Lake Ontario Model Calibration and Baseline Scenario

Prepared for
Regions of York and Durham

November 2011

Prepared by
Contents

1. Background and Purpose .................................................................................................. 1-1
2. Effluent and Mixing Zone Requirements ...................................................................... 2-3
   2.1 Near Field Zone Requirements ............................................................................... 2-3
   2.2 Far Field Effluent and Mixing Zone Requirements .................................................. 2-3
3. CORMIX Model and Near Field Analysis ..................................................................... 3-4
   3.1 Key Input Parameters ............................................................................................... 3-4
     3.1.1 Ambient Lake Currents ...................................................................................... 3-4
     3.1.2 Existing Outfall Diffuser .................................................................................... 3-5
     3.1.3 Effluent flow and Port Opening Size .................................................................... 3-5
     3.1.4 Summary of Input Parameters ............................................................................. 3-6
   3.2 Results .......................................................................................................................... 3-7
4. MIKE-3 Model Set-Up ....................................................................................................... 4-1
   4.1 Model History and Data Use ....................................................................................... 4-1
   4.2 Model Parameters ........................................................................................................ 4-1
   4.3 Model Set-Up under Lake Ontario Ambient Conditions ............................................. 4-2
5. MIKE-3 Model Calibration .................................................................................................. 5-1
6. Baseline Modelling – 520 ML/d ....................................................................................... 6-1
   6.1 Existing Outfall ........................................................................................................... 6-1
   6.2 Effluent Certificate of Approval Requirements ......................................................... 6-1
   6.3 Provincial Water Quality Objectives .......................................................................... 6-1
   6.4 Duffins Creek ............................................................................................................. 6-2
   6.5 Total Phosphorus in Lake Ontario under the 520 ML/d Baseline Scenario .......... 6-6
   6.6 Un-Ionized Ammonia Levels in Lake under 520 ML/d Baseline Scenario .... 6-11
7. Summary and Conclusions ............................................................................................... 7-1
   7.1 Summary of Results ..................................................................................................... 7-1
     7.1.1 CORMIX MODEL: Near-Field Analysis ................................................................. 7-1
     7.1.2 MIKE 3 MODEL: Far-Field Analysis .................................................................... 7-1

Figures

Figure 3-1 ADCP locations .................................................................................................... 3-4
Figure 3-2 Maximum peak flow through the outfall with different port diameters .......... 3-6
Figure 3-3 Plan View 520 ML/d – Coordinate System Used By CORMIX ....................... 3-8
Figure 4-1 Bathymetry of Lake Ontario (2430 GRID) ......................................................... 4-4
Figure 4-2 Bathymetry of the Duffin Creek WPCP Study Area (90 m Fine resolution Grid) ................................................................................................................................. 4-5
Figure 5-1 Comparison of Modelled Lake Current SPEED with OPG – ADCP Measurements .............................................................................................................. 5-3
Figure 5-2  
Comparison of Modelled Lake Current Direction with OPG-ADCP Measurements .............................................................. 5-4
Figure 5-3  
NWRI Current Speed Comparisons – 5 m Depth - 2007 ................................. 5-6
Figure 5-4  
NWRI Current Direction Comparisons – 5 m Depth - 2007 .......................... 5-7
Figure 5-5  
MOE Offshore ADCP Comparisons – 2007 .................................................. 5-9
Figure 5-6  
MOE Offshore ADCP Comparisons - 2007 .................................................... 5-10
Figure 5-7  
MOE Nearshore ADCP Current Speed Comparisons - 2007 ......................... 5-12
Figure 5-8  
MOE Nearshore ADCP Current Direction Comparisons - 2007 ..................... 5-13
Figure 5-9  
Comparison of Model Temperature Predictions vs OPG Temperature Data ... ........................................................................................................ 5-15
Figure 5-10  
Comparison of Model Temperature Predictions vs NWRI Temperature Data ........................................................................................................ 5-16
Figure 5-11  
Comparison of Model Temperature Predictions vs MOE Offshore Temperature Data .......................................................................................... 5-17
Figure 5-12  
Comparison of Model Temperature Predictions vs MOE Nearshore Temperature Data .......................................................................................... 5-18
Figure 6-1  
Transect Locations for Water Quality Survey - Station Identification Numbers Start at Shoreline and Increase Offshore ........................................... 6-3
Figure 6-2  
75th Percentile TP by Station ........................................................................ 6-4
Figure 6-3  
Howell Presentation - TP Offshore Lake Ontario ............................................ 6-5
Figure 6-4  
Total Hours above PWQO for TP .................................................................. 6-6
Figure 6-5  
Total Hours above PWQO for TP with Added Flow from Duffins Creek .... 6-7
Figure 6-6  
Percent of 5,750 hours TP above PWQO with Duffins Creek ....................... 6-7
Figure 6-7  
Percent of 5,000 hours TP above PWQO without Duffins Creek .................... 6-8
Figure 6-8  
Peak Instantaneous TP Levels ....................................................................... 6-9
Figure 6-9  
Peak Instantaneous TP Levels with Added Flow from Duffins’ Creek ......... 6-9
Figure 6-10  
Average Surface TP Levels with Duffins’ Creek ............................................ 6-10
Figure 6-11  
Average TP levels without Duffins Creek ...................................................... 6-10

Tables

Table 3-1  
25th Percentile Lake Current Speeds for OPG Station .................................... 3-5
Table 3-2  
25th Percentile Lake Current Speeds for additional Stations ..................... 3-5
Table 3-3  
Key CORMIX Model Characteristics ......................................................... 3-6
Table 3-4  
Dilution ratio and CORMIX predictions at different flow rates – Outfall EA . ........................................................................................................ 3-7
Table 4-1  
MIKE3 Model Characteristics – 2006 and 2001 .......................................... 4-2
Table 5-1  
NWRI Fnorm DATA - 2007 ............................................................................. 5-8
Table 5-2  
MOE Offshore Fnorm Data - 2007 ................................................................ 5-8
Table 5-3  
MOE Nearshore Fnorm DATA - 2007 ............................................................. 5-11
Table 6-1  
Spatial and Temporal Extent of Surface TP Plume ....................................... 6-8
1. Background and Purpose

For effluent discharges, the Ministry of Environment (MOE) has guidelines for the near field effluent dilution and far field effluent mixing requirements. In 2006, computer modelling to assess near field effluent dilution and plume dispersion was completed as part of the Schedule C Class EA (Class EA) for the Duffin Creek WPCP Stage 3 expansion. The Expansion EA identified the preferred solution for expanding treatment capacity at the Duffin Creek WPCP to 630 ML/d. This expansion is referred to as the Stage 3 expansion, as it is the third phase of plant development. The Stage 3 expansion is planned to be completed by February 2012. It includes expansion and enhancement of treatment processes at the Duffin Creek WPCP to provide 630 ML/d capacity, while also providing additional phosphorus removal and nitrification capacity. It also provides for expansion and upgrade of the sludge treatment facilities.

The CORMIX model was used to estimate the near field dilution. The underlying model assumption was to use worst case dilution scenario under calm lake conditions. It showed that the Ministry of the Environment (MOE) dilution requirement of 20:1 for near field zone will be met by the existing outfall until the flows reach an average day flow of 560 ML/d. However, as a condition of approval for the Stage 3 Expansion, MOE required that the flow from the outfall should not exceed 520 ML/d.

In 2006, outfall discharge modelling was also completed to assess far field dilution and to see whether the treated discharge, after initial dilution and dispersion, meets Provincial Water Quality Objectives (PWQOs) for total phosphorus (TP) and un-ionized ammonia (UIA). The MIKE-3 hydrodynamic and water quality model, a three-dimensional model, was used to delineate the outfall plume and identify whether treated effluent meets PWQOs. The modelling results helped to identify the preferred expansion alternative; in particular the need to provide additional phosphorus and ammonia removal as part of the plant expansion and establish stricter TP and ammonia limits for the expanded plant. These stricter TP and ammonia limits are now part of the existing CofA requirements for the plant.

The MIKE 3 model was run at flows of 560 ML/d, with revised UIA effluent levels as a result of the addition of nitrification at the plant. The modelling results at the time indicated that on average UIA and TP levels were below the PWQO limits at 560 ML/d. In addition, the model illustrated that as a consequence of nitrification being added as part of the expansion, the UIA plume will decrease in size, and the concentrations at the Ajax WSP intake from the pre-expansion conditions, and the potential impact of ammonia on the raw water supply, would decrease. Only for very short periods of time did the modelling show that at 560 ML/d UIA and TP concentrations would be above the PWQO.

Since the modelling work carried out in 2006, MOE has outlined a new operating limit of 520 ML/d for the existing outfall and additional background lake data has become available. As a result the MIKE-3 model has been updated and re-calibrated, and a new baseline scenario of 520 ML/d flow has been run.
The purpose of this report is to describe the CORMIX and MIKE-3 models. In particular, the report details the results of re-calibration of the MIKE-3 model using updated water quality and Acoustic Doppler Current Profiler (ADCP) data. In addition to updating and calibrating the models, results from the baseline scenario run (520 ML/d) are also presented to provide a basis for future comparisons.
2. Effluent and Mixing Zone Requirements

The Ministry of Environment (MOE) requires that lake ambient conditions and effluent discharges be evaluated through lake modelling to meet surface water quality objectives and for deriving effluent requirements. The basic modelling elements are divided into “near field” modelling and “far field” modelling. Each modelling element is discussed below.

2.1 Near Field Zone Requirements

The near field zone refers to the portion of the effluent plume between diffuser ports to the location where the discharged effluent plume has effectively completed its initial mixing with the ambient lake water. An outfall must be designed with a diffuser that can provide adequate mixing based on the following:

- A discharge diffuser should provide a minimum initial dilution of 20:1, over the full range of effluent flows and ambient conditions.
- The Provincial Water Quality Objectives (PWQO) should be met at the edge of the near field zone.
- The near field zone should not interfere with other uses, such as water supply intakes, other effluent discharges, bathing beaches, fish spawning areas, or fish migration routes.
- The near field zone should be as small as possible.

The CORMIX model has been used to estimate the near field dilution. The model is specifically designed to assist in the prediction of plume behavior from various types of outfall configurations, under various lake and effluent conditions.

2.2 Far Field Effluent and Mixing Zone Requirements

After initial dilution is established, the next procedure is to determine the far-field dilution. This is where a whole lake model - such as MIKE 3 is used to delineate the plume after the initial momentum and buoyancy have dissipated. The far-field model is used to determine the size of the mixing zone where the PWQO is not achieved. In particular, the plumes’ potential effects on Lake water quality and surrounding water uses (e.g. drinking water intakes, near shore recreation, etc) are identified. The MIKE 3 model was calibrated to demonstrate realistic simulations of the lake conditions. It was then used to define the mixing zone for TP and UIA.

In past discussions, it is noted that MOE recommends for near field zones and mixing zones to be less than half the length of the outfall/diffuser, which in case of existing outfall is 591 m. The modelling scenarios presented have been evaluated against this criterion.
3. CORMIX Model and Near Field Analysis

CORMIX is a mixing zone model for assessment of near field dilution and mixing zones resulting from continuous point source discharges such as the Duffin WPCP outfall. The model emphasizes the role of boundary interaction to predict steady-state mixing behavior and plume geometry. The subsection below describes the selection of key input parameters.

3.1 Key Input Parameters

The basic characteristics used in the CORMIX model relate to the location and configuration of the outfall diffuser, effluent flow, and the ambient lake conditions. New data collected since the Expansion EA in 2006 was used to update and calibrate the CORMIX model. A description of those changes is summarized below.

3.1.1 Ambient Lake Currents

Lake currents are measured with Acoustic Doppler Current Profilers (ADCP). A number of ADCPs are located in the vicinity of the outfall as depicted in Figure 3-1.

![ADCP locations](image)

The OPG ADCP operates year round and has been functional since 2001. Current speed data for the OPG station is in Table 3-1. The other meters were deployed in 2007 but only for portions of the year. Current speed data for the other stations is in Table 3-2. The OPG location is considered to characterize the required bottom currents most accurately, due to its proximity to and similar depth as outfall diffuser (approximately 9 m). Accordingly, OPG ADCP data from 2001-2010 was used in the CORMIX model.
For lake currents, the MOE specifies the use of the 25th percentile statistic for quantifying ambient conditions. The OPG ADCP data was partitioned by season and the yearly data were enumerated to determine the low speed 25th percentile. It is well known that during the late fall to early spring period, higher speeds are observed due to higher energy storms passing through the lake. The season wise spread recorded lake current speeds from 2001-2010 is presented in Table 3.1. The current speed used for the CORMIX model was the average for the spring-summer season which was 0.044 m/s.

### Table 3.1

<table>
<thead>
<tr>
<th>Year/Season</th>
<th>Jan–Mar (m/s)</th>
<th>Apr–Jun (m/s)</th>
<th>Jul–Sep (m/s)</th>
<th>Oct–Dec (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>0.081</td>
<td>0.034</td>
<td>0.041</td>
<td>0.068</td>
</tr>
<tr>
<td>2002</td>
<td>0.109</td>
<td>0.050</td>
<td>0.0407</td>
<td>0.075</td>
</tr>
<tr>
<td>2003</td>
<td>0.071</td>
<td>0.045</td>
<td>0.044</td>
<td>n/a</td>
</tr>
<tr>
<td>2004</td>
<td>n/a</td>
<td>n/a</td>
<td>0.055</td>
<td>0.058</td>
</tr>
<tr>
<td>2005</td>
<td>0.051</td>
<td>0.039</td>
<td>0.067</td>
<td>n/a</td>
</tr>
<tr>
<td>2006</td>
<td>0.057</td>
<td>0.058</td>
<td>0.057</td>
<td>n/a</td>
</tr>
<tr>
<td>2007</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>0.072</td>
</tr>
<tr>
<td>2008</td>
<td>0.092</td>
<td>0.057</td>
<td>0.011</td>
<td>0.107</td>
</tr>
<tr>
<td>2009</td>
<td>0.060</td>
<td>0.031</td>
<td>0.039</td>
<td>0.050</td>
</tr>
<tr>
<td>2010</td>
<td>0.047</td>
<td>0.038</td>
<td>0.048</td>
<td>0.060</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>0.065</strong></td>
<td><strong>0.044</strong></td>
<td><strong>0.044</strong></td>
<td><strong>0.070</strong></td>
</tr>
</tbody>
</table>

### Table 3.2

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>25th Percentile (m/s)</th>
<th>Start Time</th>
<th>End Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>MOE Offshore</td>
<td>0.036</td>
<td>Apr 3</td>
<td>Nov 26</td>
</tr>
<tr>
<td>2007</td>
<td>Moe Nearshore</td>
<td>0.023</td>
<td>Apr 3</td>
<td>Nov 26</td>
</tr>
<tr>
<td>2007</td>
<td>NWRI</td>
<td>0.041</td>
<td>Apr 10</td>
<td>Jul 9</td>
</tr>
<tr>
<td>2007</td>
<td>NWRI</td>
<td>0.124</td>
<td>Jul 12</td>
<td>Oct 23</td>
</tr>
</tbody>
</table>

### 3.1.2 Existing Outfall Diffuser

The existing outfall is 1.1 kilometres into the lake with a 183m diffuser that has 63 evenly spaced ports. The ports are arranged in a staged diffuser configuration, staggered at an angle of 22.5° to the centre line to allow for maximum dispersion of the effluent. The existing configuration is consistent with the 2006 configuration and has not changed.

### 3.1.3 Effluent flow and Port Opening Size

The diffuser port diameter and opening schedule is established based on the available head loss in the outfall at peak flow conditions. Figure 3-2 provides the peak flows and outfall head loss for different port diameters. The CORMIX model is then run using the port diameter to determine the average flows at which the 20:1 dilution is achieved. In the Expansion EA, the
A number of key parameters used in the CORMIX model that have changed since the Expansion EA are detailed in Table 3-3.

<table>
<thead>
<tr>
<th>Model Characteristic</th>
<th>2006 (Expansion EA)</th>
<th>2011 (Outfall EA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Data</td>
<td>OPG data 2001</td>
<td>OPG data 2001-2010</td>
</tr>
<tr>
<td>Current Speed</td>
<td>4 m/s (25th percentile of OPG data from 2001)</td>
<td>4.4 m/s (25th percentile of OPG data from 2001-2010)</td>
</tr>
</tbody>
</table>

The parameters used in CORMIX are listed below.

- Average depth of diffuser: 9 m
- Average depth in Area downstream: 10 m
- Unbounded receiving water
- Uniform density structure
• Ambient current speed 0.044 m/s
• Wind speed 5 m/s
• Bottom friction 0.035 Manning’s N
• Ambient water temperature 15 °C
• Diffuser distance offshore 1000 m
• Port diameter 0.225 m @ 520 MLD
• Riser height 1.0 m
• Staged diffuser configuration, perpendicular to current
• Number of ports 63
• Port spacing 2.9 m (183 m length / 63)
• Effluent flow 520 ML/d
• Effluent Temperature +2, +5, -2 °C

The temperature difference was found to have no impact on the dilutions and initial plume behavior.

### 3.2 Results

With the above inputs parameters, the CORMIX model was run and the results are detailed in Table 3-4. At the baseline flow of 520 MLD, the CORMIX model predicted the initial dilution to be 21:1. The dilution fell below the MOE requirement of 20:1 at 580MLD. The long-list of alternatives to be assessed as part of this Outfall EA includes approaches to improve the dilution of the existing outfall, including detailed analysis of port sizing.

<table>
<thead>
<tr>
<th>Flow (MLD)</th>
<th>Dilution Ratio</th>
<th>X downstream (m)</th>
<th>Y Offshore (m)</th>
<th>Half-Width (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>520</td>
<td>21 : 1</td>
<td>45</td>
<td>413</td>
<td>159</td>
</tr>
<tr>
<td>580</td>
<td>20 : 1</td>
<td>45</td>
<td>515</td>
<td>171</td>
</tr>
</tbody>
</table>

Figure 3-3 shows the coordinate system used by CORMIX.
FIGURE 3-3
Plan View 520 ML/d – Coordinate System Used By CORMIX
4. **MIKE-3 Model Set-Up**

The DHI Software MIKE-3 platforms, a three-dimensional hydrodynamic and water quality model, was used to delineate the plume. Lake Ontario is thermally stratified during the summer months, and to accurately model the currents in the near shore, a dynamic three-dimensional model is required. The MIKE-3 model is the tool used to assess whether the treated discharge after initial dilution and subsequent dispersion meets the PWQOs.

### 4.1 Model History and Data Use

- Historically this model has been use for last 15-20 years and is approved for use by the Ministry of Environment (MOE). It uses baseline data from the whole lake. Most recently, the model was calibrated during the preparation of the Schedule C Class Environmental Assessment for “Provision of Additional Capacity at the Duffin Creek Water Pollution Control Plant” (September 2006). The model calibration and the associated results were used were relied upon by the MOE to make project and approval related decisions.

- The model has since been improved upon. It now uses a new refined grid of Lake Ontario with 90 m resolution, which allows the existing diffuser to be spread over two grids. This has resulted in an improved simulation of the effluent plume momentum and the advection-dispersion process in the far-field.

- In addition to other data, the Region and TRCA and MOE monitoring results were also used to establish ambient water quality conditions.

- The new water quality and current data were used to refine the model parameters. The calibration with new water quality data and the current data was successful; though, some locations had better model agreement than others. Generally, the model has better current predictions in the weakly to non-stratified periods. The temperature response of the model was good for the entire period of simulation.

### 4.2 Model Parameters

The MIKE-3 model is based on the fully non-linear three dimensional representation of mass, momentum and energy fluid motion. The model has the additional capacity of nesting fine grid models inside course grid to allow detailed modelling of areas of interest. The non-hydrostatic version was used as it provides the most accurate simulations for Lake Ontario.

The following salient model parameters were used in the modelling:

- Non-Hydrostatic hydrodynamic engine
- Time step 30 second Max Courant # 6.5
- Smagorinsky coefficient = 0.4
- Dispersion factors: 0.1 horizontal, 0.001 vertical
• Wind stress coefficient constant at 0.0026 and variable
• Heat exchange coefficients 0.5, 0.9, 0.395, 0.571, -1, -75, 0.1, 1, as ordered

Since the completion of Class EA, the model was updated based on the following new information:

• A new refined grid of Lake Ontario 90 m resolution.
• New current information: In 2007 three new Acoustic Doppler Current Profiler (ADCP) current meters were installed in the area; two by MOE and one by National Water Research Institution (NWRI). In the earlier modelling, current information was obtained from only one current meter installed by Ontario Power Generation (OPG).
• New Wind Field from the National Oceanic and Atmospheric Administration (NOAA) Mesascale Atmospheric model – other studies with City and CCIW have found that wind fields provide better accuracy than single airport station.
• Higher vertical resolution – Other studies have shown better accuracy resulting from it.
• Used a more accurate transport-advection scheme in the model.
• New 90m grid allowed existing diffuser to be spread over two grids.
• Water quality results based on testing undertaken by the Regions and the TRCA for the years 2007, 2008 and 2009.

Stricter effluent limits with respect to total phosphorus.

A summary of the changes in the modelling parameters since the 2006 Expansion EA are summarized in Table 4-1.

### TABLE 4-1
**MIKE3 Model Characteristics – 2006 and 2001**

<table>
<thead>
<tr>
<th>Parameter/Assumption</th>
<th>2006 (Expansion EA)</th>
<th>2011 (Outfall EA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modelling Grid</td>
<td>132 m resolution</td>
<td>90 m resolution</td>
</tr>
<tr>
<td>Modelling Period</td>
<td>April – Sep 2001 (6 months)</td>
<td>April – November 2007 (8 months)</td>
</tr>
<tr>
<td>Current Data</td>
<td>Based on data from 1 station</td>
<td>Based on data from 4 stations</td>
</tr>
<tr>
<td>Ambient TP</td>
<td>0.01 mg/L</td>
<td>0.011 mg/L in the nearshore 0.007 mg/L in the offshore</td>
</tr>
<tr>
<td>Ambient Ammonia</td>
<td>0.0 mg/L</td>
<td>0.008 mg/L</td>
</tr>
<tr>
<td>Average flows</td>
<td>560 ML/d</td>
<td>520 ML/d</td>
</tr>
<tr>
<td>Effluent TP</td>
<td>1 mg/L</td>
<td>0.6 mg/L</td>
</tr>
<tr>
<td>Effluent Ammonia</td>
<td>10 mg/L Nov- Apr, 6 mg/L May-Oct</td>
<td>10 mg/L Nov- Apr, 6 mg/L May-Oct</td>
</tr>
</tbody>
</table>

Due to above updates, the model has better temperature response including better velocity correlations.

### 4.3 Model Set-Up under Lake Ontario Ambient Conditions

Lake bathymetry refers to the lake bottom elevations that exist in the area, which will influence a lake’s assimilation capacity. The MIKE-3 Lake Ontario model is based on a
2,430 m grid of the whole lake. Nested versions of 810, 270 and 90 m are used to focus in on the area around the Duffin Creek outfall/diffuser. The bathymetry of the lake was obtained from the National Oceans and Atmospheric Administration (NOAA) project for Great Lakes Bathymetry, available on CD, Volume G2 (www.ngdc.noaa.gov/mgg/greatlakes/).

Figure 4-1 shows the whole lake and the nested version, while Figure 4-2 shows the 90 m detailed grid. The model grid has been rotated so that a smooth east-west shoreline is produced for the 90 m grid; this is a standard technique for modelling shoreline features.
FIGURE 4-1
Bathymetry of Lake Ontario (2430 GRID)
FIGURE 4-2
Bathymetry of the Duffin Creek WPCP Study Area (90 m Fine resolution Grid)
Other data used in the model included water quality, temperature, pH and currents. The existing background water quality helps determine the effect of the effluent discharge on the environment. The existing nearshore water quality for Lake Ontario was determined using the Regions, TRCA and MOE monitoring information.

The temperature of the Lake will have an effect on the buoyancy of the effluent plume and how the effluent disperses, once it is discharged. Temperature also affects the conversion of ionized ammonia (NH₄⁺), and un-ionized ammonia (NH₃). The ammonia that is converted is dependent on pH and temperature. Lake currents speed and direction, will affect the rate of dispersion and direction of the effluent plume.

The model is driven with hourly wind speed and direction from Pearson Airport. Additional meteorological data consisting of air temperature, relative humidity and cloudiness are also used to provide the thermodynamic forces responsible for heating and cooling of the lake water.

Daily water surface elevation data at Kingston are provided to the model to maintain observed water depths. Hydraulic flow (daily) from the Niagara River is applied at the mouth of the river. Water temperatures from the Environment Canada buoy in Lake Erie augment the Niagara River flow data. The cooling water flow from the Pickering NGS was not included in the model. The cooling water discharge is confined to the very near-shore area and does not influence the area of interest.

The non-hydrostatic mode and Quickest-Sharp transport scheme were used. The turbulence scheme selected was the mixed k/e Smagorinsky formulation.

The model is setup to provide continuous simulations from April to November. This period is the most sensitive time for taste and odour problems at water treatment plants and is also the most productive period for aquatic growth. In addition, the continuous simulations cover the periods when low dilutions would occur due to slow currents. Cool weather periods are associated with the higher energy events in the Great Lakes when water speeds are elevated. Integrating the hourly predictions can determine the plume delineation, which provides the spatial extent of the regions where the PWQOs are achieved or exceeded.
5. **MIKE-3 Model Calibration**

Calibration involves testing the model to see how closely it simulates existing conditions. Once it is calibrated, the model can be used to determine the effluent plume behaviour and assess the water quality impacts due to the effluent discharge. The model was calibrated based on the existing data described above, including bathymetry, water quality, pH, currents and temperature.

Extensive testing was performed on the model to ensure the accuracy of the predictions. Many simulations have been made with different airports around the lake and Pearson has consistently provided the best agreement with observed data. NOAA has made available the hourly wind field covering Lake Ontario at a 5 km resolution. The wind field is more reliable than Pearson as it does not have any missing data or zero values. In addition, the wind field more accurately represents the effects of pressure cells over the lake surface. Wind based on one station is uni-directional over the lake, while the NOAA data is variable and more realistic. An Acoustic Doppler Current Profilers (ADCP) has been deployed by Ontario Power Generation at Pickering NGS for many years. The data collected has been used to calibrate the hydrodynamic currents predicted by the MIKE-3 model.

The accuracy of the model predictions are based on the Fourier Norm, or Fnorm. The calculation involves variance between the two vector components of velocity. In model terms the velocity is computed as a V component in the onshore-offshore (north-south) direction and the U component in the alongshore (east-west) direction. Equation (1) describes the Fourier Norm as:

$$ F_N = \frac{\sqrt{\sum_{t=1}^{N} (\vec{v}_o - \vec{v}_c)^2}}{\sqrt{\sum_{t=1}^{N} \vec{v}_o^2}} $$

where $\vec{v}_o = \text{observed data and } \vec{v}_c = \text{computed data.}$ A sample calculation would be:

$$ \frac{[(U_o-U_c)^2 + (V_o-V_c)^2]}{(U_o^2 + V_o^2)} $$

A value of 0 means the model prediction is identical to the ADCP data. A value of 1 or more means the difference between the predicted vector component and observed vector component is larger than the amplitude of the vector. The Fnorm score is a standard test of the model predictions and the good scores are usually in the range of 0.9, lower scores say 0.8 are very good and rare. The data are based on either 60 or 30 minute samples depending on how often the ADCP stores data. Our results for current velocity show Fnorm values ranging from 0.6 to 0.9. Therefore, the model fit is considered good.

The model run was initiated in the spring time when the lake is thermally well-mixed at 4°C. This is also a standard technique of assigning a uniform temperature throughout the lake. The model then simulates the currents and heating/cooling through the summer and fall period. The temperatures and velocities predicted by the model are stored at
hourly/half-hourly intervals, depending on the ADCP sampling frequencies. The Fnorm is then calculated from the observations and model predictions.

The vertical resolution (Z-Coordinate system) was 2 m with 40 layers, sufficient depth for thermal stratification events to be well reproduced.

The wind stress was initially set constant at 0.0026, however predicted speeds were often greater than the observations, so the stress was reduced and set to vary depending on wind strength. The predicted speeds reduced to levels in better agreement with the observations.

Figures 5-1 and 5-2 show the predicted current speeds and directions for the OPG ADCP data from 2007 at the 1m depth layer. However, the ADCP only recorded data from October to December. From a modelling perspective, the trends are predicted correctly and results are acceptable.
FIGURE 5-1
Comparison of Modelled Lake Current SPEED with OPG – ADCP Measurements

ADCP Speed [m/s]
Model Speed [m/s]

OGP Surface

[Graph showing comparison of ADCP and model speed over time]
FIGURE 5-2
Comparison of Modelled Lake Current Direction with OPG-ADCP Measurements

ADCP [deg]  
Model Direction [deg]

OPG Surface
The overall Fnorm for the OPG ADCP was 0.67, a very good score meaning the model was able to accurately simulate the currents late in the year even after starting in May.

The NWRI ADCP data was partitioned into two periods as the meter was pulled for servicing from the water for several days at the start of July, the missing data were replaced with zero speed and direction to provide a complete data set. Figures 5-3 and 5-4 show the current speed and direction results at the 5 m depth layer.
FIGURE 5-3
NWRI Current Speed Comparisons – 5 m Depth - 2007

NWRI 5m Depth

FIGURE 5.4
NWRI Current Direction Comparisons – 5 m Depth - 2007
The 5 m layer Fnorm for this period was 0.84; a very good result. By comparison, the results for using Pearson Airport wind data indicated Fnorm value to be 1.32. Table 5-1 provides a breakdown of the Fnorm scores for the three depths.

**TABLE 5-1**  
NWRI Fnorm DATA - 2007

<table>
<thead>
<tr>
<th>Month</th>
<th>5m depth</th>
<th>10m depth</th>
<th>18m Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>April - November</td>
<td>0.84</td>
<td>0.89</td>
<td>1.06</td>
</tr>
<tr>
<td>April - May</td>
<td>0.89</td>
<td>0.94</td>
<td>0.91</td>
</tr>
<tr>
<td>May 1 – June 1</td>
<td>0.98</td>
<td>0.97</td>
<td>0.93</td>
</tr>
<tr>
<td>June 1 – July 1</td>
<td>0.99</td>
<td>1.07</td>
<td>1.09</td>
</tr>
<tr>
<td>July – August</td>
<td>0.75</td>
<td>0.80</td>
<td>1.11</td>
</tr>
<tr>
<td>August – September</td>
<td>0.82</td>
<td>0.93</td>
<td>1.24</td>
</tr>
<tr>
<td>September – October</td>
<td>0.72</td>
<td>0.77</td>
<td>1.06</td>
</tr>
<tr>
<td>October – November</td>
<td>0.57</td>
<td>0.62</td>
<td>0.99</td>
</tr>
</tbody>
</table>

The MOE Offshore ADCP had continuous records from April to October. The overall Fnorm score was 0.854 at the 1 m depth, which is very good. Figures 5-5 and 5-6 show the current speed and direction time series. As with the NWRI data, the directional agreement is very good but the current speed variance is what reduces the correlation. Table 5-2 provides more details of the Fnorm analysis.

**TABLE 5-2**  
MOE Offshore Fnorm Data - 2007

<table>
<thead>
<tr>
<th>Month</th>
<th>1 m depth</th>
<th>6 m depth</th>
<th>12 m depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr - Nov</td>
<td>0.85</td>
<td>0.88</td>
<td>1.01</td>
</tr>
<tr>
<td>May – Jun</td>
<td>0.83</td>
<td>0.91</td>
<td>1.15</td>
</tr>
<tr>
<td>Jun – Jul</td>
<td>0.98</td>
<td>0.95</td>
<td>1.22</td>
</tr>
<tr>
<td>Jul – Aug</td>
<td>0.95</td>
<td>0.92</td>
<td>1.04</td>
</tr>
<tr>
<td>Aug – Sep</td>
<td>0.81</td>
<td>0.95</td>
<td>0.94</td>
</tr>
<tr>
<td>Sep – Oct</td>
<td>0.82</td>
<td>0.86</td>
<td>0.93</td>
</tr>
<tr>
<td>Oct - Nov</td>
<td>0.66</td>
<td>0.63</td>
<td>0.67</td>
</tr>
</tbody>
</table>
FIGURE 5-5
MOE Offshore ADCP Comparisons – 2007
FIGURE 5-6
MCE Offshore ADCP Comparisons - 2007

MOE Offshore Direction
The MOE nearshore ADCP also had a long term record and the overall score was 0.90 at the 1 m depth. The meter depth was only 6 m. The data from July onwards had many small data gaps which made analysis difficult as data replacement was required. The missing data was at depth as it appears the lake elevation may have fluctuated and the bottom bin was often missing. Figures 5-7 and 5-8 show the comparisons. Table 5-3 provides more details of the Fnorm analysis. The nearshore zone has much higher frequency current reversals and is dominated by an easterly current direction.

**TABLE 5-3**
MOE Nearshore Fnorm DATA - 2007

<table>
<thead>
<tr>
<th>Month</th>
<th>Surface</th>
<th>6 m depth</th>
<th>10 m depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr - Nov</td>
<td>0.90</td>
<td>1.01</td>
<td>NA</td>
</tr>
<tr>
<td>May – Jun</td>
<td>0.94</td>
<td>1.04</td>
<td>NA</td>
</tr>
<tr>
<td>Jun – Jul</td>
<td>0.86</td>
<td>1.00</td>
<td>NA</td>
</tr>
<tr>
<td>Jul – Aug</td>
<td>0.95</td>
<td>1.00</td>
<td>NA</td>
</tr>
<tr>
<td>Aug – Sep</td>
<td>0.81</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Sep – Oct</td>
<td>0.93</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Oct - Nov</td>
<td>0.82</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>
FIGURE 5-7
MOE Nearshore ADCP Current Speed Comparisons - 2007

MOE Nearshore Speed

Speed (m/s)


ADCP Speed    Model Speed
FIGURE 5-8
MCE Nearshore ADCP Current Direction Comparisons - 2007
Overall the model has accurate prediction in the spring and fall period. The stratified period is more challenging and the accuracy drops off, but still has good directional response while the current speeds do not. The MOE nearshore location is shallow and may be affected by longshore wave action. The offshore meters generally underestimate peak events, which may be due to insufficient vertical resolution or not large enough wind stress.

The temperature predictions for each ADCP are shown in Figures 5-9 to 5-12.
FIGURE 5-9
Comparison of Model Temperature Predictions vs OPG Temperature Data

[Graph showing comparison between ADCP Temperature and Model Temperature over time]

OPG ADCP Temperature

Temperature (°C)


FIGURE 5-10
Comparison of Model Temperature Predictions vs NWRI Temperature Data

NWRI Bottom Temperature

Temperature (°C)


ADP Temp [deg C]  Model Temp [deg C]
FIGURE 5-11
Comparison of Model Temperature Predictions vs MOE Offshore Temperature Data

Temperature (°C)


MOE Offshore bottom Temperature

Model Temperature [°C]  
AOOF [°C]

COPYRIGHT 2013 BY CH2M HILL CANADA LIMITED • ALL RIGHTS RESERVED • COMPANY CONFIDENTIAL
FIGURE 5-12
Comparison of Model Temperature Predictions vs MOE Nearshore Temperature Data

MOE Neashore bottom Temperature

Temperature (°C)

The ADCP only measures temperature at the meter depth. The model reproduces the spring and summer period quite well. There are upwelling/downwelling events that are simulated, although the temperature dips are not as large as observed. The correlation between the MOE offshore temperature and the predicted temperature at the ADCP depth is 0.918, which is a very good score.
6. Baseline Modelling – 520 ML/d

One of the conditions of the approval of the Schedule C Class Environmental Assessment for the “Provision of Additional Capacity at the Duffin Creek Water Pollution Control Plant” (September 2006) was that the outfall limitations be addressed before flows reached 520 ML/d. This is the minimum flow at which the MOE assumed that dilution requirements of 20:1 would not be met. Consequently, 520 ML/d is the flow considered as the baseline for modelling, which future flows and outfall configurations will be modeled against. Parameters modeled were total phosphorus and un-ionized ammonia.

6.1 Existing Outfall

The existing outfall is approximately 1 km offshore with a 183m long diffuser. The diffuser was represented in the model as two sources adjacent to each other but aligned offshore. The flow rate (520 ML/d) was set at 260 ML/d in each grid cell with the exit velocity set to 2.4 m/s. The exit direction was offshore and the vertical angle was set to 10° above vertical. This representation provides the proper momentum produced by the diffuser – although it is spread over the one layer and two grid cells. The flow is released in the bottom layer. There are no methods in the model software to allow variable depth - spatial releases based on ambient buoyant conditions such as those predicted by near-field models like CORMIX.

6.2 Effluent Certificate of Approval Requirements

The Certificate of Approval was revised in 2007 to reflect the expansion requirements identified in the Schedule C Class EA for “Provision of Additional Capacity at the Duffin Creek Water Pollution Control Plant” and the Minister’s conditions of approval. The CofA requirements that were taken into consideration for use in the baseline model scenario are:

- Total Phosphorus: 0.6 mg/L
- Total Ammonia Nitrogen: 5 mg/L
- Un-ionized Ammonia Nitrogen 0.1 mg/L

The above concentrations were used in modelling effluent levels.

6.3 Provincial Water Quality Objectives

Phosphorous is considered a nuisance nutrient that may affect the surrounding aquatic environment. In particular, Total Phosphorus (TP) has been shown to contribute to increased algal formation at concentrations greater than the interim Provincial Water Quality Objective (PWQO) of 0.02 mg/L in lakes.

Un-ionized ammonia (UIA) is an important measure of the level of effluent toxicity to aquatic organisms. The PWQO for UIA is 0.02 mg/L. Un-ionized ammonia is calculated from the measured value of total ammonia based on both temperature and pH data from the measured location.
6.4 Duffins Creek

Duffins Creek is a contributor to pollutant loading to the Lake. Consequently, the model was run with and without the influence of Duffins Creek for comparison purposes.

The Toronto & Region Conservation Authority (TRCA) provided time series of flow from Duffins Creek on an hourly basis. Monthly Event Mean Concentrations (EMC) for TP was provided as well. The EMC were used as input of concentration of TP in the Creek flow. It was assumed that the ammonia levels were zero as there should be no sources along the Creek.

Ambient Lake Levels for TP

An extensive water quality survey program was performed for the period 2007 to 2009 by the Region and Toronto Region Conservation Authority. Seven transects were sampled several times each year for TP, soluble reactive phosphorus, total suspended solids, conductivity and E.coli for a total of 24 data points. Figure 6-1 shows the locations of each transect, the shoreline station would be labeled 10 and then each offshore station would be 110, 140, 1,100 m offshore and 1,500 m offshore. The MOE uses the 75th percentile to define the ambient water quality. Figure 6-2 shows the 75th percentile for each station. The ambient TP level would be most likely be found at the furthest offshore stations, away from shoreline discharges and the diffuser. The average of the 75th percentile of the offshore stations is 0.011 mg/L. The web site http://theskua.com/wqapp/wqapp.html, has all the data plotted.

Dr. Howell, of the MOE, presented results of his survey of the TP levels in Lake Ontario at the 2010 Lake Erie Millenium Network – April 2010, “Patterns in Nutrients over Dressena-Cladophora Impacted Shoreline” Slide 7 is presented, which show the TP levels offshore of Port Hope in Figure 6-3. The offshore levels of TP range from 0.004 mg/L to 0.007 mg/L. Therefore, it is proposed that the ambient levels of the Lake Ontario grid (2,430 m resolution be set at 0.007 mg/L and the nested grids in the nearshore area of Duffins Creek ambient level set at 0.011 mg/L.
FIGURE 6-1
Transect Locations for Water Quality Survey - Station Identification Numbers Start at Shoreline and Increase Offshore
FIGURE 6-2
75th Percentile TP by Station

75th Percentile Phosphorus by Station

TP µg/L

Station Name
FIGURE 6-3
Howell Presentation - TP Offshore Lake Ontario
6.5 Total Phosphorus in Lake Ontario under the 520 ML/d Baseline Scenario

TP was modelled as a conservative parameter meaning no assimilation was assumed in the model. There will be some assimilation in the actual plume as biological processes convert the TP into biomass. The results presented herein are therefore conservative, and impacts under existing conditions are expected to be less.

The model was run to simulate lake conditions from April 1 to November 27 for a total of 5,750 hours. The hourly average TP levels were enumerated for the surface layer and the total number of hours the TP level was above the PWQO of 0.02 mg/L were determined with just the effluent discharge and with the added input from Duffins Creek, as shown in Figures 6-4 and 6-5, respectively. Figures 6-6 and 6-7 show the percent of time that PWQO are exceeded with just the effluent discharge and with added flow from Duffins Creek.

FIGURE 6-4
Total Hours above PWQO for TP
FIGURE 6-5
Total Hours above PWQO for TP with Added Flow from Duffins Creek

FIGURE 6-6
Percent of 5,750 hours TP above PWQO with Duffins Creek
A summary of the spatial and temporal extent of the TP surface plume is presented in Table 6-1. The results indicate that PWQO are exceeded over 60% of the 5,750-hour timeframe in an area over 17 hectares surrounding the outfall. The total area where PWQO for TP are exceeded is approximately 1,300 hectares. The results further indicate that Duffins Creek has minor impact on TP levels in the effluent plume, but does influence TP concentrations in the near shore.

**TABLE 6-1**
Spatial and Temporal Extent of Surface TP Plume

<table>
<thead>
<tr>
<th>Hours above PWQO (0.02mg/L)</th>
<th>Number of grids (90m x 90m)</th>
<th>Number of grids (90m x 90m) with Duffins’ Creek</th>
<th>Area (ha)</th>
<th>Area (ha) with Duffins’ Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>4,000 to 5,000</td>
<td>22</td>
<td>23</td>
<td>17.8</td>
<td>18.6</td>
</tr>
<tr>
<td>3,000 to 4,000</td>
<td>47</td>
<td>47</td>
<td>38.1</td>
<td>38.1</td>
</tr>
<tr>
<td>2,000 to 3,000</td>
<td>79</td>
<td>78</td>
<td>64</td>
<td>63.1</td>
</tr>
<tr>
<td>1,000 to 2,000</td>
<td>172</td>
<td>176</td>
<td>139</td>
<td>142.5</td>
</tr>
<tr>
<td>1 to 1,000</td>
<td>1,608</td>
<td>1,594</td>
<td>1,302</td>
<td>1,291</td>
</tr>
</tbody>
</table>

The model results were analyzed to determine the instantaneous impact using the peak concentration in each grid point observed over the 5,750 hour simulation, as well as to estimate average surface TP levels. The peak concentrations with the effluent only and with the addition of flow from Duffins’ Creek are illustrated on Figures 6-8 and 6-9, respectively. Figure 6-10 and 6-11 illustrates the average surface TP levels for the effluent discharge.
FIGURE 6-8
Peak Instantaneous TP Levels

FIGURE 6-9
Peak Instantaneous TP Levels with Added Flow from Duffins’ Creek
The results indicate that on average PWQO for TP is exceeded in a very small area of the whole lake, but on a local scale it covers a large area. The extent of the 10% of time above PWQO isopleth is 1,710 m to the west, 1,080 m to the east and 810 m to the south – centered over the diffuser. Using the 10% isopleths, the mixing zone is therefore defined as 1,170 m to the west, 1,080 m to the east and 810 m offshore. The highest average level is 0.054 mg/L and is located at the discharge points as expected. For peak concentrations the surface
plume is observed to travel westward and then reverse and move back and forth as shown by the direction plots presented in the calibration section. The cumulative impact of the plume is determined by integrating the predictions over the simulation period. The peak levels will not occur simultaneously; rather each grid point will experience a peak at different times during the simulation period.

The areas of the lake impacted by elevated TP levels due to the discharge are mainly toward the west and extend offshore as well as onshore. There is a small easterly impacted area, which demonstrates the majority of currents are toward the west in this area of Lake Ontario. These simulations do not account for any assimilation of TP to the environment. If the surface plume is transported beyond the 90 m grid boundaries, it is likely that the plume will return at a highly diminished level since some of the TP would be assimilated in the environment. The areas shown are more likely the result of slow currents and short term current reversals rather than long term buildup of TP. Observations in the past several years show this to be the case as seen in the TRCA and MOE sampling survey, the plume is not readily apparent.

The size of the mixing zone is a result of the poor initial dilution produced by the diffuser.

6.6 Un-Ionized Ammonia Levels in Lake under 520 ML/d Baseline Scenario

Ambient Ammonia levels were surveyed in 2008 by the MOE. Figure 6-12 show the ammonia levels on survey date July 29, 2008. The entire data set can be found at http://theskua.com/ajax. The 75th percentile of all data from the five surveys is 0.008 mg/L. The ambient levels in the lake were set to this value.
The Un-Ionized Ammonia (UIA) was calculated using the predicted surface layer concentration of ammonia and the corresponding temperature in the grid, along with the pH measured at the Ajax WTP intake. Ammonia was also modelled as a conservative parameter. The Ajax data was daily and the model data were hourly. It was assumed that the pH was constant over the grid for the day of record. The synoptic data were used to determine the UIA, and then the hours above the PWQO of 0.02 mg/L were enumerated. The simulation results were partitioned into a winter and summer period – as required by MOE – and since the ammonia levels in the effluent vary in these periods.

Figures 6-13 and 6-14 (total hours) and Figures 6-15 and 6-16 (percent of time) show the results. The area impacted is not dominated by a particular direction, as was found with the TP results. The corresponding peak UIA levels are shown in Figures 6-17 and 6-18; the winter peak level is 0.064 mg/L and the summer peak levels is 0.122 mg/L. The average UIA levels in the surface layer are presented in Figure 6-19 and 6-20; the highest average level is 0.019 mg/L in the winter and 0.032 mg/L in the summer. The UIA levels are lower in the winter, even with the effluent ammonia level higher than summer, because of the colder water temperatures affecting the UIA factor. Figures with Duffins’ Creek are not included as there is assumed to be no ammonia in the Creek discharge, the Creek’s influence is some dilution water at the mouth.
FIGURE 6-13
UIA Hours above the PWQO (0.02 mg/L) - Winter Period

FIGURE 6-14
UIA hours above PWQO (0.02 mg/L) - Summer Period
FIGURE 6-15
Percent of time UIA above PWQO – Winter Period

FIGURE 6-16
Percent of Time UIA above PWQO - Summer Period
FIGURE 6-17
Peak UIA Levels for Winter Period

FIGURE 6-18
UIA Peak Levels Summer Period
Table 6-2 presents a summary of the spatial and temporal extent of the UIA surface plume. The effect of Duffins’ Creek causes some increases and decreases due to dilution and changing the shoreline distribution.
TABLE 6-2
Spatial and Temporal Extent of Surface UIA Plume

<table>
<thead>
<tr>
<th>Hours above PWQO (0.02mg/L)</th>
<th>Number of grids (90m x 90m) without Duffins’ Creek</th>
<th>Number of grids (90m x 90m) with Duffins’ Creek</th>
<th>Area (ha) without Duffins’ Creek</th>
<th>Area (ha) with Duffins’ Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>400 to 500</td>
<td>1</td>
<td>1</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>300 to 400</td>
<td>2</td>
<td>2</td>
<td>1.6</td>
<td>1.6</td>
</tr>
<tr>
<td>200 to 300</td>
<td>3</td>
<td>3</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>100 to 200</td>
<td>15</td>
<td>15</td>
<td>12.1</td>
<td>12.2</td>
</tr>
<tr>
<td>1 to 100</td>
<td>218</td>
<td>215</td>
<td>176.6</td>
<td>174.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Winter Period November 1 to April 30</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Summer Period May 1 to October 31</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>400 to 500</td>
<td>36</td>
<td>38</td>
<td>29.1</td>
<td>30.8</td>
</tr>
<tr>
<td>300 to 400</td>
<td>49</td>
<td>48</td>
<td>39.7</td>
<td>38.9</td>
</tr>
<tr>
<td>200 to 300</td>
<td>91</td>
<td>91</td>
<td>73.7</td>
<td>73.7</td>
</tr>
<tr>
<td>100 to 200</td>
<td>314</td>
<td>312</td>
<td>254</td>
<td>252</td>
</tr>
<tr>
<td>1 to 100</td>
<td>2,608</td>
<td>2,617</td>
<td>2,112</td>
<td>2,119</td>
</tr>
</tbody>
</table>

Using the same 10% above the PWQO isopleths, the mixing zone for UIA is:

- Winter — 180 m east and 90 m south of diffuser
- Summer — 270 m east, 270 m south, and 540 m west of the diffuser.

As in the TP results, the poor initial dilution produced by the existing diffuser account for the size of the mixing zone.

From a drinking water quality perspective, the predicted ammonia time series at the depth layer (7) representative of the Ajax Intake is shown in Figure 6-21. The UIA, based on the temperature at layer 7 and the same location as the Ajax Intake is shown in Figure 6-22. The peak ammonia level occurs in mid June, but the peak UIA occurs later in September due to a change in the lake temperature and pH. The peak UIA level is well below the PWQO for UIA (0.02 mg/L).
FIGURE 6-21
Ajax Intake Ammonia Time Series

Ammonia at Ajax Intake depth
FIGURE 6-22
Ajax Intake UIA time series

UIA at Ajax Intake depth

[Graph showing UIA at Ajax Intake depth over time]
The Pickering NGS discharge will pull in some of the lake water with diluted effluent and then discharge it back to the lake with a small temperature increase. The increase in temperature has the potential to raise the level of UIA in that water – however the discharge is not included in this model.
7. **Summary and Conclusions**

7.1 **Summary of Results**

7.1.1 **CORMIX MODEL: Near-Field Analysis**

- The CORMIX near field analysis indicates that the initial dilution of the existing diffuser is 21:0 at the baseline flow of 520 MLD.

7.1.2 **MIKE 3 MODEL: Far-Field Analysis**

- The calibration with ADCP currents was successful; some locations had better model agreement than others. Generally the model has better predictions in the weakly to non-stratified periods. The temperature response of the model was very good for the entire period of simulation.

- The existing discharge, modelled over two grid points, simulated the momentum of the plume and the advection-dispersion process in the far-field.

- The model predicted the spatial and temporal extent of the effluent plume for both TP and ammonia. UIA was subsequently determined from synoptic temperature and pH data. Integration of the hourly results and using the PWQO limits, the model results were used to define the extent of the mixing zone for UIA and TP.

- The results indicate that on average PWQO for TP at 520 ML/d is exceeded in a very small area of the Lake. Using the 10% of time above PWQO isopleths, the mixing zone is 1,710 m to the west, 1,080 m to the east and 810 m to the south – centered over the diffuser. The highest instantaneous (1 hour) level is 0.054 mg/L and is located at the discharge points.

- While the peak TP was found to be above the PWQO in a larger area than average, the spatial and temporal extents of these exceedances are very limited.

- The results indicate that the UIA mixing zone is much smaller than that for TP. Out of 5,750 hours of simulation (April to November) the areas ranged from: 2,110 Ha had between 1 and 100 hours over the PWQO and less than 30 Ha had between 400 and 500 hours. Using the same 10% above the PWQO isopleths as in the TP method, the mixing zone for UIA is:
  - Winter - 180 m east and 90 m south of diffuser,
  - Summer – 270 m east, 270 m south and 540 m west of the diffuser.

- While, the peak UIA was found to be above the PWQO, the spatial and temporal extents of these exceedances are very limited; again much less than that for TP. The UIA levels at the Ajax Intake were reviewed from a drinking water quality perspective and were noted to be well below the PWQO.
The model results that included the flow from Duffins’ Creek showed there is some shoreline impact from the Creek with TP, while the UIA results showed the Creek flow provides some relief due to dilution, as the Creek is assumed to be free of ammonia.