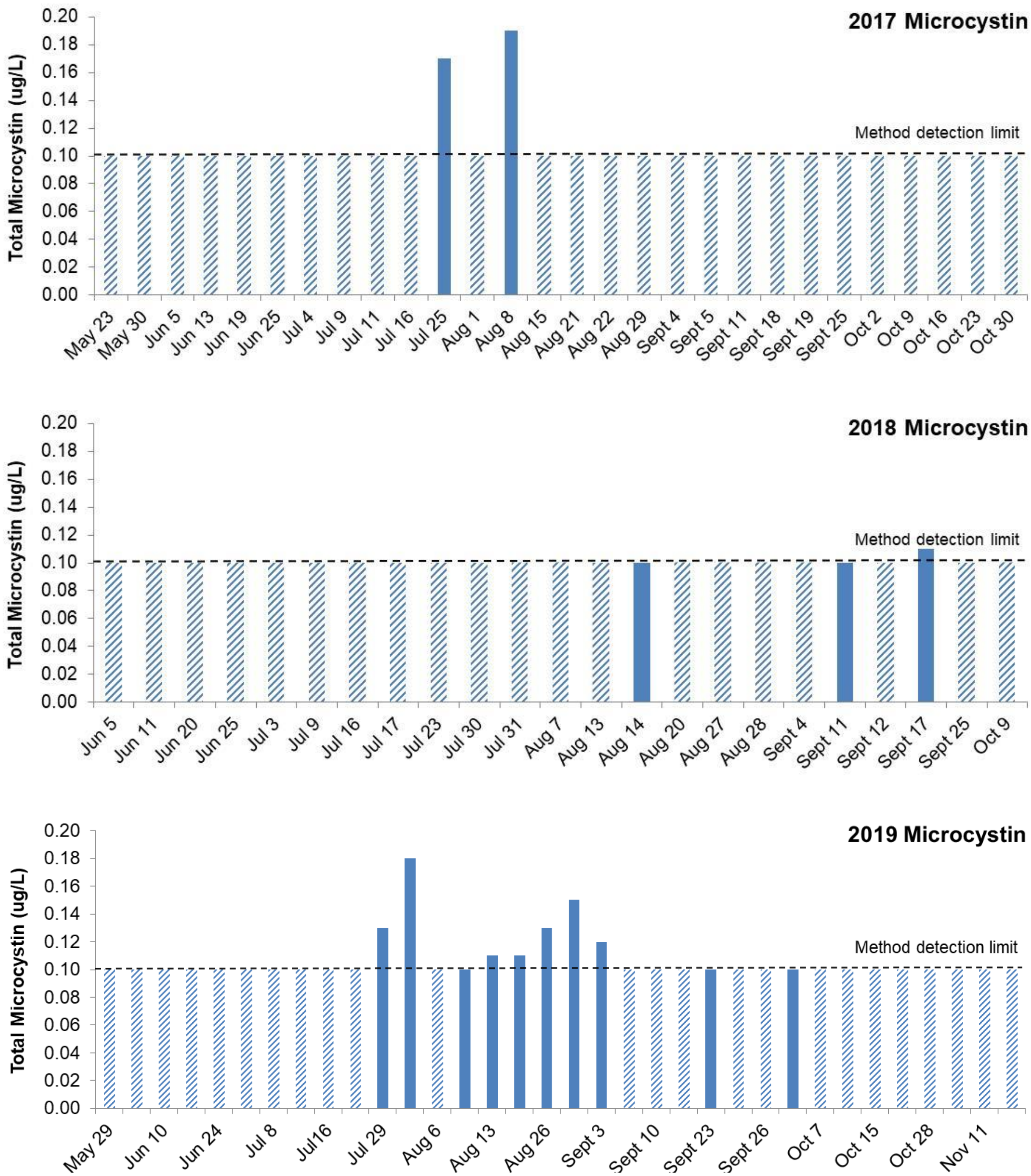


Figure 8. Microcystin concentrations at the TAWTP raw water intake from 2016-2019. The 2017-2019 graphs includes results from municipal as well as SSEA sampling. All samples from the RSWTP had concentrations <0.1 µg/L, so a graph was not included.

Potential for Event-driven Fluctuations in Water Quality

Modelling of water current speed and direction in the vicinity of the TAWTP showed that currents could move along shore in either direction at the intake location but tend to move more strongly and persistently from the west-northwest (Hodgins 2009). The approved Severn Sound Assessment Report (SSAR) for the Severn Sound Source Protection Area defined an event-based Intake Protection Zone 3 (IPZ3) for the TAWTP intake (SGBLSSPC 2015, Figure 9), which shows that parts of Hogg Bay west of the intake have greater potential impact from a fuel spills perspective. It follows that an algae bloom within the same IPZ3 area could similarly affect the intake more quickly than from other parts of the bay. At the RSWTP, the currents are generally strongly directed downstream from the mouth of the Severn River at the intake. For both intakes, it is important to reiterate the value of spill contingency planning through documents such as the Township's QMS Operational Plan, due to water movement and vulnerability of the intakes due to their shallow depths.

Existing Significant Drinking Water Threats have been identified in the SSAR following a risk assessment and threat confirmation exercise for both intakes. Due to the locations of the intakes, severe turbidity episodes are unlikely. Both intakes are located near pleasure craft channels. The RSWTP intake is located downstream of the Port Severn Sewage Treatment Plant (STP) (District of Muskoka) and the bridge crossing the Severn River downstream of the dam at Lock 45 (Trent Severn Waterway) at the main outlet of the Severn River into Severn Sound. Dispersion and current modelling studies carried out at Port Severn (Gore and Storey, 1998) indicated that the RSWTP intake would not be significantly impacted by the Port Severn STP discharge.

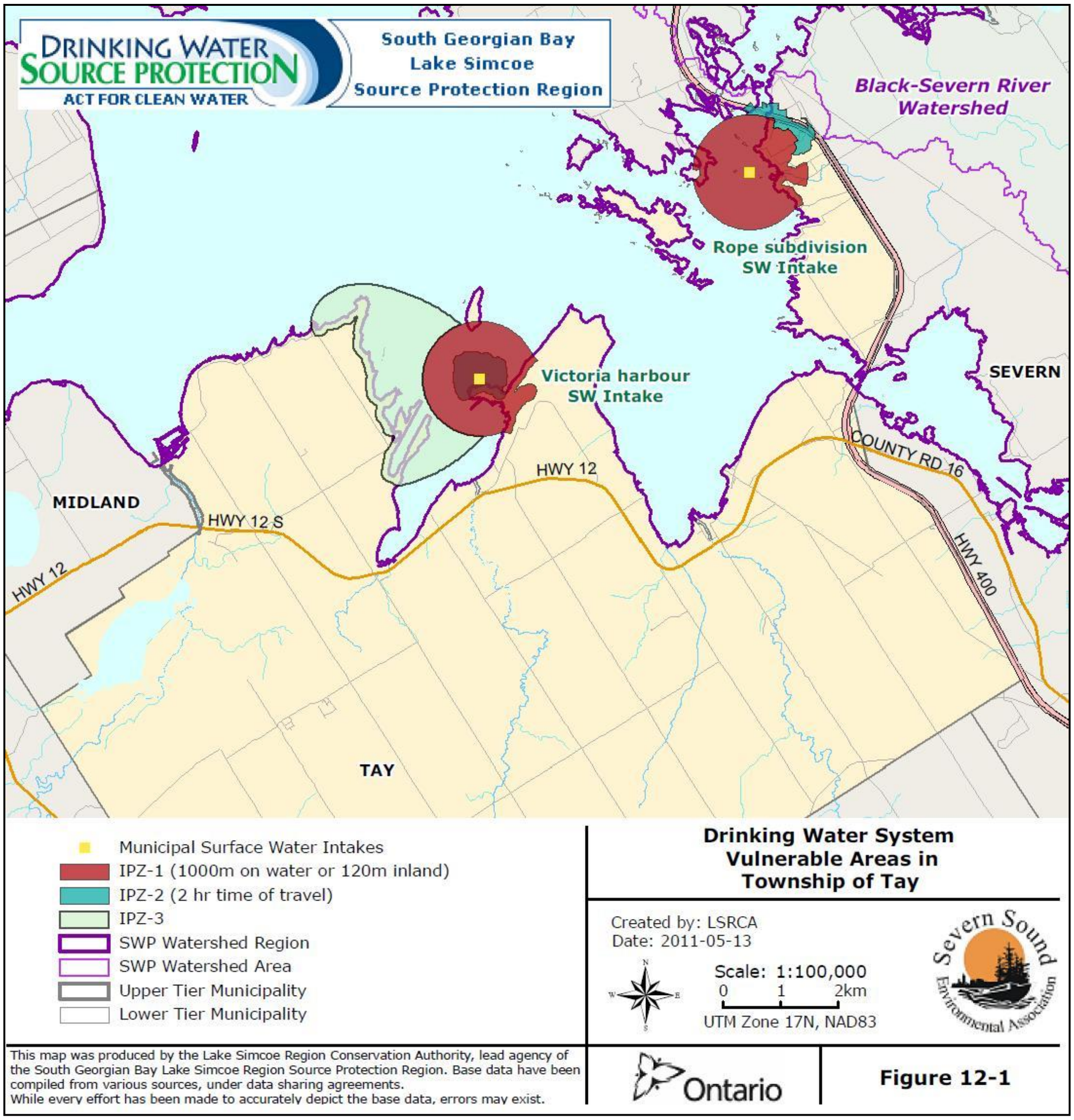


Figure 9. Location of drinking water intakes in Tay Township, as well as intake protection zones 1-3 (South Georgian Bay-Lake Simcoe Source Protection Committee, 2015).

Summary

Water quality characteristics were assessed for the Tay Area WTP (TAWTP) and Rope Subdivision WTP (RSWTP) over the period of 2015-2019 in support of the Township's drinking water license renewal at both treatment plants. In summary:

- At both intakes, Operational Guidelines (OGs) for alkalinity and pH were consistently met, however the OGs for organic nitrogen was consistently not met
- The Maximum Acceptable Concentration (MAC) for nitrate was consistently met at both intakes

- At both intakes, Aesthetic Objectives (AOs) for sodium, chloride and sulphate were consistently met, however AOs for temperature, colour, turbidity and dissolved organic carbon were often or consistently not met
- While the AO for sodium was met, values at both intakes often exceeded 20 mg/L, which necessitates the local Medical Officer of Health being notified
- Concentrations of all metals with Ontario Drinking Water Standards (ODWS) were low and consistently met MACs, with the exception of aluminum and iron which occasionally exceeded AOs at the TAWTP
- *E. coli* densities were generally low, and never exceeded 100 CFU/100 mL at either intake
- Algae biomass is low to moderate in the vicinity of both intakes depending on the time of year, with peaks in mid to late summer
- Nuisance algae taxa that cause taste and odour and produce microcystin toxins are present, however taxa producing microcystin are not in high abundance
- Taste and odour compounds were measurable at both intakes, often at levels that can be detected by the average person, and were highest in mid to late summer, coinciding with the highest seasonal algae biovolumes
- Total microcystin concentrations at both intakes were low, and met the ODWS
- Water quality data from the open water sites PM1, PM2 and PS were invaluable as indicators of general characteristics of the source waters for both water intakes, from which trends and current conditions were described

A summary of trends shows that for many water quality parameters, quality has improved since the last assessment period from 2010-2014 (Table 5). Those that have worsened include sodium and chloride at all sites, and sulphate at PS.

Table 5. Summary of medians over each period, 2010-2014 and 2015-2019 along with the direction of change using a 2-sample Wilcoxon test. Cells coloured in blue indicated beneficial change, while cells in red indicate unfavourable change in terms of ODWS. Uncoloured cells indicate no change or one that is neutral in impact. Note that *E. coli* results apply to the TAWTP (PM6) and RSWTP (listed under PS). DOC – dissolved organic carbon

Parameter	PM1 2010-2014	PM1 2015-2019	PM1 Trend	PM2 2010-2014	PM2 2015-2019	PM2 Trend	PM6 2010-2014	PM6 2015-2019	PM6 Trend	PS 2010-2014	PS 2015-2019	PS Trend
Alkalinity mg/L ($CaCO_3$)	70.65	76.30	inc	68.80	74.35	inc	70.50	75.50	inc	60.55	72.60	inc
Chloride (mg/L)	15.70	19.60	inc	16.10	19.50	inc	17.21	20.10	inc	20.40	31.40	inc
Colour (TCU)	15.60	16.40	no	14.20	15.45	no	20.10	16.80	no	21.00	16.40	dec
Sodium (mg/L)	10.15	11.90	inc	10.40	12.05	inc	11.70	12.20	inc	14.20	18.05	inc
pH	8.06	7.96	dec	8.04	7.94	dec	7.91	7.84	dec	7.88	7.93	no

Parameter	PM1 2010-2014	PM1 2015-2019	PM1 Trend	PM2 2010-2014	PM2 2015-2019	PM2 Trend	PM6 2010-2014	PM6 2015-2019	PM6 Trend	PS 2010-2014	PS 2015-2019	PS Trend
Sulphate (mg/L)	9.75	9.08	dec	10.10	9.40	no	10.10	9.60	no	8.60	10.65	inc
DOC (mg/L)	4.70	4.60	no	4.70	4.60	no	5.00	4.50	dec	5.45	5.10	dec
Organic Nitrogen (µg/L)	298	290	dec	286	286	no	301	283	dec	342	340	no
Secchi depth (m)	3.1	3.1	no	2.8	3.0	no	n.a.	n.a.	n.a.	3.2	3.9	inc
Temp. 1m off bottom (°C)	19.3	20.4	no	17.3	18.9	no	16.7	16.2	no	20.0	20.3	no
E. coli CFU/100mL	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2	0	dec	1	0	dec

Recommendations

In order to continue supporting the Township and providing valuable information on raw water conditions for the TAWTP and RSWTP, SSEA recommends the following:

- Tay Township continue weekly raw water sampling at both intakes, and include geosmin and MIB sampling at least from May-October. Given the low values, routine microcystin sampling may not be necessary. Instead, it is recommended that:
  a) sampling be conducted biweekly when microcystin tended to be detectable (July-September) OR
  b) the Township and SSEA staff visually monitor the surface waters around both intakes for blue-green algae blooms, and test for total microcystin if blooms are suspected
- Township continue supporting SSEA-led raw water sampling at the TAWTP for general water chemistry, nutrients and algae
- Township continue supporting SSEA open water sampling in Hogg Bay (PM1, PM2) and Severn River mouth (PS) locations. Data from these stations are critical in being able to describe trends, current conditions, and predict future water quality conditions that will influence both drinking water intakes
- Maintain communications on both sampling programs to ensure no overlap in sample analysis, and continued data sharing
- Continue to ensure that spill contingency plans are in place and up-to-date, and are reviewed regularly

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Appendix A – Recent water quality summary statistics, 2015-2019

Station	Year	Statistic	Total Alkalinity mg/L $CaCO_3$	Gran Alkalinity mg/L $CaCO_3$	Conductivity µS/cm	pH	Silicate mg/L	Calcium mg/L	Chloride mg/L	Potassium mg/L	Magnesium mg/L	Sodium mg/L	Sulphate mg/L
PM1	2015	Min	69.6	67.8	198	7.87	1.38	21.8	13.4	0.93	4.77	8.45	7.5
PM1	2015	Median	78.6	76.9	218	8.02	1.63	24.6	16.4	1.06	5.50	10.25	8.6
PM1	2015	Max	82.3	80.7	238	8.22	2.00	27.5	19.6	1.30	6.06	12.10	10.4
PM1	2015	StDev	3.9	4.2	12	0.13	0.19	1.7	1.7	0.12	0.39	1.08	0.9
PM1	2016	Min	63.5	61.9	192	7.57	0.74	21.5	15.2	0.88	4.39	9.43	7.0
PM1	2016	Median	69.4	67.9	213	7.90	1.20	23.2	17.1	1.02	5.08	10.65	8.2
PM1	2016	Max	70.6	68.9	224	8.31	1.52	23.9	18.9	1.17	5.82	12.50	9.6
PM1	2016	StDev	2.0	2.0	8	0.20	0.27	0.8	1.1	0.10	0.41	0.85	0.7
PM1	2017	Min	66.0	64.6	211	7.85	1.00	23.2	16.7	0.06	0.29	0.70	7.7
PM1	2017	Median	78.0	76.5	251	7.94	1.40	27.0	23.3	1.27	5.80	14.00	9.5
PM1	2017	Max	82.5	81.5	264	8.23	2.04	83.4	26.4	4.70	16.40	65.40	10.4
PM1	2017	StDev	5.0	5.0	19	0.11	0.30	16.5	3.3	1.09	3.65	15.86	0.9
PM1	2018	Min	71.3	69.6	230	7.74	1.20	24.2	19.5	1.07	5.11	11.00	8.2
PM1	2018	Median	76.4	74.7	235	7.84	1.55	26.5	20.7	1.24	5.98	12.65	9.7
PM1	2018	Max	86.3	85.4	257	8.36	1.84	29.6	24.7	1.34	6.63	15.30	11.4
PM1	2018	StDev	4.2	4.4	9	0.20	0.21	1.4	1.4	0.09	0.48	1.07	1.0
PM1	2019	Min	67.2	65.8	209	7.86	0.72	24.0	18.0	1.11	4.57	9.30	7.3
PM1	2019	Median	77.5	76.0	247	8.02	1.12	26.1	23.3	1.21	5.72	13.75	9.2
PM1	2019	Max	80.2	79.0	266	8.26	1.84	27.5	27.2	1.31	6.08	16.70	10.0
PM1	2019	StDev	3.9	4.0	17	0.11	0.35	1.0	3.0	0.06	0.48	2.20	0.9
PM2	2015	Min	67.8	66.0	193	7.85	1.32	21.4	13.4	0.93	4.64	8.20	7.8
PM2	2015	Median	75.3	73.3	212	8.00	1.58	24.4	16.0	1.04	5.29	9.91	8.7
PM2	2015	Max	79.7	78.2	230	8.11	1.96	27.2	19.2	1.22	6.05	12.50	10.4
PM2	2015	StDev	4.1	4.2	12	0.09	0.17	1.5	1.6	0.09	0.38	1.17	0.9
PM2	2016	Min	57.9	57.0	187	7.49	0.64	19.4	15.4	0.92	3.91	9.51	7.5
PM2	2016	Median	68.4	66.8	211	7.88	1.18	22.9	16.8	1.02	5.11	10.65	8.5
PM2	2016	Max	74.4	72.7	241	8.09	1.48	25.7	21.2	1.18	5.87	13.70	9.7
PM2	2016	StDev	4.1	3.9	13	0.16	0.29	1.5	1.7	0.09	0.54	1.14	0.6
PM2	2017	Min	63.3	62.2	196	7.77	0.92	21.4	15.6	0.99	4.21	10.20	7.6

Station	Year	Statistic	Total Alkalinity mg/L $CaCO_3$	Gran Alkalinity mg/L $CaCO_3$	Conductivity µS/cm	pH	Silicate mg/L	Calcium mg/L	Chloride mg/L	Potassium mg/L	Magnesium mg/L	Sodium mg/L	Sulphate mg/L
PM2	2017	Median	75.3	74.0	249	7.95	1.30	26.8	23.9	1.32	5.81	14.30	10.1
PM2	2017	Max	79.2	78.1	269	8.09	1.76	76.2	28.1	3.02	10.80	39.60	10.8
PM2	2017	StDev	6.1	6.1	25	0.09	0.24	14.9	3.6	0.54	1.73	7.68	1.1
PM2	2018	Min	71.0	69.4	223	7.67	1.24	24.3	17.7	1.06	5.04	10.20	8.6
PM2	2018	Median	76.3	74.9	235	7.82	1.44	26.8	20.9	1.24	5.76	12.65	10.0
PM2	2018	Max	78.8	76.6	264	8.26	1.76	28.5	26.2	1.35	6.62	16.60	11.6
PM2	2018	StDev	2.6	2.6	12	0.18	0.19	1.5	2.8	0.09	0.50	1.81	1.0
PM2	2019	Min	49.3	48.0	159	7.68	0.70	17.3	14.7	0.95	3.29	8.39	6.0
PM2	2019	Median	75.3	73.8	240	8.02	0.98	25.5	21.6	1.20	5.52	13.05	9.5
PM2	2019	Max	77.0	75.7	261	8.15	1.76	26.8	26.8	1.31	6.04	16.70	10.5
PM2	2019	StDev	9.2	9.2	31	0.14	0.32	3.3	3.7	0.12	0.92	2.56	1.4
PM6	2015	Min	67.3	65.5	200	7.69	1.32	22.1	13.4	0.98	4.96	8.41	7.3
PM6	2015	Median	75.0	73.8	213	7.97	1.60	24.4	16.9	1.07	5.25	10.35	8.5
PM6	2015	Max	80.2	79.6	230	8.13	1.92	26.5	19.0	1.20	6.09	11.70	10.5
PM6	2015	StDev	4.0	4.2	10	0.12	0.16	1.4	1.7	0.09	0.35	1.11	0.9
PM6	2016	Min	56.5	55.3	188	7.49	0.56	20.3	15.7	0.87	3.99	10.10	7.5
PM6	2016	Median	69.2	67.3	217	7.84	1.19	23.8	17.9	1.01	5.28	11.40	8.7
PM6	2016	Max	75.0	73.5	240	8.16	1.40	25.7	21.3	1.22	6.00	13.40	9.6
PM6	2016	StDev	4.7	4.6	13	0.20	0.28	1.7	1.9	0.10	0.56	1.16	0.6
PM6	2017	Min	58.7	56.8	190	7.82	1.00	20.0	15.7	0.97	3.92	8.25	7.5
PM6	2017	Median	76.0	74.5	254	7.90	1.25	26.9	24.3	1.31	5.73	14.45	10.1
PM6	2017	Max	80.5	79.6	269	8.19	1.76	62.2	27.7	1.77	15.20	17.50	10.9
PM6	2017	StDev	6.8	7.1	26	0.11	0.20	10.9	4.0	0.22	2.95	3.10	1.2
PM6	2018	Min	72.3	70.7	231	7.53	1.20	24.5	18.0	1.13	5.15	9.85	8.7
PM6	2018	Median	76.4	74.8	239	7.83	1.44	26.9	22.5	1.24	6.05	13.45	9.9
PM6	2018	Max	79.3	77.8	267	8.19	1.74	29.0	26.9	1.38	6.65	17.70	11.3
PM6	2018	StDev	2.4	2.4	12	0.18	0.19	1.3	2.8	0.08	0.48	2.13	0.9
PM6	2019	Min	57.8	56.6	182	7.75	0.52	20.3	15.8	0.98	3.88	9.23	6.4
PM6	2019	Median	75.2	74.2	247	7.98	0.98	25.9	23.0	1.19	5.47	14.15	9.5
PM6	2019	Max	80.2	79.3	275	8.18	1.82	28.1	29.3	1.36	5.98	17.50	9.9
PM6	2019	StDev	9.1	9.2	33	0.13	0.39	2.7	4.8	0.11	0.72	2.76	1.4
PS	2015	Min	43.5	42.2	138	7.50	1.30	13.4	10.5	0.80	2.57	7.06	4.9
PS	2015	Median	62.7	60.8	213	7.88	1.52	20.8	21.8	1.09	4.39	12.88	8.0
PS	2015	Max	82.8	81.5	304	8.22	1.80	29.0	38.8	1.65	6.50	22.30	12.7

Station	Year	Statistic	Total Alkalinity mg/L $CaCO_3$	Gran Alkalinity mg/L $CaCO_3$	Conductivity µS/cm	pH	Silicate mg/L	Calcium mg/L	Chloride mg/L	Potassium mg/L	Magnesium mg/L	Sodium mg/L	Sulphate mg/L
PS	2015	StDev	16.2	16.0	75	0.25	0.14	6.0	12.8	0.34	1.65	6.73	3.5
PS	2016	Min	58.2	56.6	207	7.46	0.52	21.3	20.5	1.15	4.14	12.30	8.6
PS	2016	Median	70.8	69.4	261	7.94	0.81	24.9	27.6	1.27	5.32	16.60	9.9
PS	2016	Max	74.2	72.2	270	8.26	1.28	27.7	32.0	1.44	6.00	20.40	11.1
PS	2016	StDev	4.1	4.0	17	0.27	0.23	1.6	3.2	0.09	0.55	2.30	0.7
PS	2017	Min	43.9	43.0	157	7.62	0.60	6.7	15.5	0.07	0.21	5.27	6.7
PS	2017	Median	71.8	70.9	271	7.83	1.34	24.7	31.7	1.32	5.17	16.80	11.2
PS	2017	Max	79.1	77.2	321	8.12	1.70	30.1	39.3	1.86	6.62	26.20	12.8
PS	2017	StDev	11.6	11.5	52	0.16	0.35	6.6	7.7	0.48	1.89	5.93	1.9
PS	2018	Min	60.2	59.0	214	7.48	0.92	21.7	23.5	1.21	4.33	13.10	8.3
PS	2018	Median	78.6	77.0	295	7.92	1.62	28.4	35.2	1.57	6.01	19.10	11.0
PS	2018	Max	81.0	79.3	317	8.32	1.88	31.5	40.7	1.76	6.60	24.50	12.8
PS	2018	StDev	7.3	7.2	36	0.27	0.31	3.1	6.1	0.17	0.78	3.64	1.6
PS	2019	Min	34.0	32.4	122	7.50	0.40	12.7	12.4	0.80	2.40	7.00	5.1
PS	2019	Median	75.1	73.4	301	8.02	0.81	26.4	37.9	1.42	6.13	20.30	11.3
PS	2019	Max	79.2	77.9	307	8.43	1.68	28.0	40.3	1.72	6.46	23.60	12.0
PS	2019	StDev	13.4	13.4	57	0.24	0.36	4.4	9.1	0.25	1.26	4.87	2.1

Station	Year	Statistic	Chlorophyll *a* µg/L	Dissolved Inorganic Carbon mg/L	Dissolved Organic Carbon mg/L	Ammonia+ Ammonium µg/L	Nitrate+ Nitrite µg/L	Total Kjeldahl Nitrogen µg/L	Organic Nitrogen µg/L	Total Phosphorus µg/L	Secchi Depth m	Turbidity NTU	Colour TCU
PM1	2015	Min		15.2	4.2	6	2	257	243	8.7	3.1		9.8
PM1	2015	Median		17.4	4.9	16	18	298	276	12.8	3.5		15.8
PM1	2015	Max		19.8	5.2	46	156	348	332	17.3	4.0		27.0
PM1	2015	StDev		1.4	0.3	12	53	28	27	2.7	0.3		4.9
PM1	2016	Min		15.1	3.5	6	2	275	257	8.6	2.1	1.1	9.1
PM1	2016	Median		15.9	4.6	20	4	316	294	12.8	3.1	1.4	14.8
PM1	2016	Max		17.3	6.7	32	92	357	339	17.3	3.9	2.5	27.5
PM1	2016	StDev		0.7	1.0	7	29	26	26	2.4	0.6	0.5	5.8
PM1	2017	Min		15.0	3.9	24	1	273	241	10.3	1.5	1.0	11.2
PM1	2017	Median		17.7	4.8	35	8	342	310	13.5	2.7	1.6	21.6
PM1	2017	Max		19.0	5.5	66	254	405	357	28.1	4.5	2.6	37.9
PM1	2017	StDev		1.3	0.5	13	80	43	36	5.5	0.8	0.5	7.7
PM1	2018	Min		15.3	3.0	8	4	265	233	8.4	1.5	0.7	8.2
PM1	2018	Median		17.1	3.9	32	18	320	286	11.9	3.0	1.3	13.8
PM1	2018	Max		21.2	4.6	52	168	348	316	15.0	3.9	4.4	28.0
PM1	2018	StDev		1.4	0.5	11	50	29	26	2.2	0.7	1.1	6.1
PM1	2019	Min		14.8	3.8	14	4	283	239	11.0	1.9	0.7	11.2
PM1	2019	Median		18.0	4.7	29	11	305	280	13.0	2.9	1.9	15.8
PM1	2019	Max		20.3	5.0	46	174	359	313	16.5	5.0	3.0	34.4
PM1	2019	StDev		1.6	0.4	11	61	24	23	1.9	0.8	0.7	8.0
PM2	2015	Min		15.1	4.2	4	2	260	246	8.1	2.4		8.9
PM2	2015	Median		16.5	4.7	16	27	294	265	10.3	3.0		16.3
PM2	2015	Max		19.2	5.1	42	160	313	295	15.2	4.3		26.8
PM2	2015	StDev		1.2	0.3	11	59	17	20	2.6	0.6		4.9
PM2	2016	Min		13.6	3.2	8	2	264	245	7.6	2.8	0.8	8.9
PM2	2016	Median		15.7	4.4	19	3	309	292	12.5	3.2	1.6	14.0
PM2	2016	Max		17.6	6.6	32	60	365	349	16.7	4.0	2.1	27.3
PM2	2016	StDev		1.0	1.0	8	22	33	33	2.7	0.4	0.4	5.6
PM2	2017	Min	0.2	12.8	3.8	18	1	260	238	8.2	2.0	1.2	11.1
PM2	2017	Median	1.1	17.3	5.0	31	21	340	316	12.5	2.6	1.7	22.2
PM2	2017	Max	2.3	19.2	5.9	52	126	396	356	13.7	4.8	2.3	37.4
PM2	2017	StDev	0.6	2.0	0.6	10	43	40	34	1.8	0.8	0.3	8.2
PM2	2018	Min	0.9	16.0	2.8	10	2	240	198	8.6	1.9	0.9	7.5

Station	Year	Statistic	Chlorophyll *a* µg/L	Dissolved Inorganic Carbon mg/L	Dissolved Organic Carbon mg/L	Ammonia+ Ammonium µg/L	Nitrate+ Nitrite µg/L	Total Kjeldahl Nitrogen µg/L	Organic Nitrogen µg/L	Total Phosphorus µg/L	Secchi Depth m	Turbidity NTU	Colour TCU
PM2	2018	Median	1.1	17.1	3.9	34	46	314	278	12.7	2.6	1.6	12.2
PM2	2018	Max	4.0	17.9	4.7	52	134	346	316	17.8	3.8	3.3	30.4
PM2	2018	StDev	0.9	0.5	0.6	11	40	37	36	2.7	0.7	0.7	6.8
PM2	2019	Min	0.3	11.0	3.6	12	2	268	232	8.8	1.5	1.3	10.1
PM2	2019	Median	0.9	17.4	4.7	30	16	290	266	11.3	2.9	1.9	15.7
PM2	2019	Max	2.4	20.1	5.6	44	124	336	294	13.3	3.9	3.0	46.6
PM2	2019	StDev	0.8	2.7	0.6	10	42	22	22	1.7	0.6	0.5	11.2
PM6	2015	Min		15.5	4.2	12	2	263	229	7.6			11.5
PM6	2015	Median		16.6	4.6	22	42	287	267	11.5			15.2
PM6	2015	Max		19.4	5.5	58	160	366	308	15.3			24.6
PM6	2015	StDev		1.1	0.4	13	59	32	28	2.7			3.9
PM6	2016	Min		13.6	3.5	6	2	264	258	8.4			10.3
PM6	2016	Median		15.8	4.6	18	4	328	303	13.0			15.7
PM6	2016	Max		17.7	6.6	36	58	372	362	15.2			29.9
PM6	2016	StDev		1.0	1.1	8	18	32	31	2.2			5.4
PM6	2017	Min		13.7	4.1	18	1	258	234	6.9			11.6
PM6	2017	Median		16.8	5.1	31	26	337	315	11.6			22.4
PM6	2017	Max		20.5	5.6	60	126	406	368	14.3			37.4
PM6	2017	StDev		1.9	0.5	11	45	43	38	2.1			7.8
PM6	2018	Min		16.2	2.8	8	4	231	203	8.7			6.1
PM6	2018	Median		17.1	3.9	30	39	324	284	12.2			13.2
PM6	2018	Max		18.1	4.6	54	114	363	328	16.9			22.4
PM6	2018	StDev		0.5	0.6	12	35	40	35	2.6			5.1
PM6	2019	Min	0.4	13.0	3.5	18	2	271	237	7.6			12.8
PM6	2019	Median	0.6	17.7	4.9	29	19	305	286	12.2			16.9
PM6	2019	Max	1.3	20.4	8.2	40	146	350	326	16.1			44.4
PM6	2019	StDev	0.3	2.4	1.3	7	51	27	29	2.5			10.8
PS	2015	Min		10.0	5.1	6	2	292	270	9.1	2.1		10.9
PS	2015	Median		14.2	5.5	20	11	358	341	11.2	2.9		19.6
PS	2015	Max		18.0	6.1	30	100	372	348	15.6	4.2		40.1
PS	2015	StDev		3.4	0.3	7	31	25	24	1.8	0.7		9.5
PS	2016	Min		14.2	3.9	8	2	293	281	6.7	2.9	0.7	10.8
PS	2016	Median		16.2	5.1	15	2	358	339	10.5	3.9	1.2	14.8
PS	2016	Max		17.2	6.4	26	28	381	369	13.6	5.3	1.5	25.1

Station	Year	Statistic	Chlorophyll *a* µg/L	Dissolved Inorganic Carbon mg/L	Dissolved Organic Carbon mg/L	Ammonia+ Ammonium µg/L	Nitrate+ Nitrite µg/L	Total Kjeldahl Nitrogen µg/L	Organic Nitrogen µg/L	Total Phosphorus µg/L	Secchi Depth m	Turbidity NTU	Colour TCU
PS	2016	StDev		0.8	0.7	6	8	24	22	2.0	0.8	0.3	4.3
PS	2017	Min		10.1	4.6	12	1	304	280	8.2	2.0	0.9	11.9
PS	2017	Median		15.4	5.1	22	14	366	346	9.5	4.2	1.0	22.8
PS	2017	Max		19.0	6.2	28	62	422	401	11.5	5.3	1.4	37.8
PS	2017	StDev		2.7	0.5	5	17	36	38	0.9	1.1	0.2	8.9
PS	2018	Min		13.9	4.4	8	2	277	263	8.0	2.8	0.4	10.3
PS	2018	Median		17.0	4.6	26	7	370	344	9.2	4.2	0.9	13.6
PS	2018	Max		18.6	5.5	58	68	428	390	12.7	5.1	1.3	31.7
PS	2018	StDev		1.5	0.3	13	18	39	36	1.5	0.8	0.3	6.7
PS	2019	Min		7.8	4.5	12	1	276	242	7.8	2.3	0.5	11.5
PS	2019	Median		17.5	5.1	26	7	353	326	10.0	4.3	1.3	15.5
PS	2019	Max		19.4	5.5	38	88	374	362	11.4	5.5	1.6	48.6
PS	2019	StDev		3.4	0.3	7	27	29	34	1.2	1.1	0.3	10.9

Appendix B – Long Term Summary Statistics and Long Term Trend Analysis for Water Quality

Station	Parameter	Units	First Year	Last Year	# Years	Min	Max	Median	StDev	Mann Kendall Test, *p* value	Trend
PM1	Ammonia+Ammonium	µg/L	1997	2019	23	10	44	25	10	**0.05**	**inc**
PM1	Calcium	mg/L	1997	2019	9	23.2	27.6	25.6	1.5	0.92	none
PM1	Chloride	mg/L	1997	2019	12	11.8	23.3	16.2	4.0	**4.41E-05**	**inc**
PM1	Colour	TCU	2012	2019	8	12.0	22.5	15.8	3.9	0.90	none
PM1	Conductivity	µS/cm	1997	2019	17	197	251	220	15	**0.02**	**inc**
PM1	Dissolved Organic Carbon	mg/L	2010	2019	9	3.9	5.0	4.7	0.3	0.40	none
PM1	Gran Alkalinity	mg/L $CaCO_3$	2012	2019	8	66.4	76.9	72.3	4.3	0.40	none
PM1	Magnesium	mg/L	1997	2019	9	4.86	6.31	5.50	0.45	0.36	none
PM1	Nitrate+Nitrite	µg/L	1997	2019	23	3	78	12	18	**2.13E-03**	**dec**
PM1	pH	-	1997	2019	14	7.84	8.25	8.03	0.10	**0.02**	**dec**
PM1	Potassium	mg/L	1997	2019	10	1.02	1.49	1.17	0.14	1.00	none
PM1	Secchi Depth	m	1997	2019	23	2.2	4.0	3.3	0.4	**2.69E-03**	**dec**
PM1	Sodium	mg/L	1997	2019	10	7.4	14.0	10.7	2.0	**0.03**	**inc**
PM1	Sulphate	mg/L	2010	2019	9	4.3	10.6	9.2	1.8	0.76	none
PM1	Total Alkalinity	mg/L $CaCO_3$	2012	2019	8	67.9	78.6	73.7	4.3	0.40	none
PM1	Total Kjeldahl Nitrogen	µg/L	1997	2019	23	297	371	340	22	0.17	none
PM1	Total Nitrogen	µg/L	1997	2019	23	307	475	377	38	0.07	none
PM1	Total Phosphorus	µg/L	1997	2019	23	11.8	16.0	12.8	1.3	0.53	none
PM2	Ammonia+Ammonium	µg/L	1969	2019	48	6	56	20	11	0.34	none
PM2	Calcium	mg/L	1993	2019	12	22.9	27.0	24.3	1.5	0.84	none
PM2	Chloride	mg/L	1993	2019	15	9.7	23.9	15.4	4.1	**1.01E-05**	**inc**
PM2	Chlorophyll a	µg/L	1973	2019	40	0.7	6.0	2.4	1.4	**4.35E-06**	**dec**
PM2	Colour	TCU	1993	2019	11	6.9	22.2	14.0	4.7	0.22	none
PM2	Conductivity	µS/cm	1993	2019	20	173	249	216	18	**0.01**	**inc**
PM2	Dissolved Inorganic Carbon	mg/L	1993	2019	9	15.2	17.4	17.0	0.8	0.25	none
PM2	Dissolved Organic Carbon	mg/L	1993	2019	12	3.2	5.0	4.4	0.5	0.09	none
PM2	Gran Alkalinity	mg/L $CaCO_3$	2012	2019	8	65.5	74.9	71.6	3.6	0.11	none

Station	Parameter	Units	First Year	Last Year	# Years	Min	Max	Median	StDev	Mann Kendall Test, *p* value	Trend
PM2	Magnesium	mg/L	1993	2019	13	4.68	6.21	5.49	0.40	0.68	none
PM2	Nitrate+Nitrite	µg/L	1969	2019	48	3	105	22	21	0.16	none
PM2	pH	-	1993	2019	17	7.82	8.23	8.01	0.10	**0.01**	**dec**
PM2	Potassium	mg/L	1993	2019	14	0.94	1.92	1.11	0.24	0.27	none
PM2	Secchi Depth	m	1969	2019	48	1.9	4.1	2.6	0.6	**0.01**	**inc**
PM2	Sodium	mg/L	1993	2019	14	6.1	14.3	10.0	2.4	**7.58E-04**	**inc**
PM2	Sulphate	mg/L	1993	2019	12	4.3	13.3	10.0	2.3	0.11	none
PM2	Total Alkalinity	mg/L $CaCO_3$	1996	2019	9	67.2	79.5	75.3	4.1	0.60	none
PM2	Total Kjeldahl Nitrogen	µg/L	1969	2019	48	285	400	340	31	**7.93E-04**	**dec**
PM2	Total Nitrogen	µg/L	1969	2019	48	293	445	385	31	0.06	none
PM2	Total Phosphorus	µg/L	1969	2019	48	10.0	23.0	13.9	3.3	**1.29E-09**	**dec**
PM6	Ammonia+Ammonium	µg/L	2011	2019	9	16	28	26	5	0.20	none
PM6	Calcium	mg/L	2012	2019	8	23.8	27.3	25.8	1.2	0.55	none
PM6	Chloride	mg/L	2012	2019	8	16.5	24.3	18.3	3.4	0.06	none
PM6	Colour	TCU	2012	2019	8	13.7	30.9	17.3	6.1	0.90	none
PM6	Conductivity	µS/cm	2011	2019	9	215	254	231	15	0.48	none
PM6	Dissolved Organic Carbon	mg/L	2012	2019	8	4.0	5.2	4.7	0.4	0.06	none
PM6	Gran Alkalinity	mg/L $CaCO_3$	2012	2019	8	67.8	75.9	72.4	3.1	**0.03**	**inc**
PM6	Magnesium	mg/L	2012	2019	8	5.13	6.41	5.73	0.41	0.72	none
PM6	Nitrate+Nitrite	µg/L	2011	2019	9	10	98	56	32	0.36	none
PM6	pH	-	2011	2019	9	7.73	8.06	7.88	0.11	0.61	none
PM6	Potassium	mg/L	2011	2019	9	1.03	1.42	1.26	0.12	0.26	none
PM6	Sodium	mg/L	2011	2019	9	10.1	14.9	11.7	1.8	**0.05**	**inc**
PM6	Sulphate	mg/L	2012	2019	8	8.6	10.4	10.0	0.8	0.52	none
PM6	Total Alkalinity	mg/L $CaCO_3$	2012	2019	8	69.6	77.8	73.8	3.4	**0.01**	**inc**
PM6	Total Kjeldahl Nitrogen	µg/L	2011	2019	9	285	341	319	20	0.48	none
PM6	Total Nitrogen	µg/L	2011	2019	9	327	418	368	34	0.36	none
PM6	Total Phosphorus	µg/L	2011	2019	9	10.3	14.0	11.4	1.2	0.08	none
PS	Ammonia+Ammonium	µg/L	1992	2019	24	6	35	20	8	**1.04E-03**	**inc**
PS	Calcium	mg/L	2010	2019	8	20.8	28.4	25.4	2.3	0.55	none

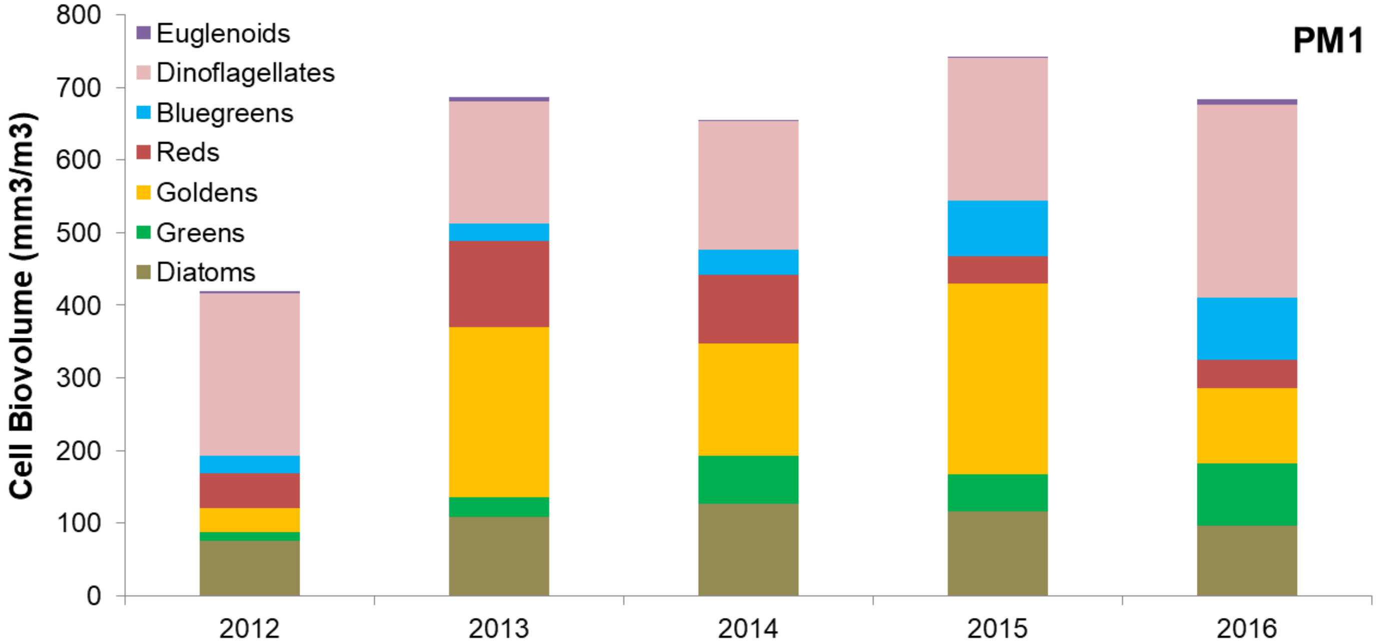
Station	Parameter	Units	First Year	Last Year	# Years	Min	Max	Median	StDev	Mann Kendall Test, *p* value	Trend
PS	Chloride	mg/L	1999	2019	10	12.6	37.9	25.6	8.5	**3.58E-04**	**inc**
PS	Colour	TCU	2012	2019	8	13.6	29.5	19.1	5.4	0.28	none
PS	Conductivity	µS/cm	1992	2019	18	176	301	243	32	**0.03**	**inc**
PS	Dissolved Organic Carbon	mg/L	2010	2019	9	4.6	6.0	5.3	0.4	**0.03**	**dec**
PS	Gran Alkalinity	mg/L $CaCO_3$	2012	2019	8	55.2	77.0	68.2	7.3	**0.01**	**inc**
PS	Magnesium	mg/L	2010	2019	8	4.39	6.13	5.23	0.60	0.11	none
PS	Nitrate+Nitrite	µg/L	1992	2019	24	2	23	7	6	0.60	none
PS	pH	-	1992	2019	15	7.80	8.18	7.91	0.12	0.59	none
PS	Potassium	mg/L	2010	2019	9	1.09	1.57	1.27	0.15	0.08	none
PS	Secchi Depth	m	1992	2019	24	1.9	4.5	3.5	0.6	0.16	none
PS	Sodium	mg/L	2010	2019	9	10.0	20.3	16.6	3.5	**0.01**	**inc**
PS	Sulphate	mg/L	2010	2019	9	4.4	11.3	9.9	2.2	**0.01**	**inc**
PS	Total Alkalinity	mg/L $CaCO_3$	2012	2019	8	56.0	78.6	69.7	7.4	**0.01**	**inc**
PS	Total Kjeldahl Nitrogen	µg/L	1992	2019	24	337	410	370	19	**0.02**	**dec**
PS	Total Nitrogen	µg/L	1992	2019	24	360	445	384	20	**2.07E-03**	**dec**
PS	Total Phosphorus	µg/L	1992	2019	24	9.0	14.0	10.8	1.3	0.44	none

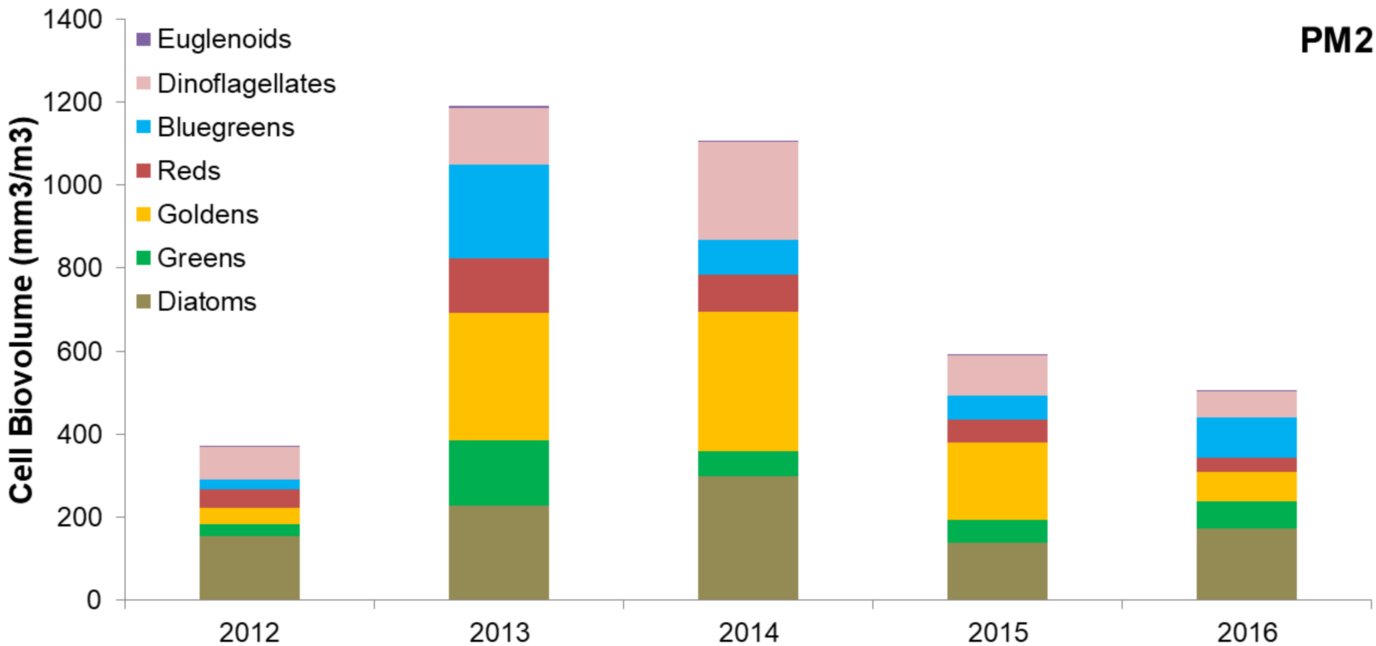
Appendix C – Algal Taste and Odour and Toxin Compounds from Station PM6 (SSEA data)

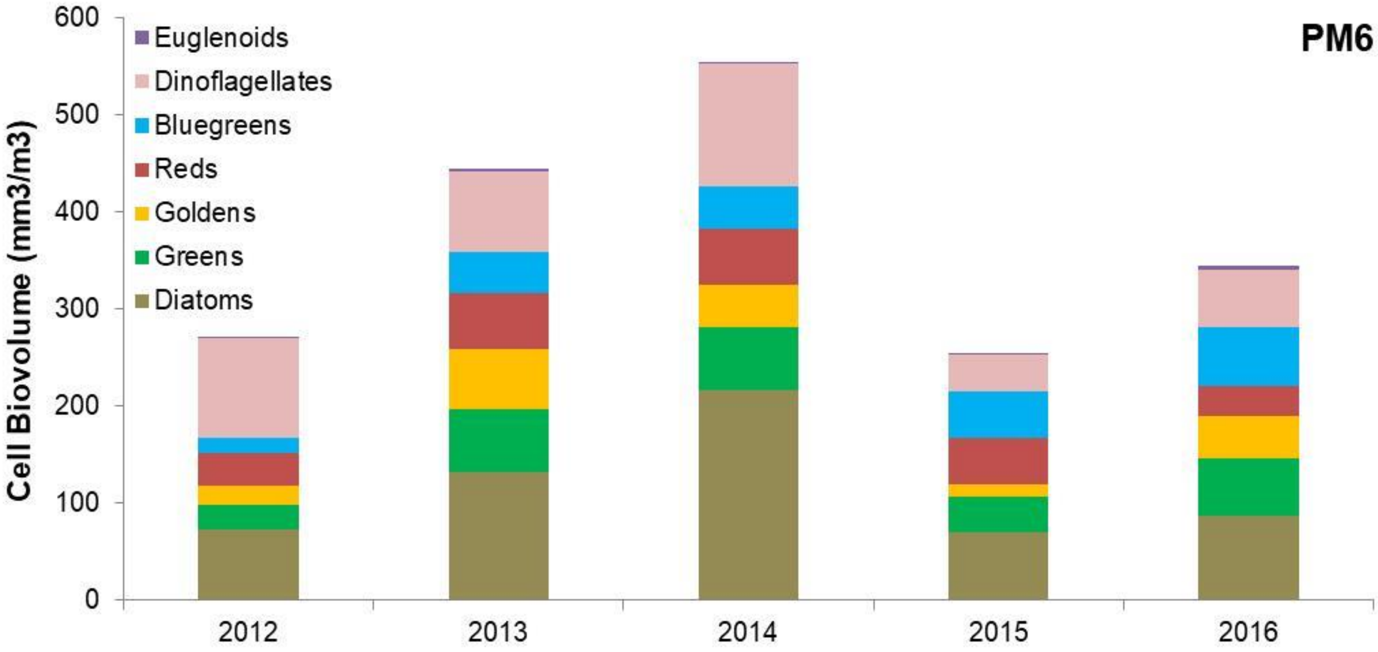
Date	Geosmin* (ng/L)	2-Methyl isoborneol* (ng/L)	Total Microcystin† (µg/L)
28/06/2016	6	<3	<0.10
12/07/2016	6	<3	<0.10
26/07/2016	5	5	0.14
09/08/2016	6	5	0.16
23/08/2016	4	4	<0.10
06/09/2016	8	6	<0.10
20/09/2016	8	5	<0.10
11/07/2017	6	<3	<0.10
25/07/2017	6	5	0.17
08/08/2017	5	10	0.19
21/08/2017	7	7	<0.10
05/09/2017	9	6	<0.10
19/09/2017	6	14	<0.10
17/07/2018	6	4	<0.10
31/07/2018	8	6	<0.10
14/08/2018	8	9	<0.10
28/08/2018	10	11	<0.10
11/09/2018	10	10	0.10
25/09/2018	6	7	<0.10
09/10/2018	8	5	<0.10
16/07/2019	15	<3	<0.10
30/07/2019	12	7	0.18
13/08/2019	10	5	0.11
27/08/2019	n.d.	n.d.	0.15
10/09/2019	9	<3	<0.10
24/09/2019	7	<3	<0.10
08/10/2019	7	<3	<0.10

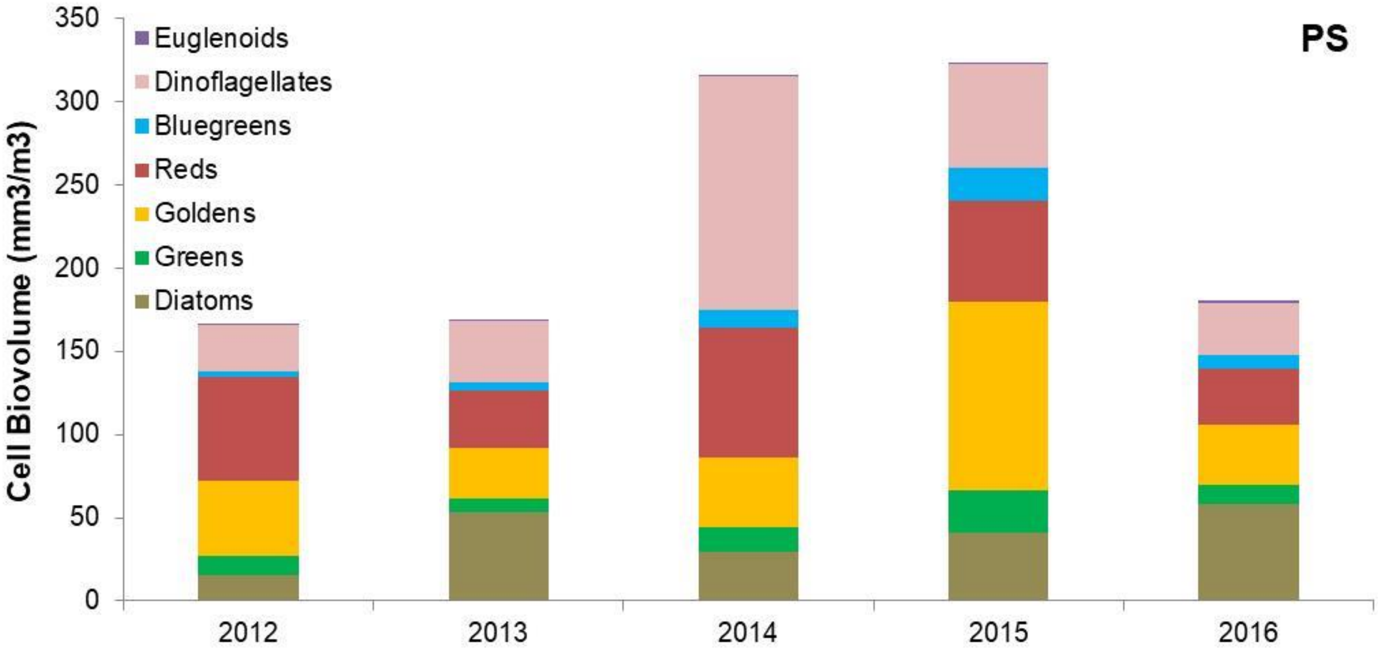
*method detection limit for Geosmin and MIB is 3 ng/L
†method detection limit for total microcystin is 0.10 µg/L

Appendix D - Annual algae biovolume by major algal classes from 2012-2016 for PM1, PM2, PM6 and PS

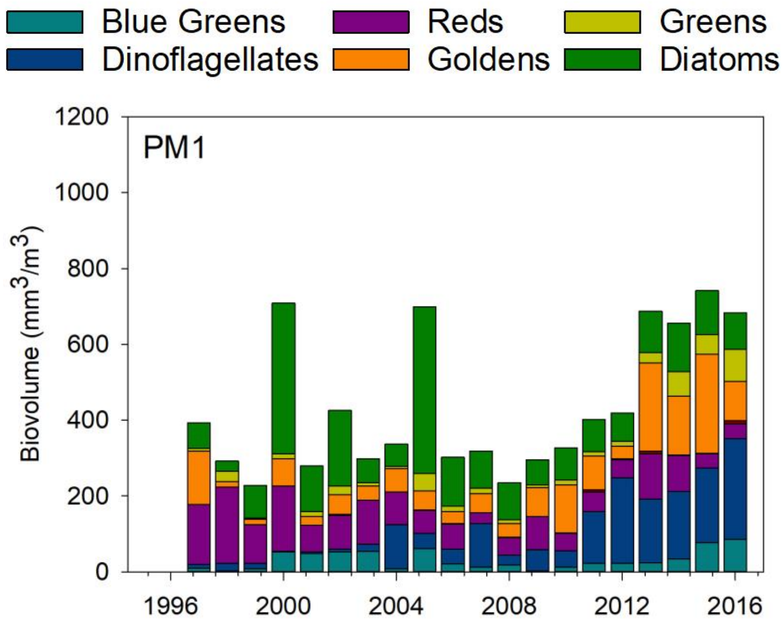


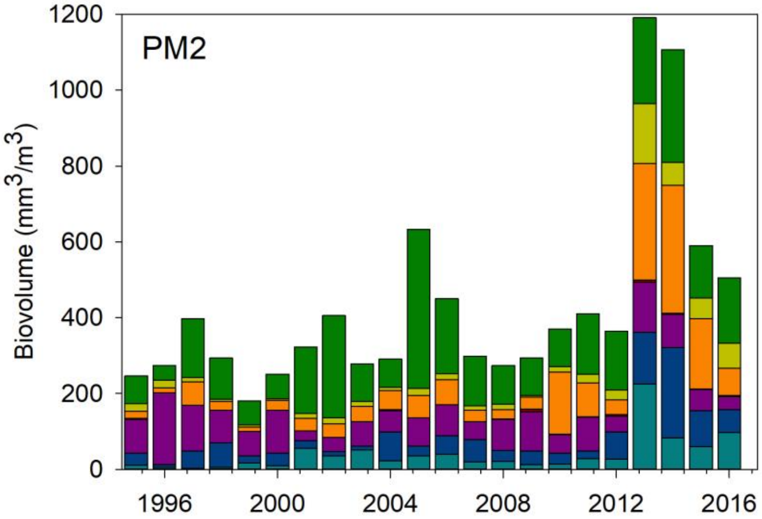


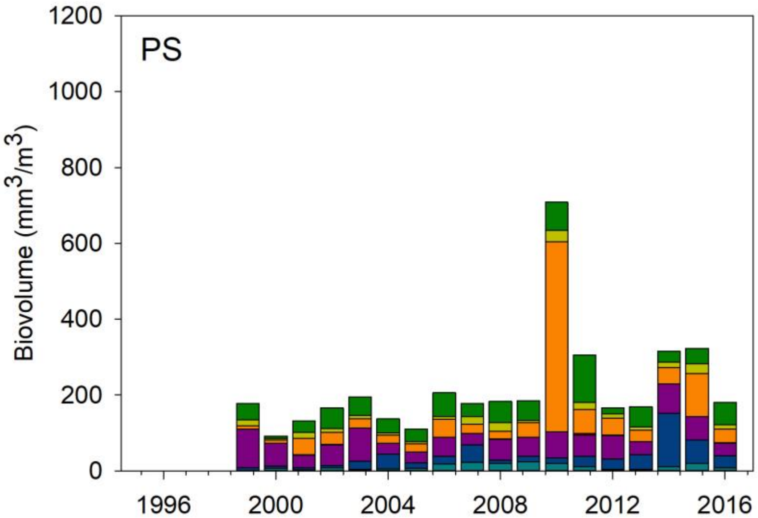

PM6
Cell Biovolume (mm3/m3)
0
100
200
300
400
500
600
Euglenoids
Dinoflagellates
Bluegreens
Reds
Goldens
Greens
Diatoms
2012
2013
2014
2015
2016


PS
Cell Biovolume (mm3/m3)
0
50
100
150
200
250
300
350
Euglenoids
Dinoflagellates
Bluegreens
Reds
Goldens
Greens
Diatoms
2012
2013
2014
2015
2016

Appendix E - Annual algae biovolume by major algal classes from 1994-2016 for PM1, PM2, PS




PM2
Biovolume (mm3/m3)
0
200
400
600
800
1000
1200
1996
2000
2004
2008
2012
2016


PS
Biovolume (mm3/m3)
0
200
400
600
800
1000
1200
1996
2000
2004
2008
2012
2016