Appendix E Sensitivity Analysis Memo

Stantec

Memo

To:	Juraj M Cunderlik, Ph.D., P.Eng. Mississippi Valley Conservation Authority	From:	Igor Iskra, Ph.D., P.Eng. Stantec Consulting Ltd.
Project/File:	163401646	Date:	September 22, 2022

Reference: Sensitivity Analysis of Some Parameters on Results of Assimilative Capacity Study – Mississippi River at Carleton Place

INTRODUCTION

The Town of Carleton Place (the Town) in consultation with the Ministry of the Environment, Conservation and Parks (MECP) has identified a need to update the Assimilative Capacity (AC) Study of the Mississippi River at the effluent discharge location of the Carleton Place Wastewater Treatment Plant (WWTP). The previous AC study was prepared by Stantec Consulting Ltd. (Stantec) in 2009 (Stantec, 2009). The Town retained Stantec to conduct an updated AC study in support of their proposed WWTP upgrades. The updated AC study was completed on August 15, 2022 (Stantec, 2022).

The updated AC study of the Mississippi River at Carleton Place was reviewed by the Mississippi Valley Conservation Authority (MVCA) and a sensitivity analysis of some critical parameters was requested. In particular, MVCA requested:

- to reduce the 7Q20 by 10% and examine sensitivity of low flow conditions on the AC study results.
- to increase the 75th percentile of baseline water quality by 18% for total ammonia and total phosphorus. This increase is based on the results of the Mississippi Lake Study (MVCA, 2019) which found that concentrations of nutrients generally increase by 18% between inflow and outflow from Mississippi Lake.
- to re-run CORMIX model for new flow and water quality condition.
- to derive a set of new effluent criteria for total phosphorus and total ammonia (if required).

This memo summarizes the results of the sensitivity analysis for total phosphorus and total ammonia for a scenario with reduced 7Q20 and increased 75th percentile of baseline concentrations.

RESULTS

As requested by MVCA, the 7Q20 was reduced by 10% from 3.88 m^3/s to 3.49 m^3/s. The maximum daily effluent flow of the upgraded WWTP, outfall design, configuration of six diffusers, bathymetry, water temperature and other modeling input parameters were the same as in AC Study (Stantec, 2022).

Scenario 1 represents the water quantity and quality conditions evaluated in the AC study (Stantec, 2022) as per the Ontario Ministry of Environment and Energy (MOEE, now known as MECP) Procedure B-1-5 (MOEE 1994a) and Water Management – Policies, Guidelines and Provincial Water Quality Objectives

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(MOEE, 1994 & 1999). Scenario 1 represents the conservative modelling conditions, such as the 7Q20 flow in the receiver, 75th percentile ambient concentrations, design effluent flow rate, and maximum effluent concentrations.

Scenario 2 represents an additional level of stress on top of conservative conditions in Scenario 1. The 7Q20 flow was further decreased and background concentrations were increased. A summary of Scenario 1 and 2 is presented in **Table 1**.

Table 1 Modelling Scenarios

Parameters	Flow, m^3/s		Total Phosphorus, mg/L		Total Ammonia, mg/L	
	Receiver	Effluent	Receiver	Effluent	Receiver	Effluent
Scenario 1	3.88	0.43	0.016	0.3	0.014	4.0
Scenario 2	3.46	0.43	0.019	0.3	0.017	4.0

A dilution-mixing scenario with ambient and effluent conditions for Scenarios 1 and 2 was run using a CORMIX model. The results for the WWTP effluent dilution modelling for two flow scenarios are presented in **Table 2.** In both scenarios, the geometry of the effluent diffuser (6 nozzles over 10 m) and location (middle of the main river channel) provide substantial initial mixing and dilution.

Table 2 CORMIX Dilution Ratios

Downstream Distance, m	5 m	10 m	20 m	46 m	63 m	100 m
Scenario 1	6.3	6.7	7.4	9.0	10.0	10.0
Scenario 2	6.2	6.6	7.3	9.0	9.0	9.0

In Scenario 1, the effluent is fully mixed with the ambient environment at 63 m from the diffuser. Average ambient velocity at these conditions is 0.097 m/s.

In Scenario 2, the effluent is fully mixed with the ambient environment at 46 m from the diffuser. Average ambient velocity at these conditions is 0.086 m/s.

Total phosphorus is a parameter of concern in the AC study. Total phosphorus is not toxic to aquatic life, but excess concentrations can lead to changes in aquatic ecosystems (e.g., reduced biodiversity, reduced oxygen conditions, toxic algae blooms, impaired aesthetics and recreational opportunities). In the updated AC study (Stantec, 2022), it is proposed to reduce the existing phosphorus limit from 1 mg/L to 0.3 mg/L and reduce total phosphorus load from 22 kg/day to 11.1 kg/day. The proposed effluent concentration of 0.3 mg/L is protective of the environment, reduces phosphorus load in comparison with current conditions and is in line with the MECP design consideration for sewage treatment plants with phosphorus removal and filtration

The 75th percentile of total phosphorus in the Mississippi River is 0.016 mg/L. This ambient concentration was used in Scenario 1. Ambient concentration of total phosphorus in Scenario 2 was increased to 0.019 mg/L as per MVCA directions.

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Table 3 shows changes in total phosphorus in the mixing zone for Scenarios 1 and 2. It was noted that phosphorus concentrations in the mixing zone for Scenario 2 increased by 5-12% in comparison with Scenario 1. Taking into account that stressed conditions in Scenario 2 have very low probability and, if occur, will have short duration, no changes to the proposed ECA limits for total phosphorus are recommended. Additionally, treatment of total phosphorus below 0.3 mg/L will be very costly for the Town.

Table 3 Total Phosphorus in Mixing Zone, mg/L

Downstream distance, m	5 m	10 m	20 m	46 m	63 m	100 m
Scenario 1	0.061	0.058	0.054	0.048	0.044	0.044
Scenario 2	0.064	0.062	0.057	0.050	0.050	0.050

Scenarios 1 and 2 were run for total ammonia and un-ionized ammonia. Total ammonia is the sum of un-ionized ammonia (NH3) and ionized ammonia (NH4). Typically, an equilibrium exists between NH3 and NH4, which is governed by pH and water temperature.

The 75th percentile of total ammonia in the Mississippi River is 0.014 mg/L. This ambient concentration was used in Scenario 1. The 75th percentile total ammonia concentration in Scenario 2 was increased to 0.017 mg/L as per MVCA directions.

Table 4 shows changes in total ammonia in the mixing zone for Scenarios 1 and 2. It was noted that changes in total ammonia in the mixing zone are up to 10%, but absolute concentrations remain relatively low.

Table 4 Total Ammonia, mg/L

Downstream distance, m	5 m	10 m	20 m	46 m	63 m	100 m
Scenario 1	0.647	0.609	0.553	0.457	0.413	0.413
Scenario 2	0.659	0.620	0.563	0.460	0.460	0.460

In assimilative capacity studies, un-ionized ammonia is of primary interest as it potentially can be toxic in lower concentrations. The PWQO for un-ionized ammonia is 0.02 mg/L N.

Worst case summer conditions were used for un-ionized ammonia modeling. Highest monthly summer water temperature of 25.0 degrees C and highest summer pH of 7.44 were used for modeling.

Table 5 shows changes in un-ionized ammonia in the mixing zone for Scenarios 1 and 2. The PWQO for un-ionized ammonia is met immediately at the outfall for Scenarios 1 and 2.

Table 5 Un-ionized Ammonia (Summer Conditions), µg/L

Downstream distance, m	5 m	10 m	20 m	46 m	63 m	100 m
Scenario 1	10.1	9.5	8.6	7.1	6.5	6.5
Scenario 2	10.3	9.7	8.8	7.2	7.2	7.2

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CONCLUSION

Effluent limits for the WWTP treated effluent presented in AC study (Stantec, 2022) were derived as per MECP guideline documents and based on the conservative modelling conditions (e.g., 7Q20 flow in the receiver, 75th percentile ambient concentrations, design effluent rate, and maximum effluent concentration). Scenario 1 in this assessment corresponds to modeling conditions presented in Stantec (August 15, 2022).

A sensitivity analysis for total phosphorus and total ammonia was requested by MVCA. The MVCA requested an additional level of conservatism, by reducing the 7Q20 flow by 10% and increasing the 75th percentile of baseline total ammonia and total phosphorus by 18%. Scenario 2 in this assessment corresponds to stressed conditions requested by MVCA.

Scenarios 1 and 2 were run using the existing CORMIX model. It was found that changes in flows and ambient water quality result in an increase of total phosphorus and total ammonia in the immediate mixing zone by 5-12%.

As expected, phosphorus concentrations in Scenario 2 are somewhat higher than in Scenario 1. However, stressed conditions in Scenario 2 have very low probability and, if they were to occur, will have short duration. Therefore, no revision of the ECA limits presented in AC study (Stantec, 2022) is recommended. Additionally, treatment of phosphorus below 0.3 mg/L will be very costly for the Town. The proposed ECA limits already reduce the existing phosphorus limit from 1 mg/L to 0.3 mg/L and reduce total phosphorus load from 22 kg/day to 11.1 kg/day. The proposed limit for phosphorus for the proposed plant is protective of the environment, reduces phosphorus load in comparison with current conditions and is in line with the MECP design consideration for sewage treatment plants with phosphorus removal and filtration.

Un-ionized ammonia meets the PWQO in the immediate mixing zone for Scenarios 1 and 2. Proposed total ammonia limits are protective of the environment.

No revision of the ECA limits for total phosphorus and ammonia presented in AC study (Stantec, 2022) is proposed based on this analysis.

CLOSURE

We trust this information is satisfactory for your purposes. If you have any questions, please contact the undersigned.

REFERENCES

MVCA 2019 Mississippi Lake Study, April 2019. Preliminary Results.

Stantec 2009 Receiving Water Assessment Review for Carleton Place Water Pollution Control Plant Discharge to Mississippi River, May 20, 2009.

Stantec 2022 Assimilative Capacity Study – Mississippi River at Carleton Place, Final Report, August 15, 2022.

Ministry of Environment & Energy (MOEE) 1994a. Deriving Receiving-Water Based, Point-Source Effluent Requirements for Ontario Waters, Procedure B-1-5, PIBS# 3302, July 1994.

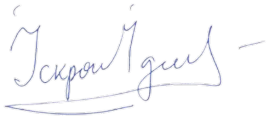
Reference: Sensitivity Analysis of Some Critical Parameters on Results of the Assimilative Capacity Study – Mississippi River at Carleton Place

Ministry of Environment & Energy (MOEE) 1994b. Provincial Water Quality Objectives, July 1994.

Ministry of the Environment. 1999. Provincial Water Quality Objectives, PIBS 3303E, Queen's Printer for Ontario. July 1994, reprinted February 1999.

Best regards,

STANTEC CONSULTING LTD.



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