Water Environment Association of Ontario

Young Professionals Committee and Student Design Competition Sub-Committee

and the

Ontario Ministry of the Environment, Conservation and Parks

In Collaboration with

The Corporation of the City of Barrie

WEAO STUDENT DESIGN COMPETITION 2025

PROJECT STATEMENT

Biosolids Treatment Efficiency and Resource Recovery at the City of Barrie Wastewater Treatment Facility

AUGUST 2024

1.0 INTRODUCTION

The topic of the 2025 WEAO Student Design Competition is biosolids treatment efficiency and nutrient recovery at the City of Barrie Wastewater Treatment Facility (Barrie WwTF). The Barrie WwTF treats municipal wastewater from residential, commercial, and industrial sources, as well as domestically produced hauled wastes.

The goal of the project is to enhance biosolids treatment efficiency while also supporting nutrient recovery at the Barrie WwTF. The design teams are asked to evaluate the current processes and identify initiatives that will improve digester capacity and performance, reduce biosolids volume, and examine nutrient recovery opportunities. Phase 1 proposals will provide recommendations to improve digester capacity and performance through deploying methods within the existing physical infrastructure of the WwTF (i.e. operational modifications and minor capital investments). Phase II proposals will provide recommendations on dewatering to reduce biosolids volume and supporting nutrient recovery through dewatering centrate side stream treatment.

2.0 BACKGROUND – THE WASTEWATER TREATMENT FACILITY

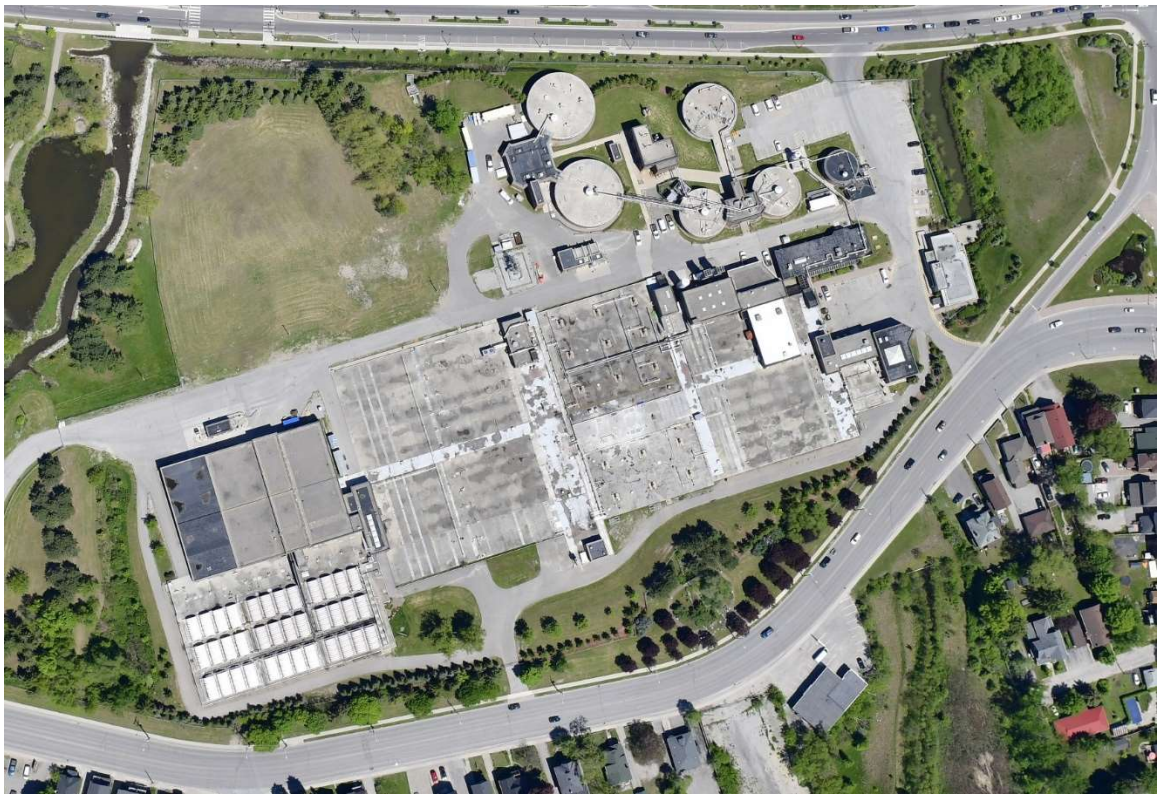


Figure 1: Aerial photo of the City of Barrie Wastewater Treatment Facility

The Barrie WwTF is owned and operated by the City of Barrie in accordance with the terms and conditions of the Amended Environmental Compliance Approval (ECA) 0284-B2ML52 issued August 28, 2018 and Air ECA 6401-C2FKWA dated June 2, 2021.

The Barrie WwTF is located at the west side of Lake Simcoe in Kempenfelt Bay.

Address: Barrie WwTF
249 Bradford St
Barrie, Ontario
L4N 3B6

The Barrie WwTF treats all residential, commercial, and industrial generated wastewater in the City of Barrie, excluding a few septic systems located within the City. Wastewater travels to the WwTF via 530 km of sanitary sewer and 13 pumping stations with associated force mains.

The Barrie WwTF is a regulated Class IV wastewater treatment facility. The major processes that are used to treat the wastewater include:

- raw sewage pumping,
- automated mechanical screening,
- grit removal,
- primary sedimentation,
- conventional activated sludge with high purity oxygen aeration,
- secondary clarification,
- enhanced phosphorus removal with dual point chemical addition,
- rotating biological contactors,
- rapid sand filtration, and
- UV disinfection.

The treated effluent is discharged through a 1.2 meter diameter 316 m length outfall extending into Kempenfelt Bay of Lake Simcoe.

The Barrie WwTF was first built in 1931 as a septic tank on the periphery of urban settlement. Since this time, the plant has continued to expand and grow corresponding to population growth and increasing regulatory requirements. The area surrounding the plant has also been developed and is currently primarily residential and commercial use. This, combined with the fact that the Barrie WwTF is also adjacent to a pristine public beach and park, makes it critical that the facility limits potential negative public perception for noise, odour, or awareness.

Table 1: Plant Capacity

Rated Capacity of the WwTF	76,000 m^3/day
Hourly Peak Capacity of the WwTF	156,000 m^3/day

The influent wastewater is treated in several stages for removal of total suspended solids, organics, total ammonia nitrogen, and total phosphorus (TP) and receives year-round disinfection before being discharged into Lake Simcoe. See influent characteristics in Table 2.

In 2015 the Lake Simcoe Phosphorus Reduction Strategy came into enforcement for the Barrie WwTF. This significantly decreased the TP that the City of Barrie was able to discharge into Lake Simcoe from a limit of 0.18 mg/L (monthly average) to 0.1 mg/L (yearly average) and an objective of 0.15 mg/L (monthly average) to 0.07 mg/L (yearly average). Furthermore, the total annual mass of TP that the City of Barrie is able to discharge into Lake Simcoe was also set at 2774 kg/year. This has significant implications for growth of the City of Barrie because as flows increase, the ultimate discharge TP concentration must decrease accordingly in order to achieve the total annual TP mass requirement.

Sludge management at the Barrie WwTF utilizes anaerobic sludge digestion for the stabilization process. Waste activated sludge is thickened in rotary drum thickeners prior to entry into an aerobic blending tank where it is mixed with primary sludge from the primary clarifiers. Blended sludge is directed to one of three primary digesters (PD), two 1,580 m^3 volume and one 3,800 m^3 volume, for stabilization. The digested sludge is then directed into a secondary digester and finally a biosolids holding tank for storage. Biosolids are land applied on agriculture land according to the Non Agriculture Source Material requirements under O. Reg. 267/03 during the months of April to November. For the months of December to March and during particularly wet periods, biosolids are hauled to a biosolids storage facility (BSF) in Oro-Medonte. The BSF is located at 630 Line Seven North in Oro-Medonte and operated in accordance with the terms and conditions of Provisional Certificate of Approval A252707 dated March 26, 2008.

In 2023, the Barrie WwTF had an average raw sewage total daily flow of 58,160 m^3/day with a maximum daily flow of 80,071 m^3/day. Based on 2023 plant information, the following data is noted below in Table 2.

Table 2: 2023 Annual Average Raw Wastewater Characteristics

Parameter	**Concentration (mg/L)**	**Loading (kg/d)**
Biological Oxygen Demand (BOD_5)	203	11,114
Total Suspended Solids (TSS)	306	15,997
Total Phosphorus (TP)	5.04	289
Total Ammonia Nitrogen (TAN)	25.3	1,388

The Barrie WwTF ECA effluent discharge requirements are outlined below in Table 3.

Table 3: City of Barrie WwTF ECA Effluent Discharge Criteria

Parameter	Concentration *(mg/L)*		Loading *(kg/d)*
	Objective[1]	**Limit[2]**	**Limit**
$cBOD_5$	10	15	1,140
Total Suspended Solids	10	15	1,140
Total Phosphorus	0.12	0.18	13.7
Total Ammonia Nitrogen: Jun 1 - Oct 31	3	4	304
Total Ammonia Nitrogen: Nov 1 - May 31	8	10	760
E. coli *(CFU)* [3]	100	200	-
pH	6.5 - 8.5	6.0 - 9.5	-

Notes: [1]based on single sample result, [2]monthly average, [3]monthly geometric mean density

The Lake Simcoe Phosphorus Reduction Strategy requirements, which are also outlined in the ECA, are noted below in Table 4. These TP limits supersede those in Table 3 in terms of annual average concentration and annual loading.

Table 4: City of Barrie WwTF Lake Simcoe Phosphorus Reduction Strategy Limits

Lake Simcoe Phosphorus Reduction Strategy Compliance Limits	
Average Annual Concentration Total Phosphorus Limit (mg/L)	0.1
Average Annual Concentration Total Phosphorus Objective (mg/L)	0.07
Annual Total Phosphorus Loading Limit (kg/year)	2,774

2.1 BACKGROUND – BIOSOLID TREATMENT CAPACITY

The Barrie WwTF solids handling process is nearing the limit of its current capacity, particularly in terms of anaerobic primary digestion. This potentially poses significant challenges for the facility as the City is expected to grow in population significantly over the near future, projections estimate a population of 200,000 by 2031 and 300,000 by 2051. This growth in population will correspond to an increase in contaminate loading to the Barrie WwTF with an associated increase in organic loading to the digesters. Further complicating the solids handling process is the fact that one 1,580 m^3 PD had to be brought offline in 2021 for required maintenance. This has reduced the digestion capacity by 25%.

The anaerobic PDs receive flow from the aerobic blending tank which combines thickened waste activated sludge and primary sludge. The annual average daily flow in and out of the PDs and the yearly average of biosolids leaving the Barrie WwTF may be seen below in Table 5.

Table 5: City of Barrie WwTF Primary Digester and Biosolids Haulage Yearly Average Daily Flow

Year	Average of PD #1 Flow *(m3/day)*	Average of PD #2 Flow *(m3/day)*	Average of PD #3 Flow *(m3/day)*	Average of Biosolids Haulage *(m3/day)*
2017	111	89	181	341
2018	116	85	173	367
2019	110	88	177	366
2020	109	82	166	353
2021	134	61*	188	374
2022	116	0	195	297
2023	118	0	203	309

** PD2 was brought offline for required maintenance in September 2021.*

Prior to PD2 coming offline, the sludge flow balance between the digesters was 25%, 25%, and 50% for PD1, PD2, PD3, respectively. As may be seen in the data, PD1 has a higher flow than PD2 due to it receiving all scum that is removed from the primary clarifiers.

The impact of PD2 coming offline was slightly dampened as a result of an initiative that was implemented in 2022 to optimize the primary sludge concentration in the primary clarifiers at the WwTF. This initiative significantly increased the primary sludge concentration and thus reduced the volume of primary sludge by approximately 25%.

The typical digester effluent quality from the blending tank, PDs, and the secondary digester is outlined below in Table 6.

Table 6: City of Barrie WwTF Average Digester Feed and Effluent Quality (2017 – 2023)

Process Unit	Alkalinity *(mg/L CaCO3)*	Ammonia *(mg/L)*	pH	TS *(%)*	Vol Fatty Acids *(mg/L)*	Volatile Solids *(%)*
Blending Tank	1,154	204	4.1	4.1	2,420	79.9
Primary Digester 1	2,268	636	7.2	2.3	199	65.6
Primary Digester 2*	2,704	740	7.3	2.3	115	64.6
Primary Digester 3	3,064	854	7.4	2.4	191	65.3
Secondary Digester	3,139	865	7.4	2.3	197	64.3

** Data to Sept 2021*

As noted in the background above, biosolids produced at the Barrie WwTF are land applied during the summer months and stored at the BSF during the winter and wet periods. Previous seven-year total annual biosolid field application and BSF storage is outlined below in Table 7. Also listed is supernatant that is generated during the storage process and is returned to the headworks of the

Barrie WwTF. Approximately 10 – 12 trucks leave the Barrie WwTF each business day hauling biosolids. This is associated with considerable environmental impact from the greenhouse gas emissions associated with the truck haulage. The traffic also results in increased wear and tear on municipal infrastructure as well as potential health and safety concerns from the volume of trucks from biosolids traveling in the area surrounding the Barrie WwTF.

Table 7: City of Barrie Biosolids Haulage and Supernatant Annual Volumes (2017 – 2023)

Year	WwTF to Field *(m3)*	WwTF to Storage *(m3)*	Total WwTF from Plant *(m3)*	Storage to Field *(m3)*	Supernatant Returned *(m3)*
2017	54,242	82,402	136,644	53,933	45,035
2018	58,382	76,413	134,795	50,315	45,152
2019	51,332	82,602	133,933	44,057	49,799
2020	51,829	79,222	131,050	61,993	36,302
2021	55,152	81,370	136,522	58,240	25,536
2022	44,199	64,302	108,501	50,374	22,473
2023	46,321	66,071	112,392	63,254	19,439

Further detailed information on the performance of the WwTF, particularly the biosolid stabilization process, biosolids haulage and field application may be seen in the provided supplemental information.

2.2 BACKGROUND – RESOURCE RECOVERY AND ENERGY UTILIZATION

Biogas is produced during the anaerobic process in the primary digesters. The biogas is primarily composed of methane at a concentration of approximately 60%. The generated biogas is used at the Barrie WwTF in two combined heat and power (CHP) 250kW generators, one 55HP boiler and one 100HP boiler. Historical gas production and how it is utilized is outlined below in table 8. As may be seen, not all biogas is fully utilized and is thus flared to the environment. The reason for this is insufficient gas utilization capacity and also due to existing CHP control and instrumentation, only one generator may operate at a time.

Table 8: City of Barrie WwTF Biogas Production (2017 – 2023)

Year	Biogas Utilized *(m3)*	Biogas Flared *(m3)*	Total Biogas *(m3)*
2017	1,480,913	422,866	1,903,780
2018	1,403,575	561,999	1,965,574
2019	1,394,024	693,757	2,087,781
2020	1,413,913	640,191	2,054,103
2021	1,292,093	762,859	2,054,952
2022	1,389,514	641,042	2,030,557
2023	1,460,132	729,808	2,189,940

In 2019 the City of Barrie declared a climate emergency and has a goal of reducing overall greenhouse gas (GHG) emissions below 2018 levels by 2030

and to be net-zero by 2050. In order to achieve these goals novel and innovative strategies must be implemented. One aspect to reduce GHG emissions could include full utilization of WwTF generated biogas.

3.0 OBJECTIVES

The Design Team will provide the following:

- Phase 1: Preliminary design for enhanced capacity and performance of digesters to process the increased loading associated with the future population growth projections to 2051.
    - >60% volatile solids destruction during anaerobic digestion
    - Estimate additional biogas production
- Phase 2: Conceptual design for dewatering in which the Barrie WwTF may benefit from improved biosolids removal and nutrient recovery opportunities

4.0 DESIGN CRITERIA

Water Quality

- Adherence to the Environmental Compliance Approval effluent limits and no decrease in performance in terms of effluent water quality, including pollutant loadings, based on the last three years.

Digester Performance

- Increase in digester performance for volatile solids destruction and gas production.

Proposed designs must take into consideration the rated capacity of the Barrie WwTF, projected population growth for the City, and limitations of the footprint of the existing plant. At no time should the improvement of one element lead to the deterioration of performance in any other element.

5.0 SCOPE OF WORK

The project documents should address the following elements:

Phase 1 – Preliminary Design

Provide a proposal to enhance the digesters' capacity and performance to achieve >60% volatile solids destruction with associated population growth. An estimate of the biogas produced associated with the increased loading from projected population growth for 2051. The proposed methods must take into consideration the limitations of the footprint of the existing plant and not result in expanding existing physical infrastructure. For example, methods for consideration could include modifying operational processes (e.g. primary

clarifier optimization or primary sludge thickening), or small capital/technology that fits within the existing physical infrastructure.

The proposal should include an analysis of historical data of digester performance, a review and comparison of various methods to improve digester performance, the engineering feasibility of implementing the methods, and the recommended method.

Phase 2 – Conceptual Designs for Dewatering and Nutrient Recovery

Propose how dewatering could be used to improve biosolids removal and support nutrient recovery, including examining side stream treatment. A conceptual design must be provided, including comparisons of technologies/methods, biosolids removal and storage requirements, biosolids nutrient concentrations, additional nutrient recovery by-products if applicable, and if relevant, effluent and/or dewatered centrate characteristics.

6.0 DESIGN REPORT REQUIREMENTS

The design should address the following points:

Background

- Analysis of the existing digester capacity and performance, including examining how performance changed 4 years prior to and after one of the digesters was taken offline. Characteristics to be analyzed include % volatile suspended solids destruction, hydraulic retention time, solids retention time, volatile suspended solids loading, biogas production, and flow in and out of the digesters,
- Identification of challenges of the existing plant design with regard to digester capacity and performance, and
- Identification of anticipated future population growth and wastewater demands in terms of flow, concentrations, digester capacity and biosolids storage.

Phase 1

- Comparative discussion of alternative processes and techniques to enhance digester capacity and performance;
- An economic cost-benefit analysis should be conducted for the preferred and alternative methods;
- Selection of the preferred process (utilizing a decision matrix);
- Expected improvement in digester performance for volatile solids reduction and biogas production;
- Identify limitations of the preferred approaches and how they may be minimized through addressing other plant processes/design in order to improve digester performance, etc.;

- Preliminary sizing of major equipment or installations, including an outline of process control systems;
- Methods used to minimize environmental impact during construction;
- Preliminary capital cost estimate;
- Operating and maintenance cost estimates; and
- Implementation schedule and the need for pilot work to verify the preferred alternatives for scale up application.

Phase 2

- Conceptual designs of the process or processes for dewatering and dewatering centrate side stream treatment for nutrient recovery; and
- Estimates of the biosolids volume reduced and biosolids storage requirements, including comparison to anticipated growth projections and wastewater demands,
- Estimates of the reduction in biosolids nutrients concentrations,
- Viability of side stream treatment for nutrient recovery,
- Estimates of the associated cost, income or cost avoidance, and if relevant, effluent and/or dewatered centrate characteristics.

There is no limit to the number of appendices attached to the design report. However, the appendices must contain, as a minimum, the following:

- Calculations indicating the expected digester performance, biogas production, and biosolids volume reduction and storage requirements, and any effects on the treatment process (either to the liquid or solid streams) of the proposed design. Include all calculation spreadsheets;
- Manufacturer data sheets and catalogues of all major equipment; and
- Design drawings (see below for details).

7.0 DESIGN DRAWING REQUIREMENTS

Design drawings must be provided that clearly show the layout of the proposed Barrie WwTF retrofit(s). As a minimum, the following three drawings must be included:

1. Site plan for the Phase 1 retrofit;
2. Process schematic for Phase 1 retrofit; and
3. A drawing identifying Phase 2 sites and preliminary layouts.

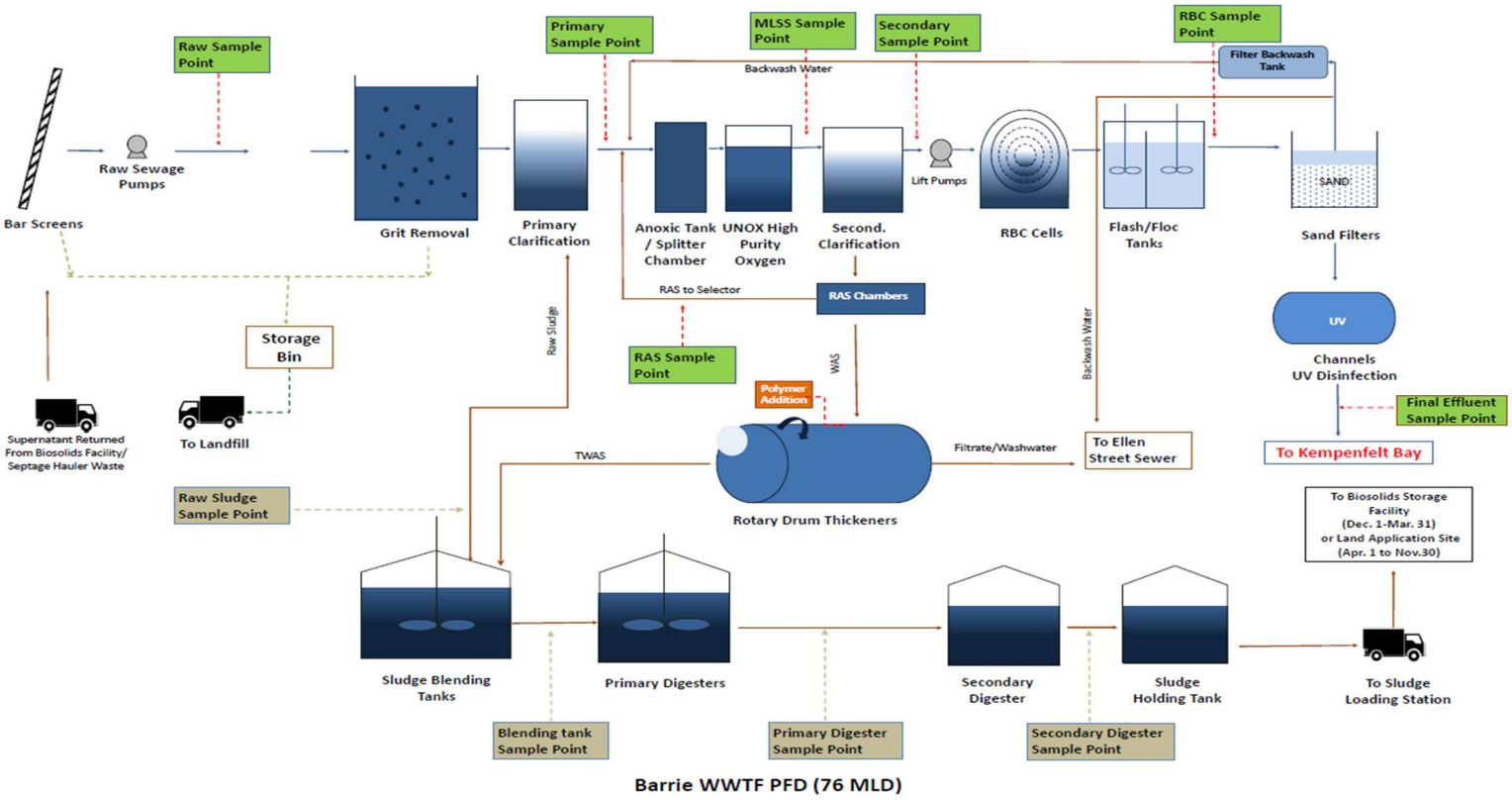
The drawings must be in PDF format as an appendix in the design report.

8.0 SUPPLEMENTAL INFORMATION

The following documents are provided to the participating teams, via Google Drive, to aid in the preparation of the design:

- Historical data of the Barrie WwTF, including digester influent and effluent quality and volumetric flow,
- Barrie WwTF Environmental Compliance Approval, and
- Barrie WwTF design drawings.

Appendix A – Plant Process Flow Diagram



Barrie WWTF PFD (76 MLD)