Water Quality on the Toronto-Mississauga Waterfront after the July 8, 2013 Deluge

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On the evening of July 8, 2013 heavy thunderstorms passed the largest urban centre in Canada dropping exceptional amounts of rain. 126 mm of rain fell at Pearson Airport that day, breaking the record at Pearson of 121.4 mm on Oct. 15th, 1954 due to Hurricane Hazel.
The Runoff Event
- Weather Conditions
- Tributary Discharge

Immediate Effects on Nearshore Water Quality
- Measured patterns of suspended solids, phosphorus and fecal indicators
- Water column stratification
- Loaded phosphorus

Where Did the Runoff distribute?
- Modelled nearshore circulation features in the days after the event
2 pm EDT: Thunderstorm development along stationary frontal zone and warm moist air mass

4:50 pm EDT: Slow moving thunderstorms arrive in the Toronto area dropping 126.00 mm of rain at Pearson in a few hours.
River Discharge (Daily Mean) July 2 to July 15, 2013

Based on Environment Canada Water Survey of Canada data
Lake Measurements and Sampling Plan:

- Continuous surface measurement over track for conductivity, temperature, turbidity, nitrate, fluorescence features.
- Water samples (red squares) for lab analysis (nutrients, major ions, fecal indicators, physical features).
- Water column profiles of temperature, turbidity, beam attenuation, conductivity, fluorescence features.
Toronto Waterfront
July 9, 2013
Surface waters highly turbid (except SW Toronto Island)

- Apparent shore-parallel flow towards the east

Note: sensor was out of range >130 FTU
Water Column Strongly Stratified: But Variable With Location

Beam Attenuation - 660 nm (m$^{-1}$)

Temperature (°C)

Depth (m)

West End

East End

West End

East End

Beam Attenuation - 660 nm (m$^{-1}$)

Temperature (°C)

Depth (m)

West End

East End

Beam Attenuation - 660 nm (m$^{-1}$)

Temperature (°C)

Depth (m)

West End

East End

West End

East End

Attenuation Coefficient

Floating Plume

Sinking mid-depth plume

9
Profiles used to interpolate 3D model of water column by kriging (EVS software)

Wide temperature gradient with depth; complex pattern of stratification with multiple density gradients

Suspect upwelling in recent past
Discharge Loaded to Nearshore in Surface and Mid-depth Layers

Toronto Harbour

Credit River

Etobicoke Creek

Humber River

Offshore

River Discharge Floating

Discharge Sinking

Attenuation Coefficient (m) 660 nm

0.0  2.8  5.6  8.5  11.3  14.1  16.9  19.7  22.6
July 9, 2013

Numbers Indicate:
TP (ug/L)
Lab measured

- Total Phosphorus (TP) highly enriched in surface waters
- TP levels over track estimated from linear regression with turbidity and interpolated by kriging

Note: TP estimates are under estimates >120 FTU due turbidity sensor out of range
Estimating Total Phosphorus Loaded to Survey Area by Event (as July 9)

- TP was well correlated with suspended solids.

- Field surrogates of suspended solids (i.e. turbidity) can be used to estimate TP concentration.

- Much of the phosphorus discharged was bound to particulate material.
Procedure Used to Estimate Event Water Column Load to Study Area

- Estimate TP concentration over depth profiles using TP to turbidity regression
- Interpolate TP water column model from profiles by 3D kriging
- Calculate water column volume of survey area; estimate TP mass in volume
- Estimate TP mass in same volume given background nearshore TP levels
- Subtract estimated background TP mass from mass estimated on July 9

Nearshore Background TP used is based on 2013 data collected on June 11 and July 31 between 3 and 20 m in eastern Toronto
Volume of area monitored: $1.004 \times 10^9$ cubic meters
Mass of P in volume: 36.75 metric tons
Estimated background phosphorus mass: 9.54 metric tons

Amount attributable to event (as of July 9): 27.21 metric tons
Fecal pollution indicator E. coli strongly elevated in surface waters

- Levels elevated in areas subject to greatest influence of runoff

Numbers indicate:
E. coli (CFU/100mL)
Fecal Pollution Indicators: *E.coli* and Fecal Streptococci

- Levels of *E.coli* highly correlated with those of fecal streptococci
- Fecal streptococci counts generally higher than those of *E.coli*
- Levels of *E.coli* somewhat correlated with TP
- While other parameters (nitrate, turbidity, dissolved P) exhibited a degree of co-variation with *E.coli*, TP appeared to be the strongest single correlate
Hydrodynamic Modelling to Support Broader Interpretations of Runoff Event

- MIKE3 DHI hydrodynamic modelling software used to infer water column structure, lake circulation and nearshore mixing of tributary discharge over the period surrounding the July 8, 2013 runoff event

- Whole lake circulation modeled in 3D for April 1 to December 1, 2013 in parallel with additional modeling of tributary discharge mixing in GTA nearshore for time surrounding the storm event
- Horizontal grid scale areas with proximity to shoreline; enhanced in the GTA area
- Combined sigma and z layering scheme (16 strata with up to 12 extra in deeper water)
- Water inflows from 28 gauged tributaries and Niagara River; tributary temperatures available for selected GTA sites and otherwise estimated from published trends
As inferred from field survey, weak to moderate shore-parallel flow towards the east occurred near the height of the discharge event.

Not shown is flow at depth which mostly was slower and also towards the east.
Preliminary Tracking of Distribution of Discharge by the Proportion of Tributary Water Contributed to Water Column

- “Relative Concentration” procedure used: concentration of water in the lake discharged by specific tributaries estimated

- Gauged tributaries between Credit River and Rouge River over period July 5 to 12 treated as combined runoff source

- Predicted distribution of tributary discharge over study area similar to that observed in the field survey

- Discharge mostly limited to a surface layer except at shallow depth along the shoreline
Surface
July 10
Hour 0000

Surface
July 11
Hour 0000
Some dilution, however, pattern similar to July 9 persists

Surface
July 10
Hour 1200

Surface
July 11
Hour 1200
Note strong dilution and offshore dissipation of discharge contribution
MODIS Satellite Image July 11, 2013

NASA MODIS image - July 11, 2013
(source: NOAA Great Lakes Coastwatch)
Upwelling on July 11, 2013

- Upwelling on July 11
- Brings hypolimnetic water into nearshore areas impacted by the July 8 storm
- Likely dilutes and disperses runoff from the event
The Runoff Event

- Elevated tributary discharge associated with the July 8 storm appeared centred between Credit River and Toronto Island/Harbour

Immediate Effects on Nearshore Water Quality

- Levels of suspended solids, phosphorus and fecal indicators highly elevated in surface water
- Water stratification confines runoff to surface layer and to a limited extent, mid-water column layers

Where Did the Runoff distribute?

- Tributary discharge associated with the July 8 storm appeared to be largely focused between the Credit River and Toronto Island until about July 11
- An upwelling event on July 11 appeared to dilute and push runoff offshore
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