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KESWICK

WATER POLLUTION CONTROL PLANT EXPANSION

CLIENT: REGIONAL MUNICIPALITY OF YORK | **TEAM:** HATCH MOTT MACDONALD

2015 ACEC-CCE AWARD SUBMISSION

Hatch Mott MacDonald

Project Description

RAS WAS pumping station and clarifiers

The Keswick Water Pollution Control Plant (WPCP) Expansion was initiated by the Regional Municipality of York (York Region) to provide additional treatment capacity to service future development within the Town of Georgina. York Region retained Hatch Mott MacDonald (HMM) to implement this major initiative with responsibility for engineering and overall project management of the plant expansion encompassing design, public/stakeholder and government agency consultation, equipment pre-selection, technical reviews, environmental compliance, operational analysis, and contract administration. The Keswick WPCP was expanded from an average daily flow rate of 12,070 to 18,000 m^3/d while satisfying stringent effluent requirements imposed by the Ministry of the Environment and Climate Change (MOE) to protect Lake Simcoe. It features a tertiary ultrafiltration membrane system, a new headworks building, expansion of the secondary treatment processes, ultraviolet (UV) disinfection, a new outfall into Lake Simcoe and other upgrades. A key process element of the plant expansion was to provide tertiary ultrafiltration (UF) membranes to meet MOE's stringent total phosphorus (TP) effluent requirements. The expansion project resulted in a state-of-the-art wastewater treatment plant using the **first tertiary UF membrane system in Ontario**.

View of Lake Simcoe

Lake Simcoe is a highly valued and shared resource that provides a source of drinking water for eight municipalities. It is also popular for recreational use, and an important area for fish and wildlife habitat. The UF membrane technology will consistently deliver low phosphorus effluent from the plant resulting in improved water quality for these purposes. The plant expansion will also provide the necessary infrastructure to accommodate the planned residential and commercial growth in accordance with the Region's Official Plan and the Approved Secondary Plans.

Project Objectives, Solutions and Achievements

The primary objectives of the project were to increase the treatment capacity of the Keswick WPCP by 50% from an average day flow (ADF) of 12,070m^3/d to 18,000m^3/d and to meet the stringent MOE mandated total phosphorous effluent requirements. The expansion project had to be implemented while keeping the existing WPCP in continuous operation and within compliance.

View of membrane building and clarifier

To meet these stringent effluent requirements, HMM took the initiative to review and evaluate tertiary treatment alternatives. The state-of-the-art tertiary UF membrane technology was identified as the recommended technology in the design of the plant expansion. This technology is capable of reliably and consistently delivering very low phosphorus limits that are required at the Keswick WPCP.

This recommendation was significant as this was the first application of tertiary membrane design and treatment process for municipal wastewater in Ontario.

HMM worked with the Owner and GE-Zenon (Vendor) to complete detailed design, including a detailed testing program to verify the performance of the membranes. The test program and the results were submitted to the MOE to obtain approval for the expanded treatment facility.

Technical Excellence & Innovation

The Keswick WPCP discharges to the sensitive Lake Simcoe watershed which is regulated by the province's Lake Simcoe Protection Plan established under the Lake Simcoe Protection Act (2008). The Act was established to address water quality issues in Lake Simcoe, including discharge of excessive phosphorus levels. Addressing the challenges created by the multiple environmental constraints and meeting stringent provincial final effluent requirements was the primary focus of the project.

Typical membrane cassette

High phosphorus loadings encourage algal growth resulting in critically low dissolved oxygen concentrations in deep portions of the Lake leading to declining fish populations. Phosphorus loading targets were established to reduce the amount discharged to surface waters and to meet the long-term reduction goals set by the Phosphorus Reduction Strategy under the Lake Simcoe Protection Plan. In keeping with this Strategy, stringent effluent phosphorus targets were established for the expanded Keswick WPCP. The expanded Keswick WPCP is required to achieve a Total Phosphorus (TP) effluent objective of 0.07 mg/L and compliance criteria of 0.10 mg/L monthly average concentration.

Membrane ultrafiltration, a process using membranes with pore sizes in the range of 0.02 micron was installed at the plant. The system consists of pre-screening and five ZeeWeed® 1000 Membrane trains supplied by GE-Zenon. This is an immersed membrane process that consists of outside-in, hollow-fiber modules submerged directly in the feed-water. Treated effluent from each membrane train is collected in a header and conveyed to a UV disinfection system prior to discharge to the Lake.

During the first year of operation and stress testing, the team found that several factors were adversely impacting the operation and/or performance of the membranes, including cold water temperatures, feed quality in terms of colloidal solids, and operating parameters such as cleaning cycles. Due to lack of similar experience at municipal treatment plants in Ontario/Canada, the team conducted numerous comprehensive investigations to identify potential causes of the operational issues periodically experienced at the facility and to identify mitigation measures.

After extensive investigation and study efforts, the team proposed several modifications to improve and optimize the system performance which ensured the high performance of the membrane system at all times without jeopardizing the productivity of the system. The proposed enhancements included:

- Additional 150 membrane modules;
- Additional alum dosage point and mixing upstream of the membranes (programmable adjustment to operate automatically based on operating parameter set points) to address the colloidal solids issues ;
- Modification to the start/stop triggers of the permeate pump system to operate the membranes at a more constant flow; and
- In-cycle aeration (programmable adjustment on an as-needed basis) to prevent in-cycle fouling of the membranes.

V4 membrane module

Based on preliminary results, these modifications have successfully improved the operation and performance of the UF membrane system. **The cold weather membrane performance testing conducted at the Keswick WPCP has set the benchmark for tertiary membrane wastewater treatment technology application in Ontario and in Canada.**

Level of Complexity and Project Challenges

Project design and construction challenges included:

- Extremely soft and unstable soils;
- High groundwater table;
- Restrictive existing site footprint combined with the inability to acquire additional property;
- Regulated wetlands within the construction boundary;

- Construction and commissioning of the new WPCP expansion while keeping the existing plan in operation and within compliance;
- Management and coordination of multiple contractors and equipment suppliers; and
- Introduction of a new treatment process (ultrafiltration membranes) in Ontario with specific testing parameters, limited to certain time of year.

Each of these challenges added complexity to the project. Detailed below are some examples of how the team addressed these challenges.

Size and Scope on an Existing Site

Flow splitting from secondary clarifier

Unlike greenfield construction, the plant expansion was a dynamic process due to constantly changing demands from the operating facility. Managing the project schedule became difficult at times due to limited opportunity to complete tasks sequentially. Construction of the project involved approximately 80 staff and 20 equipment suppliers/installers during peak conditions, all working concurrently and in tandem with each other; and commissioning new processes and incorporating them into an active treatment facility while always ensuring compliance.

The new UF membrane system replaced the existing tertiary sand filtration system. During the commissioning of the membrane system, special planning and implementation were needed to split the secondary effluent flow between the existing sand filters and the new membrane facility. Special considerations ensured that the sand filters stayed sufficiently wet at all times for proper operation, and were available to treat all the incoming flows while at the same time, conveying sufficient flows through the membrane facility to thoroughly test it. While this was ongoing, the project team conducted testing and sampling to ensure that adequate treatment was provided prior to discharging any effluent to Lake Simcoe.

Construction Dewatering Constraint

In the initial stages of the project, constant construction dewatering was required because of the high groundwater table. The construction dewatering from the WPCP was initially discharged into a small adjacent creek that ultimately flowed to the Maskinonge River. The existing passive dewatering system also discharged into the creek at the same location.

Construction of clarifier

However, shortly after the start of dewatering, the project team noted that the additional groundwater flow into the Maskinonge River was causing the ice to melt, creating unsafe conditions for the public to enjoy winter recreational activities. As a result, the project team ceased dewatering immediately and limited construction activities at the WPCP until this issue was addressed.

To reinstate dewatering and restart construction as quickly as possible, the project team immediately embarked on investigating alternative locations for groundwater discharge. The investigation concluded that the most suitable location was the existing WPCP effluent outfall. This finding was further reinforced and confirmed by the completion of a hydraulic analysis to ensure the existing outfall; including the in-lake diffuser system could be modified to accommodate the dewatering groundwater flow.

The modifications included the installation of additional diffuser ports and the removal of some of the caps on existing diffuser ports. New valves were also installed at the WPCP to enable a portion of the groundwater flow to be conveyed to the small creek to maintain the aquatic function of this tributary of the Maskinonge River.

Membrane Cold Weather Performance Variation

Since the Keswick WPCP expansion was the first tertiary membrane treatment application in Ontario, both the MOE and the Region were very cautious about the performance of the membrane system, especially under the extremely cold Canadian winter environment. The membrane system was required to undergo an extensive series of testing and monitoring for 12 months including a cold-water performance test.

As part of this test, the membranes were required to treat high flows combined with high solids at a cold secondary effluent temperature (at 10°C or lower) over a two week time period as the cold temperatures would increase the viscosity of the secondary effluent. The combination of high flows, high solids and cold temperatures represented a worst case operating condition for the UF membranes.

The first year of operation and stress testing revealed that several factors were adversely impacting the operation and/or performance of the membranes, including cold water temperatures, feed quality related to colloidal solids, and operating parameters such as cleaning cycles. Due to lack of similar experience at municipal treatment plants in Ontario/Canada, the team conducted numerous comprehensive investigations to identify the root causes and potential mitigation measures.

Piping for the membrane system

The project team developed a comprehensive program to investigate opportunities to improve and optimize the system performance. This investigation was conducted during cold temperatures and included testing the system performance over a range of coagulant dosages, flow rates and feed quality to membranes, including high solids loading stress tests. Opportunities to optimize the system performance by adjusting the recovery rates and providing in-cycle aeration were investigated. In addition, to identify an optimized cleaning schedule, the team conducted a full scale testing of the effectiveness of maintenance and recovery chemical cleans to address organic and inorganic membrane fouling. Testing, sampling and compiling trending data was carried out on a day-by-day basis to evaluate the effectiveness of the modifications, and ultimately propose and implement system enhancements. Based on preliminary results, these modifications have successfully improved the operation and performance of the facility using UF membrane. The cold weather membrane performance testing conducted at the Keswick WPCP has set the benchmark for tertiary membrane wastewater treatment technology application in Ontario and in Canada.

Contribution to Economic, Social and/or Environmental Quality of Life

With the increased treatment capacity and improved quality of effluent discharged to Lake Simcoe, the project made significant contributions to the economic, social and environmental quality of life.

The Keswick WPCP discharges to Cook's Bay located within the sensitive Lake Simcoe watershed, which is a highly valued and shared water resource that provides drinking water for surrounding municipalities. It is also popular for recreational use, and an important area for fish and wildlife habitat. The province's Lake Simcoe Protection Plan established under the Lake Simcoe Protection Act (2008) addresses water quality issues in Lake Simcoe, such as limiting phosphorus levels. The upgraded Keswick WPCP with the tertiary membrane system significantly reduced the total phosphorous loading to Lake Simcoe by 667kg/year. The UF membrane technology will consistently deliver low phosphorus effluent from the plant resulting in improved water quality for the community and the natural environment.

In addition, the timely commissioning of the entire project has provided the community with the necessary infrastructure that enables the Region to go forward with the planned residential and commercial growth in the area.

TECHNICAL HIGHLIGHTS

Ultrafiltration (UF) membranes were installed at the Keswick Water Pollution Control Plant (WPCP) to achieve the final effluent Total Phosphorus (TP) limits required by the Ministry of the Environment and Climate Change (MOE). The expanded Keswick WPCP is required to achieve a TP effluent objective of 0.07 mg/L and compliance criteria of 0.10 mg/L, based on monthly average concentrations. Conventional tertiary filtration, which is typically used at wastewater treatment plants to polish effluent are not capable of reliably and consistently achieving TP limits <0.1 mg/L.

HMM conducted an evaluation of "Best Available Technologies" that would achieve the required limits and were based on a set of criteria including: compatibility with the existing facility, space requirement, ability to consistently achieve the effluent requirements, operation and maintenance requirements, and capital and operating costs. UF membranes were selected since they had a smaller footprint that could be accommodated at the site, and were proven (outside of Canada in similar climates) to consistently achieve the required effluent limits.

Membrane ultrafiltration is a solids separation process using membranes with pore sizes in the range of 0.02 micron. The UF system at the Keswick WPCP consists of pre-screening and five ZeeWeed® 1000 membrane trains supplied by GE-Zenon. During a filtration cycle, feed water is drawn through the membranes by applying a vacuum where particulate and colloidals solids are filtered out. At the end of each filtration cycle, a backwash is performed to dislodge solids from the surface of the membranes. Membranes undergo regular chemical "maintenance cleans" and monthly intensive "recovery cleans" to control fouling and restore permeability.

Since this is the first full scale application at a municipal wastewater treatment plant in Ontario, MOE required that a comprehensive one year performance test be conducted. The objective was to verify that the UF membrane process is capable of achieving the design objectives and compliance criteria on a long-term basis under a range of operating conditions that could be encountered under full scale operation.

Lessons Learned During the First Year of Full-Scale Operation

The UF membranes have been in continuous operation for over one year, and have been exposed to the critical low temperature (winter) and the high flow (spring and fall) periods. During this year, stress testing was also conducted on each UF membrane train to simulate the range of flows and conditions that would be encountered during full-scale operation.

Flow (or flux through the membranes), feed quality, and temperature are key parameters that can affect the performance of the membranes. The system can be very sensitive to changes in the feed quality and temperature. This is challenging for this application as the UF membranes are downstream of a biological treatment process, which is a dynamic process. As such, the feed quality to the membranes is constantly changing and intensive monitoring and operation of upstream processes is critical for the optimum performance of the membranes.

One of the key operating parameters for membranes is the transmembrane pressure (TMP), which is the vacuum pressure required to pull water through the membrane, and can be an indication of the degree of membrane fouling. Periodically, the system experienced low TMP alarms occurring as a result of membrane fouling attributed to a change in colloidal solids in the feed water to the membranes. Cold temperatures and high flow rates (high flux) also contributed to the occurrence of the alarms. The system underwent a series of tests to identify opportunities to address the degree of membrane fouling and maintain the TMP within an appropriate range. These tests included investigating the impact of adjusting the following parameters, including:

- Reduced flux (additional membranes).
- Range of coagulant dosages upstream of the membranes.
- Intensive sampling of the feed quality to membranes.
- Range of recovery rates (e.g. reducing the cycle time between backwashes).
- Effectiveness and timing of in -cycle aeration to dislodge solids from the surface of the membranes within a filter cycle.
- Scheduling and duration of maintenance and recovery chemical cleans to address organic and inorganic membrane fouling.

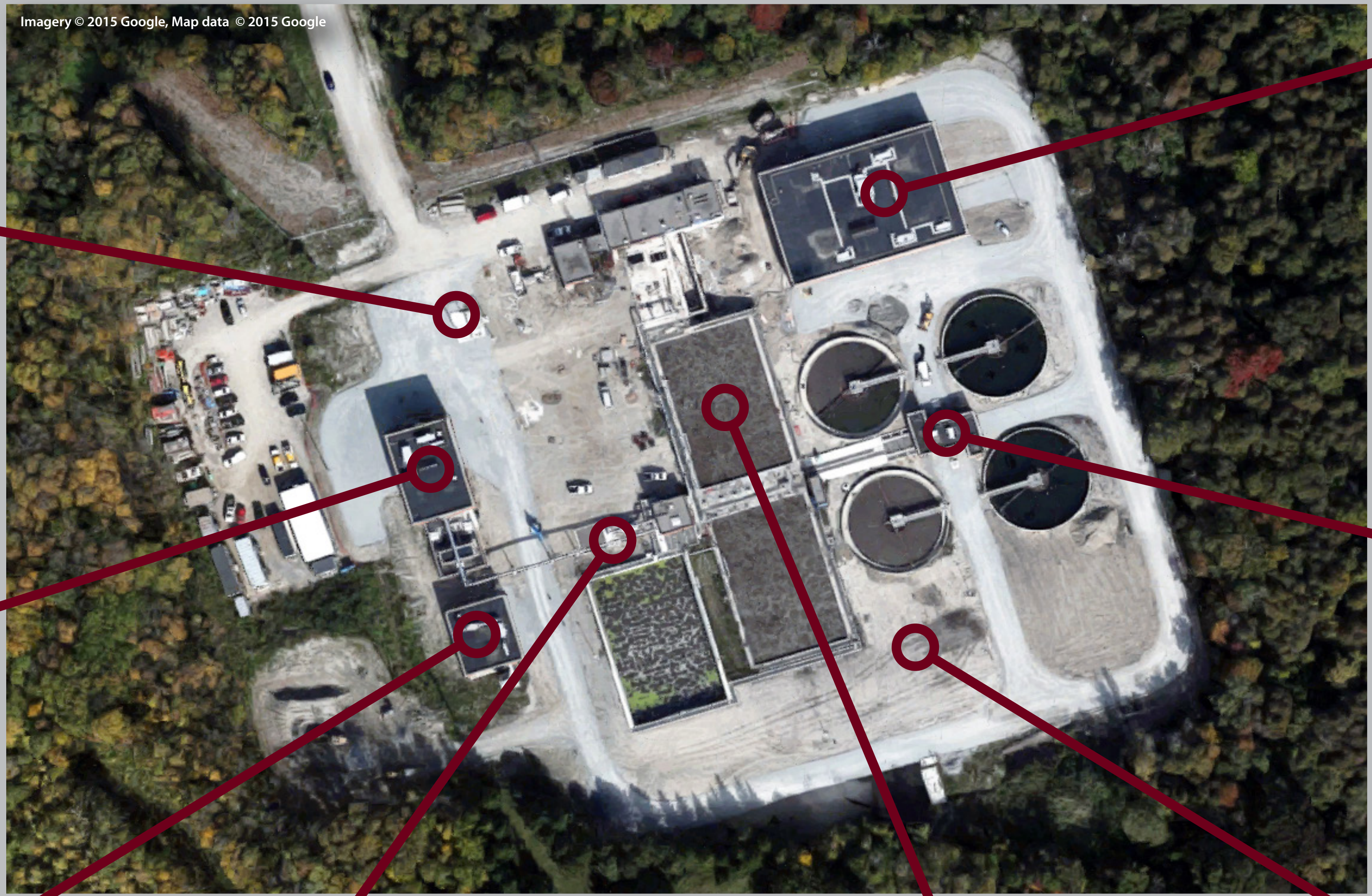
As a result of the tests, several of the above modifications were implemented and have successfully improved the operation of the UF membrane facility. The results of the one year performance test confirmed that the UF membranes are capable of consistently producing an excellent quality effluent, and the plant was in compliance with the new final effluent limits at all times.

The lessons learned during the design and first year of operation of the UF membranes is an important step in the advancement of advanced nutrient removal at municipal wastewater treatment plants. Tertiary level treatment is becoming a requirement at an increasing number of wastewater treatment plants in Ontario to protect the health of receiving water bodies.

KESWICK WATER POLLUTION CONTROL PLANT EXPANSION

Sludge Loading Facility

Headworks Facility



Interior View of the Membrane Building

RAS/WAS Pumping Station and Clarifiers

Generator Building

Odour Control Facility

Aeration Tank in Operation

Original WPCP Layout - 2006