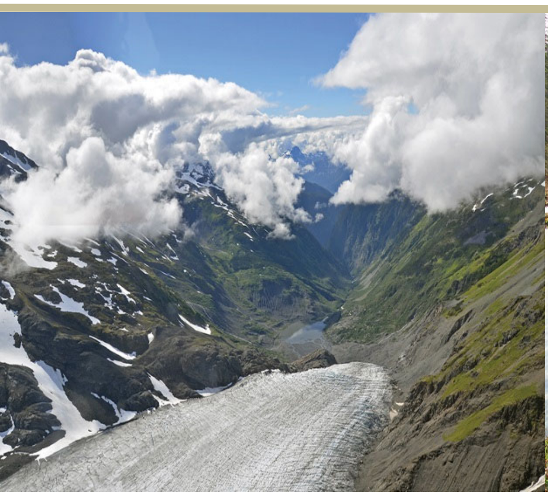
Master Plan for Enhanced Biosolids Management and Biogas Utilization



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EXECUTIVE SUMMARY

Tetra Tech Canada Inc. (Tetra Tech) was retained to investigate the potential of utilizing the current assets managed by Utilities Kingston (UK) to produce renewable natural gas (RNG) that could then be used to reduce the carbon footprint of the City of Kingston (City). This Master Plan report is the culmination of the work undertaken by Tetra Tech to identify the "preferred strategy" by which UK and the City may attain their RNG-generation objectives.

Since UK is interested in establishing a strategy comprised of integrated systems and, potentially, multiple facilities and locations, the study has proceeded as a Master Plan conducted in accordance with the requirements of Schedule A projects following Approach 1 as outlined in the Municipal Class Environmental Assessment (Class EA) document.

The work was initially triggered by UK's interest in identifying alternative strategies to: manage biosolids in a way that would enhance biogas production. Given developments in Ontario regarding: the consideration of wastes as resources within the context of a circular economy; the more effective management of source-separated organics (SSO) with the objective of eliminating the landfilling of these materials; and, the identification of opportunities for the generation and utilization of RNG, UK expanded the scope of the study to include alternative systems that would entail the codigestion of biosolids generated at the Utility's wastewater treatment plants (WWTPs) with waste organics both collected by the City and generated by the industrial, commercial, and institutional (IC&I) sector to enhance the generation of biogas as a source of RNG. In this way UK together with the City would generate a renewable resource that would reduce reliance on petroleum-based fuel and reduce greenhouse gas (GHG) emissions thereby moving UK's residents to a more sustainable future.

The Master Planning Study has been completed as follows:

1. Description of existing conditions related to the infrastructure for the processing of biosolids by UK;
2. The evaluation of alternative technologies and selection of a "short list" for further assessment;
3. Compilation of the short list of technologies into a series of alternative options or strategies for assessment based on a detailed technical assessment; and
4. Comparative evaluation of the alternative strategies based on the results of the assessment.

A detailed outline of the technical studies and associated assessments and comparative evaluation undertaken to identify the "preferred" alternative with which to achieve the Purpose for the Undertaking is provided in Section 5.0 of this report.

The completion of step 2 and step 3, above, established the technical basis for the definition of 5 alternative strategies comprised of different processing technologies assembled into varying processing systems. Two of the alternatives entailed the preprocessing of SSO and then blending of this material with the biosolids at one of the Utility's WWTPs. The fifth alternative entailed the development of a "stand-alone" codigestion facility located at the City-owned Knox Farm property.

The opportunity which UK will address by the subject Master Plan is as follows:

Utilities Kingston is presently positioned to address both the enhancement of the management of the biosolids generated at the Cataraqui Bay and Ravensview WWTPs and to consider the introduction of the codigestion of these solids streams with waste organics both collected by the City and generated by the IC&I sector. This opportunity has arisen, in part, from the developments in Ontario regarding:

- The consideration of wastes as resources within the context of a circular economy;
- The increased interest in the province for the more effective management of waste organics with the objective of eliminating the landfilling of these materials; and
- The identification of opportunities for the generation and utilization of RNG thereby reducing the City's carbon footprint.

For the purposes of this Master Plan, the Undertaking is described as:

The enhancement of the production of biogas through enhancements to the biosolids processing trains at the City's 2 WWTPs and including the possible codigestion of the biosolids and waste organics both collected by the City, as SSO and generated by facilities in the IC&I sector.

UK has completed the subject Master Plan to identify the "preferred alternative system" in relation to the stated Undertaking.

A total of five alternative systems were identified over the course of the study. These are as follows:

- Optimize infrastructure at the Cataraqui Bay WWTP by expanding the existing mesophilic anaerobic digestion (MAD) process with capability to operate in temperature-phase anaerobic digestion (TPAD) process.
- Optimize infrastructure at Cataraqui Bay WWTP by expanding the existing MAD process together with biological hydrolysis (BH) as a sludge pretreatment ahead of the MAD process.
- As the second alternative, listed above, but with dewatered raw sludge being transported from the Cataraqui Bay WWTP for processing at the Ravensview WWTP.
- As the second alternative with the inclusion of waste organics from third-party sources such as the SSO collected by the City.
- Develop an integrated biosolids and SSO processing facility at a greenfield development site. The opportunity site for consideration would be located within the property boundary of Knox Farm.

A "do nothing" alternative, which entailed continuation of the current practice of processing sludge separately at the UK's two WWTPs and without the introduction of a waste organics processing component was identified for the purposes of comparison of the alternative enhancement strategies with existing conditions.

The alternatives were assessed based on the following elements:

- Detailed description and depiction of the processing components and processing trains that comprise each of the alternative strategies.
- Calculation of the estimated changes in the production of biosolids and biogas within each of the strategies.
- Detailed description of either the operational changes to the existing processing infrastructure or development of a new processing complex contemplated in each of the alternative strategies.
- Analysis of the materials transport requirements as well as the determination of the size of the development footprint required for the processing components of each strategy.
- Calculation of the "best" net present value (i.e., lowest cost and highest potential revenue) and the "lowest" net present value (i.e., highest capital and operating costs and lowest potential revenue) for each of the strategies. These calculations included the estimation of potential revenues from wheeling the biogas into available natural gas pipelines and generation and refinement for each of the strategies.

- Identification of sensitive land uses and significant natural environmental features that may by located in the vicinity of each of the alternatives.

The detailed description and assessment of the alternative strategies established the technical basis upon which the evaluation was completed for the purposes of the subject Master Plan.

The comparative evaluation of alternative systems resulted in the selection of a “preferred system” in relation to the Undertaking. The preferred system is as follows:

> *Develop an integrated biosolids and SSO processing facility at a greenfield development site. The opportunity site for consideration would be located within the property boundary of Knox Farm.*

This Master Plan report, together with the technical assessment reports and the record of consultation will be posted by the UK at locations available to stakeholders. A Notice of Completion of the Master Plan study will be released which will identify the locations where these documents may be reviewed.

TABLE OF CONTENTS

LIST OF TABLES IN TEXT

LIST OF FIGURES IN TEXT

APPENDIX SECTIONS

APPENDICES

ACRONYMS & ABBREVIATIONS

Acronyms/Abbreviations	Definition
BAF	Biologically Aerated Filter
BH	Biological Hydrolysis
BH-AD	Biological Hydrolysis-Anaerobic Digestion
CAS	Conventional Activated Sludge
Cataraqui Bay	Cataraqui Bay Wastewater Treatment Plant
CFU	Colony-Forming Units
CH4	Methane
City	City of Kingston
CM2	Regulated metal content of a NASM exceeds that of CM1 NASM but does not exceed the concentration set out in Table 2 for aqueous or non-aqueous CM2 material, whichever applies
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
CP1	Pathogen-based category based on Origin, typically based on NASM Categories 1 and 2
CP2	Pathogen-based classification defined as NASM Category 3 which includes sewage biosolids
EA	Environmental Assessment
H2S	Hydrogen Sulfide
HRT	Hydraulic Retention Time
L&Y	Leaf and Yard Waste
MAD	Mesophilic Anaerobic Digestion
MEA	Municipal Engineers Association
MECP	Ministry of Environment, Conservation, and Parks
MOP 8	Maximum Operating Pressure
N and N2	Nitrogen
NASM	Non-Agricultural Source Materials
NMA	Ontario Nutrient Management Act
O.Reg.	Ontario Regulation
O_2	Oxygen
P	Phosphorous
PSA	Pressure Swing Adsorption

Acronyms/Abbreviations	Definition
Ravensview	Ravensview Wastewaster Treatment Plant
RDT	Rotary Drum Thickeners
RNG	Renewable Natural Gas
SSO	Source-Separated Organics
TAD	Thermophillic Anaerobic Digestion
TPAD	Temperature-Phased Anaerobic Digestion
TS	Total Solids
UK	Utilities Kingston
VS	Volatile Solids
VSD	Volatile Sludge Destruction
WAS	Waste Activated Sludge
WWTP	Wastewater Treatment Plan

LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of Utilities Kingston and their agents. Tetra Tech Canada Inc. (Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than Utilities Kingston, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this document is subject to the Limitations on the Use of this Document attached in the Appendix or Contractual Terms and Conditions executed by both parties.

1.0 INTRODUCTION AND PURPOSE

1.1 Study Background

Utilities Kingston (UK) retained Tetra Tech Canada Inc. (Tetra Tech) to undertake the review and assessment of options, or strategies, for enhancing biogas generation and managing biosolids at the UK's Ravensview and Cataraqui Bay wastewater treatment plants (WWTPs). Since UK is interested in establishing a strategy comprised of integrated systems and, potentially, multiple facilities and locations, the study has proceeded as a Master Plan conducted in accordance with the requirements of Schedule A projects following Approach 1 as outlined in the Municipal Class Environmental Assessment (Class EA) document, Municipal Class Environmental Assessment (MCEA) October 2000, as amended in 2007, 2011 and 2015, the Municipal Engineers Association (MEA).

Given developments in Ontario regarding: the consideration of wastes as resources within the context of a circular economy; the more effective management of source-separated organics (SSO) with the objective of eliminating the landfilling of these materials; and, the identification of opportunities for the generation and utilization of renewable natural gas (RNG), UK expanded the scope of the study to include alternative systems that would entail the codigestion of biosolids and waste organics both collected by the City of Kingston (City) and generated by the industrial, commercial, and institutional (IC&I) sector. In addition, and further to the interest in considering codigestion systems, UK identified the Knox Farm property as a prospective centralized location which would accept raw feedstocks (i.e., wastewater sludge from the two WWTPs as well as SSO and Leaf and Yard (L&Y) waste) transported from the two WWTPs and via SSO and L&Y waste collection vehicles from sources within the City.

1.2 Class Environmental Assessment and Master Planning Process

In Ontario, the Environmental Assessment (EA) process requires that proponents examine and document the environmental effects that may result from major projects or activities. The principles associated with environmental planning, including the definition of the "environment" are well known. There are, however, some key principles that are worth identifying. These are as follows:

- Identify the problem/opportunity which will establish a description of the Undertaking for the purposes of the EA.
- Describe a reasonable range of alternatives which entail functionally different solutions to the Undertaking as well as alternative methods for implementing the preferred solution.
- Identify and consider the effects of each alternative on the natural, social, cultural, technical, and economic/financial environment.
- Complete a systematic evaluation of alternatives in terms of their relative "advantages" and "disadvantages" to determine their net environmental effects. The evaluation process must be sequential in that it increases in detail as the planning process moves from the consideration of alternatives to the Undertaking through the evaluation of alternative methods.
- Undertake consultation with potentially affected parties which will include the public, interested Indigenous communities and review agencies. The consultation process must begin early in the planning process.
- Provide clear and complete documentation of the planning process followed which will allow for a traceable and replicable decision-making process.

Because the subject initiative entails the expansion/development of municipal infrastructure, the planning process that has been followed to meet the requirements of the Ontario EA Act has complied with the Municipal Class EA (MCEA) process. This process was approved in 1987 by the then Minister of the Environment for municipal projects having similar, predictable, and preventable impacts. This Class EA streamlines the planning process for municipal infrastructure projects, including wastewater projects, that are typically recurring; similar in nature; relatively limited in scale; exhibit a predictable range of environmental effects; and, are responsive to mitigation measures.

The specific requirements of the MCEA planning process depend on the type and complexity of the project which will drive its potential effects on the environment. This planning process includes five phases as follows:

- Phase 1: Identify the **problem (deficiency)** or the **opportunity**.
- Phase 2: Identify **alternative solutions** to address the problem or opportunity by taking into consideration the existing environment and establish a **preferred solution** considering public (including Indigenous communities) and review agency input.
- Phase 3: Examine alternative methods of implementing the preferred solution based on the existing environment, public (including Indigenous communities) and review agency input, anticipated environmental effects and methods of minimizing negative effects and maximizing positive effects.
- Phase 4: Document the planning, design and consultation processes followed in an **Environmental Study Report** and make the documentation available to the public (including Indigenous communities) and review agencies.
- Phase 5: Complete all required contract drawings and documents for **construction and monitoring** to ensure adherence to environmental provisions and commitments.

The infrastructure projects subject to the MCEA planning process are organized into four “Schedules” according to their complexity and the potential for impacts on the environment.

The MCEA planning process includes how a municipal jurisdiction may plan for a group of integrated systems, or projects, on a more strategic basis. The Master Planning process is used for planning future infrastructure by creating a “roadmap” for the subsequent implementation of desired modifications to existing infrastructure and the development of new infrastructure by way of individual projects. UK is looking for a preferred strategy to enhance the management of biosolids generated by its two WWTPs while establishing a sustainable means to enhance the generation of methane to be used as a renewable resource. This interest has led to the identification of the codigestion of biosolids generated at the WWTPs with the organic wastes that are collected by the City via its green bin kitchen waste collection program and generated by the IC&I sector. The most effective way to undertake the assessment of the environmental effects of these broader, integrated systems, is by way of a Master Plan.

The Master Plan must address at least the first 2 phases of the MCEA process. The Ontario Ministry of Environment, Parks and Conservation (MECP), however, recognizes that there are “infinite” ways of conducting them. The approach chosen by UK would correspond to the needs of UK. The most appropriate way by which the Master Plan was undertaken in this instance was to follow “Approach #1” as outlined in the MCEA document. This approach has entailed the completion of Phase 1 and Phase 2 of the MCEA process. Generally, components of the “preferred solution”, or prospective projects, may proceed directly to design and construction (Schedule A/A^{+} projects); proceed to design and construction subject to Screening and submission of the Project file for review (Schedule B projects); or to the completion of further assessment in accordance with Phase 3 and Phase 4 of the MCEA (Schedule C) prior to implementing the project (Phase 5). The next steps to be undertaken at the discretion of UK after the completion of the Master Plan have been described in Section 6.0 of this document.

1.3 Problem/Opportunity Statement

The MCEA document states that municipalities generally undertake projects in response to certain identified problems or deficiencies. The document goes on to state that, on the other hand, there may be opportunities that need to be addressed.

The opportunity which UK will address by the subject Master Plan is as follows:

UK is presently positioned to address both the enhancement of the management of the biosolids generated at the Cataraqui Bay and Ravensview WWTPs and to consider the introduction of the codigestion of these solids streams with waste organics both collected by the City and generated by the IC&I sector. This opportunity has arisen, in part, from the developments in Ontario regarding:

- The consideration of wastes as resources within the context of a circular economy;
- The increased interest in the province for the more effective management of waste organics with the objective of eliminating the landfilling of these materials; and
- The identification of opportunities for the generation and utilization of RNG thereby reducing the City's carbon footprint.

For the purposes of this Master Plan, the Undertaking is described as:

The enhancement of the production of biogas through enhancements to the biosolids processing trains at the City's two WWTPs and including the possible codigestion of the biosolids) and waste organics both collected by the City, as SSO and generated by facilities in the IC&I sector.

UK has completed the subject Master Plan to identify the "preferred system" in relation to the stated Undertaking.

1.4 Study Organization

The Master Plan Study has been completed as follows:

1. Description of existing conditions related to the infrastructure for the processing of biosolids by UK;
2. The evaluation of alternative technologies and selection of a "short list" for further assessment;
3. Compilation of the short list of technologies into a series of alternative options or strategies for assessment based on a detailed technical assessment; and
4. Comparative evaluation of the alternative strategies based on the results of the assessment.

A detailed outline of the technical studies and associated assessments and comparative evaluation undertaken to identify the "preferred" alternative with which to achieve the Purpose for the Undertaking is provided in Section 5.0 of this report.

2.0 EXISTING CONDITIONS

2.1 Existing Wastewater Treatment Facilities

The City is located on the eastern side of Lake Ontario and is home to a population of 161,175 in the metropolitan area with 123,798 in the City according to Canada's 2016 Census. The City's wastewater collection system is split between three regions and services an approximate area of 8,300 ha. The three regions include Kingston West, Kingston Central, and Kingston East, with an estimated 90% of the population evenly divided between Kingston West and Kingston Central.

2.1.1 Cataraqui Bay Wastewater Treatment Plant

The Cataraqui Bay WWTP located at 409 Front Street was constructed in 1962. The facility was upgraded in 2002 and is currently undergoing a major expansion to increase plant capacity, improve the quality of treated wastewater, and upgrade equipment. Cataraqui Bay receives wastewater flow from the Kingston West region. The system operates under Environmental Compliance Approval (ECA) Number 2144-87TJYB.

The upgrades currently under construction at the site will increase capacity from 38,800 m^3 to 55,000 m^3 per day. This expansion is expected to be completed by 2020 and is based on the outcome of the revised Sewage Infrastructure Master Plan finalized in 2010. The upgrade work includes an expansion of the plant's headworks and primary clarifiers, replacement of the secondary treatment system, electrical and instrumentation upgrades, and site-wide building and process improvements.

The four-year construction project began in October 2016.

The upgrades include:

- Phase 1: Increasing the plant's wastewater treatment capacity from the current 38,800 m^3 per day to 55,000 m^3 per day (average flow), which includes the redirection of the King-Portsmouth Pumping Station to the Cataraqui Bay WWTP by 2020.
- Phase 2: Increasing the plant's wastewater treatment capacity to 68,000 m^3 per day (average flow). Projected to be online by 2036.

Table 2-1: Existing and Upgraded Treatment Technology

Treatment Component		Existing	Upgraded
Liquids Train Technology	**Preliminary Treatment**	Preliminary treatment consists of two manually cleaned aerated grit tanks, followed by two mechanically cleaned bar screens (bar screens will be replaced by perforated plate fine screens).	The two steps of the existing process will be reversed so that screening will occur before grit removal.
	Primary Treatment	Influent enters primary settling tanks. Primary effluent passes through aeration tanks.	Primary treatment tanks will be extended into the aeration tanks to allow for the additional hydraulic and treatment capacity. Performance will be enhanced through chemically enhanced primary treatment.

Treatment Component		Existing	Upgraded
	Secondary Treatment	Influent passes into secondary clarifiers where it is treated through a conventional activated sludge (CAS) process. Secondary sludge is combined with primary effluent and is aerated to promote biological growth before being passed through a final clarifier to remove sludge.	Primary effluent will be directed to the biologically aerated filter (BAF) system. The BAF process uses submerged media and aeration to promote the growth of biomass in order to achieve biochemical oxygen demand (BOD) removal, TSS removal, and nitrification. The BAF facility also has a chemical treatment system for alkalinity adjustment.
	Disinfection	Secondary effluent passes into a chlorine contact tank, where chlorine is added to the water. Residual chlorine is removed through a dechlorination system before discharge.	Two existing secondary clarifiers will be converted into chlorine contact tanks.
	Dechlorination	Calcium thiosulfate is injected into the plant effluent water downstream of the chlorine contact tank to dechlorinate.	A new dechlorination room will be constructed, however, the process will stay the same.
Solids Train Technology	**Sludge Thickening**	The solids train consists of rotary drum thickeners, anaerobic digesters, sludge holding tanks, dewatering centrifuges, open sludge drying bed, and an open biosolids storage pad. Waste activated secondary sludge is pumped to the Rotary Drum Thickeners RDT) before being pumped to the digesters.	The following processes will be used: ▪ Dedicated thickening process using a gravity thickener. ▪ Co-thickening of the backwash residuals (back-up operation). Two gravity thickener tanks will be retrofitted from the existing secondary clarifiers. Existing secondary clarifiers will be offline so there will be no secondary sludge. Backwash residuals from the BAF process will be thickened using two gravity thickeners retrofeed from two existing secondary clarifiers. Thickened BAF backwash residuals will be pumped to the two existing RDTs before being sent to the digesters. During certain periods of time of construction, the BAF will be online and the RDTs will be offline for electrical upgrades. During this time period the BAF backwash residuals will be co-thickened.
	Anaerobic Digestion	Sludge is anaerobically digested.	Sludge is anaerobically digested. Digester expansion, which was originally recommended in the 2012 Class EA, will be deferred, as the existing digesters have capacity for short-term needs. New digestion capacity is not expected to be needed until 2029. Upgrades to the existing digester mixing systems and heat exchangers will be deferred form upgrades to coincide with a future digester cleanout, re-gas proofing and re-roofing project.
Dewatering and Biosolids Storage	**Dewatering**	Biosolids are dewatered using centrifuges and a biosolids drying bed.	A new Dewatering and Biosolids Storage Facility will be constructed. Digested sludge will be pumped to the new centrifuges by new rotary lobe sludge transfer pumps.

Treatment Component		Existing	Upgraded
	Biosolids Storage	Dewatered biosolids are stored on site at the sludge storage pad when land application is not permitted.	The new facility will store dewatered cake in two buildings and will have capacity for 240 days of biosolids cake storage. The new biosolids cake storage facility (similar to Ravensview WWTP) will be constructed. A key difference from the Ravensview WWTP is that the cake will be moved by gravity, not pumped. This will result in a different consistency than is currently seen at Ravensview.
Digester Gas Utilization		Currently, digester gas is collected from each digester and the sludge holding tank, is compressed, and injected back into the digester for mixing. Excess gas is either routed to the boilers or to the waste gas flare.	The existing mixing system and waste flare system will remain unchanged. A new digester gas booster will be provided to boost the digester gas pressure to the boilers at the BAF facility.

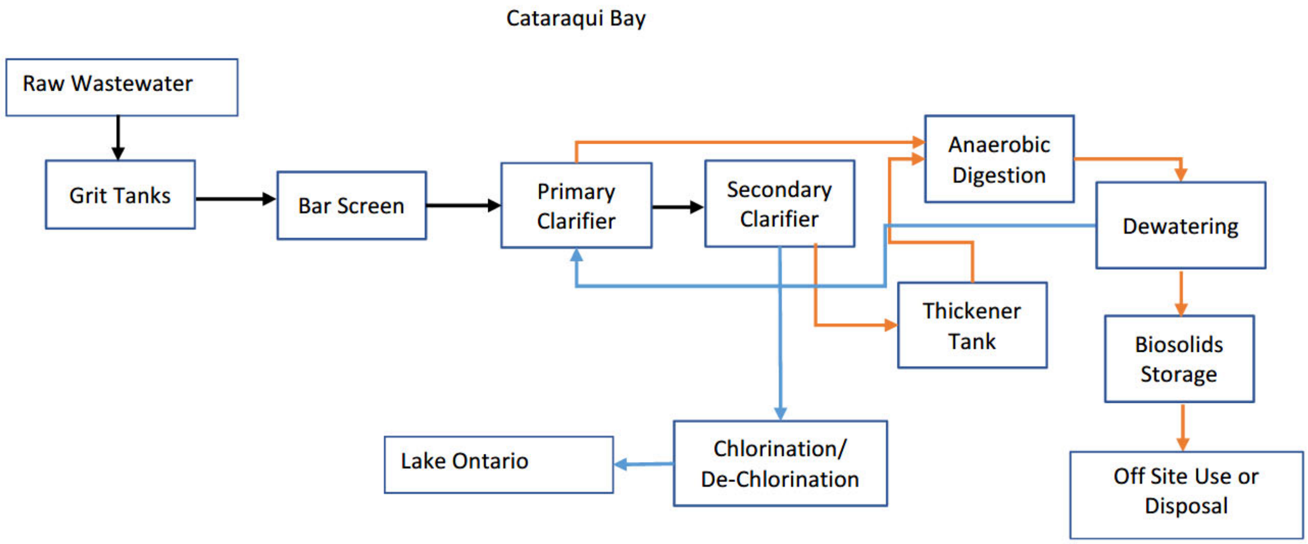
The upgrades to Cataraqui Bay are summarized in the following major components:

- Demolition of the existing Septage Receiving Station;
- A new and expanded Headworks Building to house two fine screens, two vortex grit tanks, and their auxiliary systems;
- Connection of the primary clarifiers and aeration tanks to create four new retrofitted primary clarifiers;
- A new BAF Facility, which will consist of:
  - Six BAF cells;
  - A Primary Effluent Pumping Station;
  - Two BAF backwash residual tanks;
  - Process Equipment Space; and
  - Administration and laboratory functions.
- An expanded chlorine contact tank;
- Diffuser upgrades for the existing two outfalls;
- A new Dewatering and Biosolids Storage Facility to house two centrifuges and two biosolids bunkers;
- A new prefabricated centrate pumping station;
- Two new gravity thickeners to treat BAF backwash residuals retrofitted from the existing secondary clarifiers;
- An expanded Chemical Building to house new chlorinators;
- A retrofitted Dechlorination Building to house chemical storage and dosing equipment;
- A new electrical substation and back-up generator located close to the site entrance;
- Two new tunnels to connect to the BAF Facility and Dewatering and Biosolids Storage Facility; and

- Decommissioning of Plant C East and the Plant D secondary clarifiers[1].

The upgraded treatment process at Cataraqui Bay is illustrated on Figure 2-1.

Figure 2-1: Upgraded Cataraqui Bay Treatment

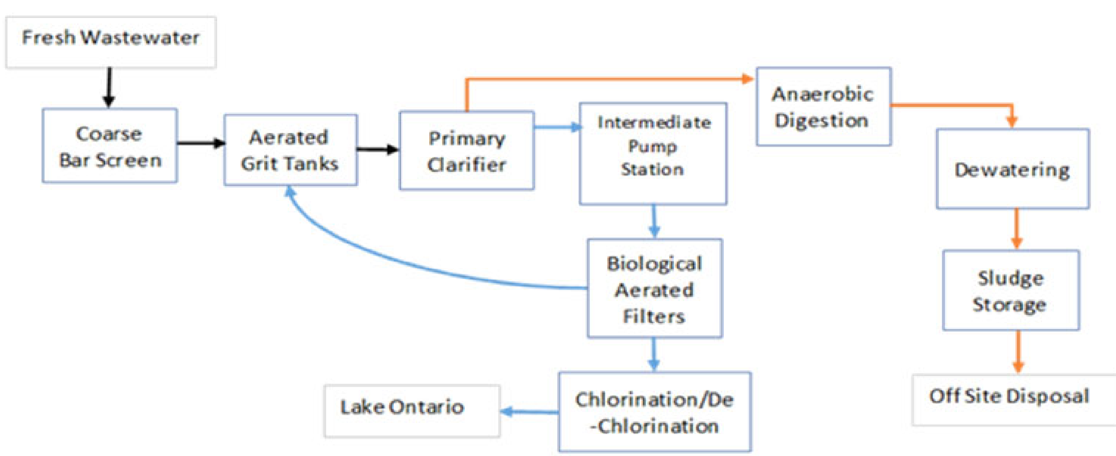


2.1.2 Ravensview Wastewater Treatment Plant

The Ravensview WWTP, located at 947 County Road #2, was constructed in 1957 as the first wastewater treatment plant in the City. The plant was upgraded in 1974, in 1993, and most recently between 2006 to 2009 (with a $115,000,000 capital project). The plant is designed to process 95,000 m^3 of waste per day, primarily generated from the Central to East regions of the City.

The current wastewater treatment process is illustrated on Figure 2-2.

Figure 2-2: Ravensview Wastewater Treatment Flow Diagram



[1] Cataraqui Bay Wastewater Treatment Plant Upgrades Design Report, January 2016.

2.1.3 The Cana Wastewater Treatment Plant

The Cana WWTP was constructed in the early 1970s for the Cana Home-Building Cooperative. In 1991, the City acquired the facility and it is currently maintained and operated by UK. Cana was upgraded to a sequencing batch reactor (SBR), completed in 2018, and currently meets all requirements for discharge. Sludge from Cana is currently transported to Ravensview for digesting. The Cana WWTP is not considered a viable option for enhancement.

2.2 Existing Biosolids Management Practices

Both Cataraqui Bay and Ravensview have undergone changes to their respective processes from the time of commissioning. For the purposes of this review, the following descriptions outline the processes for the respective facilities that match the period of background data that is presented in Section 3.2.2, Section 3.2.3, and Section 3.2.4.

The current process at both plants is comprised of primary settling, biological treatment, thickening, digestion, biosolids dewatering, and storage.

For biological treatment, both facilities use the BIOSTYR® process, which is an up-flow submerged media BAF. As an attached growth process, BIOSTYR is carried out in a series of individual cells containing submerged buoyant media, which provides surface area for microorganisms to attach and grow. Extra activated sludge falls off of the media and is filtered and removed as waste activated sludge (WAS).

The WAS is then pumped to the Digesters for stabilization and methane production.

For the purpose of describing the biosolid characteristics, for Ravensview and the pre-design of Cataraqui Bay, the following will be detailed:

- Ravensview, two mesophilic, one thermophilic digester, and one storage tank;
- Cataraqui Bay, two mesophilic digesters plus one storage tank;
- Dewatering; and
- Storage.

2.2.1 Biosolids Characteristics, Quantities and Projections

2.2.1.1 Characteristics

Wastewater biosolids are the residual material from the sludge treatment works after the sludge has been stabilized in the digestion process. Biosolids primarily consist of nutrients, organic matter, and micronutrients, such as copper and zinc. They may also contain trace amounts of other elements, such as arsenic, lead, and mercury.

Table 2-2 summarizes biosolids characteristics from the UK's two WWTPs compared with typical values in the MECP Design Guidelines (2008) and Metcalf and Eddy (2003). Most of the characteristics for UK's biosolids are comparable to typical values in design guidelines and literature.

Table 2-2: Cataraqui Bay and Ravensview WWTP Biosolids Characteristics

Biosolids Type	Parameters	Cataraqui Bay WWTP	Ravensview WWTP	Typical Design Guidelines
Raw Sludge	TS%	3.82	4.15	2-6.5[1] Ave. 4.0
	VS%	82.8	68.2	60
	TS (mg/L)	38,239	n/a	
	VS (mg/L)	31,497	n/a	
Digested Sludge	TS%	2.32	2.10	2-6[1] Ave. 4.0
	VS%	64.9	49.1	45
	TS (mg/L)	21,489	n/a	
	VS (mg/L)	13,936	n/a	
Dewatered Cake	TS%	14.0	28.6	15-30[1]
	VS%	64.5	48.0	
	TS (mg/L)	140,146	n/a	
	VS (mg/L)	90,631	n/a	

Sources: Cataraqui Bay and Ravensview WWTP Annual Reports, 2015 – 2017.
Notes:
[1] All values are yearly average from monthly data between 2015 and 2017.
Design Guidelines for Sewage Works, MECP (former MOECC) (2008)

The Ontario Nutrient Management Act (NMA) (O.Reg. 267/03) was enacted to minimize the risk to public health and the environment when non-agricultural source materials (NASM), including sewage biosolids, are applied to land. Under the NMA, WWTPs are considered to be generators of Category 3 NASM. Biosolids generated from Category 3 NASM are required to meet CM2 criteria for regulated metals and CP1 or CP2 criteria for pathogens as set out in the Regulation when applied to agricultural land as a nutrient.

Table 2-3 summarizes the concentrations of 11 metals of concern regulated under NMA in biosolids generated from Cataraqui Bay WWTP and Ravensview WWTP as compare with the quality requirements for NASM CM1 and CM2 biosolids.

Table 2-3: Cataraqui Bay and Ravensview WWTP Biosolids Metal Content as Compared to NMA Standards

Element	Cataraqui Bay WWTP (2015 – 2016)	Ravensview WWTP (2015 – 2016)	CM1 NASM (1)	CM2 NASM (2)
Arsenic	2.4	4.8	13	170
Cadmium	1.0	0.8	3	34
Chromium	53	75	210	2,800
Cobalt	1.6	4.5	34	340

Element	Cataraqui Bay WWTP (2015 – 2016)	Ravensview WWTP (2015 – 2016)	CM1 NASM (1)	CM2 NASM (2)
Copper	**482**	**747**	100	1,700
Lead	16	51	150	1,100
Mercury	0.8	**0.9**	0.8	11
Molybdenum	**7.1**	**8.0**	5	94
Nickel	20	24	62	420
Selenium	**3.6**	**4.3**	2	34
Zinc	**657**	**660**	500	4,200

Notes:
All units are expressed as mg per kg of total solids, dry weight.
Bolded values indicate values exceeding CM1 NASM limits.
Column 3 of Table 1 of Schedule 5 Regulated Metal Content of NASM under Nutrient Management Act, 2002 (O. Reg. 267/03)
Column 3 of Table 2 of Schedule 5 under NMA, 2002 (O. Reg. 267/03)

Based on the data from 2015 to 2016, biosolids generated from both plants are low in above regulated metal concentrations. These biosolids can be used on agricultural land that meet the quality criteria in a manner consistent with the practice acceptable under the NMA. Biosolids from both plants meet the metal requirements for Category CM1, except for copper, mercury, molybdenum, selenium and zinc (bolded) that requires management as CM2C. It is important to ensure that the projected metal concentrations for future productions also remain below the maximum concentrations stated in the regulations.

In addition to metal content, it may also be beneficial to review additional requirements for biosolids quality related to pathogens prior to land application. The pathogen content of NASM that is sewage solids or contains human body waste (CP2 Pathogen Criteria) as compared with the pathogen analysis from plant biosolids samples is summarized in the table below.

Table 2-4: Cataraqui Bay WWTP and Ravensview WWTP Biosolids Pathogen Content as Compared to NMA Standards

Pathogen	Cataraqui Bay WWTP	Ravensview WWTP	CP1 NASM [1]	CP2 NASM [2]
E. coli	9,183 CFU/g	22,203 CFU/g[3]	1,000 CFU per gram of total solids, dry weight	2,000 CFU per gram of total solids, dry weight
Salmonella	Data not available	Data not available	3 CFU or MPN per 4 gram of total solids, dry weight	n/a
Giardia	Data not available	Data not available	No detectable level in 4 gram of total solids, dry weight	n/a
Cryptosporidium	Data not available	Data not available	No detectable level in 4 gram of total solids, dry weight	n/a

Notes:
[1]CFU refers to colony-forming units. This methodology is used for determining number of coliform counts in a given sample.
[2]Column 3 of Table 2 of Schedule 6 Pathogen Content of NASM (O. Reg. 267/03)
[2]Column 3 of Table 3 of Schedule 6 Pathogen Content of NASM (O. Reg. 267/03)
[3]Due to repairs to the Thermophilic and one Mesophilic digesters this does not represent expected quality

2.2.1.2 Quantities

The plant flow and sludge data were obtained from Cataraqui Bay WWTP and Ravensview WWTP Annual Reports for the years 2015 to 2017, and are summarized in Table 2-5 and Table 2-6 below.

Table 2-5: Historical Annual Effluent and Biosolids Quantities in Cataraqui Bay WWTP (2015 to 2017)

Cataraqui Bay		2015	2016	2017	Average
Effluent	Volume (m^3/yr)	9,527,449	9,962,485	10,965,006	10,151,647
Raw Sludge	Volume (m^3/yr)	23,332	25,117	25,267	24,572
Volume of raw sludge generated per volume of effluent	L/m^3	2.4	2.5	2.3	2.4
Dewatered Cake	Volume (m^3/yr)	4,086	4,358	3,734	4,059

Sources: Cataraqui Bay WWTP Annual Report Data, 2015 - 2017

Table 2-6: Historical Annual Effluent and Biosolids Quantities in Ravensview WWTP (2015 to 2017)

Ravensview		2015	2016	2017	Average
Effluent	Volume (m3/yr)	21,972,284	20,609,884	31,499,468*	21,291,084
Raw Sludge	Volume (m3/yr)	52,896	55,075	61,106	53,986
Volume of raw sludge generated per volume of effluent	L/m3	2.4	2.7	1.9*	2.5
Dewatered Cake	Volume (m3/yr)	4,999	3,816	5,577	4,408

Sources: Ravensview WWTP Annual Report Data, 2015 – 2017
Notes:
* The flows in 2017 were abnormally larger than previous years due to high lake level in 2017 summer. Effluent value in 2017 will be treated as an outlier and excluded in the calculation for projections.

According to Table 2-5 and Table 2-6, the volume (L) of raw sludge generated per volume (m^3) of treated wastewater are 2.4 L/m^3 and 2.5 L/m^3 for Cataraqui Bay WWTP and Ravensview WWTP, respectively. These values are close to, but below the typical value of 3.2 L/m^3 suggested by MECP Guidelines for a primary sedimentation plant with phosphorus removal. The total solids (TS%) of raw sludge are 3.82% and 4.15% for Cataraqui Bay WWTP and Ravensview WWTP, respectively. For the purposes of this analysis, it was assumed that TS% of raw sludge will be the same in the future and the same values of TS% were used for sludge projection. It should be noted that the two plant processes combined sewer and extraneous flow sources, thereby explaining the lower raw sludge generation.

These values were used as the basis for the future biosolids projections up to year 2037.

2.2.1.3 Projections

Sludge production was estimated based on population growth in the City (Statistics Canada) and typical human deposit (solids) generated per capita (g/ca/day), in conjunction with the sludge data from the WWTP Annual Reports for 2015 to 2017, inclusive.

The City's population grew slowly between 2011 and 2016, increasing by 1.03% from 114,928 to 117,660. For the purposes of the analysis, it was assumed that the population growth trends for the City would follow the same rate as in the previous intercensal period to complete the projections from 2022 to 2037. Serviced population was estimated based on the City wastewater collection system serviced by the two WWTPs. Cataraqui Bay WWTP services Kingston West (3,953 ha, 44,400 POP), which accounts for 38% of the total population, and Ravensview WWTP collects wastewater flow from Kingston Central (2,919 ha, 54,600 POP) and East (1,386 ha, 10,200 POP), which accounts for 55% of the City's total population. In addition, the Cana WWTP, located north of the Highway 401, services the Cana subdivision, which will not be covered in this detailed analysis.

Future biosolids production, utilizing the projected serviced population and quantity of sludge generated from each of the WWTPs, is summarized in Table 2-7 below.

Table 2-7: Projected Annual Biosolids Production in Cataraqui Bay WWTP up to Year 2037

	Year	Serviced Population	Raw Sludge			Dewatered Cake		
			Total Volume	Production Concentration	Total Mass*	Total Volume	Production Concentration	Total Mass**
			(m3/yr)	(g/cap.d)	(kg/yr)	(m3/yr)	(g/cap.d)	(kg/yr)
Collected Data	2015	44,200	23,332	54	877,658	4,086	33	528,237
	2016	44,410	25,117	57	926,990	4,358	36	586,002
	2017	44,621	25,267	62	1,015,571	3,734	36	585,120
Projected Data	2022	45,692	25,278	58	966,993	4,177	35	582,717
	2027	46,788	25,885	58	990,199	4,277	35	596,701
	2037	49,061	27,142	58	1,038,296	4,485	35	625,684

Notes:
The average undigested sludge solid concentration over the three years (2015-2017) was 58 g/cap.d, which is below the typical value of 100 g/cap.d for CAS w/P removal suggested by MECP Sewage Works Design Guideline (2008).
The average digested sludge solid concentration over the three years (2015-2017) was 35 g/cap.d, which is below the typical value of 68 g/cap.d for CAS w/P removal suggested by MECP Sewage Works Design Guideline (2008).

Raw sludge and dewatered cake production (in mass) were calculated based on undigested sludge and digested solids production concentration per capita multiplied by the projected population of the same year. It should be noted that the average undigested sludge production concentration per capita of 58 g/cap.d was far below the typical value of 100 g/cap.d for a CAS process as suggested in the MECP Guidelines. As expected, the average digested solids production concentration per capita of 35 g/cap.d was also below the typical value of 68 g/cap.d.

Figure 2-3: Projected Biosolids Production in Cataraqui Bay WWTP up to Year 2037

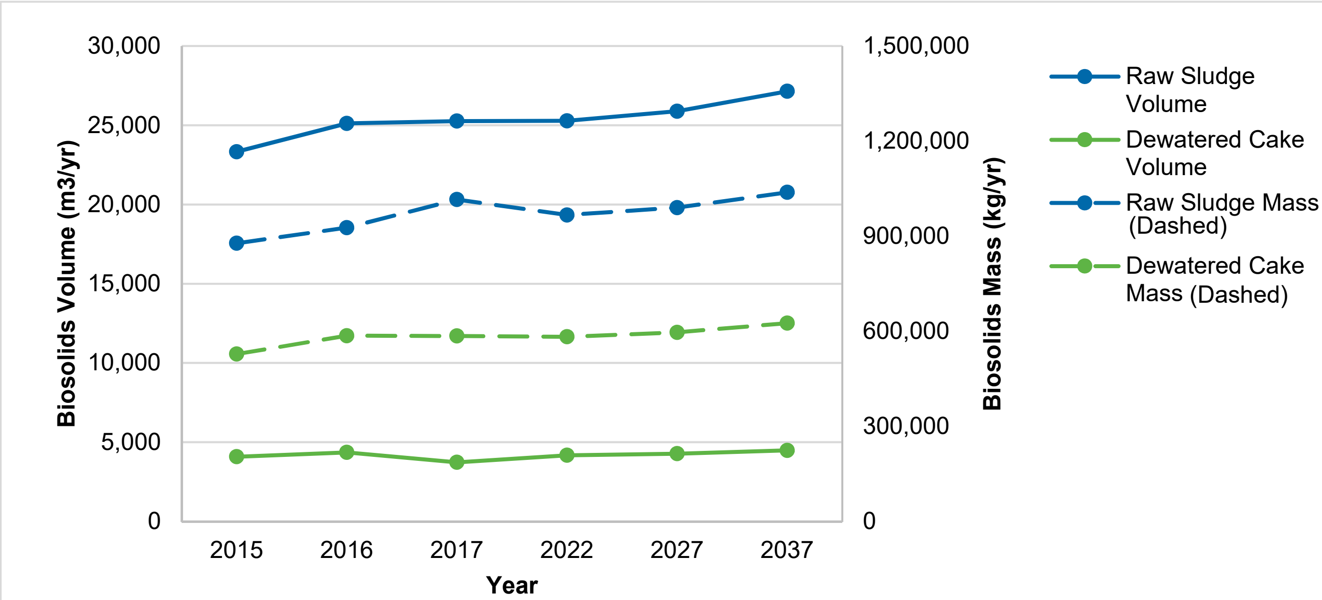


Table 2-8: Projected Annual Biosolids Production in Ravensview WWTP up to Year 2037

	Year	Serviced Populatio n	Raw Sludge			Dewatered Cake		
			Total Volume	Production Concentration	Total Mass*	Total Volume	Production Concentration	Total Mass**
			(m3/yr)	(g/cap.d)	(kg/yr)	(m3/yr)	(g/cap.d)	(kg/yr)
Collected Data	2015	64,508	52,896	100	2,354,531	4,999	68	1,601,081
	2016	64,814	55,075	100	2,365,725	3,816	68	1,608,693
	2017	65,123	61,106	100	2,376,972	5,577	68	1,616,341
Projected Data	2022	66,685	55,673	100	2,434,016	4,935	68	1,655,131
	2027	68,286	57,009	100	2,492,429	5,054	68	1,694,851
	2037	71,603	59,778	100	2,613,493	5,299	68	1,777,175

Notes:
Plant effluent and raw sludge volume in 2017 was treated as an outlier due to high lake level in 2017 summer, and excluded in the calculation for projections.
Data are not available for Ravensview WWTP. Undigested sludge solid concentration of 100 g/cap.d and digested sludge solid concentration of 68 g/cap.d (CAS w/P removal) were used for projections (MOECC Sewage Works Design Guidelines, 2008).

The same methodology was used to project raw sludge and dewatered cake production for Ravensview WWTP. Typical undigested sludge production concentration of 100 g/cap.d and digested solids production concentration of 68 g/cap.d were used for the calculations.

The projected annual biosolids production from the two plants to 2037 (Table 2-9) were used as a basis for developing and reviewing the various alternative biosolids management options.

Figure 2-4: Projected Biosolids Production in Ravensview WWTP to Year 2037

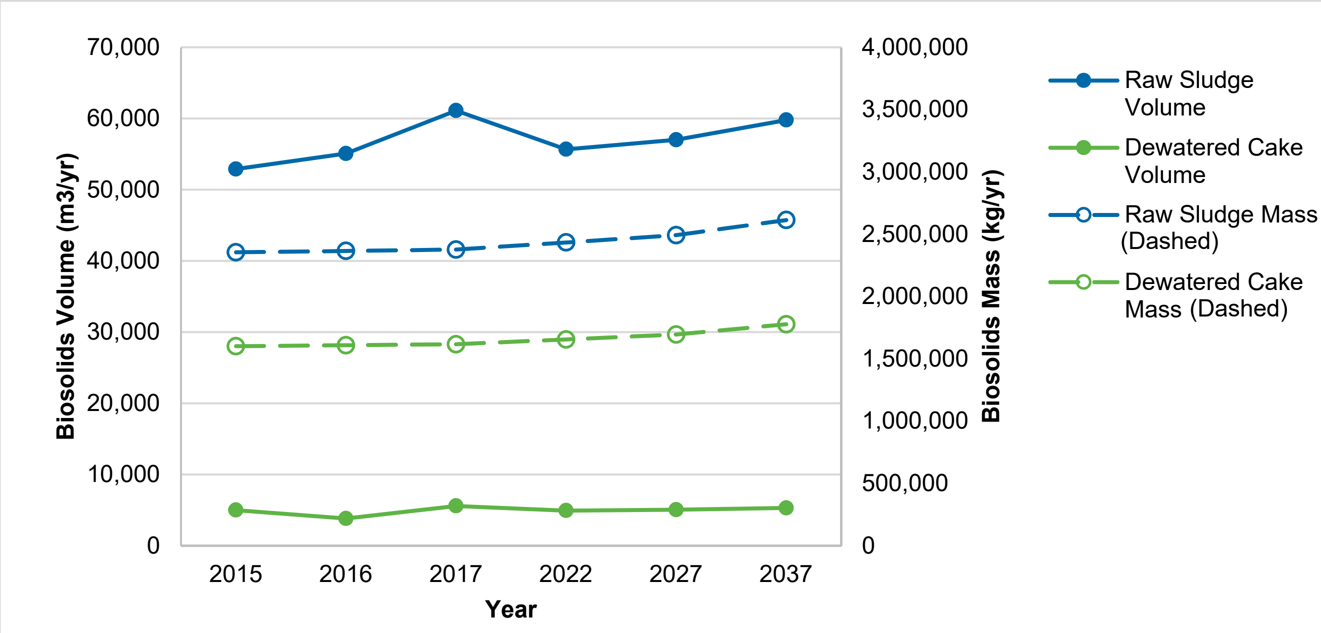


Table 2-9: Total Annual Biosolids Production in Year 2037

Facility	Raw Sludge		Cake	
	Volume (m^3/d)	Mass (kg/d)	Volume (m^3/d)	Mass (kg/d)
Cataraqui Bay	74	2,957	12	2,004
Ravensview	164	7,094	15	5,810
Total	238	10,051	27	7,814

2.2.2 Existing Biosolids Treatment Capacity

2.2.2.1 Cataraqui Bay

Table 2-10 summarizes the treatment capacities of the existing sludge treatment components in Cataraqui Bay WWTP.

Table 2-10: Biosolid Process Design Parameters in Cataraqui Bay WWTP

Unit	Size/Capacity	Description
WAS Holding Tanks (four tanks)	230 m^3 (each) 920 m^3 (total)	Two WAS holding tanks with two positive displacement blowers providing air to the fine bubble membrane diffusers within the tank. Two WAS sludge pumps are rated at 34.7 L/s each.
Rotary Drum Thickener (two thickeners)	125 m^3/hr (each) 1,250 m^3/d (total)	Currently both thickeners are operated approximately five hours per day, seven days per week.

Unit	Size/Capacity	Description
		WAS is thickened in rotary drum thickeners prior to being pumped to digesters.
Thickened WAS Holding Tanks (two tanks)	590 m^3 (each) 1,180 m^3 (total)	With two TWAS pumps each rated at 600 m^3/hr.
Primary Digesters (Digester No. 3)	3,060 m^3	Hydraulic retention time (HRT) in primary digester is 34 days.
Secondary Digester (Digester No. 2)	1,620 m^3	With capability of operating as a primary digester. Volatile destruction is 54% in secondary digester. Equipped with two digested sludge pumps each rated at 12.6L/s.
Digested Sludge Holding Tank (Digester No. 1)	1,540 m^3	
Dewatering Centrifuge (one unit)	10.6 L/s (638 L/min)	Centrifuge is operated 8 hours per day, 2 to 3 days per week. Historically has dewatered digested biosolids to 16% TS with 99% of solids capture.

2.2.2.2 Ravensview

Table 2-11 summarizes the design parameters of key sludge process components in the Ravensview WWTP.

Table 2-11: Biosolid Process Design Parameters in Ravensview WWTP

Unit	Size/Capacity	Description
Mesophilic Digesters (two tanks)	2,465 m^3 (each tank) 4,930 m^3 (total)	Both tanks are equipped with four vertical draft tube mechanical mixers. Tanks are heated by continuous sludge recirculation through hot water tube type heat exchangers. The two primary clarifiers can be operated in series or in parallel, and normally in-series mode operation. Three sludge circulation pumps each rated at 30L/s.
Secondary Digester (one tank)	3,700 m^3	Not heated or continuously mixed. Equipped with external pump recirculation system used to maintain sludge consistency and minimize solids accumulation. Two sludge transfer pumps each rated at 11 L/s.
Thermophilic Anaerobic Digester (one tank)	2,465 m^3	Primary digester with the ability to conduct temperature-phased anaerobic digestion. Two sludge circulation pumps each rated at 132 L/s.
Dewatering Centrifuge (two units)	9.1 L/s (each) (546 L/min) 1,092 L/min (total)	Historically has dewatered digested biosolids to 30% TS.

2.2.3 Biosolids Storage Requirements

Biosolids storage requirements were developed based on providing 180 days of storage for biosolids generated at Cataraqui Bay WWTP and Ravensview WWTP. Based on O. Reg. 267/03, restricted land application applies from December 1 to March 31 (4 months) when the ground is covered by snow or frozen. Provision of 180 days of storage would allow sufficient storage for the restricted period, while providing some buffering capacity in the event that land application is not possible outside the restriction period. The NMA requires storage capacity for 240 days. The UK management plan includes contingency to landfill if storage capacity is exceeded.

The design biosolids storage requirements for the two plants are provided in Table 2-12. Biosolids generation rates were developed based on standard mesophilic anaerobic digestion (MAD). Pretreatment and stabilization processes will have an impact on the biosolids generation rate and will affect storage requirements and options.

Table 2-12: Biosolids Storage Requirements in Year 2037

Standard Anaerobic Digestion	Cataraqui Bay WWTP	Ravensview WWTP
Biosolids Mass	2,004 kg/d	5,810 kg/d
Generated Cake Volume	12 m^3/d	15 m^3/d
Biosolids Storage Requirements (1)	2,160 m^3	2,700 m^3

Notes:
The Nutrient Management Act stipulates 240 days of required biosolids storage for agricultural uses.

Storage facilities for storage of biosolids cake is provided at the sites of Cataraqui Bay WWTP and Ravensview WWTP. A review of existing storage capacities on site for the two plants is provided in Table 2-13. The existing storage facilities on-site can provide sufficient capacities for sewage generated biosolids to 2037.

Table 2-13: On-Site Biosolids Storage Capacities at Cataraqui Bay and Ravensview

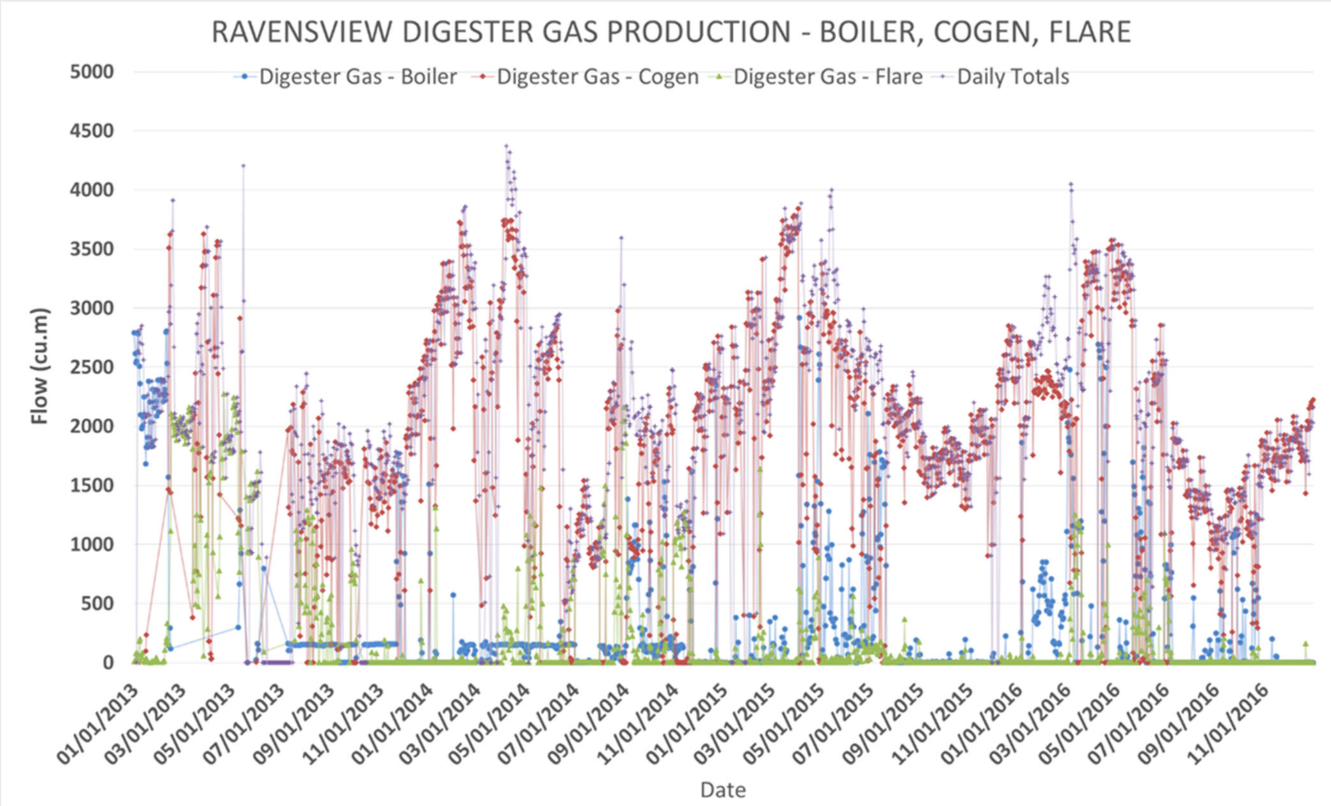
Facility	Unit	Size/Capacity
Cataraqui Bay WWTP	Sludge Drying Beds	8,200 m^3
Ravensview WWTP	Enclosed Cake Storage Facility	6,000 m^3

2.3 Existing Biogas Generation and Utilization

2.3.1 Biogas Characteristics, Quantities and Projections

Ravensview's total biogas flow (generator, flare, and boiler) varies from about 1,000 m^3 to 4,000 m^3 per day (or 25 cfm to 100 cfm) and is highly variable with consistently more biogas collected in the spring of the year. Figure 2-5 summarizes historic biogas flow in 2013 to 2016 from the Ravensview WWTP. The biogas chemistry data showed that Ravensview biogas has excellent concentration of methane, with no oxygen or nitrogen levels. The data provided is 10 to 12 years old. Siloxane levels were found to be very high and considering the age of these results Tetra Tech recommends retesting all gas chemistry. At this time no further samples have been taken as the digesters at Ravensview have been down.

Figure 2-5: Ravensview Digester Gas Production



Cataraqui Bay's total biogas flow (flare and boiler) varies from about 1,000 m^3 to 3,000 m^3 per day (or 25 cfm to 75 cfm) and is highly variable with consistently more biogas collected in the spring of the year. Figure 2-6 summarizes historic biogas flow in 2013 to 2016 from Cataraqui Bay WWTP.

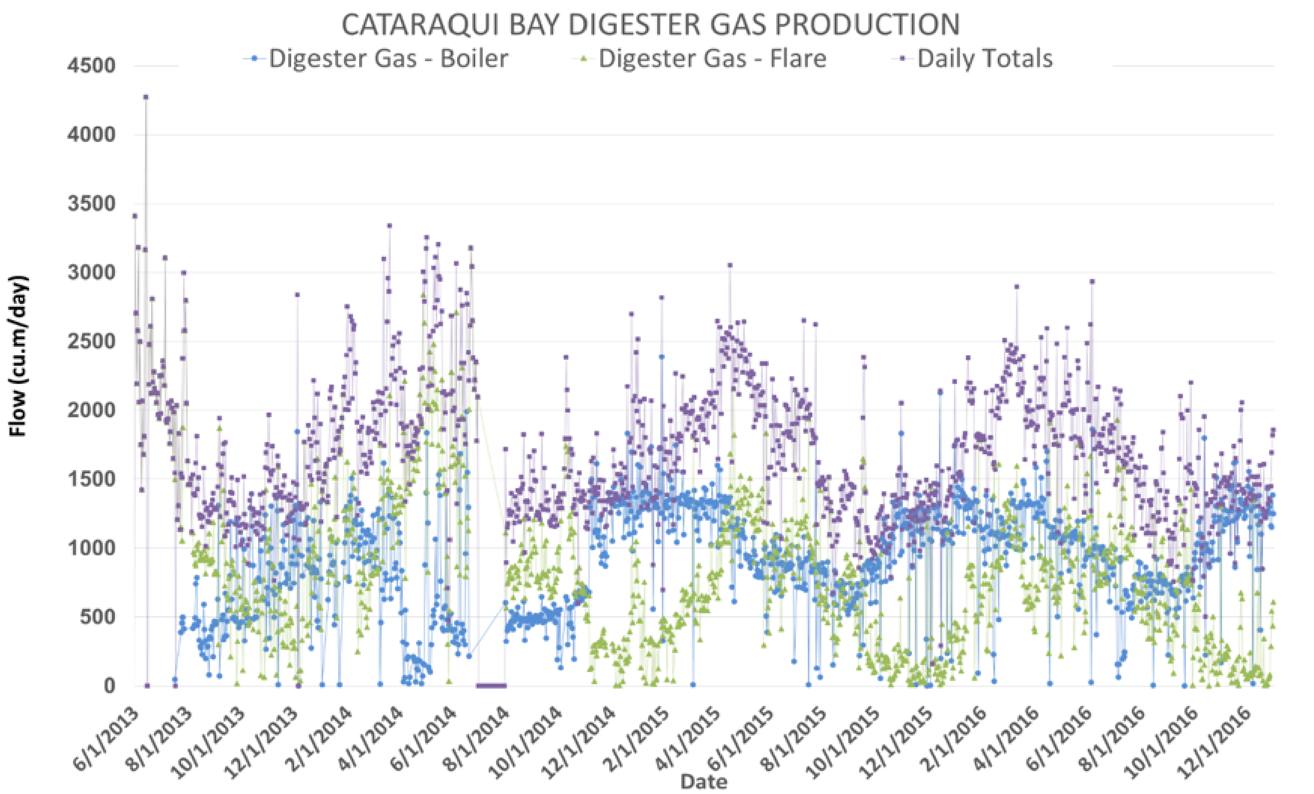


Figure 2-6: Cataraqui Bay Digester Gas Production

The biogas chemistry data showed that Cataraqui Bay's biogas has an excellent concentration of methane, with no oxygen or nitrogen levels. The data provided is three years old. Siloxane levels were found to be very low so Tetra Tech recommends retesting to confirm the siloxane levels.

With the planned upgrade/enhancements of the Cataraqui Bay digesters, it is expected that the biogas output may change. With the addition of SSO, it is expected that the biogas characterization will change and that O_2 and N_2 levels will increase. Further, the addition of SSO may introduce aromatics to the biogas. (http://www.biogas-renewable-energy.info/biogas_composition.html).

As will be shown in Section 3.0, it is expected that some of the technology options will increase the production of biogas, and hence increase the amount of methane that may be available for use.

2.3.2 Existing Biogas Treatment Capacity

Cogeneration of electricity and heat is currently employed at Ravensview WWTP but not at Cataraqui Bay WWTP. Both facilities also dispense generated gas for boilers and flares. This technique to convert biogas to energy is very common at WWTPs throughout Canada and the USA because it reduces the amount of electricity that must be purchased from the grid to operate the WWTP. This self-generation of electricity reduces costs because the cost of self-generated electricity is less compared to purchasing electricity from the grid. In addition, the heat from the generation equipment can be harnessed and employed to keep the WWTP digesters operating at peak temperature, especially in the winter months. Additional heat may also be recovered for use in building heating and meeting other on-site needs. Any excess gas that cannot be used for either electrical production or for heat can otherwise be flared.

2.3.3 Existing Biogas Demands

The biological hydrolysis (BH) process reduces the required HRT of sludge within digesters and enables the digesters to operate at a higher solids content. This allows for not only the indigenous sludge treatment to the WWTPs, but also the import of additional organic materials, such as high-strength liquid or food waste, and fats oils and grease. These wastes have a high organic content and low inert-solids content, which make them ideal for codigestion and generating biogas with limited effects on solids production.

Further to discussions with technology vendors, typical VSD for the digestion of SSO is about 80%. By codigestion of SSO with municipal sludge at Cataraqui Bay, the overall VSD is expected to reach 60%. This translates to achieving the same amount of cake biosolid production with a 56% increase in biogas production.

Codigestion of SSO would result in a further increase in dewatering centrate (36 m^3/d) returning to the plant headworks. Though this volume is not considerable, it contains a high level of nutrients (i.e., 207 kg/d of nitrogen and 121 kg/d of phosphorus) in the dewatering centrate. Although not being covered in this report, the estimated nitrogen and phosphorus mass loadings are presented in Section 3-1.

In the event that the additional organic loading cannot be managed in the existing liquid treatment train, an “add-on” side-stream process may be required as either a pretreatment or a post-treatment step to handle the extra nutrient loadings from the dewatering centrate. The side-stream process would require further evaluation based on the specific technology selected and design target VS destruction at the conceptual design stage.

3.0 ALTERNATIVE SYSTEMS

3.1 Alternative 1 – Do Nothing

3.1.1 Description of Alternative

Under Alternative 1, sludge treatment, the current practice of processing sewage sludge separately at the WWTPs will continue. Both primary sludge and WAS are passing through thickening, MAD, secondary digester settling and dewatering at Cataraqui Bay WWTP (shown on Figure 3-1). Only primary sludge is subject to temperature-phased anaerobic digestion (TPAD), secondary digester settling and dewatering at Ravensview WWTP (shown on Figure 3-2).

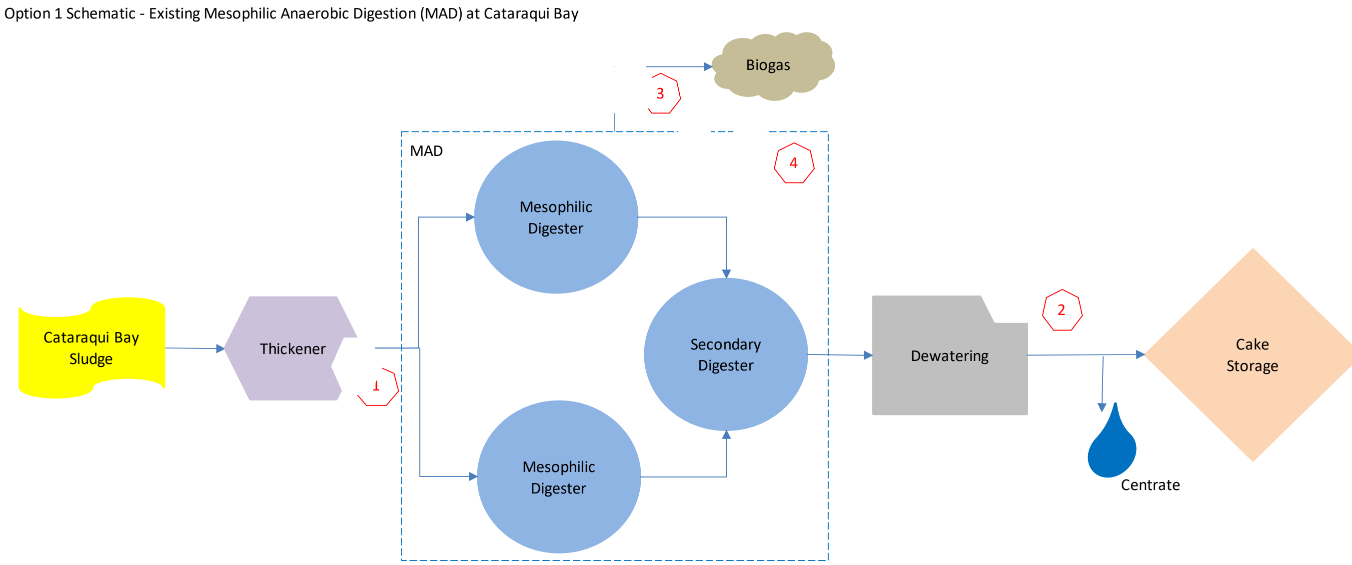


Figure 3-1: Existing Solid Treatment Process at Cataraqui Bay WWTP

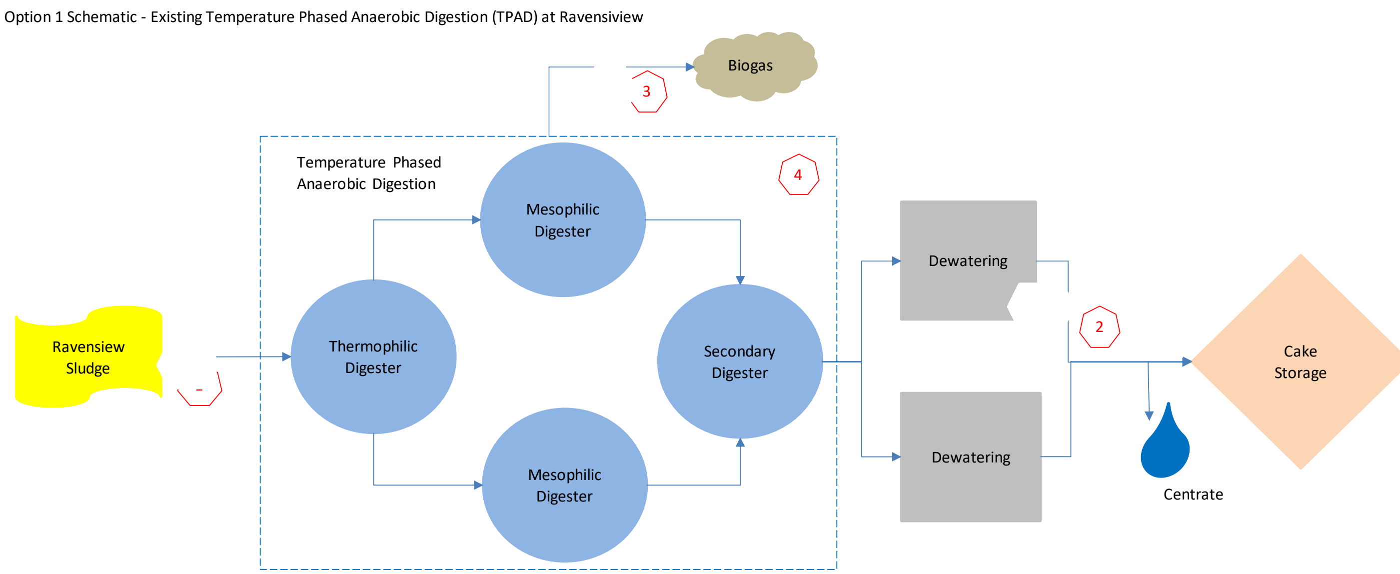


Figure 3-2: Existing Solid Treatment Process at Ravensview WWTP

3.1.2 Impact on Existing Facilities

The following assumptions and approaches were used to estimate biosolid production and biogas generation:

1. Under all the other alternatives, sludge produced in the UK's two WWTPs will be processed in one centralized location.
2. Solids production and biogas yield estimates are calculated based on mass balance for the entire solid treatment train, consider the solid treatment process system boundary shown on Figure 3-1 and Figure 3-2.
3. Flow fluctuations of the raw sludge production were not considered in the estimation of sludge quantities.

4. Projected values of total sludge produced from both plants in the year 2037, i.e., sludge volume, total solid loading, and volatile solid loading, were used as the process input in all options.

5. Raw sludge from Cataraqui Bay WWTP was assumed to consist of 50% primary sludge and 50% WAS, while sludge from Ravensview WWTP only consists of primary sludge.

6. Estimation of cake biosolid production and biogas yield were based on 15-day HRT in mesophilic digestion phase for all digestion scenarios.

7. Based on plant historical data, convertible chemical oxygen demand (COD) in volatile solids (VS) of primary sludge and WAS were assumed to be 1.65 kg COD/kg VS and 1.47 kg COD/kg VS, respectively. Convertible COD in the blended sludge was calculated in proportion to the percentages of primary sludge and WAS in the feedstock.

8. Based on industrial experience at similar facilities, (VSD rates were assumed to be 40% for conventional MAD, 50% for TPAD, and 54% for Biological Hydrolysis – Anaerobic Digestion (BH-AD). Combined VSD was used to estimate VS residual after digestion and biosolid production.

9. The methane (CH_4) converted from COD under anaerobic conditions is 0.4 L CH_4/g COD = (25.29 L/mole)/(64 g COD/mole CH_4). Biogas flow was calculated based on 65% CH_4 in the total gas flow.

10. Nutrient mass loadings (i.e., nitrogen and phosphorus) of the dewatering centrate produced under the current operation condition at each plant were used as the baseline for evaluation. It should be noted that Ravensview has a larger volume of dewatering centrate with lower concentration of nutrients.

The "Do Nothing" alternative is presented solely to provide a comparative baseline for the evaluation of alternative options and is not considered a viable strategy for this study. Table 3-1 shows the anticipated results.

Table 3-1: Estimated Biosolids Production and Biogas Generation in the Year 2037

	Cataraqui Bay	Ravensview	Total
		Feedstock	
Sludge Volume (m^3/d)	74	164	238
TS Loading (kg/d)	2,957	7,094	10,051
VS Loading (kg/d)	2,448	4,837	7,285
		Biosolids	
Biosolids (m^3/d)	12	15	27 [1]
TS (kg/d)	1,978	5,810	7,788 [1]
VS in Cake (kg/d)	1,469	2,792	3,887 [1]
Nitrogen in Cake (kg/d)	59	174	233
Phosphorus in Cake (kg/d)	22	63	85
		Centrate	
Centrate (m^3/d)	62 [2]	147 [3]	209
Nitrogen in Centrate (kg/d)	44 [2]	3 [3]	47
Phosphorus in Centrate (kg/d)	34 [2]	29 [3]	63

	Cataraqui Bay	Ravensview	Total
		Biogas	
Biogas (m^3/d)	1,061	2,770	3,831 [1]
Methane in Biogas (m^3/d)	611	1,596	2,207 [1]

Notes:
[1]. The baseline for biosolid production and biogas yield under Options 2-5.
[2]. The baseline for dewatering centrate produced under Options 2 and 4.
[3]. The baseline for dewatering centrate produced under Option 3.

3.1.3 Cost Analysis

The Do Nothing scenario sets out the basis for comparison. Each Alternative derived hereafter is compared to the Do Nothing scenario using a change in cash flow over a 20-year period. It is assumed that the cost for the Do Nothing alternative would entail comparing the construction of new digesters in another location instead of upgrading the digesters at Cataraqui Bay. The primary changes are then:

- Cost of investment, including engineering costs (15% of capital), permitting costs, the cost of capital and when it would be spent, increase/decrease in operating costs, revenues (primarily carbon-based income), avoidance costs (tipping fees) and other cash flow impacts.
- Increase or decrease in the use of vehicles for transport of sludge or cake.
- Use of one set of digesters in any of the three potential locations.
- Diverting the SSO to one of the WWTP instead of contracting out (as one scenario).
- Gas cleaning general cost ($2,500,000).

The cost analysis is done with proformas and the final analytical number is Net Present Value (NPV) using a discount rate of 5%. For all capital work, estimates for installations are considered conservative, and a +- 15% factor has been included. These results are shown in the final NPV calculations best (lowest cost and highest revenue) and lowest (highest cost and lowest revenue).

Similarly, as there is a wide variance of carbon-based gas prices ($15 to $25 per GJ), these variances have also shown additively in the best and lowest results.

Also, of note, as many of the alternatives are interlinked, some scenarios have been broken out (i.e., dewatering) to assess whether it is a cost-effective stand-alone alternative.

Detailed cash flow statements/pro-forma for all following scenarios are shown in Appendix 1.

3.2 Alternative 2 – Optimize Infrastructure at Cataraqui Bay

3.2.1 Description of Alternative

Based on the primary assessment of alternative stabilization technologies, the following options were developed for the upgrades to the solids treatment train at Cataraqui Bay WWTP:

- Option 2A – Expansion of the existing MAD process with capability to operate in TPAD.
- Option 2B – Expansion of the existing MAD process with the inclusion of BH ahead of MAD.

Each of the above two options is described further in the following sections. For the purpose of developing alternative sludge treatment options, the following assumptions were made:

- The blended sludge from the two plants was assumed to consist of 80% primary sludge and 20% WAS based on raw sludge generation quantities from the two plants;
- A typical three-day HRT for either thermophilic digester or BH system was assumed in evaluation; and
- The process equipment/footprint will be located on the existing site.

3.2.1.1 Alternative 2A – Upgrade Existing MAD to TPAD

TPAD utilizes the advantages of the greater thermophilic digestion rate, which is generally four times faster than mesophilic digestion. The process can be operated in either of two modes, thermophilic or mesophilic. The thermophilic phase is designed to operate at 50°C to 60°C with a three to five-day HRT. Through greater hydrolysis and biological activity in the thermophilic phase, the system tends to enhance VSD and gas production as compared to single-phase mesophilic digestion. The mesophilic phase is designed to operate at 35°C with a ten-day or greater detention time (Metcalf & Eddy). The mesophilic phase provides additional VSD and conditions the sludge for further processing. TPAD process will also accomplish high pathogen kill to produce CP1 NASM biosolids.

The process upgrades for Alternative 2A would include:

1. Transporting dewatered primary sludge from Ravensview and blending with sludge generated at Cataraqui Bay.
2. One thermophilic digester with a capacity of 3-day HRT.
3. Two mesophilic digesters with a capacity of 15-day HRT each.
4. Operating the existing secondary digester as digested sludge holding tank.
5. Two dewatering centrifuges to handle digested sludge.

Figure 3-3 presents the process flow schematic of this option.

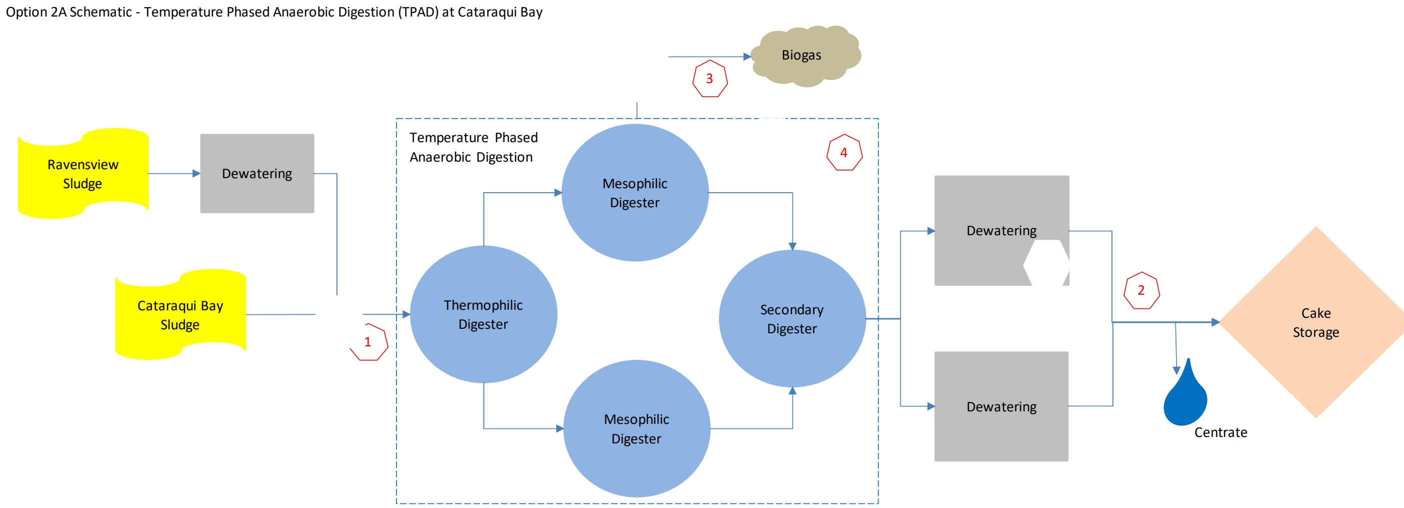


Figure 3-3: Upgrades to TPAD at Cataraqui Bay WWTP

3.2.1.2 Alternative 2B – Inclusion of BH with MAD

BH has been short-listed as a sludge pretreatment technology in the preliminary assessment. A BH system provides similar process benefits as thermophilic digesters by breaking down complex compounds into simpler forms to enhance digestion efficiency. BH systems generally increase biogas yield from domestic sewage sludge by 25% or more and increase the capacity of existing digester infrastructure by two to three times. These systems consist of six serial reactor vessels in a plug-flow process (referred to as "Six-Pack" BH systems) whereby sludge is heated to 42°C in the first reactor. Over the course of progression through the remaining reactors, the temperature is reduced to between 35°C to 40°C prior to entering the mesophilic digesters. The overall HRT within the BH system is approximately three days.

To incorporate a BH system upfront of the existing MAD at Cataraqui Bay, Option 2B would require the following upgrades:

1. Transporting dewatered sludge from Ravensview and blending with sludge generated at Cataraqui Bay.
2. One "Six-Pack" BH system upfront of mesophilic digesters.
3. Two mesophilic digesters with a capacity of 15-day HRT each.
4. Operating existing secondary digester as digested sludge holding tank.
5. Two dewatering centrifuges to handle digested sludge.

Figure 3-4 exhibits a process flow schematic of Option 2B.

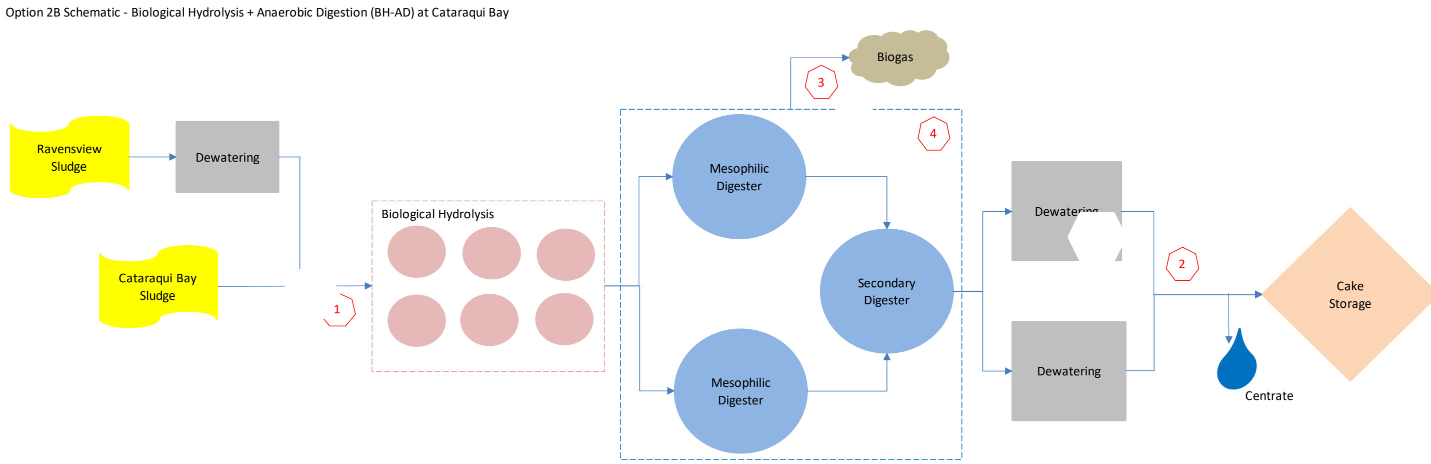


Figure 3-4: Upgrades with Addition of BHP at Cataraqui Bay WWTP

3.2.2 Impact on Existing Facilities

3.2.2.1 Biosolid and Biogas Production

Table 3-2 lists biosolid production and biogas yield under Alternative 2A and Alternative 2B side by side. Both processes could enhance downstream digester efficiency and biogas yield. With the multi-phase digestion process, the first step of anaerobic digestion is recognized to be the rate-limiting step. Through enhanced hydrolysis and biological activity in either thermophilic or BH step, the overall digestion tends to have greater VSD and gas production.

Alternative 2B (BH-AD) is expected to produce less biosolids (24 m^3/d) and more biogas (4,408 m^3/d) than Option 2A (TPAD). Unlike TPAD, which operates as a complete-mixed reactor, the BH system operates in a batch hold process, where only a portion of sludge in each reactor is transferred forward once per hour. This plug-flow fashion within the BH system ensures that all sludge spends most of the design HRT within the BH vessels, thereby being fully hydrolyzed and acidified prior to digestion. Thus, BH-AD tends to provide a higher VSD than TPAD. Commercial pilot results and literature data suggest that typical VSD for TPAD is 50% while BH-AD could achieve 54% VSD.

From a mass balance point of view, biogas yield is proportional to the amount of VS destroyed biochemically. The gas production rate of a typical anaerobic digester treating a combination of primary sludge and WAS should be approximately 0.8 m^3/kg to 1 m^3/kg of VS destroyed. Specific gas production from the two plants was determined based on the historical plant performance data of VSD, since the amount of gas produced is a function of temperature, HRT, and VS loading. The specific gas production rate of 1.65 m^3/kg of VS and 1.47 m^3/kg of VS were used for primary sludge and WAS, respectively, to feature the sewage sludge produced in the two plants. The two main constituents of biogas are methane (CH4) and carbon dioxide (CO_2). Literature suggests that typical CH4 concentration should be 60% to 70% by volume (MOP 8). Hence, 65% of CH4 in biogas was used for estimating the biogas yield under different options.

Table 3-2: Estimated Biosolid and Biogas Production for Alternative 2A and Alternative 2B

	Alternative 2A – TPAD	Alternative 2B – BH-AD
	Feedstock	
Volume (m^3/d)	116	116
TS Loading (kg/d)	10,051	10,051
VS Loading (kg/d)	7,285	7,285
	Biosolids	
Volume (m^3/d)	26	24
% Decreased Based on Option 1*	96%	92%
TS (kg/d)	6,408	6,117
VS in Cake (kg/d)	3,642	3,351
Nitrogen in Cake (kg/d)	192	184
Phosphorus in Cake (kg/d)	70	67
	Centrate	
Additional Centrate (m^3/d)	28	29
Additional Nitrogen Loading (kg/d)	113	121
Additional Phosphorus Loading (kg/d)	86	89
	Biogas	
Biogas (m^3/d)	3,563	3,857
Methane in Biogas (m^3/d)	2,052	2,507
% Increased Based on Option 1*	106%	115%

Notes: * The percentages of decreased biosolid production and increased biogas generation are based on the biosolid/biogas production under Option 1 – Do Nothing.

3.2.2.2 Operational Impact

With TPAD and BH-AD, the filamentous foaming issue is expected to be improved. The thermophilic step in the TPAD process requires attention to corrosion protection given the high temperature of operation and handling of high ammonia levels in the return flow. It should be noted that there would be an additional 28 m^3/d to 29 m^3/d of dewatering centrate from bringing primary sludge from Ravensview to Cataraqui Bay. This additional centrate containing high ammonia and phosphorus content may affect the treatment capacity of the existing plant liquid train. Although not being covered in this report, estimated nitrogen and phosphorus mass loadings are presented in Table 3-2. In the event that the additional organic loadings cannot be managed in the existing liquid treatment train, side-stream processing may be required to provide equalization for the dewatering centrate. This "add-on" side-stream process will need further evaluation based on the specific technology selected and design target VS destruction at the conceptual design stage.

3.2.2.3 Transportation and Footprint Requirements

Sludge generated from Ravensview will be dewatered and then trucked to Cataraqui Bay. Implementing either TPAD or BH-AD would require the same transportation effort. One truck haulage of 15 km per day is expected assuming a 40 m^3 truck is used.

Although the total tankage requirements for a "Six-Pack" BH system and one thermophilic digester are the same, the BH system would require a smaller footprint as compared to one thermophilic digester. The footprint for mesophilic digesters is the same for both systems because the designed HRT was assumed to be 15 days for the mesophilic stage across all options. In addition, as the existing centrifuge is to be decommissioned, two new centrifuges would be required for dewatering.

The following assumption was made for developing the biosolid storage requirements:

- The cake storage capacity is based on 180 days of biosolid storage during restricted land application period as outlined in Table 2-12.

The existing biosolids storage pad at Cataraqui Bay has recently been expanded with a capacity of 8,200 m^3. Option 2A and Option 2B would require a storage capacity of 4,680 m^3 and 4,320 m^3 for biosolid cake, respectively. Thus, the existing facility can provide sufficient capacity for biosolids generated under both options.

Table 3-3: Transportation and Footprint Requirements for Alternative 2A and Alternative 2B

	Alternative 2A – TPAD	Alternative 2B – BH-AD
	Transportation	
The volume of Dewatered Sludge	28	28
# of Trucks per Day*	1	1
Mileage (km)	15	15
	Biological Hydrolysis	
HRT (d)	-	3
# of Reactors	-	6
Required Footprint (m^2)	-	821
	Thermophilic Digester	
HRT (d)	3	-
# of Digesters	1	-
Required Footprint (m^2)	1,588	-
	Mesophilic Digester	
HRT (d)	15	15
# of Digesters	1	1
Required Footprint (m^2)	7,292	7,292
	Dewatering	
# of Units	2	2
Footprint (m^2)	600	600
Notes: * Based on 40m^3 of transportation capacity per truck.		

Based on the above comparison shown in Table 3-3, Option 2B is recommended as a preferred option between these two.

3.2.3 Cost Analysis

Proforma analysis was done on both options (2A and 2B). The capital assumptions range from $9.8M to 13.3M for Option 2A and Option 2B. This capital cost includes dewatering.

The NPV results from these are:

	Alternative 2A	Alternative 2B
Best	-$19,865	-$16,871
Lowest	-$9,499,007	-$10,870,603

These results confirm that Option 2B is financially stronger than Option 2A.

3.3 Alternative 3 – Optimize Infrastructure at Ravensview

3.3.1 Description of Alternative

Alternative 3 has a similar treatment process as Option 2B with the difference being that dewatered raw sludge is transported from the Cataraqui Bay WWTP for processing at Ravensview. This option is designed to serve as a location comparison to Option 2B. The following assumptions were made under Option 3:

- The blended sludge was assumed to consist of 80% primary sludge and 20% WAS based on raw sludge generation quantities from the two plants.
- No pre-thickening process is required prior to BH system.
- A typical three-day HRT for BH system was assumed for evaluation.
- All process equipment/footprint will be located on the existing site.

The process upgrades at Ravensview WWTP would include:

1. Transporting dewatered sludge from Cataraqui Bay and blending with sludge generated at Ravensview;
2. Replacing the existing thermophilic digester with a “Six-Pack” BH system upfront of mesophilic digesters;
3. Two mesophilic digesters with a capacity of 15-day HRT each;
4. Operating the existing secondary digester as digested sludge holding tank; and
5. Two dewatering centrifuges to handle digested sludge.

Figure 3-5 represents a process flow schematic of Option 3.

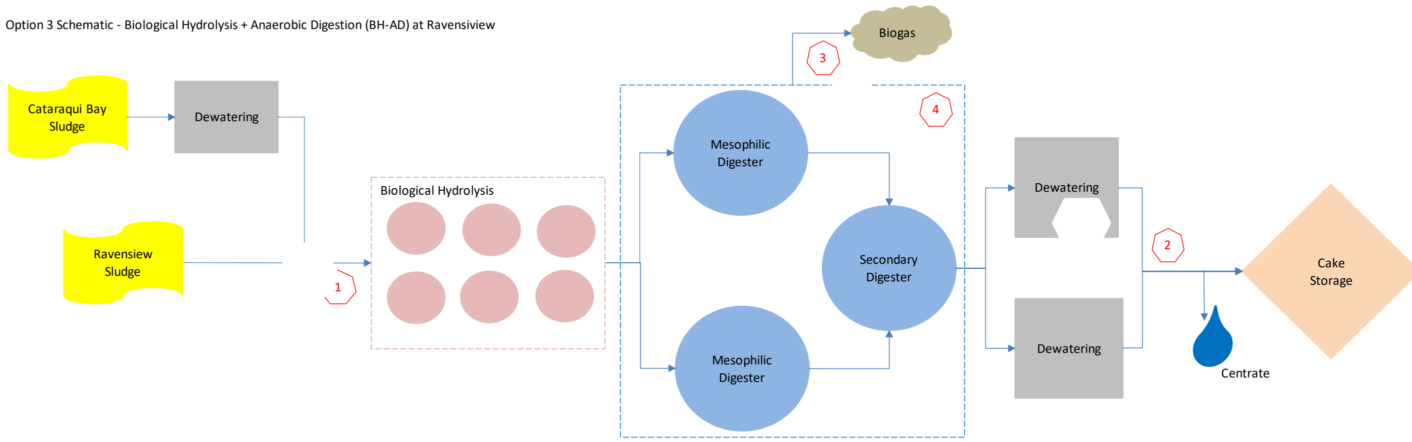


Figure 3-5: Upgrades of TPAD Process with Addition of BH system at Ravensview WWTP

3.3.2 Impact on Existing Facilities

3.3.2.1 Biosolid and Biogas Production

The treatment process of Alternative 3 is the same as Option 2B, therefore, biosolids production and biogas yield under this option are expected to be the same as Alternative 2B.

Table 3-4: Impact on Biosolid Production and Biogas Generation of Option 3

	Alternative 3 – BH-AD
Feedstock	
Sludge Volume (m³/d)	176
TS Loading (kg/d)	10,051
VS Loading (kg/d)	7,285
	Biosolids
Biosolids (m³/d)	24
% Decreased Based on Option 1*	92%
TS (kg/d)	6,117
VS in Cake (kg/d)	3,351
Nitrogen in Cake (kg/d)	184
Phosphorus in Cake (kg/d)	67
Centrate	
Additional Centrate (m³/d)	4
Additional Nitrogen Loading (kg/d)	168
Additional Phosphorus Loading (kg/d)	91
	Biogas
Biogas (m³/d)	4,408

	Alternative 3 – BH-AD
Methane in Biogas (m^3/d)	2,865
% Increased Based on Option 1*	115%

Notes: * The percentages of decreased biosolid production and increased biogas generation are based on the biosolid/biogas production under Option 1 – Do Nothing.

3.3.2.2 Operational Impact

With BH-AD, filamentous foaming is expected to be improved. BH systems require a lower operating temperature and pressure than the existing TPAD at the plant that may eliminate the staff qualification requirements for stationary engineers. According to the plant operators, the current thermophilic digester has several unsolved operating issues and is currently operating as a mesophilic digester. Incorporating a BH system with mesophilic digesters could improve the stability of the digestion operation.

Bringing active sludge from Cataraqui Bay to Ravensview would result in an additional 4 m^3/d of centrate returning back to the plant headworks. Though this volume is minimal, it contains a high level of nutrients (i.e., 168 kg/d of nitrogen and 91 kg/d of phosphorus) in the dewatering centrate. Managing this additional nutrient loading in the current wastewater treatment processes would pose a challenge to the plant's liquid train capacity. Although not being covered in this report, estimated nitrogen and phosphorus mass loadings are presented in Table 3-4. In the event that the additional organic loading cannot be managed in the existing liquid treatment train, an "add-on" side-stream process may be required as either a pretreatment or a post-treatment step to handle the extra nutrient loadings from the dewatering centrate. A side-stream process would require further evaluation based on the specific technology selected and design target VS destruction at the conceptual design stage.

3.3.2.3 Transportation and Footprint Requirements

Sludge generated from Cataraqui Bay will be dewatered and trucked to Ravensview. Alternative 3 would require the same transportation effort as Option 2B. One truck haulage of 15 km per day is expected assuming 40 m^3 truck is used.

Implementation of a BH-AD process at Ravensview would require a larger footprint than Alternative 2B. Though the total dry solids under the two options is the same, the blended raw sludge at Ravensview could only achieve 5.4% of TS, which means a much larger volume of feedstock as compared to Alternative 2B. The tankages for a BH system and mesophilic digesters are expected to be much larger than Alternative 2B in order to maintain the same HRT for digestion and achieve the same process performance.

The following assumption was made for developing the biosolid storage requirements:

- The cake storage capacity is based on 180 days of biosolid storage during restricted land application period as outlined in Table 2-12.

The existing enclosed biosolid cake storage pad at Ravensview has a capacity of 6,000 m^3. Similar to Alternative 2B, this option would require a storage capacity of 4,320 m^3 for biosolid cake. Thus, the existing facility can provide enough capacity for biosolids generated under both options.

Table 3-5: Transportation and Footprint Requirements for Alternative 3

	Option 3 – BH-AD
	Transportation
The volume of Dewatered Sludge	12
# of Trucks per Day*	1
Mileage (km)	15
	Biological Hydrolysis
HRT (d)	3
# of Reactors	6
Required Footprint (m^2)	1,084
	Mesophilic Digester
HRT (d)	15
# of Digesters	1
Required Footprint (m^2)	10,957
	Dewatering
# of Units	2
Footprint (m^2)	600

Notes: * Based on $40m^3$ of transportation capacity per truck.

3.3.3 Cost Analysis

The Ravensview analysis indicates that capital costs range from $10,696,000 to $14,471,000 but operating costs are substantially lower due to decreased hauling cost of sludge from Cataraqui Bay. The NPVs for this option are:

	Ravensview
Best	$1,802,393
Lowest	-$9,363,205

This assumes that all RNG produced at the Ravensview site can be injected into the Union/Enbridge pipeline. As noted in Section 2.5, summer consumption rates of natural gas average 53 m^3 per day. Gas generation rates as noted in Section 3.3.2.1 above would average 2,865 m^3/d or 119 m^3/d. Based on this, the Ravensview location would not be suitable to attain the maximum carbon gas credits and would furthermore be more difficult to be able to absorb the range of peaks that are anticipated to be generated over time.

3.4 Alternative 4 – Incorporate SSO at Cataraqui Bay

3.4.1 Description of Alternative

The operators of many WWTPs have found that they can increase the amount of biogas generated by accepting high-strength waste from outside sources that may not currently discharge to the treatment facility. According to the City, there are about 4,000 wet tons per year of SSO collected through green bin program.

The following assumptions were made for this Alternative:

- The blended raw sludge from Cataraqui Bay and Ravensview was assumed to consist of 80% primary sludge and 20% WAS based on raw sludge generation quantities from the two plants.
- Typical values of 20% TS and 95% VS were assumed to determine volatile content in curbside SSO.
- Convertible COD in VS of SSO was assumed to be 1.35 kg COD/kg VS. Convertible COD in the combined feedstock were calculated proportional to the percentages of SSO, primary sludge and WAS in the feedstock.
- A typical three-day HRT for BH system was assumed in evaluation.
- Based on industrial experience at similar facilities, VSD% was assumed to be 80% for SSO. Combined VSD were used to estimate VS residual after digestion and biosolid production.

Based on the preliminary assessment of codigestion at Cataraqui Bay, the upgrades under Alternative 4 would include:

1. Transporting dewatered sludge from Ravensview and blending with sludge generated at Cataraqui Bay.
2. One receiving station to pretreat SSO prior to digestion.
3. One “Six-Pack” BH system upfront of mesophilic digesters.
4. Two mesophilic digesters with a capacity of 15-day HRT each.
5. Operating existing secondary digester as digested sludge holding tank.
6. Two dewatering centrifuges to handle digested sludge.

Figure 3-6 represents a process flow schematic for Alternative 4.

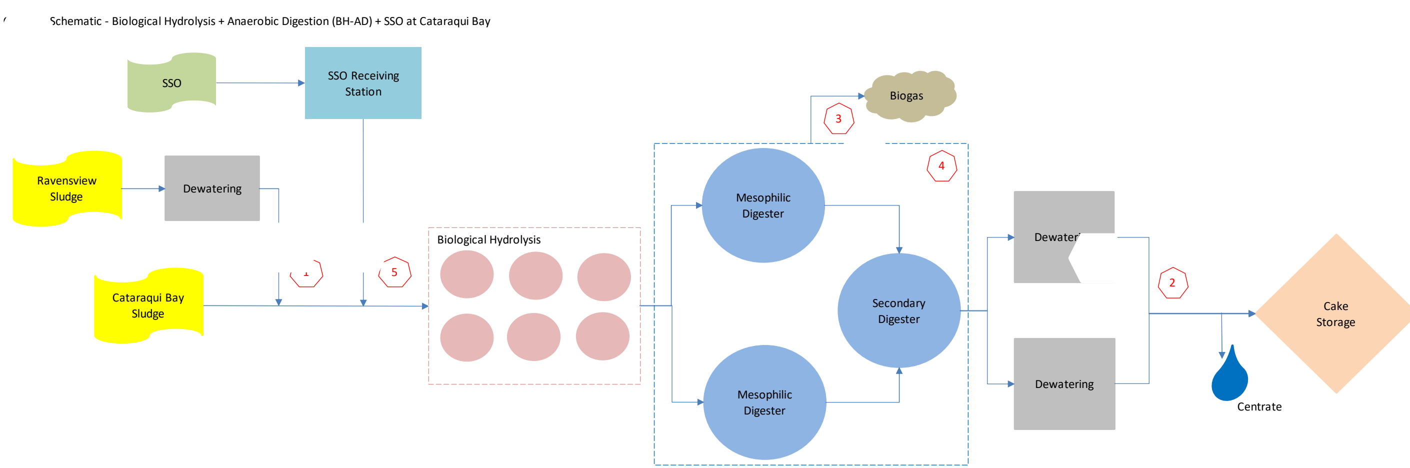


Figure 3-6: Incorporate SSO in Cataraqui Bay WWTP

3.4.2 Impact on Existing Facilities

3.4.2.1 Biosolid and Biogas Production

The BH process reduces the required HRT of sludge within digesters and enables the digesters to operate at a higher solids content. This allows for not only the indigenous sludge treatment to the WWTPs, but also the import of additional organic materials, such as high-strength liquid or food waste, and fats oils and grease. These wastes have a high organic content and low inert-solids content, which make them ideal for codigestion and generating biogas with limited effects on solids production.

Further to discussions with technology vendors, typical VSD for the digestion of SSO is about 80%. By codigestion of SSO with municipal sludge at Cataraqui Bay, the overall VSD is expected to reach 60%. This translates to achieving the same amount of cake biosolid production with a 56% increase in biogas production.

Codigestion of SSO would result in a further increase in dewatering centrate (36 m^3/d) returning back to the plant headworks. Though this volume is not considerable, it contains a high level of nutrients (i.e., 207 kg/d of nitrogen and 121 kg/d of phosphorus) in the dewatering centrate. Although not being covered in this report, the estimated nitrogen and phosphorus mass loadings are presented in Table 3-6. If the additional organic loading cannot be managed in the existing liquid treatment train, an "add-on" side-stream process may be required as either a pretreatment or a post-treatment step to handle the extra nutrient loadings from the dewatering centrate. The side-stream process would require further evaluation based on the specific technology selected and design target VS destruction at the conceptual design stage.

Table 3-6: Impact on Biosolid Production and Biogas Generation

Alternative 4 – BH-AD + SSO		
	Feedstock	
	SSO	Sludge
Volume (m^3/d)	9	116
TS Loading (kg/d)	2,192	10,051
VS Loading (kg/d)	2,082	7,285
	Biosolids	
Biosolids (m^3/d)	27	
% Increased Based on Option 1*	0%	
TS (kg/d)	6,643	
VS in Cake (kg/d)	3,767	
Nitrogen in Cake (kg/d)	199	
Phosphorus in Cake (kg/d)	73	
	Centrate	
Additional Centrate (m^3/d)	36	
Additional Nitrogen Loading (kg/d)	160	
Additional Phosphorus Loading (kg/d)	88	
	Biogas	

Alternative 4 – BH-AD + SSO	
Biogas (m^3/d)	5,969
Methane in Biogas (m^3/d)	3,880
% Increased Based on Option 1*	156%

Notes: * The percentages of decreased biosolid production and increased biogas generation are based on the biosolid/biogas production under Option 1 – Do Nothing.

3.4.2.2 Operational Impact

1. Receiving Station

Codigestion of SSO can add significant operational complexity for operators and facility managers. A receiving station with solids handling and pretreatment equipment for SSO will be required. Typically, this pretreatment equipment includes a tipping floor, loaders, feed hoppers, conveyors, bag breakers, screens, a magnetic separator, etc. In most circumstances, preparatory equipment, i.e., preprocessing units are also required to pulp SSO organics prior to entry into the digesters. One alternative may be to have this activity undertaken at another facility (privately or publicly owned and operated), and to have the pulped material shipped to the WWTP.

Operating a receiving facility presents a unique staffing requirement for operation and maintenance because of the nature of the materials. Management starts with scheduling deliveries, supervising off-loading, and tipping off non-organic compounds – all potential time-consuming tasks. Especially, for grease trap wastes, it can be challenging for operators. Grease not only clogs pipes, heat exchangers, and pumps but also adheres to inert debris, making it difficult to use screening for removal. It may require extra staffing efforts for SSO screening prior to acceptance.

2. Infrastructure Maintenance

Maintenance requirements increase because of the nature of SSO. For example, pipes, heat exchangers, and other equipment need to be cleaned more frequently. The short- and long-term capacity of the treatment facility to receive additional material will require further evaluation prior to implementation of this option.

3. Nutrient Handling

Typically, SSO comes with high-protein fraction which can significantly increase ammonia concentrations in the dewatering liquid. Additional treatment processing may be required as either a pretreatment or a post-treatment step to handle the additional loadings and volumes from dewatering centrate. High phosphorus concentration in SSO may contribute to struvite formation and increase chemical consumption for the additional phosphorus removal. SSO with a high sulfur content can result in more hydrogen sulfide produced in the digester and can complicate gas cleaning.

4. Odor Control

Odors originating from the SSO and digested gas is one of the most important yet challenging aspects of a solids handling facility. In solid treatment processes, the biosolids commonly undergo extreme turbulence, pH adjustment and/or thermal treatment. Depending on the nature of the SSO and the solid treatment used, the odor compounds released can consist of any combination of ammonia, amines, hydrogen sulfide, and organic sulfides in a wide range of concentrations.

Although SSO organics will remain in a contained environment, strategies for odor management are required to reduce additional odor concerns to the neighbourhood. In any evaluation of the treatment of odor, many factors need to be taken into consideration: loadings of “organic” odors, variability, process conditions and labor costs.

3.4.2.3 Transportation and Footprint Requirements

It has been assumed that the dewatered sludge from Ravensview and the SSO collected from curbside wastes would be trucked to Cataraqui Bay to one centralized solid treatment facility. Based on potential SSO quantities, additional transportation and traffic management efforts would be required including hours of operation, truck accessibility; on-site traffic management; and storage capacity requirements.

This option would require a SSO receiving station to house the preprocessing equipment/system. A typical SSO receiving station consists of a tipping floor, preprocessing system which opens plastic bags, hydrapulper and grit removal system, and buffer tank.

Compared with Option 2B, mesophilic digesters will require an additional 1,500 m^2 to accommodate the codigestion with SSO. The increase of the footprint would be negligible.

In addition, as the existing centrifuge is to be decommissioned, two new centrifuges would be required for dewatering.

The existing biosolid storage pad at Cataraqui Bay has recently been expanded with a capacity of 8,200 m^3. Option 4 would require a storage capacity of 4,860 m^3 for biosolid cake. Thus, the existing facility can provide sufficient capacity for biosolids generated under this option.

Table 3-7: Transportation and Footprint Requirements for Alternative 4

Alternative 4 – BH-AD + SSO	
Transportation	
Volume of Dewatered Sludge	37
# of Trucks per Day [1]	1
Mileage (km)	15
SSO Receiving Station	
Required Footprint (m^2)	2,000
Biological Hydrolysis	
HRT (d)	3
# of Reactors	6
Required Footprint (m^2)	861
Mesophilic Digester	
HRT (d)	15
# of Digesters	1
Required Footprint (m^2)	8,832
Dewatering	
# of Units	2

Alternative 4 – BH-AD + SSO	
Footprint (m^2)	600
Cake Storage [2]	
Volume (m^3)	4,860
Additional Footprint (m^2)	Not Required

Notes:
[1] Based on $40m^3$ of transportation capacity per truck.
[2] The cake storage capacity is based on 180 days of biosolid storage during restricted land application period as outlined in Section 3.2.3.

3.4.3 Cost Analysis

This analysis was done with the most favourable candidate (2B), but the results of the analysis can be applied to any of the options.

The added SSO capital cost for this option is $7,594,000, and there are added costs for personnel and utilities. The initial quantity of SSO that was used for comparison is 4,000 tonnes per year, which represents the amount of SSO generated from City's curbside collection. This option assumes the cost of disposal for SSO would be diverted to the project revenue. The change in NPV is shown below:

Table 3-8: Change in NPV

	Option 2B with SSO	Option 2B
Best	-$3,542,858	-$16,871
Lowest	-$14,391,492	-$10,870,603

Based on this comparison, the addition of 4,000 tonnes of curbside generated SSO is not recommended, primarily due to the high capital cost. If this quantity is increased, from potential other sources, the outcome would be:

Table 3-9: Outcome from Potential other Sources

	2B with 4,000 Tonnes SSO	2B with 5,000 Tonnes SSO	2B with 6,000 Tonnes SSO	2B with 8,000 Tonnes SSO	2B with 10,000 Tonnes SSO	2B with 12,000 Tonnes SSO
Best	-$3,542,858	-$115,557	$2,812,527	$4,720,379	$14,524,860	$20,381,027
Lowest	-$14,391,492	-$11,618,756	-$9,345,239	-$8,746,518	-$251,168	$4,295,867

The improvement of NPV is derived from two incremental factors. These are revenue derived from tipping fees, and an increase in the generation of RNG. No increase in capital is required for the incremental throughput. The comparisons assume that the increased tonnages carry tipping fees similar to that of the current cost to dispose SSO.

3.5 Alternative 5 – Integrate Processing of Biosolids and SSO at Knox Farms

3.5.1 Description of Alternative

Alternative 5 involves the “greenfield” construction of a new SSO resource recovery and codigestion facility at Knox Farms. Option 5 has the same process flow as Option 4 but lacking an existing liquid treatment process train.

The following assumptions were applied to this Alternative:

- The blended dewatered sludge from Cataraqui Bay and Ravensview was assumed to consist of 80% primary sludge and 20% WAS based on raw sludge generation quantities from the two plants.
- Typical values of 20% TS and 95% VS were assumed to determine volatile content in curbside SSO.
- Convertible COD in VS of SSO was assumed to be 1.35 kg COD/kg VS. Convertible COD in the combined feedstock were calculated proportional to the percentages of SSO, primary sludge and WAS in feedstock.
- A typical three-day HRT for BH system was assumed in evaluation.
- Based on industrial experience at similar facilities, VSD% was assumed to be 80% for SSO. Combined VSD were used to estimate VS residual after digestion and biosolid production.
- All process equipment/footprint will be located within the property boundary of Knox Farm.

The major process components at Knox Farms would include:

1. One receiving station for preprocessing of SSO.
2. Transporting SSO and dewatered sludge from WWTPs to Knox Farm and blending it in a sludge blending tank.
3. An optional “Six-Pack” BH system upfront of mesophilic digestion.
4. Two mesophilic digesters with a capacity of 15-day HRT each.
5. One secondary digester served as digested sludge holding tank.
6. Two dewatering centrifuges to handle digested sludge and store biosolid cake on site.
7. Transporting out dewatering centrate to WWTPs.

Alternatively, after digestion (Step 5 above), the digested sludge would be utilized by local farmers in a liquid form (see process flow in red dashed line shown on Figure 3-8).

Figure 3-7 illustrates a process flow schematic for Option 5.

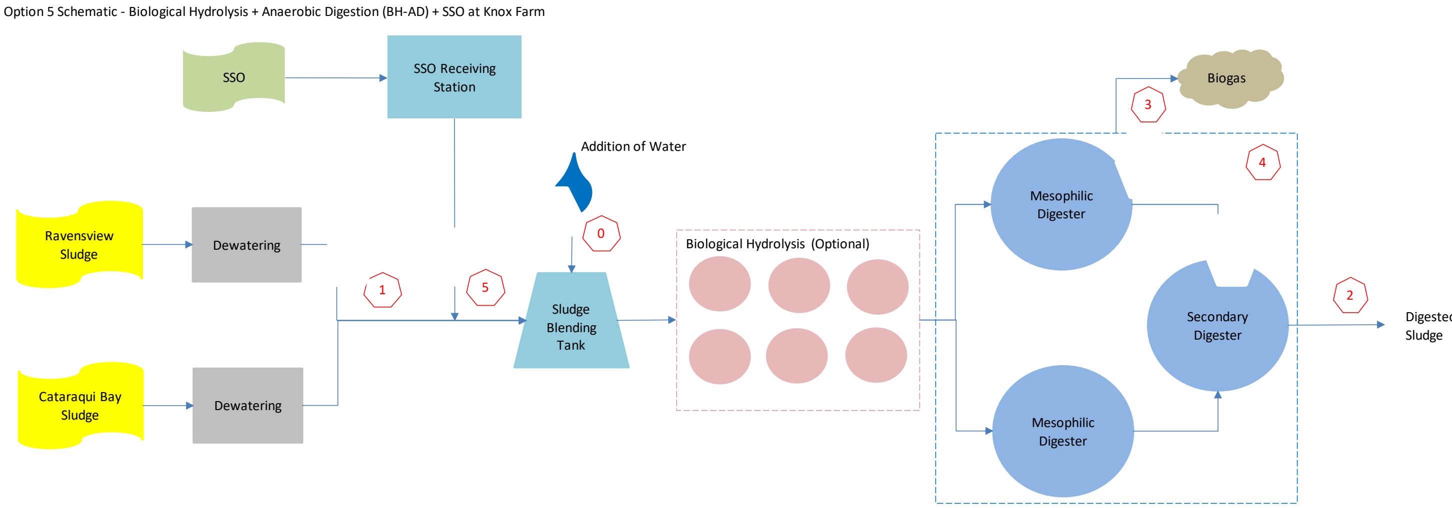


Figure 3-7: SSO Resource Recovery and Codigestion Process at Knox Farm

3.5.2 Impact on Existing Facilities

3.5.2.1 Biosolids and Biogas Production

The codigestion process is similar to Alternative 4, therefore, biosolids production and biogas yield under this Alternative are expected to be similar with same biosolids production and a 56% increase in the generation of biogas.

The 4,000 wet tonnes of SSO collected within the City only accounts for a small portion of the whole feedstock. The overall VSD could not be improved significantly. Higher VSD and greater biogas yield would be anticipated if increase the percentage of SSO in the feedstock.

As shown in Table 3-10, 75 m^3/d of liquid would be used for pulping and solid mixing. It can be recirculated through the system to minimize the use of potable water. Additionally, rainwater from the facility's downspouts could be harvest for process water needs, further reducing the use of potable water.

Table 3-10: Impact on Biosolid Production and Biogas Generation of Option 5

Alternative 5 – BH-AD + SSO			
	Feedstock		
	SSO	Dewatered Sludge	Liquids
Volume (m^3/d)	9	40	75
TS Loading (kg/d)	2,192	10,051	-
VS Loading (kg/d)	2,082	7,285	-
	Biosolids		
Biosolids (m^3/d)	27		
% Increased Based on Option 1*	0%		
TS (kg/d)	6,643		

Alternative 5 – BH-AD + SSO	
VS in Cake (kg/d)	3,767
Nitrogen in Cake (kg/d)	199
Phosphorus in Cake (kg/d)	73
	Centrate
Additional Centrate (m^3/d)	98
Additional Nitrogen Loading (kg/d)	207
Additional Phosphorus Loading (kg/d)	121
	Biogas
Biogas (m^3/d)	5,969
Methane in Biogas (m^3/d)	3,880
% Increased Based on Option 1*	156%

Notes: * The percentages of decreased biosolid production and increased biogas generation are based on the biosolid/biogas production under Option 1 – Do Nothing.

3.5.2.2 Operational Impact

Codigestion of SSO with sewage sludge would result in the substantial amount of N & P loadings from the facility dewatering liquid, i.e., 207 kg/d of nitrogen and 121 kg/d of phosphorus. There is no liquid treatment on site. As shown on Figure 3-8, three options are available to manage the digested sludge and potential high-strength centrate:

- Option 1: Distribute the digested sludge as liquid fertilizer for local land application. Experiences collected from other municipalities in Ontario, e.g., Halton Region, City of Barrie, and Brantford, suggest that liquid digestate is one of the favourable options for many farmers due to the ease of handling. In some cases, digestates are distributed and stored in individual farms due the demand exceeds the supply.
- Option 2a: Dewater digestate and store the digested sludge as biosolids cake. The centrate from dewatering process can be trucked out to one of the two existing WWTPs for further treatment. Additional loading to the existing treatment plant(s) must be evaluated.
- Option 2b: Dewater digestate and store the digested sludge as biosolids cake. Construct a complete on-site wastewater treatment process to treat the liquid stream and discharge it to local sewer.

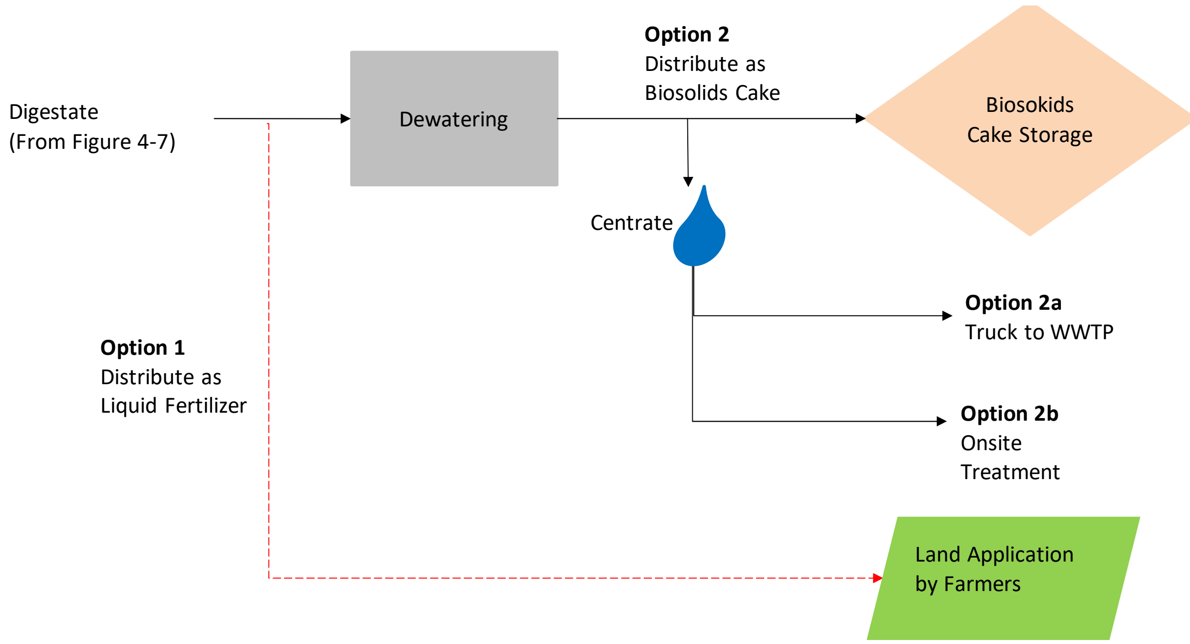


Figure 3-8: Flow Chart – Options for Biosolids Residual Management at Knox Farm

3.5.2.3 Transportation and Footprint Requirements

This centralized treatment site could have a large impact on the overall disposal and transportation costs. The dewatered sludge from Ravensview and Cataraqui Bay would require two trucks per day and additional distance by hauling SSO and dewatered sludge to this location. Similar as Alternative 4, additional transportation effort and traffic management will be required for curbside wastes collection and process: the potential SSO quantities, the necessary hours of operation, truck accessibility issue, on-site traffic management needs, and storage capacity requirements.

Like Alternative 4, codigestion of SSO at a different location would require the same footprint for the BH system and mesophilic digesters.

If the digested sludge is stored as biosolid cake, storage capacity is based on 180 days of biosolid storage during restricted land application period. The new facility would provide a storage facility with a capacity of 4,860 m^3 for biosolid cake.

Table 3-11: Transportation and Footprint Requirements for Option 5

Alternative 5 – BH-AD + SSO	
	Transportation
Volume of Dewatered Sludge	40
# of Trucks per Day [1]	2
Mileage (km)	30
	SSO Receiving Station
Required Footprint (m^2)	2,000

Alternative 5 – BH-AD + SSO	
	Biological Hydrolysis
HRT (d)	3
# of Reactors	6
Required Footprint (m^2)	861
	Mesophilic Digester
HRT (d)	15
# of Digesters	1
Required Footprint (m^2)	8,832
	Dewatering
# of Units	2
Footprint (m^2)	600
	Cake Storage [2]
Additional capacity (m^3)	4,860
Footprint (m^2)	1,800

Notes:
[1]Based on 40m^3 of transportation capacity per truck.
[2]Storage capacity is based on 180 days of biosolid storage during restricted land application period as outlined in Section **Error! Reference source not found.**.

3.5.3 Cost Analysis

The cost of constructing a new plant, initially thought to be located at the City-owned Knox Farms site would include new digesters, a new office/maintenance/personnel building, a cake storage building, and some civil works. This cost was compared to Alternative 2B, with the addition of an estimated $10M in retrofit costs of the digesters located at Cataraqui Bay. The result of comparing 2B with SSO with Knox Farms with SSO (both at 4000 tpy) is as follows:

Table 3-12: Comparing 2B with SSO with Knox Farms with SSO Results

	Option 2B with retrofit	Option 5 (alternative site)
Best	-$16,693,203	-$15,514,431
Lowest	-$27,541,837	-$27,558,551

This comparison indicates that when one includes the cost of the digester upgrade at Cataraqui Bay to building a new plant, the outcome is very similar. The cost to bring the utilities to Knox Farms was not included in the comparison.

3.6 Summary of Technical Analyses

The following Table 3-13 summarizes the overall results of the analysis shown above.

Table 3-13: Summary of Alternatives

	Base Case	Short-Listed Alternatives							
	Do Nothing	BH-AD at Ravensview	TPAD at Cataraqui Bay	BH-AD at Cataraqui Bay	BH-AD + SSO at Cataraqui Bay		BH-AD + SSO at Knox Farms		
	Input								
	Sludge	Sludge	Sludge	Sludge	Sludge	SSO	Sludge	SSO	H_2O
Volume (m³/d)	238	176	116	116	116	9	40	9	75
TS Loading (kg/d)	10,051	10,051	10,051	10,051	10,051	2,192	10,051	2,192	-
VS Loading (kg/d)	7,285	7,285	7,285	7,285	7,285	7,285			
	Biosolids								
Volume (m3/d)	27	24	26	24	27		27		
% Decrease based on Do Nothing	0	8%	4%	8%	0%		0%		
TS (kg/d)	7,788	6,117	6,498	6,117	6,643		6,643		
VS in Cake (kg/d)	3,887	3,351	3,642	3,351	3,767		3,767		
Nitrogen in Cake (kg/d)	233	184	192	184	199		199		
Phosphorous in Cake (kg/d)	85	67	70	67	73		73		
	Centrate								
Additional Centrate (m³/d)	209	4	28	29	36		98		
Additional Nitrogen Loading (kg/d)	47	168	113	121	160		207		
Additional Phosphorus Loading (kg/d)	63	91	86	89	88		121		
	Biogas								
Biogas (m³/d)	3,831	4,408	4,071	4,408	5,969		5,969		
Methane in Biogas (m³/d)	2,207	2,865	2,346	2,865	3,880		3,880		
% Increase based on Do Nothing	-	15%	6%	15%	56%		56%		

4.0 CURRENT POLICY AND MARKETS

Global trends indicate an international desire to move towards a circular economy and mitigate global effects of climate change. Methods for doing so involve the reduction of greenhouse gas (GHG) emissions through implementation measures such as placing a price on carbon. In 2016, Canada became a party to the Paris Agreement which originated to respond to global warming and aims to collaboratively reduce carbon emissions. It is not a legally binding document, but rather encourages voluntary action by the participating countries. At the provincial level, Ontario has supported this endeavor through its Climate Change Action Plan and various legislative documents, some of which are relevant for UK and are described below.

4.1 Cap and Trade Program

Ontario's Climate Change Action Plan was a five-year plan that was released in June 2016 to facilitate the reduction of GHG emissions and accelerate the use of clean technology in the province. In support of this plan, the Ontario Cap and Trade legislation was made effective January 2017. Cap and Trade is a market based system for controlling atmospheric pollution by identifying a limit on the amount of emissions a facility can produce. For emissions above this limit, a company would pay for allowances. For any amount below the identified limit, a company could sell their allowances through auction. With the change in government in 2018, the Cap and Trade program in Ontario was cancelled. At the outset of this project it was anticipated that the proposed master plan would potentially partake in the Ontario Cap and Trade program.

4.1.1 Alternatives to Ontario Cap and Trade program

There are currently two provinces that have implemented a value of injecting RNG into the gas grid. Quebec, in concurrence with the State of California have maintained the Cap and Trade system. Through the Western Climate Initiative, of which Ontario used to be a member, auction systems continue to be used to set threshold values for carbon. British Columbia has alternatively opted for a Carbon Tax. Through these initiatives, and through self-imposed increases in the amount of RNG that the two provinces want to see in the gas pipeline grids, RNG has a value ranging from $15 to $20 per GJ in Quebec and $25 to $30 per GJ in British Columbia. Both provinces have indicated that they may purchase RNG generated from other provinces at the above noted rates.

4.1.2 Waste-Free Ontario Act (Bill 151)

The Waste-Free Ontario Act builds on the intention to move towards a circular economy and puts additional responsibility of product lifecycle on the producers. It is comprised of both the Resource Recovery and Circular Economy Act and the Waste Diversion Transition Act. The justification for implementing these Acts was based on the waste generation statistics of Ontario showing increasing waste generation trends and a historical average of 75% of waste generated being sent to landfill, with little improvement in waste diversion for almost a decade.

As defined in the Resource Recovery and Circular Economy Act, 2016:

*"A **Circular Economy** is an economy in which participants strive to:*

- *minimize the use of raw materials;*
- *maximize the useful life of materials and other resources through resource recovery; and*
- *minimize waste generated at the end-of-life of products and packaging.*

***Resource Recovery** means the extraction of useful materials or other resources from things that might otherwise be waste, including through reuse, recycling, reintegration, regeneration or other activities."*

The relevance of this Act is in the potential future changes which may impact or change the economical viability of biogas projects. Ontario is developing procedures around full producer responsibility for Blue Box materials as well as a possible organic ban from landfills. This will change the climate and availability of additional feedstock for biogas opportunities, should UK choose to pursue SSO feedstock. The new government has indicated that portions of this Act will be continued.

5.0 EVALUATION OF ALTERNATIVES

As summarized in Section 1 of this report, the evaluation of the alternative strategies was completed in two parts. In Part 1, alternative technologies were evaluated to identify a “short list” of technologies which would be carried forward for assessment and evaluation at Part 2. The second part of the evaluation process entailed the organization of short-listed technologies into a series of alternative biosolids and waste organics processing trains comprised of enhancements to the UK’s existing WWTPs and the development of a new process train at a “greenfield” development site. A “do nothing” alternative was included in the Part 2 assessment. Part 2 was, in turn, completed based on two components. The first component comprised the assessment of the described alternative strategies based on a series of operational, financial, land use and natural environmental criteria; and the second comprised a comparative evaluation of the performance of the alternative strategies in relation to key criteria selected from those used in the assessment of the alternatives.

5.1 Existing WWTP Operations Review and Analysis of Alternative Technologies and Processes

The analytical work completed in the first part of the evaluation was as follows:

- The review and documentation of the existing operations at the Ravensview and Cataraqui Bay WWTPs;
- The comparative evaluation of relative “advantages” and “disadvantages” of technologies and processes associated with the pretreatment, treatment, stabilization and management of biosolids together with the codigestion of biosolids and waste organics. This entailed an evaluation of alternatives in the following categories:
  - *Sludge Pretreatment* including thickening; hydrolysis; conditioning; and, stabilization.
  - *Solids stabilization* including digestion; codigestion; post-treatment/composting; chemical stabilization; and, thermal stabilization.
  - *Biogas utilization* including on-site combined heat and power; boilers; vehicle fuel station(s); local or regional natural gas pipeline injection; and, fuel cell technology.
  - *Dewatering* including centrifuge; belt-filter press; drying beds; rotary vacuum filters; and, enhanced solar.
  - *Side-stream treatment* including the struvite recovery and anaerobic ammonium oxidation (ANAMMOX) recovery processes.
  - *Biosolids management* including land application; landfill; and, utilization as construction material.
- The identification of alternative technologies/systems for a more detailed assessment.

The alternative technologies were subject to a screening process which generated the following list for further, more detailed analysis.

Table 5-1: Technologies for Further Study

Categories	Technologies
Sludge Pretreatment	1. Thickening 2. Biological Hydrolysis
Solids Stabilization	3. Anaerobic Digestion 4. Codigestion at Ravensview (including SSO) 5. Codigestion at Cataraqui Bay (including SSO)
Biogas Utilization	6. Microturbines 7. Reciprocating Engines 8. On-Site Boiler 9. Off-Site Vehicle Fueling
Dewatering	10. Centrifuge 11. Belt-Filter Press
Biosolids Management	12. Cake/Slurry Land Application

A detailed outline of the work undertaken is provided in the Utilities Kingston report titled "Preliminary Assessment Report Kingston Biosolids and Biogas Master Plan", dated April 2018.

5.2 Analysis of Alternative Strategies

The second part of the evaluation entailed a detailed analysis of alternative options or, for the purposes of this Master Plan, alternative strategies. Five alternative strategies were defined each of which incorporated different combinations of technologies which were assessed in part 1 of the Study. The alternatives assessed are as follows:

- Optimize infrastructure at the Cataraqui Bay WWTP by expanding the existing MAD process with capability to operate in temperature-phase anaerobic digestion (TPAD) process.
- Optimize infrastructure at Cataraqui Bay WWTP by expanding the existing MAD process together with BH as a sludge pretreatment ahead of the MAD process.
- As the second alternative, listed above, but with dewatered raw sludge being transported from the Cataraqui Bay WWTP for processing at the Ravensview WWTP.
- As the second alternative with the inclusion of waste organics from third-party sources such as the SSO collected by the City.
- Develop an integrated biosolids and SSO processing facility at a greenfield development site located within the property boundary of Knox Farm.

A "do nothing" alternative, which entailed continuation of the current practice of processing sludge separately at the UK's two WWTPs and without the introduction of a waste organics processing component was identified for the purposes of comparison of the alternative enhancement strategies with existing conditions.

Each of the alternatives were assessed based on the following elements:

- Detailed description and depiction of the processing components and processing trains that comprise each of the alternative strategies.
- Calculation of the estimated changes in the production of biosolids and biogas within each of the strategies.

- Detailed description of either the operational changes to the existing processing infrastructure or development of a new processing complex contemplated in each of the alternative strategies.
- Analysis of the materials transport requirements as well as the determination of the size of the development footprint required for the processing components of each strategy.
- Calculation of the "best" NPV (i.e., lowest cost and highest potential revenue) and the "lowest" NPV (i.e., highest capital and operating costs and lowest potential revenue) for each of the strategies. These calculations included the estimation of potential revenues from wheeling the biogas into available natural gas pipelines and generation and refinement for each of the strategies.
- Identification of sensitive land uses and significant natural environmental features that may by located in the vicinity of each of the alternatives.

The detailed description and assessment of the alternative strategies established the technical basis upon which the evaluation was completed for the purposes of the subject Master Plan. A detailed outline of the work undertaken is provided in the UK report titled "Detailed Assessment Report Kingston Biosolids and Biogas Master Plan", dated July 2019. The element which was not included in the Detailed Assessment report is the assessment of the proximity of each alternative to sensitive land uses, such as residences, as well as significant natural features. The information used for these criteria was obtained from Google Earth imaging as well as from the City's and Cataraqui Conservation's web sites. The information from these sources included the City's Official Plan as well as information pertaining to the Little Cataraqui Creek Conservation Area.

As described in Section 1 of this Master Plan report, given developments in Ontario regarding the consideration of wastes as resources within the context of a circular economy; the more effective management of SSO with the objective of eliminating the landfilling of these materials; and, the identification of opportunities for the generation and utilization of RNG, UK expanded the scope of the study to include alternative systems that would entail the codigestion of biosolids and waste organics both collected by the City and generated by the IC&I sector. In addition, and further to the interest in considering codigestion systems, UK identified the Knox Farm property as a prospective centralized location which would accept raw feedstocks (i.e., wastewater sludge from the two WWTPs as well as SSO and L&Y waste) transported from the two WWTPs and via SSO and L&Y waste collection vehicles from sources within the City.

The assessment and subsequent comparative evaluation of the five alternative strategies was undertaken to demonstrate the relative performance of the two alternatives which entailed the codigestion of biosolids and waste organics (Alternative 4 Alternative 5) with the other three alternative strategies which entailed enhancements to the processing of only biosolids. This was undertaken to ensure a fulsome comparison of enhanced digestion with codigestion treatment trains.

5.3 Results

The information tabulated further to the assessment of alternative strategies is outlined in Appendix A. This information, together with that obtained from supplementary sources from the City and Cataraqui Conservation, was used to complete a comparative evaluation of the alternative strategies to select a "preferred" strategy. The tabulation of the comparative evaluation is provided in Appendix B to this report.

5.3.1 Performance of Alternative Strategies Relative to Criteria

The evaluation comprised a qualitative assessment of each of the five alternative strategies based on the following criteria.

- The increase in the generation of biogas and methane.
- The footprint required for new or expanded processing facilities.
- Materials transport requirements (i.e., sludge and/or waste organics).
- Capital and operating costs.
- Area available for expansion over the long term.
- Proximity to sensitive land uses and significant natural features.

Following are the results of the evaluation based on each of the criteria.

Generation of Biogas and Methane: All the alternative strategies enhanced or increased the generation of biogas and methane. Alternative 4 and Alternative 5; however, would generate the most relative to the other strategies. Because Alternative 4 Alternative 5 comprised the same processing train, both would generate about 396% more methane than the "Do Nothing" alternative and significantly more than the other treatment trains.

Infrastructure Required for New/Enhanced Processing Facilities: Regarding the area required to construct the enhanced/new processing trains, Alternative 1 required the least amount of space, at 10,080 m^2 and Alternative 5, the most at 14,693 m^2.

Transport of Materials: This criterion considered the performance of each alternative relative to the number of truck trips required to undertake the treatment of biosolids and waste organics. Both Alternative 4 and Alternative 5 required a greater number of truck trips since both systems would be processing waste organics including SSO.

Capital and Operating Costs: Each of the alternatives was evaluated based on the best NPV (i.e., lowest cost and highest revenue and lowest NPV (i.e., highest cost and lowest revenue). This evaluation tended to favour Alternative 1, Alternative 2, and Alternative 3 because of the higher capital and operating costs associated with managing waste organics in Alternative 4 and Alternative 5. The numbers for these two latter alternatives, outlined in the evaluation table in Appendix D are based on the input of 4,000 tonnes per year (tpa) of waste organic material. However, when costs and revenues associated with the processing of waste organics are factored into the analysis, the numbers begin to favour Alternative 4 and Alternative 5. In addition, when the quantity of waste organics processed at either the Cataraqui Bay WWTP of a stand-alone facility at Knox Farm are taken into consideration Alternative 4 and Alternative 5 become more attractive over the longer term. A fulsome analysis is provided in the Detailed Assessment report.

Area for Future Expansion: Alternative 1, Alternative 2, and Alternative 3, which entailed enhancements to the existing processing trains at the Cataraqui Bay WWTP were found to have just enough space to accommodate these enhancements. When waste organics preprocessing is added, per Alternative 4 Alternative 5, there would be insufficient space at the WWTP while the development of new processing infrastructure at the Knox Farm property would have enough space for the initial throughput capacity as well as a larger throughput capacity over the longer term. The development of an integrated facility at the Knox Farm property would provide UK and the City with the ability to expand the processing capacity beyond current demand. This is of relevance to the processing of waste organics. A codigestion facility will be required to respond to the demand to accommodate a higher annual generation of waste organics particularly with the likely advent of a ban on landfilling these materials and the increased benefit of generating a renewable source of fuel.

Proximity to Sensitive Land Uses and Significant Natural Features: Even though Alternative 5 would be in proximity to the Little Cataraqui Creek CA, it was "less intrusive" than the other alternatives. The property is owned by the City and is located almost 1 km away from the nearest residential community. Further there are no other "sensitive" land uses in proximity (i.e., 500 metres) to the property. Finally, there is enough area within the property to maintain a buffer from an integrated processing facility and surrounding, significant natural features.

5.3.2 Identification of Preferred Alternative Strategy

To begin, UK and the City have expressed interest in realizing the opportunity to enhance the generation of an alternative fuel by the codigestion of biosolids and waste organics. Only Alternative 4 and Alternative 5 would provide the capacity to achieve this expanded opportunity as stated in the Purpose for the subject Master Plan.

When Alternative 4 and Alternative 5, are compared relative to the Evaluation criteria, it is apparent that Alternative 5 would be "preferred" for the following reasons:

- A processing train developed at the Knox Farm property would be capable of significantly increasing the generation of biogas and methane.
- This alternative is the only one which has enough space to develop the initial processing facility with enough additional space to accommodate expansion of its processing capacity over the longer term thereby positively responding to both key components of the *Purpose of the Undertaking* for this Mater Plan study.
- The impacts of transporting both biosolids from the two WWTPs and waste organics can be mitigated using measures that will be evaluated and selected as part of the assessment of potential effects associated with the implementation of this preferred strategy.
- Although the NPV is the "least attractive" among the evaluated alternatives, this financial performance would be improved with the increase in the quantity of both biosolids and waste organics processed at the facility. Given the likelihood of the province issuing a ban on the landfilling of waste organics and given the interest in utilizing waste as a resource in a "circular economy" context that will benefit the residents of Kingston, it can be reasonably assumed that this increase in feedstock will occur.
- Although the preferred alternative is located adjacent to the Little Cataraqui Creek CA, there appears to be sufficient space to accommodate development and operation of both the initial and a possible expanded processing train within an area that will maximize the set back from the CA.

5.4 Consultation

Numerous processes were done to ensure that all relevant stakeholders have knowledge of the anticipated program and subsequent.

5.4.1 Notifications

Direct notifications have been made with numerous stakeholder groups throughout the process. These include:

- Sydenham District Association
- Portsmouth Neighbourhood Association
- McBurney Park Neighbourhood Association
- Williamsville Neighbourhood Association
- Kingston Home Builders Association khba@khba.ca;
- Kingston Chamber of Commerce info@kingstonchamber.ca;

- Kingston Downtown Business Association Michele@downtownkingston.ca
- Tourism Kingston visit@tourismkingston.com;
- Kingston Seniors Association info@seniorskingston.ca
- Community Response to Neighbourhood Concerns crncengagement@gmail.com
- Kingscourt Neighbourhood kingscourtca2@yahoo.com;
- Pittsburgh Community Benefit Fund secretary@pcbf.org
- Sustainable Kingston info@sustainablekingston.ca
- Various Unattributed Community e-mails provided by City of Kingston

First Nations

- William Treaties First Nations
- MNO Peterborough and District Wapiti Métis Council
- MOHAWKS OF THE BAY OF QUINTE

Municipalities

- Kingston
- Manager, Climate Initiatives
- Environment Director
- Commissioner, Community Services
- All Council via internal communications
- Prince Edward County
- Greater Napanee
- Brockville
- Gananoque
- Smiths Falls
- Loyalist Township
- Belleville
- Quinte West

Agencies

- Ontario Ministry of Environment, Conservation and Parks
- Ontario Water Consortium

- Ontario Clean Water Agency

Local Interested Businesses

Communication regarding this project with the various Stakeholder groups has been done through e-mails, phone calls or personal communications.

5.4.2 Communication with MECP

Numerous communications have been made with the MOECC (now called MECP) regarding the process. An initial presentation was done at the onset of the Master plan process, and several communications (email and phone calls) have been made between UK and the regulators regarding the progress of the process.

5.4.3 Web Site Postings

UK has advertised the plan on several sites:

- UK Web site (with links to key personnel). The web site has a posting of the final report.
- Kingstonist (local newspaper with articles summarizing the project.

5.4.4 Public Information Session & Reporting

A public presentation was made to the public on January 30, 2020, between 4:00 p.m. to 7:00 p.m. The presentation was done in the main conference room at the UK office at 85 Lappan's Lane in Kingston. Notification of the event was made on the UK website, newspaper advertisement, and direct to various stakeholders (NGOs, Aboriginal groups, MECP, City Council, general public, surrounding communities and others). The resultant presentation was attended by 17 citizens, 8 members of the surrounding community, and 2 potential equipment suppliers. Results of the presentation are shown in Appendix C.

5.4.5 Liaison with the Utility's BOD and City Council

The UK Management Team has been appraised of the Master Plan through numerous presentations and versions of the various reports throughout the sequence of the work.

Furthermore, the UK Board of Directors and City Council have been presented with updates of the Master Plan process throughout the project life.

6.0 IMPLEMENTATION PLAN

Once the Master Plan has been posted, UK may proceed to compete the approvals necessary to implement the components of the preferred strategy. Following is a description of the steps UK would take to implement the specific elements of the Master Plan.

6.1 Next Steps

Upon adoption of the Master Plan by UK and the City, a Notice of Completion of the Master Planning process will be posted, and the document would be made available to interested parties and the general public via identified outlets. This would most likely include an electronic version of the Plan together with the Preliminary and Detailed assessment reports available on the UK's and the City's web sites as well as paper copies available at prescribed locations.

It would be up to UK in collaboration with the City to decide when to continue with completion of the approvals necessary to implement the specific elements (processing system components) identified as the "Preferred Alternative Strategy" in the Master Plan.

6.2 Additional Approvals Required

When the projects are undertaken which implement the elements of the Preferred Alternative Strategy outlined in the Master Plan, it will be necessary for the applicable Schedule to be determined for those projects subject to the Municipal Class EA. There is also a key element of the approval process which would have to be accommodated within a different approvals process.

The preferred strategy consists of an integrated biosolids and waste organics processing facility, with associated civil works, located on vacant land owned by the City. The location is the Knox Farm property. The four main processing components that will comprise the facility must be taken into consideration when examining the approvals required to develop this facility at the Knox Farm location. These are:

- The pretreatment of waste organics including the tip floor for receipt of the non-hazardous waste materials and loading of the pretreatment train(s).
- The mixing of the pretreated waste organics with biosolids generated at the City's WWTPs and codigestion of the mixed feedstock.
- Capture and processing of the process biogas to generate a pipeline-quality RNG.
- The civil works required to service the facility including access/egress for transport vehicles, internal roadways, water and sanitary servicing, stormwater management infrastructure, etc.

Following is a summary outline of the subsequent approvals that would be required to develop the preferred Strategy. Before these next steps are taken; however, it would be prudent to meet with MECP staff to ensure that they agree with the following steps.

6.2.1 Pretreatment of Waste Organics

The waste organics preprocessing component of the codigestion facility would entail: the receipt and tipping of waste organics at an appropriately designed and constructed tip floor; sorting and screening of the material stream to remove contaminants such as plastic bags, packaging, etc.; and transfer of the preprocessed material to be blended with the biosolids stream. Required approvals would focus on how the design and operation of this component of the processing train will both comply with provincial regulations and provide a productive RNG-generation service while mitigating potential effects on the environment.

UK and the City have identified that initially, the codigestion facility would receive in the order of 4,000 tonnes per annum of non-hazardous organic wastes from the City's SSO collection program. The annual quantity of this material would likely increase over the lifespan of the proposed co-processing operation and this would have to be projected as part of the background work completed for the approval of this facility component.

In 2018 the provincial government issued the "Food and Organic Waste Policy Statement" pursuant to the *Resource Recovery and Circular Economy Act, 2016.* This Provincial Policy identifies the requirements associated with various means by which food and organic waste would be managed. The Policy provides support and encouragement for the innovative utilization of waste organics as well as biosolids as resources to help achieve a more sustainable economy. More specifically, clause 6.16 of the Policy states that municipalities are encouraged to plan for the management and beneficial use of biosolids including considering new and enhanced biosolids processing technologies and co-management practices. The Policy also identifies that infrastructure for the processing and utilization of waste organics must be developed in compliance with applicable environmental and land use planning approvals. Clause 6.5 of the Policy identifies that the province and municipalities as well as other planning authorities, (e.g., Conservation Authorities) should co-ordinate and complement approaches to provincial and municipal approvals to facilitate timely decisions for the development of resource recovery systems.

There is support, from the province, for the development of increased organics utilization with emphasis on innovative approaches. It is reasonable to assume that the province will see the UK's interest in developing a stand-alone, expandable facility to effectively management both biosolids and waste organics to generate a RNG as innovative.

This component of the processing train would require neither an Individual EA nor an Environmental Screening under Part II of the Ontario Environmental Assessment Act (OEAA). The design and operation of this component, however, will require Environmental Compliance Approval (ECA) "Waste" and "Air Quality/Noise" (AQ/N) under the Environmental Protection Act (EPA). The codigestion component of the facility would also require ECA (AQ/N) under the EPA. The technical and planning work to achieve these Approvals would proceed together with those required to complete the Class EA and ECA processes for the balance of the processing train.

6.2.2 Codigestion of Biosolids and Pretreated Waste Organics and Biogas Capture

UK has completed the first 2 phases of the MCEA process. Once this Master Plan has been successfully posted, the next steps will entail the completion of the balance of the Class EA considering the characteristics of the Projects which will be undertaken further to the results of the Master Planning process. Since the preferred Strategy entails the development of a stand-alone processing facility on City-owned land, the codigestion and biogas capture and cleaning components would proceed as a Schedule C Project under the MCEA process because it will entail the development of new infrastructure of a relatively significant size. The process will begin at **Phase 3 "Alternative Design Concepts for the Preferred Solution"** or, in this case Strategy, and will comprise the following steps:

- Identification of alternative designs for the preferred strategy. Typically, one or two design alternatives are identified for the purposes of the Phase 3 evaluation.
- Preparation of a detailed inventory of the natural, social and economic environments potentially *affected* by the development of the integrated codigestion facility at the Knox Farm location. This would include the transport of biosolids and waste organics to the proposed facility.
- Identification of the potential effects of the alternative designs and the associated mitigating measures for identified negative effects. Potential positive effects may also be identified for each design alternative.
- Evaluation of the design alternatives and identification of the recommended design for the integrated codigestion facility.
- Consultation with Review agencies and interested stakeholders including Indigenous Communities and the general public.
- Selection or confirmation of the preferred design.

Phase 4 "Environmental Study Report" (ESR) will entail the documentation of the work completed in Phase 3 preceded by a summary of the Master Planning process including the description of the problem, the selection of the preferred Strategy, the description of the mitigating measures which will be employed to minimize the effects of the preferred facility design. Once completed to the UK's and City' satisfaction, the ESR will be filed with the City's clerk and placed on the public record for 30 days. At the time of filing of the ESR, the public and review agencies must be notified. This will be accomplished by issuing the mandatory Notice of Completion of the ESR.

Phase 5 of the MCEA process will entail the final design and construction of the facility.

The integrated codigestion facility would require ECA (AQ/Noise) under the EPA and ECA under S.53 of the Ontario Water Resources Act (OWRA). The work undertaken to comply with these regulations would be coordinated with the ECA required for the organics preprocessing component and with the work completed in compliance with the MCEA Phase 3 steps summarized above. Documentation of this work would be completed and filed with the MECP upon filing of the ESR and issuance of the Notice of its completion.

6.2.3 Site Plan Approval of the Facility and Associated Civil Works

It will be likely that Site Plan Approval of the facility and the associated works, such as access/egress to and from the facility, water and sanitary and storm water servicing. The preparation of the required plans, drawings and report will comply with the City's specifications and would be completed together with the above-described environmental compliance work.

Finally, some land use planning work may be required if development of the Knox Farm property for the proposed codigestion facility would require Amendment to the City's Official Plan and/or Zoning By-law and provisions.

6.3 Public, Agency, Stakeholder and Indigenous Consultation Plan

Completion of the work outlined in Section 6.2 would proceed within the context of a full and transparent consultation process. Consultation will include:

- Publication of all mandatory Notices and circulation to Review Agencies, interested stakeholders, including Indigenous communities and the general public.
- A detailed communications and consultation strategy will be outlined as a key component of the study-initiation and organization process.
- Communications would utilize a Project Site developed on the UK's and City's web sites which would encourage input and interaction as the studies proceed.
- All the communications and consultation activities including the input and comments received would be documented in a comprehensive Consultation Plan.

It would be beneficial to include professional communications services provider on the team to collaborate with the environmental planning and engineering services providers to deliver a clearly presented and documented approvals process.

7.0 CLOSURE

We trust this Master Plan Report meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
Tetra Tech Canada Inc.

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/lc

APPENDIX A

ASSESSMENT OF ALTERNATIVES

Assessment of Alternatives

Alternatives to the Undertaking	Operations, Technical Criteria & Financial							Land Use & Natural Environmental Crireria	
	Biosolids Production	Biogas Generation	Operational Impact	Transport Requirements	Footprint Requirements	Capital & Operating Costs	Area for Expansion	Distance to Sensitive LUs	Distance to Env. Features.
Alternative #1: The current practice of processing sludge separately at the wastewater treatement plants (WWTPs) will continue (i.e., Do Nothing)**.** The biosolids and biogas-generation values are totals for both WWTPs.	Total Biosolids - 27 m3/d Total solids - 7,768 kg/d Volatile solids in cake - 3,887 kg/d	**Total Biogas - 3831 m3/d** Methane in biogas - 2,207 m3/d	**Current practice of processing sewage sludge** separately at the 2 WWTPs will continue. **1.** Primary sludge and waste activated sludge (WAS) pass through thickening,mespohylic anaerobic digestion (MAD) secondary digester settling and dewatwering at Cataraqui Bay. **2.** Primary sludge and thickening backwash solids are subject to TPAD, secondary digester settling and dewatering at Ranensview.	**Transport demands and patterns** would remain the same, subject to to projected popuation increases	**Additional space for expanded facilities** would,not be siignificant for the purposes of this assessment	**Cost for the "do nothing" scenario** entails the basis for comparison of the other 4 alternatives. It is assumed that the Do Nothing alterative would include the cost of upgrading the current digesters and undertaking gas cleaning.	The Do Nothing alternative will not entail a significant expansion of the existing WWTP facilities	It has been assumed that, for the purposes of this evauation, no significant new potential effects woud be imposed on the surrounding community.	It has been assumed that, for the purposes of this evauar=tion, no significant new potential effects woud be imposed on the surrounding community.
Alternative #2A: Optimize infrastructure at Cataraqui Bay WWTP by expanding the existing mesophilic anaerobic digestion (MAD) process with capability to operate in temperature-phase anaerobic digestion (TPAD) process.	**Biosolids - 26 m3/d** Total solids - 6,408 kg/d Volatile solids - 3,642 kg/d	**Biogas - 3,563 m3/d** Methane in biogas - 2,052 m3/d	**Operations upgrades to include:** **1.** Transport of dewatered primary sludge from Ranensview and blending with sludge at Cataraqui Bay. **2.** Installation of 1 TPAD with capacity = 3-day hydraulic retention time (HRT) **3.** Installation of 2 MAD with capacity=15-day HRT each **4.** Existing secondary digester converted to digested sludge holding tank **5.** Installation of 2 dewatering centrifuges for digested sludge	**Transport demands and patterns 1.** Dewatered sludge from Ravensview WWTP to Cataraqui Bay = 1 truck trip per day at15 km assuming a truck with a 40 m3 load capacity is used	**Space required for facilities:** **1.** The footprint for a a single TPAD digester = 1,588 m2. **2.** Footprint for 1 mesophilic digester =7,292 m2. **3.** 2 dewatwatering units at 600 m2 per unit.	**Cost of enhancements** would = - $2,312,997 as "best" net present value (lowest cost & highest revenue and - $12,601,479 assuiming "lowest" net present value (highest cost and lowest revenue)	There will likely be just enough space available to construct the described enhancements to the existing treatment infrastructure.	The WWTP is located just under 1 km from the nearest residential area and directly adjacent to the Invista Canada production facility.	The WWTP is located in close proximity to Catarqui Bay. There is an existing buffer between the facility and the water body. There would be no space available for any additional buffering or hieght increase of the buffers.
Alternative #2B: Optimize infrastructure at Cataraqui Bay WWTP by expanding existing MAD process together with biological hydrolysis (BH) as a sludge pre-treatment ahead of the MAD process.	**Biosolids - 24 m3/d** Total solids - 6,117 kg/d Volatile solids - 3,351 kg/d	**Biogas - 3,857 m3/d** Methane in biogas - 2,507 m3/d	**Operations upgrades include:** **1.** Blend dewatered sludge from Ravensview with sludge generated at Cataraqui Bay. **2.** 1 "six pack" BH system upfront of mesphilic digesters. **3.** 2 mesophilic digesters with capacity = 15-day HRT **4.** Existing secondary digester converted to digested sludge holding tank **5.** Installation of 2 dewatering centrifuges for digested sludge	**Transport demands and patterns** **1.** Dewatered sludge from Ravesview WWTP to Cataraqui Bay = 1 truck trip per day at 15 km assuming a truck with a 40m3 load capacity is used	**Space required for facilities:** **1.** The footprint for a a single BH-AD digester = 821 m2. **2.** Footprint for 1 mesophilic digester =7,292 m2. **3.** 2 dewatwatering units at 600 m2 per unit.	**Cost of enhancements** would = -$16,871 as "best" net present value (lowest cost & highest revenue and -$10.870,603 assuming "lowest" net present value (highest cost and lowest revenue)	As above.	As above	As above
Alternative #3: As Alternative 2B but with dewatered raw sludge being transported from the Cataraqui Bay WWTP for processing at the Ravensview WWTP.	**Biosolids - 24 m3/d** Total solids - 6,117 kg/d Volatile solids - 3,351 kg/d	**Biogas - 4,408 m3/d** Methane in biogas - 2,865 m3/d	**Operations upgrades include**: **1.** Transport dwatered sludge from Catarqui Bay and blending with sludge at Ravensview. 2. Place a "six pack" BH system with the existing thermophilic digester and upfront of the mesphilic digesters. 3. 2 mesophilic dgesters with capacity = 15-day HRT each 4. Existing secondary digester operated as a digested sludge holding tank	**Transport demands and patterns** **1.** Dewatered sludge from Cataraqui Bay WWTP to Ravensview = 1 truck trip per day at 15 km assuming a truck with a 12m3 load capacity is used	**Space required for facilities:** **1.** The footprint for 6 BH-AD digesters = 861 m2. **2.** Footprint for 1 mesophilic digester for 15-day HRT =10,975 m2. **3.** 2 dewatwatering units at 600 m2 per unit.	**Cost of enhancements** would = $1,802,393 as "best" net present value (lowest cost & highest revenue and - $9,383,205 assuiming "lowest" net present value (highest cost and lowest revenue)	As above.	As above	As above

Alternatives to the Undertaking	Operations, Technical Criteria & Financial							Land Use & Natural Environmental Crireria	
	Biosolids Production	Biogas Generation	Operational Impact	Transport Requirements	Footprint Requirements	Capital & Operating Costs	Area for Expansion	Distance to Sensitive LUs	Distance to Env. Features.
Alternative #4: As Alternative 2B with the inclusion of waste organics from thrid-party sources such as the source separated organics (SSO) collected by the City of Kingston.	**Biosolids - 27 m3/d** Total solids - 6,643 kg/d Volatile solids - 3,767 kg/d	**Biogas - 5,969 m3/d** Methane in biogas - 3,880 m3/d	**Operations upgrades include**: **1**. Transport dewatered sludge from Ravensview and blending with sludge at Cataraqui Bay **2.** Establish a receiving station ot pretreat the waste organics prior to digestion. Pretreatment is multi-faceted including the need to pulp the organics prior to entry into the digesters. Certain organics, such as grease, are more difficult to manage through the processing stream resulting in increased equipment maintenance. Odour is also an issue which must be managed. The pretreatment system is complex with unique scheduling and staffing requiements. **3.** 1 "six pack" BH system upfront of mesophilic digersters **4.** 2 mesophilic digesters with capacity = 15-day HRT each **5**. Existing secondary digester operated as a digested sludge holding tank **6.** 2 dewatering cetrifuges to handle digested sludge	**Transport demands and patterns** **1.** Dewatered sludge from Ravesview WWTP to Cataraqui Bay = 1 truck trip per day at 15 km assuming a truck with a 40m3 load capacity is used **2.** Waste organics, as both source separated (SSO) materials collected by the City and materials collected from the IC&I sector transported to the facility by collection vehicles.	**Space required for facilities:** **1.** Footprint for waste organics receiving station = 2,000 m2 **2.** Footprint for 6 BH-AD digesters = 861 m2. **3.** Footprint for 1 mesophilic digester for 15-day HRT =8,832 m2. **4.** Footprint for 2 dewatering units at 600 m2 per unit. **5.** Additional space for storage of 4,860 m3 of cake would not be required	**Cost of enhancements** would = $1,898,944 as "best" net present value (lowest cost & highest revenue and - $12,456,670 assuiming "lowest" net present value (highest cost and lowest revenue). **These numbers have been calculated assuming an annual input of SSO = 4,000 tonnes**	There will not be sufficient space to construct the pre-processing train for the waste organics.	The WWTP is located in the southwest portion of the City so access by organics collection vehicles could be via residential streets.. A residnetial community is located just uner a km from the facility, so concerns regarding odours from the organics pre-processing facility may be an issue.	The WWTP is located in close proximity to Catarqui Bay. There is an existing buffer between the facility and the water body. There would be no space available for any additional buffering or hieght increase of the buffers.
Alternative #5: Development of an integrated biosolids and SSO processing facility at a greenfield development site. The opportunity site for consideration would be located within the property boundary of Knox Farm.	**Biosolids - 27 m3/d** Total solids - 6,643 kg/d Volatile solids - 3,767 kg/d	**Biogas - 5,969 m3/d** Methane in biogas - 3,880 m3/d	**Operations development with include:** **1.** A receiving station to pre-process the waste organics feedstock **2.** Transport waste organics, collected by the City and via private contracts, as well as dewatered sludge from WWTPs to the Knox Farm site. After pre-processing, organics would be blended with sludge **3.** An optional "six pack" BH system upfront of mesophilic digestion train **4.** 2 mesophilic digesters with capacity = 15-day HRT each **5.** 1 secondary digester operated as a digested sludge holding tank **6.** 2 dewatering centrifuges for digested sludge and to store biosolid cake on site **7.** Transport dewatering concentrate to the WWTPs **8.** Co-processing train generates a sludge with high Nitrogen and Phosphorous concentrations, Since no liquid treatment at the site, options would include: distribution for land application; dewatering and storgae as biosolids cake with transport of cake to WWTPs for treatment; and dewatering to forma cake with treatment of the liquid stream at a stand-alone WWTP at the site.	**Transport requirements are:** **1.** 40 m3/d of dewatered sludge requiring transport from WWTPs to facility = 2 trucks at 60 km for a 2-way trip **2.** Transfer, via collection vehicles, of organics from City residents and businesses at about 4,000 tonnes per annum = X trucks	**Footprint requirements are:** **1.** Footprint required for facility to receive and pre-process organics = 2,000 m2 **2.** HRT = 3 days and 6 BH reactors = 861m2 **3.** HRT = 15 days and 1 mesophilic digester = 8,832 m2 **4.** 2 dewatering units which will require a footprint of 600 m2 **5.** Sufficient space for 4,860 m3 of cake storage = 1,800 m2. **6.** Space for additional structures such as access egress, weigh scales, and administrtative facilities. **7.** Construction of civil servicing infrastucture	**Cost of constructiong and operating a new integrated facility** would = - $8,149,455 as "best" net present value (lowest cost & highest revenue and - $25,467,796 assuming "lowest" net preset value (highest cost and lowest revenue)	This alterantive has more than sufficient area to accommodate the proposed operations. In addition, there is sufficient space to accommodate the development of additional capacity to pre-process increased organic waste and sludge feedstock over the longer term.if required	The property is located just north of highway 401 with direct, existing, access to Perth Road. Land uses in the vicinity of the property include a rural commercial establishment and a quarry operation. The biogas generated at the facility could be injected into the pipeline located within the Perth Road alignment.	The Knox Farm property is located adjacent to the Little Cataraqui Creek Conservation Area. It is considered that the development footprint for the facility, including a longer-term expansion of the organics pre-processing component, would be accomodated within the existing disturbed area and outside of a 100-metre natural buffer between a proposed developmet site and the Conservation Area lands.

APPENDIX B

COMPARATIVE EVALUATION OF ALTERNATIVES

Appendix B: Evaluation of Alternatives

Alternatives to the Undertaking	Increased Biogas & Methane Generation over Do Nothing	Infrastructure Required (processing facilities footprint)	Transport Requirements	Capital & Operating Costs	Area for Expansion	Proximity to Sensitive LUs and Natural Features
Alternative 1: Optimize infrastructure at Cat. Bay WWTP by expanding existing MAD with capability to operate in TPAD process	Biogas and methane increased by 234% **Increased**	Total footprint required for enhanced processing, 10,080 m^2 **More space needed**	1 truck trip per day for sludge transfer assuming a 40 m^3 load capacity **Few truck trips/larger vehicle**	NPV = -$2,312,997 (lowest cost & highest revenue). NPV - -$12,601,479 (highest cost & lowest revenue **Less attractive**	There will likely be just enough space to accommodate the infrastructure for the processing enhancements. **May be adequate**	About 1 km from residences & adjacent to Cataraqui Bay **Intrusive**
Alternative 2: Optimize infrastructure at Cat. Bay by expanding existing MAD together with BH as sludge pre-treatment	Biogas increased by 264% and methane by 310% **More Increased**	Total footprint required for enhanced processing, 9,313 m^2 **Least Space Needed**	1 truck trip per day for sludge transfer assuming a 40 m^3 load capacity **Few truck trips/large vehicle**	NPV = -$16,871 (lowest cost & highest revenue). NPV - -$10,870,603 (highest cost & lowest revenue **Attractive**	There will likely be just enough space to accommodate the infrastructure for the processing enhancements. **May be adequate**	About 1 km from residences & adjacent to Cataraqui Bay **Intrusive**
Alternative 3: As Alt. 2 but with dewatered raw sludge transported from Cat Bay to Ravensview for processing	Biogas increased 94% and methane by 82% **Increased**	Total footprint required for enhanced processing, 9,313 m^2 **Least space needed**	1 truck trip per day for sludge transfer assuming a 12 m^3 load capacity **Few truck trips/smaller vehicle**	NPV = $1,802,303 (lowest cost & highest revenue). NPV - $9,363,205 (highest cost & lowest revenue **Attractive**	There will likely be just enough space to accommodate the infrastructure for the processing enhancements. **May be adequate**	About 1 km from residences & adjacent to Cataraqui Bay **Intrusive**

Alternatives to the Undertaking	Increased Biogas & Methane Generation over Do Nothing	Infrastructure Required (processing facilities footprint)	Transport Requirements	Capital & Operating Costs	Area for Expansion	Proximity to Sensitive LUs and Natural Features
Alternative 4: As Alternative 2 with the inclusion of waste organics from third-party sources such as SSO.	Biogas enhanced by 463% and methane by 369% **Most Increased**	Total footprint required for enhanced processing, 12,893 m^2 **More space needed**	1 truck trip per day for sludge transfer assuming a 40 m^3 load capacity AND multiple truck trips per day by SSO and other waste organics collection and transport vehicles **More truck trips by multiple vehicles**	NPV = $1,898,944 (lowest cost & highest revenue). NPV - $12,456,670 (highest cost & lowest revenue These numbers have been calculated assuming an annual input of SSO = 4,0000 tonnes. As annual input tonnage increases, revenues will increase w/o increases in operating costs. **More attractive**	There will not be space available to construct the processing train for the waste organics. **Inadequate**	About 1 km from residences & adjacent to Cataraqui Bay. More space needed to accommodate SSO pre-processing facility **More intrusive**
Alternative 5: Development of an integrated biosolids and SSO processing facility at a greenfield development site. The opportunity site for consideration would be located within the property boundary of the Knox Farm.	Biogas enhanced by 463% and methane by 369% **Most Increased**	Total footprint required for enhanced processing, 14,693 m^2 **Most space needed**	1 truck trip per day for sludge transfer assuming a 40 m^3 load capacity AND multiple truck trips per day by SSO and other waste organics collection and transport vehicles **More truck trips by multiple vehicles with greater distance to processing facility.**	NPV = -$8,149,455 (lowest cost & highest revenue). NPV - $25,467,796 (highest cost & lowest revenue These numbers have been calculated assuming an annual input of SSO = 4,0000 tonnes. As annual input tonnage increases, revenues will increase w/o increases in operating costs. **Least attractive, but potentially more attractive as SSO input increases**	Enough space is available to construct the initial facility with enough space to expand as needed, over the longer term **Adequate**	Located in a rural setting within a previously disturbed portion of a City-owned property. Proximity to Little Cataraqui Creek CA can be mitigated by maximizing set back from the processing facility. **Less Intrusive**

APPENDIX C

RECORD OF CONSULTATION

TECHNICAL MEMO

ISSUED FOR REVIEW

To:	Allen Lucas	**Date:**	March 26, 2020
Cc:		**Memo No.:**	1
From:	Peter Klaassen	**File:**	704-SWM.SWOP03442-01
Subject:	Response to Questionnaire from January 30, 2020 Open House		

1.0 INTRODUCTION

Tetra Tech Canada Inc. (Tetra Tech) is pleased to submit this technical memorandum regarding the outcome of the open house undertaken between 4:00pm and 7:00pm on January 30, 2020. The open house was held in the main conference room (main floor) of the headquarters for Utilities Kingston (UK) located at 85 Lappan's Lane in the City of Kingston. The primary purpose of the open house was to attain comments on work that has been done to date on the Kingston Biosolids and Biogas Master Plan study. The public had access to information on the Utilities Kingston website prior to the session. For the event, a series of posters was put up on the wall of the conference room and attendees were able to speak directly to study experts who were in attendance. Attendees were asked sign in upon entering the conference room and each was asked to fill in a questionnaire based on their impression of the study presentation. Interested (attending and non-attending) parties were also invited to respond via email if they had further comments regarding the work to date.

A blank copy of the questionnaire is provided in Appendix 1 to this technical memorandum and copies of the posters are provided in Appendix 2.

2.0 OUTCOME

Twenty seven people signed in at the open house. Of these, seventeen declared themselves residents, two were understood to be potential contractor/suppliers, and the remaining attendees declared themselves visitors or members of the surrounding municipalities (i.e., Greater Napanee, Loyalist, Smith Falls, and Quinty West).

One further commentary was received by email from one of the contractor/supplier companies.

Of the attendees: Thirteen filled in the questionnaire; Eleven declared themselves residents, and the other two were from surrounding municipalities.

In general, the respondents to the questionnaire were supportive of the initiatives that were proposed. Where choices were requested, the following were the results:

1. UK requested respondents to assess the most favourable location for the project, given four options: Ravensview Wastewater Treatment Plant (WWTP), Cataraqui Bay WWTP, Knox Farms (Greenfield location), and a potential other location. Eight of the respondents considered the Knox Farms location as most favourable, two considered Cataraqui Bay the most favourable, one considered Ravensview the most favourable, one respondent favoured another location (Taylor Kidd Industrial Park), and the rest did not have any opinion of the location. A couple of the respondents noted that the Knox Farms property is located beside a conservation area.

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2. UK also requested that the respondents rank the most favourable use of biogas generated from any of the locations. The respondents were given five options; Electrical Generation, Heating Purposes, Purifying the biogas and injecting it into the Natural Gas Pipeline, Vehicle Fuel (Green Fuel) and any other option. Seven of the respondents favoured injection into the pipeline, two respondents favoured electric generation, two respondents favoured heating purposes, one respondent favoured vehicle fuel, and the rest did not respond.

3. Respondents were asked to prioritize potential impacts of the design for the facility. The options were noise, odour, traffic, and other potential impacts. Six respondents ranked odour as the most important impact. Three respondents indicated that traffic was the most important impact. The rest of the respondents either did not respond or noted that all impacts should be considered.

4. Respondents were asked if curbside organics should be added to the process to enhance biogas generation. Nine of the respondents either agreed or stated that it was a very good idea. Three of these respondents stated that UK should also consider other sources of organic waste such as from surrounding communities or from the Industrial, Commercial, Institutional (ICI) sectors. The remainder of the respondents did not respond to the question.

5. Respondents were asked to comment on the use of biosolids in agriculture. Seven respondents either agreed with the practice or stated that it was a positive initiative. Two respondents were concerned that there could be toxic or problematic elements that could impact the growth of farm products. The rest of the respondents either stated that they did not have enough information to comment or did not respond.

6. Respondents were asked if the timelines for the project were proper. Three respondents noted that the study should proceed as quickly as possible. Two respondents stated that they were satisfied with the timelines, and the rest either did not respond or stated that they were not capable of responding.

7. Other general comments throughout the questionnaire were either positive or in agreement with the initiatives that were presented. Staff was complemented that they had done a good job in presenting the information and several of the respondents indicated that they would be interested to see future developments in this initiative.

3.0 CONCLUSION

Based on the input from both the questionnaire, and general input given orally by the attendees, the response was positive and helpful. Most attendees showed interest in the study and asked many detailed questions. Based on the results as outlined in Section 2 above, the following appears to be the favoured approach:

Location: most of the respondents (and general attendees) favoured the Knox Farms location. General comments were that it was away from residences and close to the highway. Traffic would also be easier to handle. The location is also in the proximity of the feeder line from TransCanada pipelines and any methane gas generated from the facility would go into the Kingston gas network.

Use of Biogas: Most of the respondents and attendees favoured the injection of methane into the pipeline. This was made more evident when it was explained that there would be revenue attained from offset Carbon Credits.

Inclusion of SSO (curbside organics) in the process was either supported or promoted by a majority of the respondents and attendees as it was shown to generate substantially more biogas.

Odour was the main impact issue for most of the respondents. This was the most probable reason why Knox Farms was assessed to be the favoured location for a facility.

Most respondents suggested that the study proceed within a favourable or urgent timeline.

4.0 LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of Utilities Kingston and their agents. Tetra Tech Canada Inc. (Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than Utilities Kingston, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this document is subject to the Limitations on the Use of this Document attached in the Appendix or Contractual Terms and Conditions executed by both parties.

5.0 CLOSURE

We trust this technical memo meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
Tetra Tech Canada Inc.

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Solid Waste Management Practice
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/lm

Enclosure: Appendix 1 Blank Copy of the Questionnaire
Appendix 2 Copies of the Posters
Appendix 3 Limitations on the Use of this Document

APPENDIX 1

BLANK COPY OF THE QUESTIONNAIRE

Kingston Biosolids & Biogas Master Plan

Public Information Centre Thursday, January 30, 2020 from 4 to 7 PM.

Name: ____

Contact address: ____________________________________

Contact email: ______________________________________

Kingston Resident or property owner: Yes / No

Group or other affiliation: ______________________________

Utilities Kingston ensures your privacy is protected at all times. It is important that you understand why we collect information about you and what we do with it

We are soliciting feedback from you about Kingston's Biosolids and Biogas Master Plan. Your comments will form part of our analysis of the options and will be included in the final public report. Comments will not be attributed to an individual nor an entity. We are requesting your email and address for the sole purpose of communicating updates and/or notifications directly with you on this project. Your email and address will not be shared nor otherwise used.

Please share any general comments on the information provided by Utilities Kingston and Tetra Tech?	
Is there additional information that you would like to have seen?	
What are your thoughts on the **financial information** presented? What weight should the analysis put on costs? (1 being highest to 5 being lowest) _____	
What are your thoughts on the proposed and potential **timelines** presented?	
The proposed locations for digesters and biogas production.	circle Rank
• Ravensview Wastewater Treatment Plant	1 2 3 4
• Cataraqui Bay Wastewater Treatment Plant	1 2 3 4
• Third brownfield site such as Knox Farm	1 2 3 4
• Another site at _________________________	1 2 3 4
After reviewing the site information on the displays and the next page please rank the locations from 1 - most preferred to 4 - least preferred.	

Comments on Location:

What weight should the analysis put on site location (1 - highest to 5 - lowest) _____

Cataraqui Bay WWTP is located at 409 Front Road by Sand Bay in Kingston and is a Biological Aerated Filter (BAF) advanced secondary treatment facility servicing the west end of the City of Kingston. The plant was constructed in 1962 and upgrades began in 2016 and targeted for completion by 2021.

Ravensview WWTP is located at 947 County Rd #2, east of Fort Henry, in Kingston is a Biological Aerated Filter (BAF) advanced secondary treatment facility servicing the central and east end of the City of Kingston. The plant was originally built in 1957 and has been recently upgraded between 2006 and 2009.

Knox Farm, a brownfield site, is located west of Perth Road (CR 10) just north of highway 401. The City of Kingston already owns this site, an Environmental Assessment has been completed in 2001 and an Environmental Compliance Approval as a Waste Transfer Facility is already in place from the Cataraqui River Crossing project.

Please rank the following **end uses for the biogas**: (1 most preferred to 4 least preferred)	circle Rank
• Electrical generation	1 2 3 4
• Heating purposes	1 2 3 4
• Purifying for pipeline injection as renewable natural gas (RNG)	1 2 3 4
• Vehicle fuel	1 2 3 4
• Other options (specify) ____	1 2 3 4

Comments?

Addition of organics to produce more biogas.

- Include feed/organic to enhance
- Obtain material from existing company
- Construct facilities to receive and prepare organics for processing

What are your thoughts or comments?

Exploring options for managing biosolids. Currently biosolids are beneficially used as a nutrient rich soil amendment that are dewatered and land applied to arm fields in accordance with the Nutrient Management Act. The project will review long-term viability of this program, while considering options for further drying the material to create a fertilizer or other end uses. What are your thought or comments?

Potential impacts of the proposed plant that need to be addressed through the design and engineering controls include:

- Noise
- Odour
- Traffic
- Other impacts (specify) ____

Comments?

What weight should the analysis put on each of these? (1 highest to 5 lowest)

Other Comments

As part of the third phase of the work on this project, Utilities Kingston is developing a Master Plan in accordance with Ontario's Environmental Assessment Act and Regulations, and the public's input will be considered and reflected in the final report with comments submitted by **February 14, 2020**.

APPENDIX 2

COPIES OF THE POSTERS

Welcome Kingston Biosolids & Biogas Master Plan Open House

Please sign in and help yourself to a refreshment.

Individuals from Utilities Kingston and Tetra Tech around the room will provide additional information and answer any questions.

Fill out a questionnaire and drop off in the tray tonight or feel free to take home and return by February 14, 2020 to Utilities Kingston Office or e-mail alucas@utilitieskingston.com

Master Plan Objectives

- Given Utilities Kingston's interest in enhancing the management of biosolids and the utilization of biogas at the Cataraqui Bay and Ravensview WWTPs
- Given developments in Ontario regarding:
  - Consideration of wastes as resources within the context of a circular economy;
  - The more effective management of SSO (Source Separated Organics)
  - Opportunities to generate and use processed biogas as RNG (Renewable Natural Gas) .

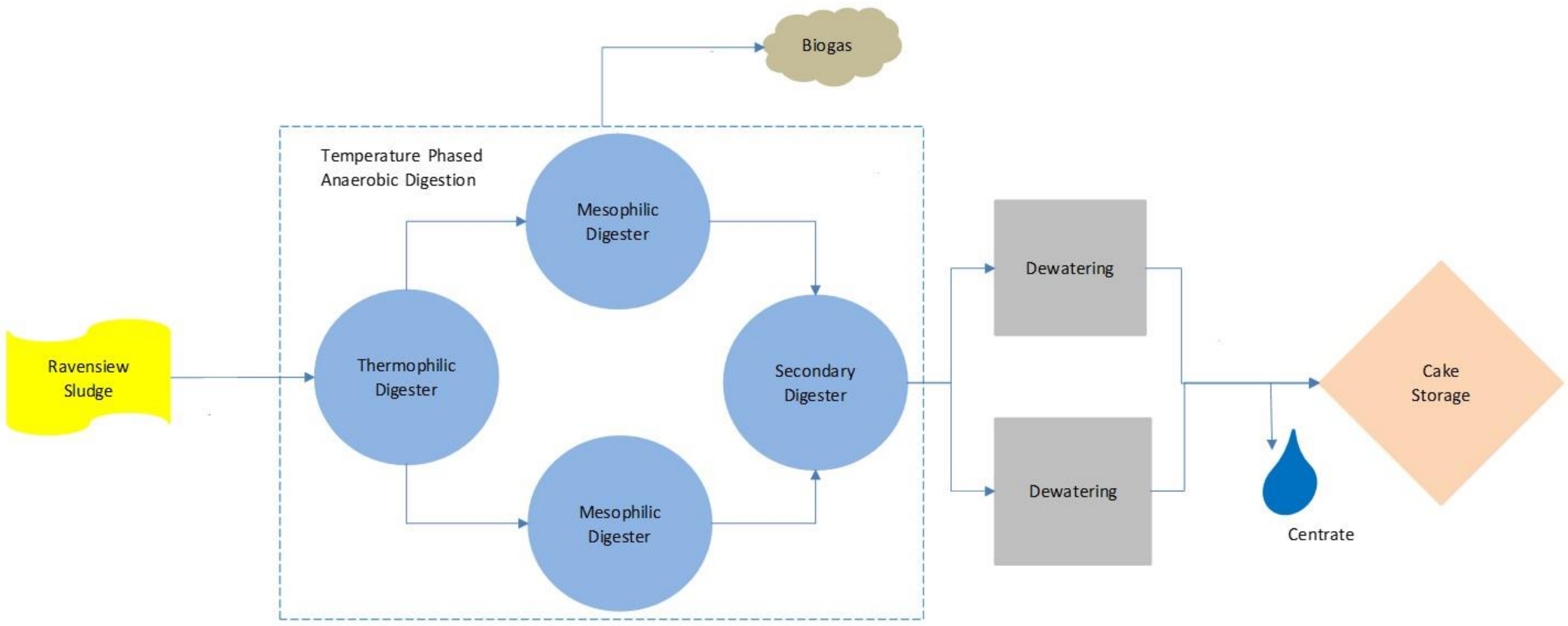
The key study objectives are:

- To identify alternative systems to manage biosolids and to enhance generation of biogas
- To evaluate alternative systems as well as alternative sites where the systems may be established
- To identify preferred systems at a preferred site(s) where biosolids would be managed and biogas used, potentially as a RNG, in an environmentally and financially sustainable manner.

Current Sites
Ravensview WWTP

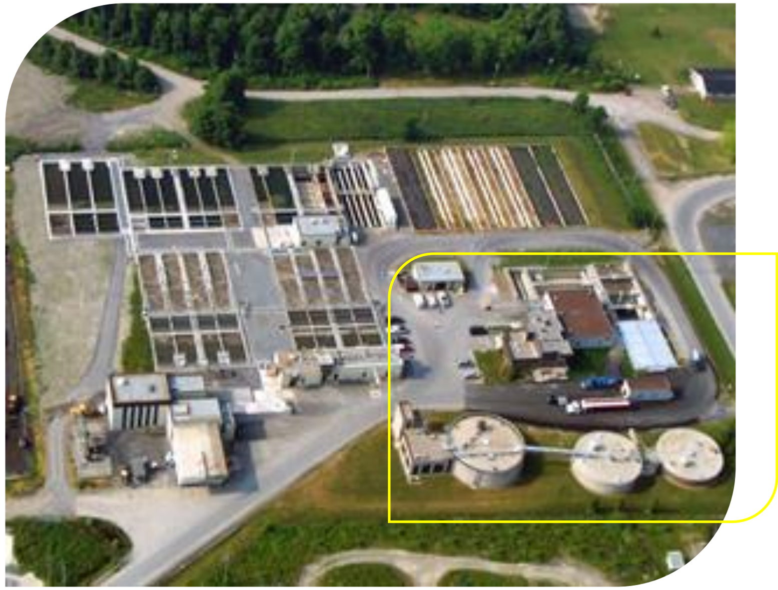
- Constructed in 1957, rated capacity 95,000 m^3/d
- A new biologically aerated filter (BAF) process was commissioned in 2009
- Co-thickened primary sludge sent to temperature phased anaerobic digestion (**TPAD**)
- ~1,600 dt/yr of biosolids
- ~850,000 m^3/yr of biogas

Current Solids Process at Ravensview WWTP

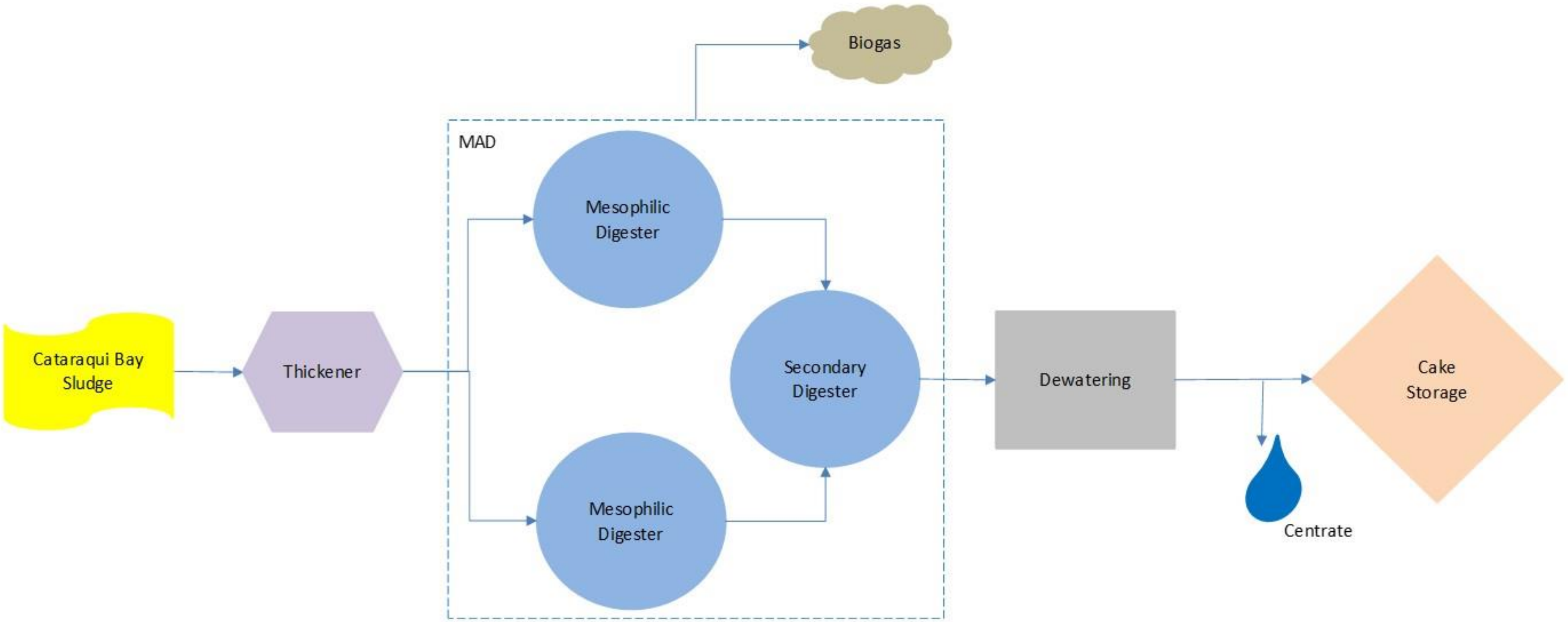


Current Sites
Cataraqui Bay WWTP

- Constructed in 1962, with rated capacity 38,800 m^3/d
- Conventional Activated Sludge (Current) upgraded to biologically aerated filter (BAF) process
- Both primary and wasted sludge sent to mesophilic anaerobic digestion (MAD)
- ~800 dt/yr of biosolids
- ~600,000 m^3/yr of biogas



Current Solids Process at Cataraqui Bay WWTP

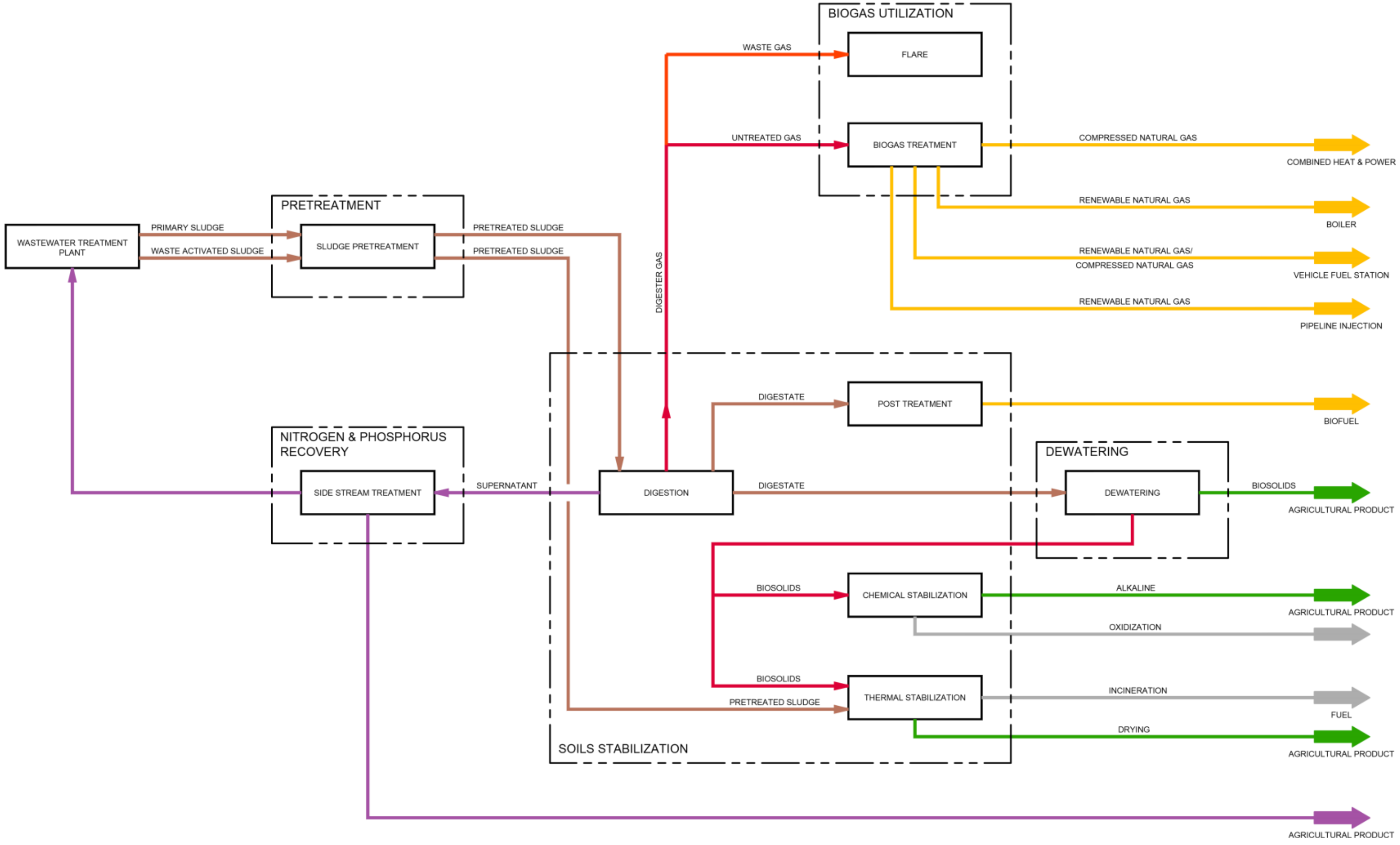


Biosolids Practice

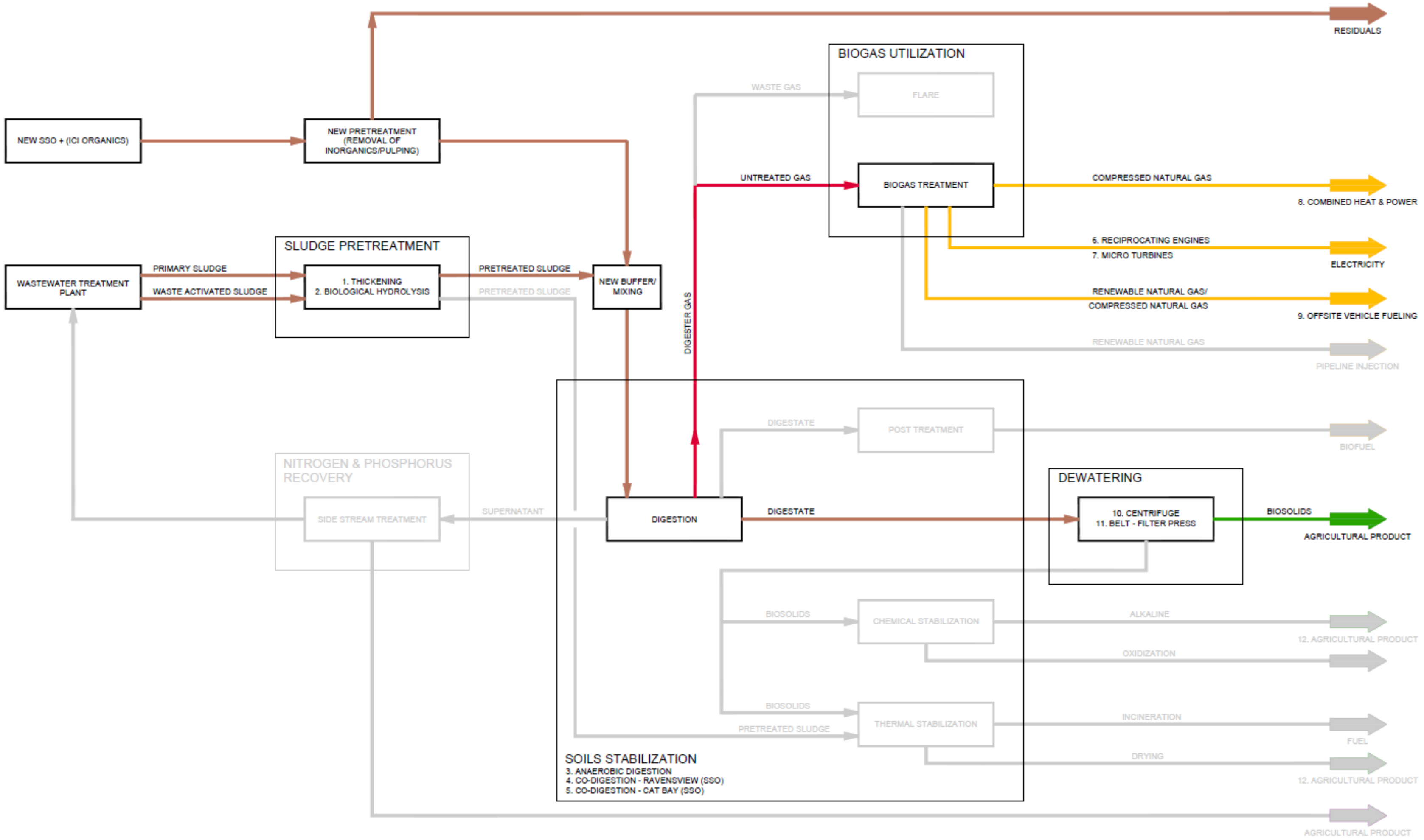
Treated Biosolids stabilized and used as Agricultural Nutrient

- Beneficial Reuse
- Accepted by Agricultural Community
- Meets provincial regulations
- Least Cost

Evaluation of Existing Operations



Final Systems for Detailed Assessment



Business Case with Shortlisted Biosolids Management Options

Shortlisted Biosolids Management Options

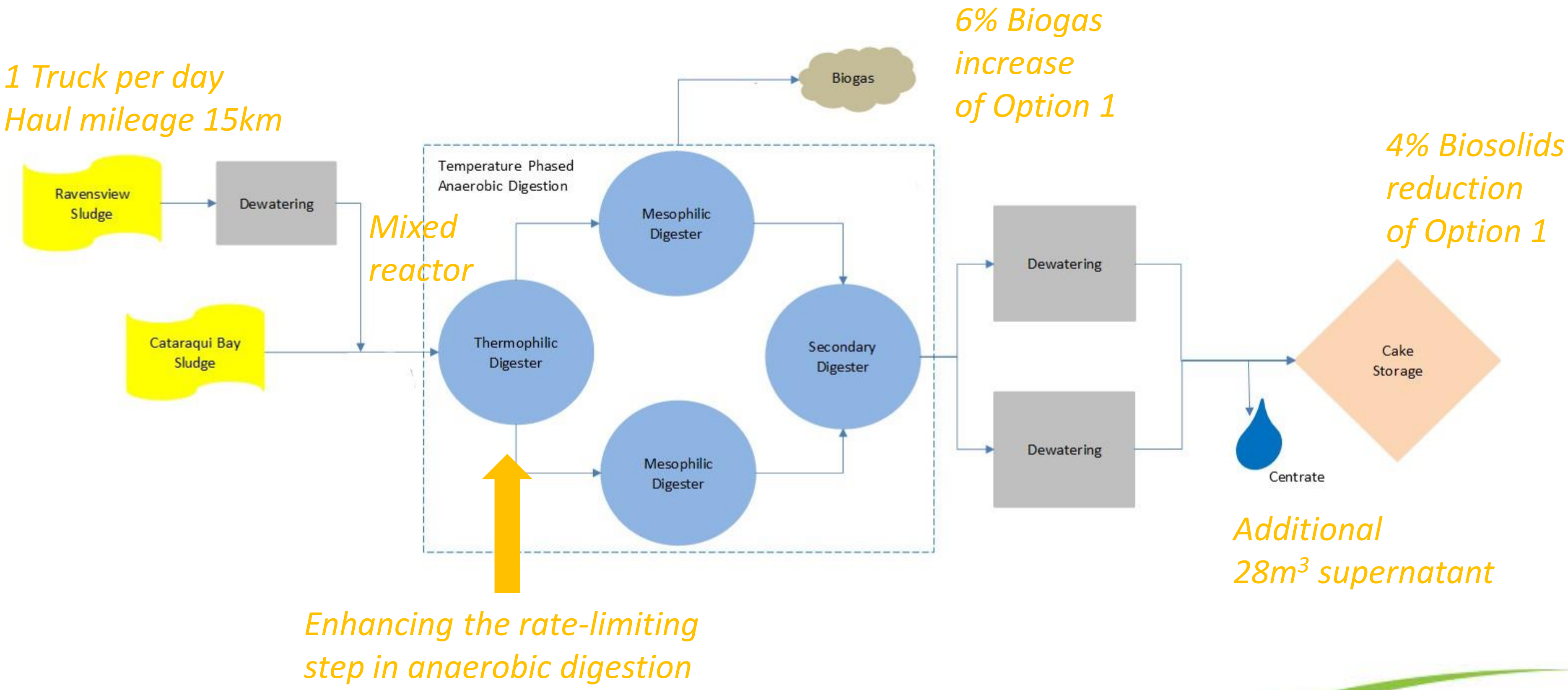
- Option 1 – Do Nothing
- Option 2 – Optimized Infrastructure at Ravensview
- Option 3 – New and Optimized Solid Treatment Facility at Cataraqui Bay
- Option 4 – Incorporate SSO into New Facility at Cataraqui Bay
- Option 5 – Integrated Biosolids and SSO Treatment Facility at new Location

Evaluation Criteria

- General cost implications
- Space availability
- Operations compatibility
- Environmental impacts
- Class EA impacts

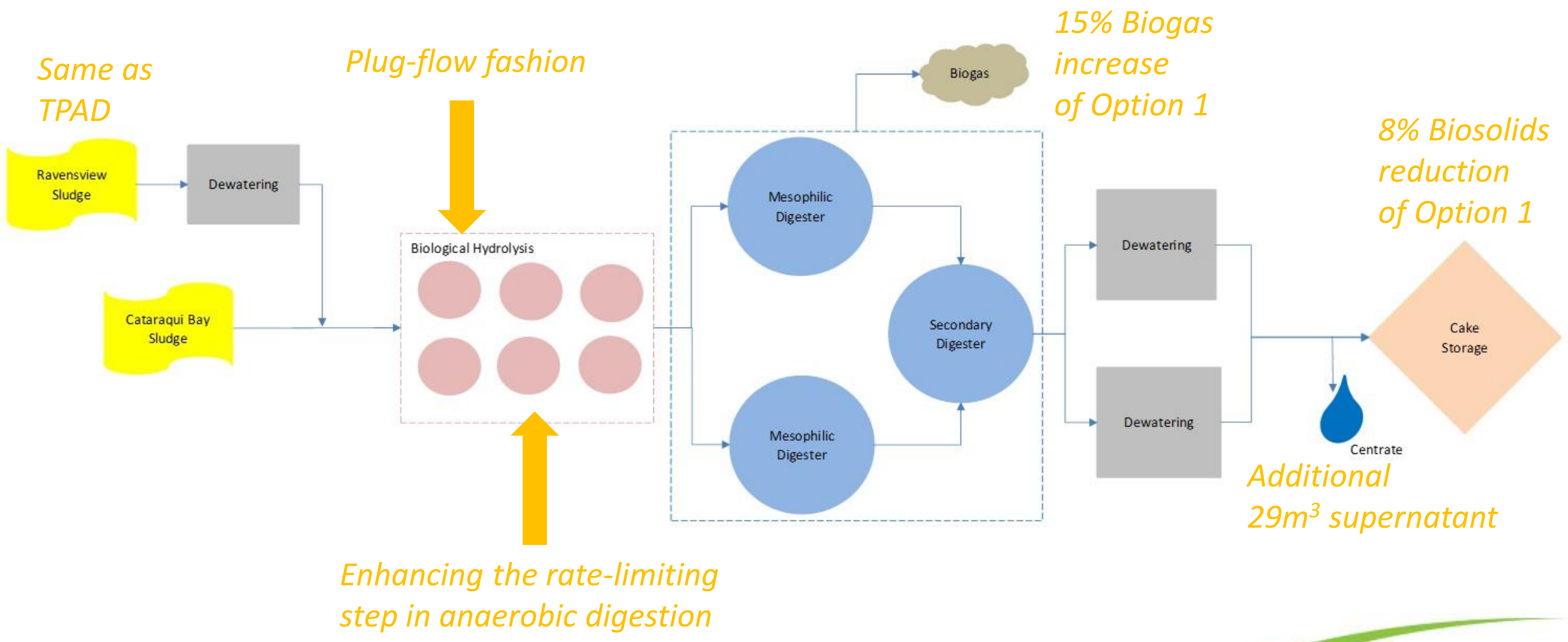
Temperature Phase Anaerobic Digestion

- Expansion of the existing MAD process with the capability to operate in TPAD



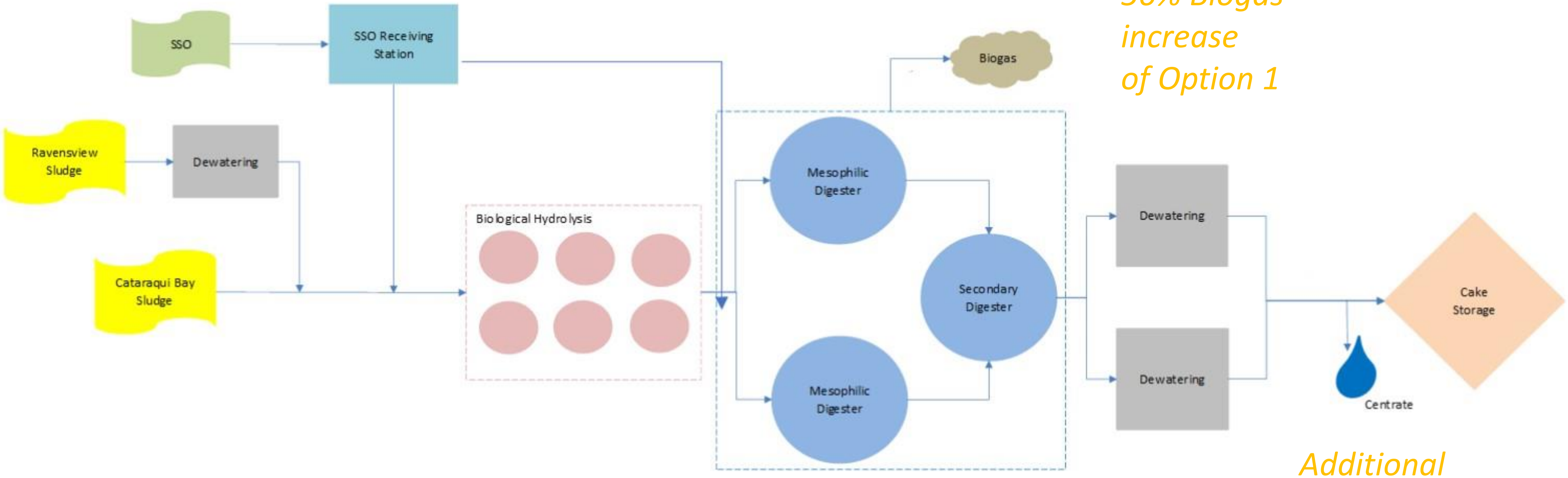
MAD with Biological Hydrolysis

- Expansion of the existing MAD process with the inclusion of Biological Hydrolysis (BH) upfront of MAD



Co-digestion with SSO

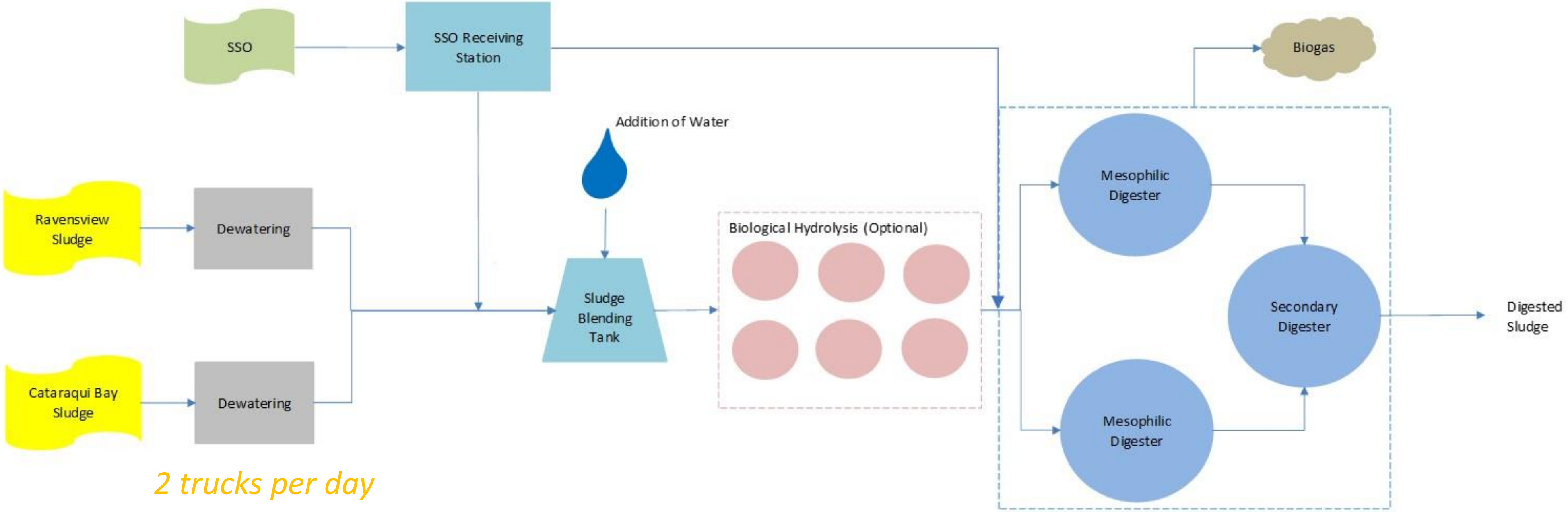
- Incorporating 4000 wt/yr of SSO collected through green bin program
- Industrial organic wastes, other WWTP raw sludges, other SSO streams



56% Biogas increase of Option 1

Additional 36m^3 supernatant

Option 5 Integrate Processing of Biosolids and SSO at New Site



2 trucks per day
Haul mileage 30km

Evaluation of Shortlisted Alternatives

	Base Case	Shortlisted Alternatives							
	Do Nothing	BH-AD at Ravensview	TPAD at Cataraqui Bay	BH-AD at Cataraqui Bay	BH-AD + SSO at Catarqui Bay		BH-AD + SSO at New Site		
	Feedstock								
	Sludge	Sludge	Sludge	Sludge	Sludge	SSO	Sludge	SSO	H_2O
Volume (m^3/d)	238	176	116	116	116	9	40	9	75
TS Loading (kg/d)	10,051	10,051	10,051	10,051	10,051	2,192	10,051	2,192	-
VS Loading (kg/d)	7,285	7,285	7,285	7,285	7,285	7,285			
	Biosolids								
Volume (m3/d)	27	24	26	24	27		27		
% Decrease based on Do Nothing	0	8%	4%	8%	0%		0%		
TS (kg/d)	7,788	6,117	6,498	6,117	6,643		6,643		
VS in Cake (kg/d)	3,887	3,351	3,642	3,351	3,767		3,767		
Nitrogen in Cake (kg/d)	233	184	192	184	199		199		
Phosphorous in Cake (kg/d)	85	67	70	67	73		73		
	Centrate								
Additional Centrate (m^3/d)	209	4	28	29	36		98		
Additional Nitrogen Loading (kg/d)	47	168	113	121	160		207		
Additional Phosphorus Loading (kg/d)	63	91	86	89	88		121		
	Biogas								
Biogas (m^3/d)	3,831	4,408	4,071	4,408	5,969		5,969		
Methane in Biogas (m^3/d)	2,207	2,865	2,346	2,865	3,880		3,880		
% Increase based on Do Nothing	-	15%	6%	15%	56%		56%		

Evaluation of Existing Operations

Biogas Utilization - Biogas Flow Summary

- Cataraqui Bay's total biogas flow (flare and boiler) varies from about 1,000 to 3,000 m^3 per day (or 25 to 75 cfm) and is highly variable with consistently more biogas collected in the spring of the year.
- Ravensview total biogas flow (generator, flare, and boiler) varies from about 1,000 to 4,000 m^3 per day (or 25 to 100 cfm) is also highly variable with consistently more biogas collected in the spring of the year.

Methane Generation – All Options

	Do Nothing	BH-AD at Ravensview	TPAD at Cataraqui Bay	BH-AD at Cataraqui Bay	BH-AD + SSO (4000 tpy) at Cataraqui Bay	BH-AD + SSO (4000 tpy) Alternative Site
Methane Generation m^3/day	2,201	2,865	2,346	2,865	3,880	3,880

Methane Generation with SSO

	No SSO	4000 tpy	5000 tpy	6000 tpy	8000 tpy	10,000 tpy	12,000 tpy
Methane Generation m^3/day	2,201	3,880	4,133	4,387	4,895	5,402	5,910

Study Outcomes

- Reset of Final Goal
  - Elimination of Cap and Trade
  - Trade with other jurisdictions
- End of Pipeline issues
- Assume that all finished sludge would be moved to one facility
- Need for Digester Upgrade at Cataraqui Bay or build new Digester at new location

Financial Outcomes – Assumptions

- Financial Comparison With Capex and Opex Changes
- Best Case – lowest Capex/Opex Costs with Highest Revenue
- Lowest Case – highest Capex/Opex with Lowest Revenue
  - +- 15% Capex used
  - $2,500,000 needed for pipeline injection
  - 10% Engineering Costs (on Capex)

Financial Review

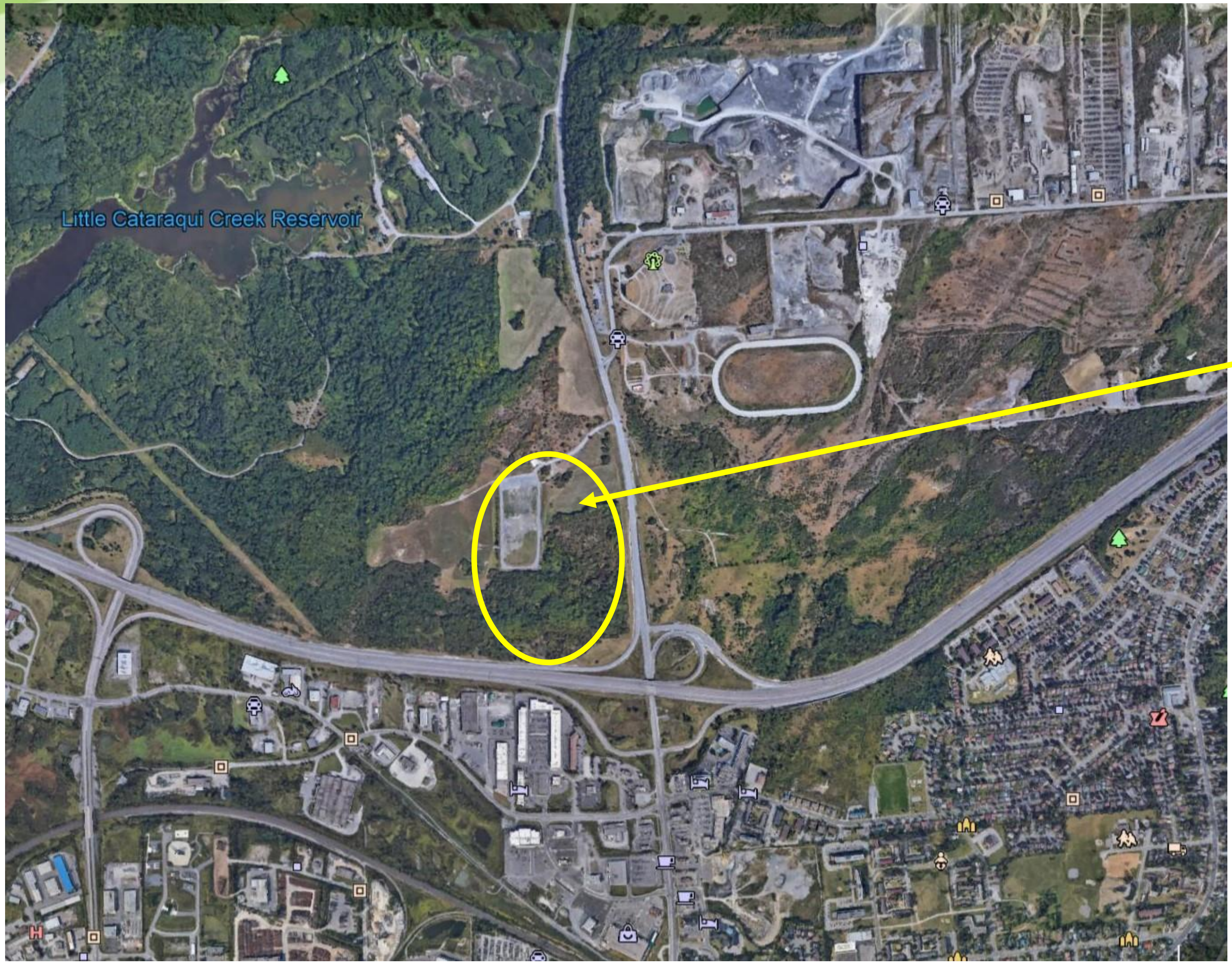
Scenario	Capital Costs +/-15%	Net Present Value Range	Biogas @57% CH_4 m^3/d	RNG as % of City Avg. Day NG
Status Quo	$14.6 million	-$13.8 million to -$2.9 million	3881	0.79%
Ravensview BH-AD	$14.0 million	-$9.4 million to +$1.8 million	4408	0.91%
Cataraqui Bay TPAD	$12.9 million	-$9.5 million to $0.0 million	4071	0.84%
Cataraqui Bay BH-AD	$12.9 million	-$10.8 million to $0.0 million	4408	0.91%
Cataraqui Bay BH-AD includes 4000 tonne SSO	$21.9 million	-$12.5 million to +$1.9 million	5969	1.23%
Cataraqui Bay BH-AD includes 12000 tonne SSO	$21.9 million	$7.4 million to +$26.9 million	9091	1.87%
New Site BH-AD includes 4000 tonne SSO *	$27.0 million	-$18.5 million to -$2.7 million	5969	1.23%

BH -Biological Hydrolysis

TPAD - temperature phased anaerobic digestion

* Includes new Digester

Alternative Site



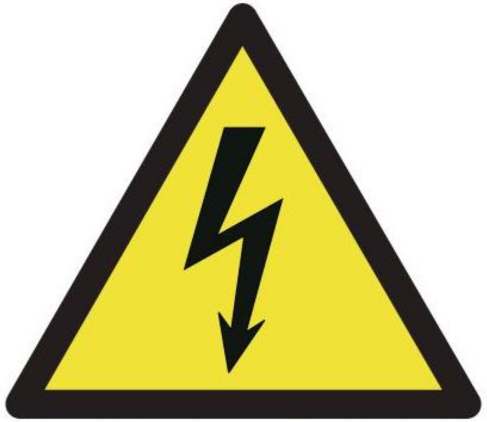
Knox Farm

- Owned by City
- Currently not used
- Room for expansion

Study Outcomes

Other Options considered

- Ravensview as Interim Digestion Facility
- UK operating its own vehicles (Green Fuel) or selling combined Renewable Natural Gas with Natural Gas for other Transporters
- Generating more electricity
- Alternative Technologies to BH-AD may be considered as they become available



APPENDIX 3

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LIMITATIONS ON USE OF THIS DOCUMENT

GEOENVIRONMENTAL

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