Spatial and temporal variability in nearshore water quality by the Duffin Pollution Control Plant Outfall

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Acknowledgements

• Regional Municipalities of York and Durham
• Duffin Water Pollution Control Plant
• Ontario Ministry of the Environment
• Environment Canada
• Toronto and Region Conservation Authority field crew
• Carolyn Brown
The Duffin Pollution Control Plant

- Originally built and operated by the province to eliminate pollution in rivers from small inefficient plants and support future growth
- Third-largest on the Canadian shores of Lake Ontario
- Treated effluent from York-Durham Sewer system
- Secondary treatment
- No bypass capability
Plant Expansion

- 2010-2012: Stage 3 expansion - 420-630 million L/day
- 2012: updates to Stage 1 and 2 P and NH$_3$ removal completed
Phosphorus Removal
Permitted: 0.5 µg/L
Average: 0.3 µg/L

Chlorination/Dechlorination

Lake Ontario

Raw Influent

Treated Effluent
Effluent is pumped through an outfall pipe 1 km from the shoreline.

- Designed to comply with OMOE policy (Bluebook procedures).
- Capacity of 630 MLD (not anticipated until 2031); 63 ports, 38 are active
- 20:1 dilution ratio brings effluent (1mg/L) to compliance with PWQO (0.020 mg/L) as quickly as possible (not practical to meet PWQO at discharge point).
Dove et al. (2009)

- Large plant on the lake ties back to Great Lakes Water Quality Agreement:
  - Volume doesn’t matter if < 1mg/L

- With the dilution ratios used, the Lake is < 10 µg/L

- Ring around the bathtub

Figure 2. Spring Total Phosphorus in Lake Ontario, Open Water Stations, 1970–2008. The solid line within each box is the median; the lower and upper ends of the boxes are the 25th and 75th percentiles, respectively; whiskers show the minimum and maximum values.
Temporal patterns in plant loads: 2007-2012

- Contentious due to beach closures and a community unhappy with algal growth
- Currently part of an Class 2 Environmental Assessment (monitoring results helped interpret models used in this EA)
- DEBATE: how low is practical? Operator/Policy view versus Public view (confusion between drinking water plant and sewage treatment plant)
- Marked decrease in loads after 2008; 2007 and 2008 maximum loads were greater than new regulations; great opportunity for nearshore studies
Daily average loadings from 2004-2012

- Plant can expand, but there is a P loading cap: no net increase observed after expansion.
- No reduction in P volume: P removal.
- It will be some time before historic levels are seen again.
Watershed loading estimates

- We have local watershed loads too:
  - Malkin et al. loads are on the low end using PWQMN data
  - TRCA and Environment Canada have been working together to estimate land-based nutrient and suspended loadings from creeks/rivers

Taken from:
Mean Total Phosphorus (μg/L)

Howell et al., 2012


The Western Durham Monitoring Program

- 2006 preliminary investigations

- Rotary Park:
  - no longer sampled by the Health Department
  - not physically safe to swim due to shoreline protection
  - Barrier beach with wildlife from river/creek area
  - Provincially significant marsh
The Western Durham Monitoring Program

- 2 boats required
- Predominantly surface water samples, however samples were taken at depth along the WWTP outfall transect
- Preliminary data (2006-2007) was made available to the MOE, who monitored the area in 2008
- Part of the International Year of Study for Lake Ontario

Sampling Locations 2007 - 2010

- Drinking water Intake
- Duffin Pollution Control Plant Outfall
- Frenchman’s Bay
- Rouge River
- Duffins Creek
- Carruthers Creek

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The Western Durham Monitoring Program

- One of the most comprehensive nearshore water sampling collection efforts in the Great Lakes;
- In total, there are: ~45 SURVEYS
- Water quality under a variety of lake conditions
- Survey design is for regional look at water quality, not to track the effluent plume

Design Re-evaluated: 2011 to 2013

- Duffin Pollution Control Plant Outfall
- Drinking water Intake
- LOBO
- OPG

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TORONTO AND REGION CONSERVATION AUTHORITY
Regional Monitoring Program

ELEVATED APPROACHES OPEN-WATER CONCENTRATIONS

TOP IS DIFFERENT FROM BOTTOM
Lake physics

To go 4 km (Duffins to Carruthers)

Onshore/Offshore: 1 cm/s $\rightarrow \approx 4.6$ days
(0.036 km/hr)
Alongshore: 10 cm/s $\rightarrow \approx 11$ hours
(0.36 km/hr)

Onshore/Offshore: 3 cm/s $\rightarrow \approx 1.5$ days
(0.108 km/hr)
Alongshore: 20 cm/s $\rightarrow \approx 6$ hours
(0.72 km/hr)
Using clips from 3D spatially interpolated data, we see the influence of the outfall, so we expect to see the influence of the outfall on surrounding water chemistry.

(Data collected by Ontario Ministry of the Environment, and processed by Toronto and Region Conservation Authority)
The outfall pipe is doing its job!
- Follows MOE waste assimilation protocols (20:1 dilution ratio within mixing zone)
- Concentrations are orders of magnitude lower near the outfall pipe entering the lake with median values below the IJC objective for open waters.
Effect vs. Diffuser ranges

- Concentrations are at least an order of magnitude lower by the bottom of the diffuser in comparison to the effluent.
• Drinking water intake

• Outfall

• Our program was NOT designed to trace the plume or define the mixing zone however given the large number of samples we have a good picture of performance
Drinking water intake

Increasing
Total Phosphorus (μg/L)

- 0 m
- 0 - 250 m
- 250 - 500 m
- 500 - 750 m
- 750 - 1000 m
- Background

2007 2008 2009 2010 2011 2012
E. Coli
– not taken at every sampling event
- Also part of a Source Water Study

E. Coli concentrations are lower at the outfall than 500 m to 1 km away.

500 m to 1 km away are zones close to Storm Drains and Duffins Creek.

Stopped as we had a good idea of where concentrations were elevated.
• WWTP outfall is not the only TP source in the region
• Within 1 km of the outfall, TP concentrations are approaching background (1 km mixing zone)
Soluble Reactive Phosphorus

After upgrades: generally at or below detection within 250 m

NOTE: Detection limit is a level that can sustain algal growth

Detection Limit = 2 µg/L (2008 on)

Mean skewed by 1 sample; 5 out of 6 samples were below detection

Not straight-forward

Upgrades to P removal
Ammonia + Ammonium

**Background**

Updates to NH$_3$ removal at the plant is reflected in lake chemistry.

**Provincial Water Quality Objective**

Detection Limit = 50 µg/L (<2008)

Detection Limit = 8 µg/L (2008 on)
Nitrate + Nitrite

- Declines in NO₃+NO₂ moving away from outfall
- Range in concentrations suggest shoreline contributes to sources

Updates to NH₃ removal: introduced nitrification thru nitrifying step feed process
Surface vs Bottom Waters by the outfall

Sample locations in 2011-2013 are approximately 100 m away from 2006-2009 sample locations

- 2006:2009 TP data have a larger range than 2011-2013 data
- 2006:2009 SRP data are elevated in comparison to 2011-2013 data
- Upgrades to P removal in plant completed in 2012 or due to distance??
- Be aware of mixing conditions at time of sampling: direction of plume?
Surface vs Bottom Waters by the outfall

Sample locations in 2011-2013 are approximately 100 m away from 2006-2009 sample locations

- Bottom waters are higher in NO$_3$+NO$_2$ than surface waters; ↑ in 2011-2013
- NH$_3$ concentrations are lower in 2011-2013 than 2006-2009
- NH$_3$ removal upgrades complete in 2012
Seasonal and Annual differences?

- **Seasonally:**
  - summer and Fall are statistically different (Nitrate, TP, SRP)

- **Temporally:**
  - KW statistical difference between years (NH₃, TP, SRP), however, Dunn’s posthoc which is very conservative says no difference therefore cannot relate to wet/dry years

Gap in winter periods, yet drinking water is taken all year in Ajax
Why do we see changes?

Total Phosphorus overlain on current data modelled by Environment Canada.
Summary

• E. Coli: concentrations by the outfall are low, and similar to lake background

• Total Phosphorus: concentrations approach background within 1 km of outfall

• Soluble Reactive Phosphorus: detection limit impedes conclusive comparisons

• Nitrate: increases in nitrate after nitrification; concentrations do not approach background within 1 km

• Ammonia: decreases in NH$_3$+NH$_4$ after plant updates to NH$_3$ removal; mean concentrations below PWQO

• Summer and Fall are statistically different for SRP, TP, and Nitrate

• Although KW tests suggest statistical temporal differences, conservative posthoc tests do not

• At this monitoring resolution, changes in nearshore water quality are observed along the timeline of plant changes
Future Directions

• Environment Canada
  – Modeling circulation in the region and the fate and transport of Phosphorus

• Ontario Ministry of the Environment
  – Examining land-based inputs and algal growth in the region

• Regions of York and Durham and TRCA
  – Another 5 years of monitoring
  – Improving SRP detection limits

• Inviting other researchers to investigate the nearshore

• For more information: