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

Chatham-Kent PUC

WEAO STUDENT DESIGN COMPETITION 2019
PROJECT STATEMENT

OPTIMIZATION OF ENERGY AND NUTRIENT RECOVERY FROM WASTEWATER

JUNE 2018

WEAO Student Design Competition 2019

Optimization of Energy and Nutrient Recovery from Wastewater

INTRODUCTION

The topic of the 2018-19 WEAO Student Design Competition is resource recovery at the Chatham Water Pollution Control Plant (CWPCP). The CWPCP treats municipal wastewater from residential and commercial/industrial sources, and also hauled wastes. Currently, the treatment plant recovers energy by using biogas produced at the plant in a combined heat and power plant.

The goal of the project is to maximize the revenue generated from recovering resources (energy, nutrients) present in the wastewater treated by the CWPCP. The design teams are asked to evaluate the current processes and identify initiatives that will improve financial returns from resource recovery. Phase I proposals will provide recommendations to improve financial returns using only the existing infrastructure (i.e. operational modifications and minor capital investments). Phase II proposals will provide recommendations on infrastructure improvements to improve financial returns above those achievable by implementing Phase I.

BACKGROUND – CHATHAM-KENT

Chatham-Kent is a municipality in Southwestern Ontario that is mostly rural with population centres of Chatham, Wallaceburg, Tilbury, Blenheim, Ridgetown, Wheatley and Dresden. The municipality was created in 1998 by the merger of Kent County and 23 townships. The population was 101,647 in 2016. More information on the community can be found on municipality’s web pages; a link to its strategic plan can be found in the supplemental information.

The Chatham-Kent Public Utilities Commission (CK-PUC) operates water and wastewater systems in the municipality. It was created in 1998 by merging the 13 public utilities commissions in the former Kent County. CK PUC is fully funded through water and sewer charges.

BACKGROUND – THE PLANT

The Chatham Water Pollution Control Plant (CWPCP) is an activated sludge wastewater treatment plant located at 100 Irwin Street in the community of Chatham. CWPCP is the largest of the nine municipal wastewater treatment facilities operated by CK-PUC serving approximately 43,550 people, and has a rated capacity of 36,000 m^3/day with a peak flow rate capacity of 72,000 m^3/day.

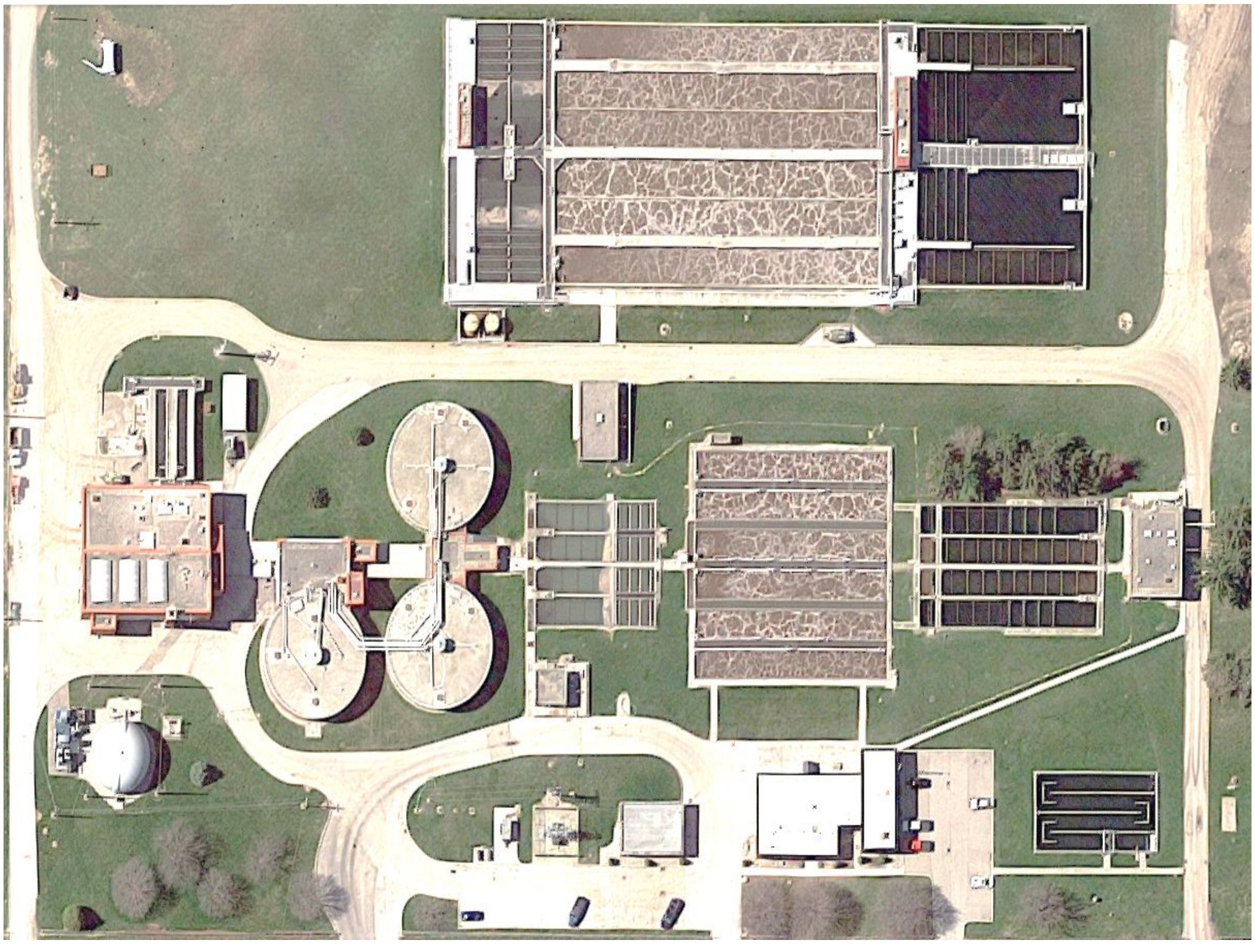

Figure 1: Aerial photo of Chatham Water Pollution Control Plant (2016)

CWPCP treats municipal wastewater from residences and businesses/industries connected to the collection system, and also accepts hauled wastewater and landfill leachate. Industries that discharge to the collection system include a corn-based alcohol producer, food processing industries, greenhouse and a few automotive based industries. Influent characteristics are provided in Table 1, and Figure 2 shows plant flows in 2017.

Table 1: Influent Characteristics of municipal wastewater treated by the CWPCP

PARAMETER	2017	2016	2015
Total Flow (1,000 m^3)	7,585.3	7,557.3	7,405.0
Avg Daily flow (1,000 m^3)	20.8	20.7	20.3
Peak day flow (1000 m^3)	62.1	67.8	63.0
TSS (mg/L)	260	169	232
BOD_5 (mg/L)	187	172	210
TP (mg/L)	5.2	4.6	5.1

TKN (mg/L)	28.3	31.6	36.6

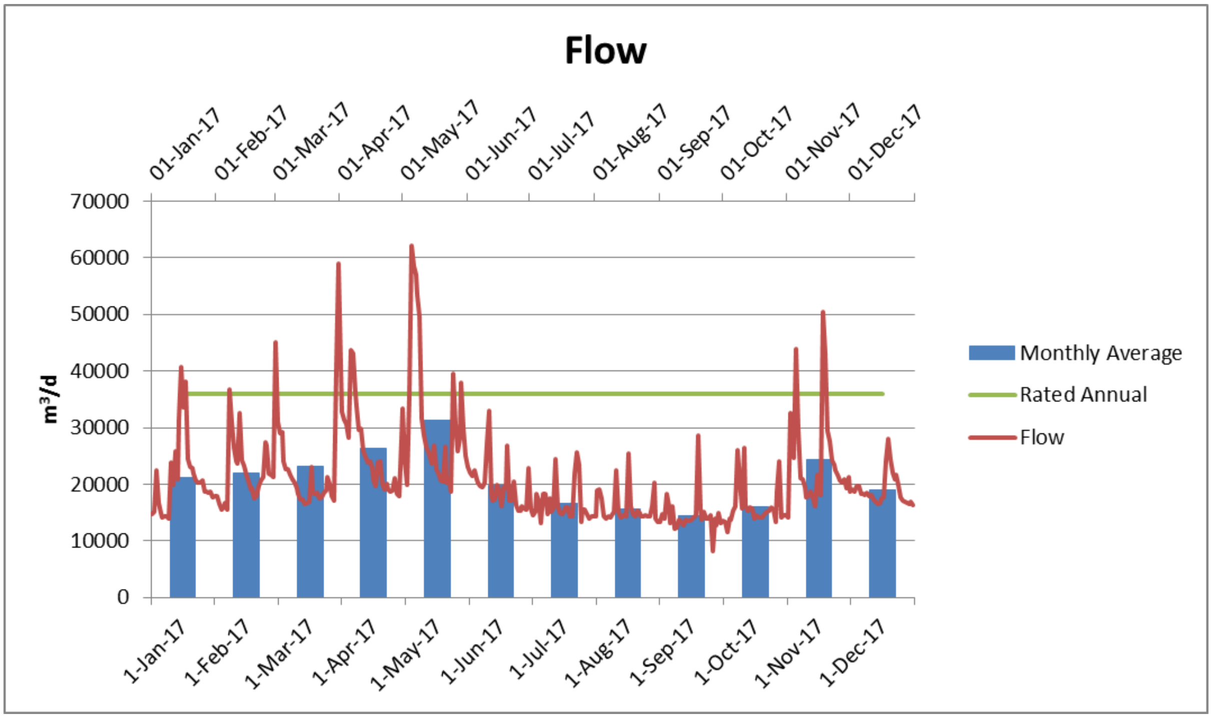

Figure 2: CWPCP plant flow from January – December 2017

The CWPCP has two treatment trains, Plant 1 and Plant 2. Each treatment train includes primary clarifiers, aeration basins and secondary clarifiers. The aeration basins have anoxic zones at the head of each basin. The number of units and their sizes are listed in Table 2, and a process flow diagram of the plant is included in Appendix A. On-site lagoons provide temporary retention of primary-treated wastewater during high flows, which is subsequently reintroduced to the plant during lower-flow periods via the Main Lift Pumping Station. Excess phosphorus is removed using chemical precipitation with ferrous chloride added at the head of the primary clarifiers.

Table 2: Number and sizes of liquid treatment processes at CWPCP

Process	Plant 1	Plant 2
Primary Clarifiers		
Surface Area (m^2)	476 (two cells)	600 (two cells)
Aeration Basins		

Volume (m^3)	6,340 (two cells each cell with three passes)	13,000 (two cells each cell with three passes)
Secondary Clarifiers		
Surface Area (m^2)	714	1,400

Final effluent is discharged to the Thames River, which flows into Lake St. Clair and is part of the Western Lake Erie basin. Effluent discharge criteria for CWPCP are listed in Table 3 as stated in Environmental Compliance Approval (ECA) number 6551-8WXKHC (refer to the ECA for more information on effluent requirements).

Table 3: ECA Effluent requirements of the CWPCP

Effluent Parameter	**Effluent limit monthly average concentration (mg/L except for E.Coli)**	**Effluent objective monthly average concentration (mg/L)**
$cBOD_5$	15	10
TSS	15	10
TAN freezing period	4	3
TAN non-freezing period	3	2
TP	0.75	0.6
Total Residual Chlorine	0.01	Non-detectable
E.Coli	200 counts per 100 mL (monthly geometic mean density)	150 counts per 100 mL

Sludge management at the CWPCP utilizes three 2,340 m^3 anaerobic digesters, each equipped with mixing equipment and piping for sludge and digester gas. Two digesters are operated as primary digesters and the third as a secondary digester. Sludge settled in primary clarifiers is transferred to primary digesters for stabilization. Primary clarifier sludge includes Waste Activated Sludge (WAS) from secondary clarifiers as WAS is co-thickened in the primary clarifiers. The biogas produced in the digesters is used as fuel for a combined heat and power plant, and excess biogas is flared. Digested sludge is dewatered in two 2.5 meter wide belt filter sludge presses that include a polymer mixing and dosing system. Dewatered sludge is transferred to sludge drying beds before final disposal where it is hauled to Ridge Landfill as top dressing.

Historical, Recent and Pending Plant Upgrades

Upgrade 1963: Plant One

- One primary clarifier with two cells having a total surface area of $476m^2$
- A diversion gate associated with primary clarifier # 1 to lagoon pumping station
- One aeration tank with two cells and three passes in each cell having a total aeration volume of $6340m^3$
- Aeration Blower room with four blowers
- One secondary clarifier with two cells having a total surface area of $714m^2$
- Two anaerobic digesters with a capacity of $2340m^3$
- Return activated sludge pumping building
- Chlorination and contact chamber

Upgrade1991- 1997: Headworks/Digester

- A head works building, receiving flows from onsite pump station and pump station number 3
- Two mechanical screens with screening conveyor
- Two grit tanks with an effective volume of $366m^3$, including grit removal system
- Leachate holding tank with a volume of $180m^3$
- Flow splitting channel
- Sulfur dioxide building
- One anaerobic digester with capacity of $2340m^3$
- External contact chamber for disinfection and dechlorination

Upgrade 2004: Plant Two

- One primary clarifier with two cells having a total surface area of $600m^2$
- A diversion gate associated with primary clarifier # 2 to lagoon pump station
- One aeration tank with two cells and three passes having a total volume of $13,000m^3$
- Four $8000m^3/hr$ capacity blowers to supply process air
- One secondary clarifier with two cells having a total surface area of $1400m^2$

Upgrade 2013: Sludge Receiving and Transfer Station

- One $74m^3$ storage capacity buried fiberglass sludge receiving tank
- Co-Generation in partnership with Entegrus Power

Co-Generation System:

- Size: 27,500 ft^3
- Capacity: 177 cfm
- Capabilities of the Co-Gen system: 250 KW
- Quality required: Composition Max: 0.5% H_2S, CO_2, CH_4, O_2
- Output in electricity: 250 KW

Upgrade 2015: Turbo Blower

- Replacement of blower. Upgrades resulted in an estimated annual reduction of 1,356,835 kWh. Project cost of $235,000 results in a cost avoidance of $135,683.50.

Upgrade 2018: Headworks and Electrical Upgrades

- Headworks Ventilation and Electrical Upgrades Project valued at $500,000.
- Electrical Upgrades Project valued at $1.1 million
- Headworks fine screening upgrade expected total cost of $400,000.00

BACKGROUND - OPTIMIZATION

Optimization is a philosophy of continuous improvement to make the best use of existing resources – people, infrastructure and funding. Successful optimization requires making data-based decisions and balancing multiple objectives, requirements and/or needs.

An example of successful optimization is the achievement of total ammonia removal and low total phosphorus discharges at the Brantford Wastewater Treatment using existing treatment infrastructure. Optimization to achieve nitrification removed a $27.75 million expansion and upgrade from the city's budget, and demonstration of phosphorus removal capabilities is deferring a $15 million expenditure on effluent filters. Case studies providing more information on Brantford's optimization activities, and also a case study on blower optimization at the Simcoe Wastewater Treatment Plant can be found in the supplemental information.

Selecting and controlling operational parameters is a key element of an optimization program. A worksheet of some typical operational parameters for activated sludge treatment plants is provided in the supplemental information as a reference.

BACKGROUND – RESOURCE RECOVERY

Globally, municipal wastewater treatment plants are broadening their objectives from removing contaminants to recovering resources as a value add product. Resources that can be recovered from municipal wastewater include:

- Energy such as biogas, heat, or kinetic energy;
- Nutrients such as phosphorus and nitrogen;
- Reusable water; and
- Other valuable constituents in municipal wastewater.

Some wastewater treatment plants are focusing on energy recovery and production to become self-reliant on energy produced at the treatment plant ("net zero") or net exporters of energy. A number of treatment plants are pursing this approach, and information on an Ontario approach to wastewater energy recovery and production can be found in the supplemental information.

Nutrient recovery and reuse is another area of resource recovery gaining interest in the municipal wastewater industry. Technologies now exist to extract nutrients from wastewater to produce commercial fertilizers. One example of nutrient recovery are technologies that create struvite from wastewater process streams, which can be marketed as a slow-release fertilizer.

BACKGROUND - CHALLENGES

CK-PUC is already pursuing resource recovery through energy recovery via the CHP system. However, there may be opportunities to improve energy recovery and implement nutrient recovery.

It is the utility's desire to maximize the benefits of the existing CHP system through revenue generation from electricity production, and offsetting heating requirements at the treatment plant. Opportunities to maximize benefits may be through process control optimization of the liquid or solid (sludge) treatment trains and/or addition of organic wastes (e.g. fats, oils and greases and organic waste from off-site sources) to increase biogas production. A summary of biogas production is provided in Table 4. Note that the CHP was not operational in 2017 and so not data is available for that period.

Table 4: Historical Biogas Production

Year	Digester Gas to CHP (m^3)	Digester Gas Flared (m^3)	Natural gas Used (m^3)
2015	488,449	230,272	488
2016	402,879	140,674	195,577
2017	0	406,768	33,843

The CWPCP is located in the Western basin of Lake Erie. Recently, the governments of Canada and Ontario released the Canada-Ontario Lake Erie Action Plan that states on page 45:

Ontario will work with municipal partners to establish by 2020 a legal effluent discharge limit (in Environmental Compliance Approvals) of 0.5 milligrams per litre of total phosphorus for all municipal wastewater treatment plants (WWTPs) in the Lake Erie basin that have an average daily flow capacity of 3.78 million litres or more

Currently, the discharge limit for total phosphorus at the CWPCP is 0.75 mg/L, which means CK-PUC must work toward maintaining a lower total phosphorus discharge than what is currently required. The treatment plant removes excess phosphorus using chemical precipitation by ferrous chloride, which is a significant operational cost and may make the phosphorus unavailable for re-use. Table 5 provides a summary of influent and effluent total phosphorus, and the amount of ferrous chloride added.

Table 5: Influent and effluent Total Phosphorus (TP) and chemical added

	2017	**2016**	**2015**
Influent TP (mg/L)	5.2	4.6	5.1
Effluent TP (mg/L)	0.3	0.42	0.28
Ferrous Chloride Added (L/d)	72	66	55

Another consideration at the CWPCP is operations staff must manage variable loading to the plant due to rainfall events, and periodic high loadings from local industries, and hauled wastewater. A summary of plant flows and loading is provided in Table 1. CWPCP also accepts hauled septage and received 2,941 m^3 in 2017. There is currently no additional quality data available on septage, as it is not sampled and analysed either in house, or by a third party lab. This is, however, being put into place later in 2018.

Variable loadings at a wastewater treatment plant pose a challenge because high flows can lead to a loss of solids from the plant and periodic or seasonal loadings from industry can upset treatment processes.

Balancing the desired outcomes of maximizing the benefits of the CHP system and reducing phosphorus discharges with the variability in process loadings poses day to day challenges for treatment plant operations. CK-PUC believes opportunities exist to optimize the system as a whole (liquid and solids treatment trains) to meet their desired outcomes while achieving good economical effluent that protects the environment and supports the local economy.

PROJECT GOAL AND SPECIFIC OBJECTIVES

The goal of the project is to maximize revenue generated from recovering resources (energy, nutrients) present in the wastewater treated by the CWPCP using existing infrastructure, and using infrastructure upgrades.

The specific objectives of the project are:

Phase 1:

- Evaluate current digester performance, biogas production and CHP performance.
- Create a conceptual plan and/or design for operational modifications and minor infrastructure improvements to improve digester gas production and CHP performance using existing liquid and solid treatment train infrastructure.

Phase 2:

- Create a preliminary design to recover additional energy resources above that achieved by Phase 1.
- Produce a conceptual design for one additional area in which the CHWTP may benefit from nutrient recovery opportunities while not decreasing the current level of TP performance.

DESIGN CRITERIA

Designs must meet the following 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.

Climate Change

- Overall reduction of greenhouse gas emissions from the CWPCP to work toward adherence to Ontario's Five Year Climate Change Action Plan (Action Area: Government, 1.2) which outlines the new government greenhouse gas pollution reduction target as 50 per cent below 2006 levels by 2030.

Cost-effectiveness

- Maximize electricity and revenue generated through the CHP system
- Target payback of 5 years on any investments; however, payback periods up to 10 years will be considered provided there are additional benefits (e.g. ease of operation, improved performance) that warrant a higher payback period

Proposed designs must take into consideration the rated capacity of the WPCP, limitations of the footprint of the existing plant and the importation of sludge from other facilities. At no time should the improvement of one element lead to the deterioration of performance in any other element.

SCOPE OF WORK

Design team proposals need to address the following elements:

Phase I

Characterization of current digester performance, biogas production and CHP performance, and a proposal to optimize the existing infrastructure through operational modifications and minor capital investments to achieve the goal of the project. The proposal can address the solid and/or the liquid treatment trains. The proposed method(s) must not include addition of major infrastructure (e.g. building an additional digester or increasing the size of an aeration basin), but could include new mechanical equipment (e.g. mixer, pump), replacement or improvement of existing mechanical equipment, and additional monitoring equipment. The proposal must not include importing organic wastes other than those already received (importing organic wastes can be addressed in Phase II). The proposal should include a review and comparison of various methods, a conceptual design of any added/modified equipment, suggested studies to gather additional information, and the engineering feasibility of implementing proposed actions.

Phase II

The design team will propose enhancements to the solids and/or liquid train to recover additional energy resources or achieve energy efficiencies from the wastewater treatment processes above that achieved by Phase 1. The enhancements can include construction of new processes, modifications of existing ones, or importing additional wastes to the treatment plant. The preferred alternative should benefit operations, lessen the environmental impact and/or reduce the cost of treatment. A preliminary design must be provided including comparisons of technologies, energy demands and preliminary economics.

The design team will also propose one other area where a nutrient recovery opportunity exists that could also lessen the environmental impact and/or reduce the cost of treatment. A conceptual design must be provided including comparisons of technology, energy demands, preliminary economics and effluent characteristics.

DESIGN REPORT REQUIREMENTS

Specifically, the Design Team must provide the following:

Background

- Characterization of current anaerobic digestion performance (e.g. volatile solids destruction), biogas production, and CHP performance relative to expected performance
- Characterization and quantification of the nutrient value of industrial loading, residential wastewater, sludge receiving, leachate and septage. Include a rationale for any estimates when plant data is not available.

- Characterization of current greenhouse gas emissions from the entire plant (combination of liquid and solid treatment trains). Include a rationale for any estimates when plant data is not available.

Phase I

- Comparison of current plant process parameters (see process parameters worksheet in supplemental information) to those of a typical activated sludge treatment plant
- An optimization plan that identifies potential process control modifications, limitations of the proposed modifications and how to overcome them. The optimization plan could also include a conceptual design for minor capital improvements that could enhance performance of the existing liquid and solid treatment system to meet the goal of the project.
- A comparison of alternative approaches to optimization.
- Identification of any monitoring and data gaps/needs, and propose studies to collect additional data or information.
- An economic cost-benefit analysis for the preferred and alternative approaches that includes operating and maintenance cost estimates, as well as pay-back periods.
- Selection of the preferred process using a decision matrix.
- Computation of the expected energy recovery yield, revenue generation, and greenhouse gas emissions of the preferred approach.
- Identification of limitations of the preferred approach and how they may be minimized.

Phase II

- Comparative discussion of alternative resource recovery processes and techniques that are relevant to the CWPCP.
- An economic cost-benefit analysis for the preferred and alternative methods including preliminary capital, operating and maintenance cost estimates, as well as pay-back periods.
- Selection of the preferred process (decision matrix)
- Expected energy recovery yield, revenue generation, and greenhouse gas emissions of the preferred process.
- Required strategies, policies and agreements for the Township on accepting external wastes for digestion improvement (if chosen as a preferred alternative)
- Identify limitations of the preferred approaches and how they may be minimized.
- Preliminary design of the preferred alternative. Designs will include preliminary sizing of major equipment or installations, including an outline of process control systems.
- Implementation schedule and the need for pilot work to verify the preferred alternative for scaled up application at the treatment plant.

Appendices must include:

- Calculations indicating the expected resource recovery, revenue generation, greenhouse gas emissions 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 and minor equipment; and

- Design drawings (see below for details).

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

1. A drawing identifying Phase I sites and conceptual layouts for minor equipment
2. A schematic identifying monitoring modifications and locations, if applicable.
3. Site plan for the Phase II retrofit including value added component;
4. Process schematic for Phase II retrofit;

The drawings must be printed on 11" x 17" landscape sheets, folded and included as an appendix in the design report. A digital copy of the drawing will also be required in PDF format.

SUPPLEMENTAL INFORMATION

The following documents are provided to aid in the preparation of the design report:

- Canada-Ontario Lake Erie Action Plan
  - (https://www.ontario.ca/page/canada-ontario-lake-erie-action-plan)
- Chatham-Kent Plan 2035
  - (https://www.chatham-kent.ca/local-government/ck-plan-2035)
- CWPCP ECA #6551-8WXKHC
- CWPCP Performance Report, 2017
- Excel Spreadsheet of CWPCP Performance 2015-2017
- Getting to Net Zero Energy – Leadership Forum hosted by SOWC and OCWA
  - (https://sowc.ca/getting-to-net-zero-energy-leadership-forum-hosted-by-sowc-and-ocwa/)
- MOECC Design Guideline for Sewage Works
- Optimization Case Studies:
  - City of Brantford
    - Nitrification https://drive.google.com/file/d/0BwwUp5Q6kEc2OEUtZU83NU9IRVk/view
    - Phosphorus Removal https://drive.google.com/file/d/1W9uluMj4Ysafm9nPZL4KLSpyvHbzhfRY/view
  - Simcoe Wastewater Treatment Plant
    - Blowers https://drive.google.com/file/d/1FyI2cgu7MMZRz3mgt7BAC9CXv5aY4FCT/view
- Optimization Guideline Manual for Sewage Works 2010, WEAO
- Optimization Process Parameters Worksheet
- The Ontario Composite Correction Program Manual for Optimization of Sewage Treatment Plants
- Wastewater Treatment Plant Optimization (by National Research Council of Canada)

Appendix A – Plant Process Flow Diagram

Process Flow Diagram