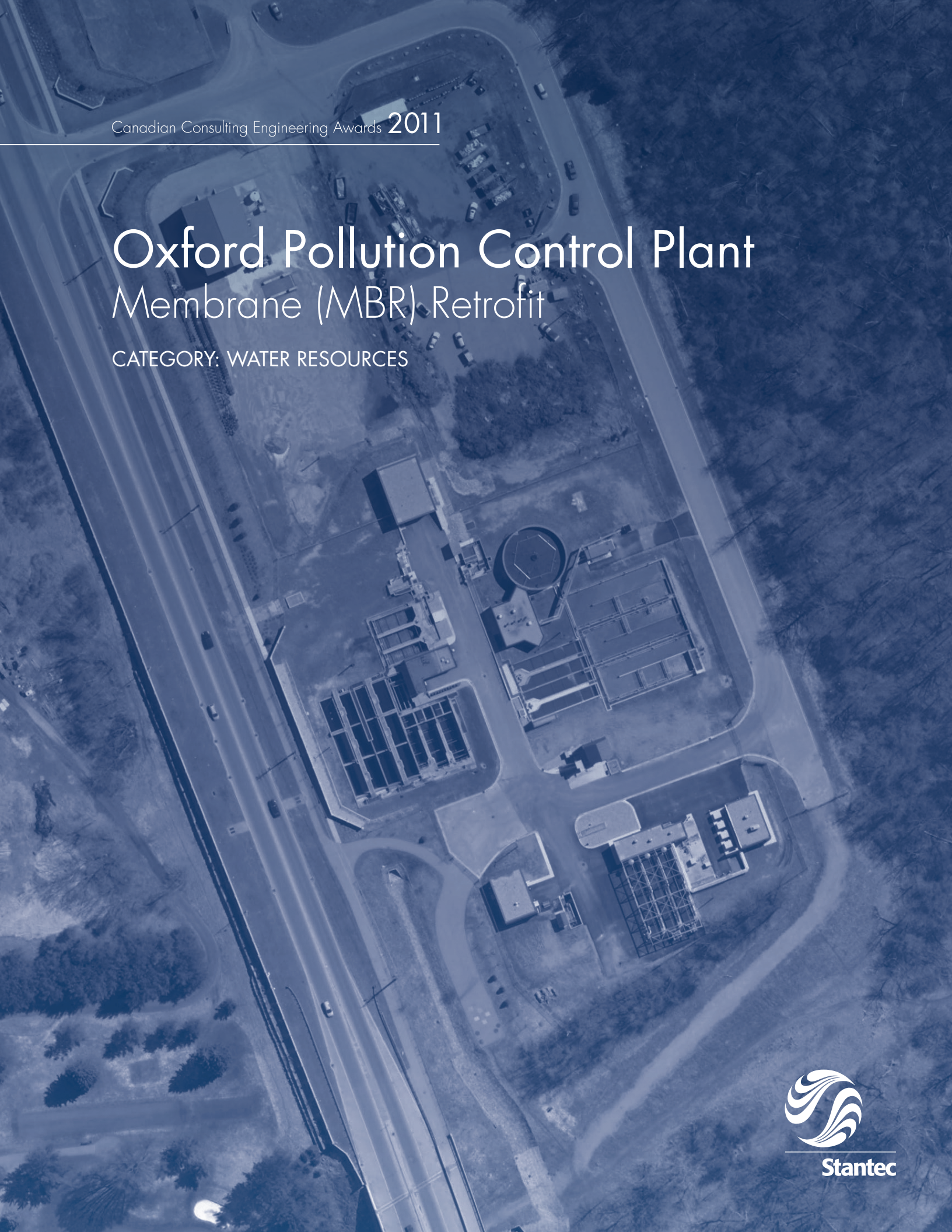
Canadian Consulting Engineering Awards 2011

Oxford Pollution Control Plant
Membrane (MBR) Retrofit

CATEGORY: WATER RESOURCES



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Executive Summary

Finding ways to upgrade aging wastewater treatment facilities is a common challenge for many cities throughout North America. But for the City of London, Ontario, the "same old" way of doing things was not enough. The city is experiencing strong growth pressure, and city officials had to determine a way to increase wastewater treatment capacity without putting too large a financial burden on the city's budget.

After examining the typical alternatives for expanding the wastewater plant, the city held a workshop to challenge a group of consultants to brainstorm solutions which would provide superior results to those already put forward. It was ultimately determined that an innovative MBR retrofit of the Oxford Pollution Control Plant offered an affordable opportunity to treat increasing wastewater at the tertiary level, at costs comparable to secondary treatment.

The City of London retained Stantec to expand the processing capacity of the Oxford Pollution Control Plant (PCP) on a highly constrained site. By leveraging Stantec's expertise from across North America, a creative, low-cost solution was identified and ultimately constructed to convert the existing plant using MBR technology.

The Oxford Pollution Control Plant MBR retrofit has proven to be a case study in successful municipal water quality engineering. Key "success stories" of the project include:

Stantec provided engineering services to study, design, and construct the largest membrane bioreactor (MBR) municipal pollution control plant (PCP) ever built in Canada.

1. The Economical Delivery of Superior Quality Effluent

The MBR retrofit was demonstrated as an economically responsible solution for improving the capacity and effluent quality of the Oxford PCP. The final design tripled the capacity of existing tankage and improved treatment performance to tertiary level quality at an overall cost comparable to secondary treatment.

Subsequent to the retrofit the capacity of the plant's second treatment section was expanded from 4,500 m^3/d to 13,600 m^3/d at a cost of $21M, representing a unit cost of $2,300/ m^3/d based upon the expanded capacity of 9,100 m^3/d.

Operation and Maintenance (O&M) and life-cycle costs are forecast to be either equivalent or superior to traditional Activated sludge process (ASP) plants

2. Creative Engineering as a Means to Control Capital Costs

Site specifics allowed the city to realize significant capital savings with an MBR retrofit, which would not have been possible with an ASP expansion. Additionally, the reuse of the existing structures avoided significant demolition costs and fit well with London's solid waste strategy of reusing materials whenever possible.

3. Minimized Social and Environmental Impact

The compact footprint of MBR water treatment allowed for design of a facility which satisfied concerns of local stakeholders regarding the negative visual impact a traditional expansion would have had on the adjacent roadways, golf course and walking paths.

Additionally, the compact nature of the MBR design allows the Oxford PCP to deliver increase facility capacity without encroaching into sensitive neighbouring lands.

While minimizing the aesthetic impact on the local community was a major consideration, avoiding negative environmental impacts to the Thames River was paramount. The Oxford PCP was designed to improve the quality of effluent to such a level that, even with the increase in capacity, downstream stakeholders receive a better quality of water than then had with the previous facility.

4. The Advancement of Membrane Bioreactor Technology

The MBR retrofit of the Oxford Pollution Control Plant is proving to be an innovative, creative way of solving a municipalities capacity needs without breaking the bank.

The success of the MBR technology deployed at Oxford is being closely monitored as options are being explored by the City of London for the future expansions at the city's largest wastewater treatment plant, the Greenway Pollution Control Centre. The Oxford plant has allowed the City to conduct a full-scale "pilot test" to confirm operational and maintenance demands, train staff, and gauge its suitability for expanding the Greenway plant.

The Oxford Pollution Control Plant membrane bioreactor retrofit is a glowing example of new technology, creativity, and engineering excellence coming together to exceed a clients expectations while preserving a client budgets.

Construction of the MBR retrofit at the Oxford Pollution Control Plant was completed in the summer of 2008.

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Oxford Pollution Control Plant Membrane (MBR) Retrofit

Project Background

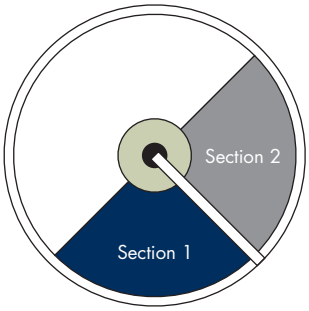
Background

Located at 1570 Oxford Street West, in London, Ontario, the Oxford Pollution Control Plant (PCP) commenced operations in 1960, and is one of 6 PCP facilities currently servicing the City of London.

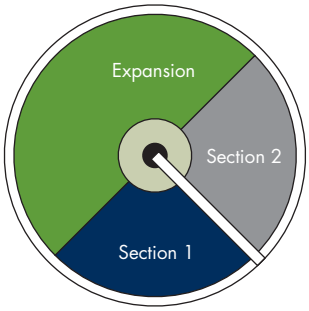
Consisting of both the original section (Section 1) rated for 5,450 cubic metres per day, and a newer section (Section 2) rated for 4,540 m^3/d the combined capacity of the Oxford PCP facility was approximately 10,000 m^3/d prior to the facility upgrades.

The Challenge

Given the high rate of residential growth within Oxford's sewer shed it was determined that the processing demand on the facility would nearly double. In order to meet that forecast usage an additional ~9,000 m^3/d treatment capacity would need to be added in the very-short term.



Pre-Expansion Capacity



Expanded Capacity

In the spring of 2006, the City of London undertook a Class Environmental Assessment (EA to evaluate options for capacity expansion to the Oxford Pollution Control Plant. After the release of the Class EA findings, the City of London spearheaded a workshop in order explore a wider range of potential solutions.

This workshop approach enabled the City of London to challenge the status quo at a very early stage, and allowed for the engagement of top-level City leadership at a critical point in the decision-making process.

The workshop approach identified a number of potential solutions for the Oxford PCP expansion, including:

- Activated Sludge Processes (ASP) with filtration and sub-options for carbon, nitrification, and de-nitrification.
- Biological aerated filters with filtration and sub-options for new aerated filter systems operating in parallel with, or after, Conventional Activated Sludge (CAS).
- A new "greenfield" membrane bioreactor (MBR), working in parallel with the existing CAS, or a retrofit MBR to Section 2 operating in parallel with the existing CAS in Section 1.
- Trickling filters/solids contact tanks with filtration.

After conducting a viability analysis for each option, it was determined that the two most feasible options for the site were:

1. Expand the plant with a new activated sludge process (ASP) designed for carbon, nitrification, and de-nitrification with filters, and blend it with the existing Section 1 and 2 CAS effluents; or
2. Retrofit Section 2 of the plant with a membrane bioreactor designed for carbon, nitrification, de-nitrification, combined with existing Section 1 CAS effluent.

A second round of advantage/challenge analysis was then conducted on these options in relation to the specific requirements of the Oxford PCP site.

This review process identified that the Section 2 activated sludge plant (composed of two rectangular, two-pass aeration tanks followed by three rectangular secondary clarifiers) was well-suited to permit an MBR retrofit with only minor structural changes. As the tanks, blowers, clarifiers, and pumping gallery areas were all large enough to accommodate the increased volume, equipment, and demands of an MBR system, it was determined that conditions would allow for a reduced scope of work for a retrofit of Section 2, which could meet the proposed 9,000 m^3/d treatment expansion.

In the fall of 2006, Stantec Consulting Ltd. was retained to undertake the design and construction of the MBR retrofit at the Oxford PCP.

Stantec Scope of Work

Stantec provided engineering services to study, design, and construct the Oxford Pollution Control Plant Expansion with an objective of expanding treatment capacity of the Oxford PCP from ~10,000 m^3/d to ~20,000 m^3/d annual average flow to serve new residential growth in the northwest quadrant of the City of London.

A range of treatment expansion alternatives was reviewed by Stantec including the addition of a third new conventional activated sludge train, and the integration of a membrane bioreactor (MBR) retrofit to the Section 2 conventional activated sludge train. After completing a number of comparative evaluations and being convinced that MBR technology had advanced to a state with acceptable risk, it was decided to proceed with the MBR retrofit to Section 2.

Benefits of this solution were forecast to include:

1. a compact footprint which would allow expansion within the existing fence line;
2. lower capital cost, reduced visual impact from the adjacent Oxford Road;
3. improved effluent quality;
4. opportunity to use membranes to achieve lower sludge thickening costs;
5. ability to expand the plant in future without encroaching on adjacent woodlands and riverine habitat.

What is a "membrane bioreactor" (MBR)?

A Membrane bioreactor (MBR) is a wastewater treatment process which combines the physical filtration of matter from water through a porous barrier (AKA membrane) with a biologically active environment which breaks down bacteria (bioreactor).

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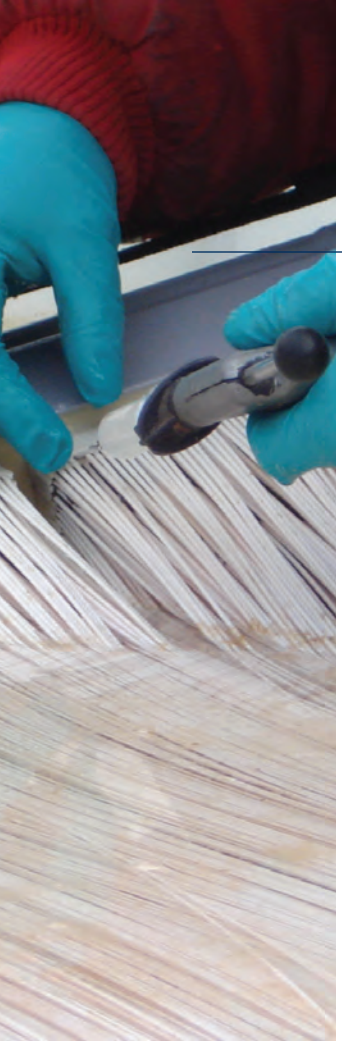
Oxford Pollution Control Plant Membrane (MBR) Retrofit

In order to achieve the objectives of this ambitious project, Stantec undertook the engineering services to deliver:

- an oversized raw sewage lift station;
- a new headworks building with oversized 2mm fine screens (120,000 m^3/d capacity);
- expanded primary clarifiers;
- a new aeration tank;
- the conversion of two aeration tanks;
- the doubling of the aeration tanks capacity from 2,250 to 4,500 m^3/d each;
- an innovative solution utilizing MBR technology to thicken waste activated sludge;
- the complete replacement of the plant's electrical system;
- the integration of a new 1MW emergency diesel generator;
- the design and construction of a new chemical storage system; and,
- the design and construction a new administration building.



Innovations, Originality and Design Excellence

The upgrades to the Oxford Pollution Control Plant resulted in the build-out of the largest membrane bioreactor (MBR) municipal pollution control plant in Canada. The final design nearly doubles the operation capacity of the original facility while minimizing the physical footprint of the plant.

The technical challenges associated with the retrofit of Section 2 to MBR operation were considerable and required numerous innovative solutions and technological advancements during the course of the project.

Use of New Membrane Bioreactor (MBR) Technology

Stantec undertook an extensive investigation into new generation MBR technologies from a variety of vendors including General Electric, Siemens and Kubota in order to satisfy concerns that MBR technology had advanced to a point where it could successfully be utilized on the scale required by the Oxford PCP.

The utilization of new generation membrane filtration systems to achieve secondary effluent disinfection has proven very successful, with effluent E.coli levels proving to be non-detectible in post installation testing.

By deploying MBR technology on the largest scale yet in Canada, Stantec has provided further evidence about the "barrier" protection offered by membranes in a pollution control setting, and advances the case for MBR usage in larger scale pollution control plant facilities.

Technical Innovations - Primary Treatment

Stantec designed a preliminary treatment process which eliminated the conventional de-gritter systems by implementing above-grade fine mesh (2 mm) rotary drum screens for the removal of fibrous materials and grit from raw wastewaters. To the best of our knowledge, this particular design concept has not been used at any other pollution control plant, but is necessary at this facility to allow more efficient functioning of the membranes.

Fine screening will increase membrane life under conditions of increased pressures and water viscosities that are encountered in cold climate applications such as this.

Design Excellence - Structural Reuse

Stantec's design demonstrated innovation by repurposing two existing structures in support of the new MBR process.

First, Stantec utilized an innovative structural design to reuse existing de-gritter tanks by converting them into a pump station and a flow splitter box. This particular design concept is necessary to allow the proper functioning of the new membrane application system and, to our knowledge, had not been previously undertaken at any other pollution control plant.

Secondly, Stantec developed a design to reuse the Section 2 secondary clarifiers by converting them into membrane tanks through the design of a novel pump layout. This creative reuse of the existing infrastructure presented a significant constructability risk but was successfully accomplished during the tank retrofit period.

Design Innovations – Membrane Filtration

During the design phase, the Stantec team developed an activated sludge thickener employing membrane filtration systems to achieve a 4.5% sludge density.

This density is significantly above a 2.5% level currently being achieved at a warm water MBR plant application in the US, and is forecast to deliver superior operating and maintenance costs savings at the Oxford Pollution Control Plant.

By focusing on innovative solutions and the Stantec design delivered a fully operational MBR project which has a small footprint, a low capital cost construction, produces a high quality effluent, and will be a trend setting design for the expansion of space-constrained plants elsewhere.

Project Complexity

The Oxford Pollution Control Plant retrofit presented many complexities related to both the physical site of the plant and the construction challenges associated with expanding a "live" facility which was already running near capacity.

Site Complexities

The physical location of the Oxford PCP presented the challenge of balancing the aesthetic presentation of the facility, the health concerns of downstream stakeholders, and the future capacity requirements of the plant.

Minimizing Visual Impact

Located on the banks of the Thames River, the plant sits aside Oxford Road, which acts as a major arterial roadway into the city. The site is also near several new, large residential areas and the prestigious Hunt Club golf course. Considerations for the aesthetic elements of the project mandated that visual impacts of the plant expansion be minimized from both the road and from adjacent residential lands.

Additional site challenges included the plants proximity to ravine habitat and planned recreational pathways. Design selection considerations therefore included protecting the recreational value of the riverbanks.

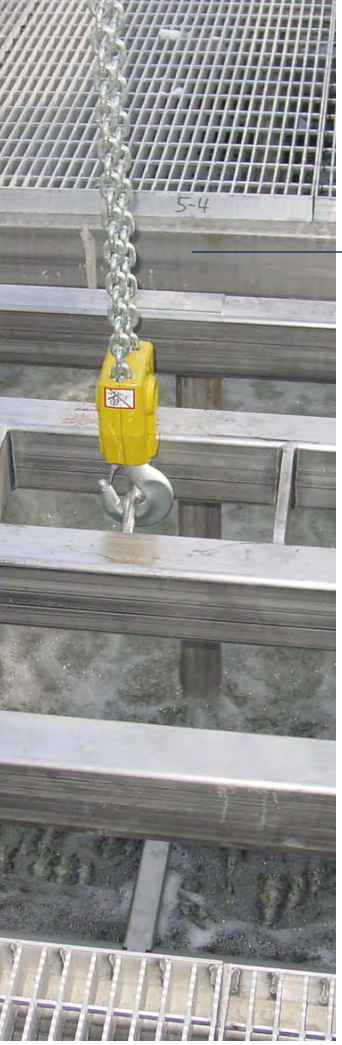
As an MBR plant requires a much smaller footprint, thus eliminating the need to expand into sensitive neighbouring lands and avoiding any visual impacts for traffic crossing the Oxford Street Bridge, it was a logical fit for this site.

Downstream Stakeholder Protection

Located upstream from multiple stakeholders including the Delaware First Nation, technology and design selection needed to be sensitive to the concerns of downstream stakeholders.

Meeting effluent limit targets was a particular concern, specifically achieving the low monthly limit of total phosphorus at less than 0.5 mg/L and summer total ammonia at less than 1.0 mg/L. Past performance at the plant suggested it would be challenging to achieve that phosphorus limit without tertiary filtration and that alkalinity could be limiting nitrification at times.

By utilizing MBR technology, the plant could was able easily achieve a less than 0.5 mg/L phosphorus limit, and alkalinity concerns were addressed by including anoxic zones in the aeration tank.



Meeting Future Capacity Requirements

The retrofit design needed to be mindful of future expansion requirements which would need to be addressed in order to deliver the ultimate build-out of a facility capable of handling a 50,000 m^3/d (50 MLD) flow.

By deploying MBR technology Stantec was able to develop a solution which (1) leave sufficient physical space for future infrastructure requirements, and (2) delivers quality of effluent output which minimizes the impact on the Thames River.

Construction Complexities

Maintaining plant operations throughout construction was a critical requirement which dictated the employment of innovative temporary measures, complex staging and comprehensive item-by-item commissioning.

Maintaining Plant Operations

The existing plant was operating near its rated flow capacity, and during wet weather periods the plant experienced extremely high flows in excess of its rated peak flow capacity. Throughout construction the continuous operation of the existing plant had to be maintained without interruption. This presented many challenges, as sections of the plant's treatment processes were taken offline for extended periods of time to allow for construction activity associated with the MBR installation.

To install the MBR equipment, the existing secondary clarifier tankage was taken offline for 6 months to allow for construction activities. This would have had the impact of reducing the plant's capacity by half; But Stantec utilized unique temporary measures to augment treatment capacity while construction was underway.

During construction flow was diverted prior to the secondary clarifiers back thru the primary clarifiers. Theses diversions allowed for the effective utilization of the primary clarifiers as secondary clarifiers. To our knowledge this diversion technique has not been previously undertaken.

This solution required additional design efforts by Stantec in order to (1) size temporary piping and channels, and (2) undertake computer modeling to assess the treatment performance and effluent quality impacts associated with the temporary operating mode.

Despite these challenges, full plant capacity was maintained while carrying out the complex retrofit.

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Oxford Pollution Control Plant Membrane (MBR) Retrofit

Complex Construction Staging

Fine screening is critical to the successful function of MBR technology, and in order to accommodate the new fine screens as a pre-treatment prior to allowing waters to contact the membranes , a new Headworks building and raw sewage pumping station needed to be constructed.

Special construction sequencing with temporary measures were required to redirect existing sewage flows during the demolition of existing structures (tanks, channels, piping, etc.,) which would free-up the physical space for the new Headworks building. This sequencing required complex tie-ins to redirect flows during over-night periods when flows were low, and need to be designed in a manner that it did not interfere with the continued operation of sanitary flows and the treatment of the final effluent. Similarly, the retrofit of the existing secondary clarifiers with MBR technology required both precise staging and numerous temporary diversions to ensure continuous plant operations throughout the retrofit process.

Complex Automation Requirements

The Oxford PCP is highly automated and essentially operates un-manned. The automated commissioning of the MBR retrofit required the integration of numerous interconnected operations between various equipment, piping, flow control valves, instruments, electrics, etc.

To ensure the existing treatment process continued to operate without interruption, it was necessary for Stantec to undertake a "hands-on" approach to SCADA systems integration (i.e., automation) on an item-per- item basis, as new process units were brought on-line.

All of the construction challenges were successfully met by the Stantec/City/Contractor team. Now that the MBR system is fully commissioned, its operation is automatically controlled through sophisticated PLC controls that regulate all aspects of it operation.

Environmental Benefits

Better Quality Effluent

Maintaining clean waterways while establishing infrastructure to supporting usage pressures from a growing populations is a challenge facing many regions. As the Oxford PCP Expansion demonstrated, it is possible to design a plant with both expanded processing capacity, and a higher quality effluent, without dramatically increasing the footprint of the physical structure.

This membrane bioreactor retrofit produces a better quality effluent than would be possible through more traditional treatment technologies thus enhancing the long-term environmental benefit to the Thames River, and accomplishes this at a capital cost that is comparable to the more traditional treatment technologies.

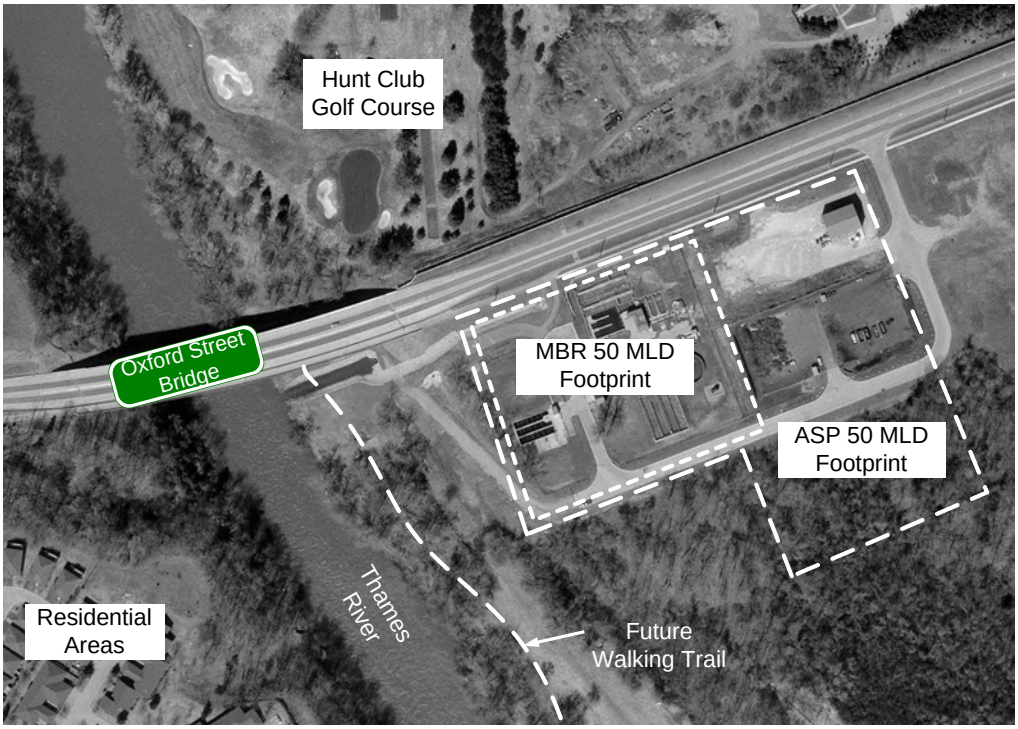
Protection of Surrounding Lands

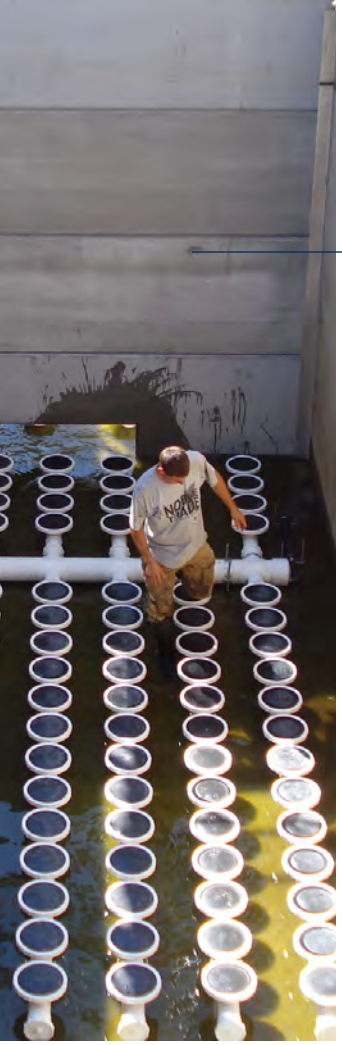
The Oxford PCP is located on the banks of the Thames River: 1) adjacent to the Oxford Street bridge crossing; 2) near ravine habitat with planned recreational pathways; 3) opposite the prestigious Hunt Club golf course; 4) near major new residential areas; and, 5) upstream of the Delaware First Nation.

Given the concerns of the community stakeholders, it was recognized that any Oxford PCP expansion must be completed in a manner that reduces the visual impact to traffic crossing the Oxford Street bridge, maintains the recreational value of nearby ravine habitat, minimizes the impact on adjacent residential lands, and is sensitive to the concerns of downstream stakeholders such as the First Nations.

The change to a compact MBR technology allows the plant to remain within the existing fence line even at its ultimate build-out to 50,000 m^3/d capacity. This will preserve adjacent woodlands and ravine habitat that would otherwise be sacrificed when space for a traditional treatment process expansion is required.

The smaller footprint also eliminated community concerns regarding the visual impact of the plant, while the higher quality effluent satisfied the concerns of downstream stakeholders.





Economic and Social Benefits of the MBR Design

Economic Benefits

Extensive effort was made to compare the capital, operation and maintenance (O&M), and life-cycle costs for an MBR retrofit versus a traditional activated sludge/filter expansion. The site specifics allowed the city to realize significant capital savings with an MBR retrofit, which would not have been possible with an ASP expansion. Also, reusing the existing structures avoided significant demolition costs and fit well with London's solid waste strategy of reusing materials whenever possible.

The MBR retrofit enabled key cost saving opportunities: screening and de-gritting was undertaken in one step using rotary drum, 2-mm fine screens, existing infrastructure (tanks, equipment, buildings, etc.,) was reused, and the retrofit was integrated into existing infrastructure to minimize new construction and thereby reduce costs.

Additional MBR O&M costs were considered for membrane replacement, energy for air scour blowers, and chemicals for membrane cleaning. With a five-year membrane replacement frequency, the 20-year life-cycle cost for an MBR system was found to be comparable to that of conventional treatment solutions.

Social Benefits

By producing a superior quality of effluent the Oxford PCP maintains the quality of water within the Thames River and protects the downstream communities from the potential consequences of under-treated water

Owners Expectations

Future Applications

A major consideration in the decision on whether to choose MBR or traditional activated sludge for the Oxford plant was its application for future expansions at the city's largest wastewater treatment plant, the Greenway Pollution Control Centre. With MBR technology in place at the Oxford plant, the city could operate the system as a full-scale pilot test to confirm its operational and maintenance demands, train staff, and gauge its suitability for expanding the Greenway plant.

Affordability

The MBR retrofit will achieve tertiary level treatment performance at a cost comparable to secondary treatment. The project was tendered in fall 2006 for $21M. The design flow capacity for the MBR process is 13,500 m^3/day, comprising 4,500 m^3/day of existing flow and 9,000 m^3/day of expanded flow capacity. On a per-unit flow basis, the resulting unit cost for treatment is in the range of $1,555 per 1,000 m^3/day (or $7 per MIGD).

After comparing these various factors, the project team ultimately agreed that retrofitting the Oxford plant for MBR technology was the most efficient, economical, and responsible means for expanding the plant's capabilities. And the solution could not come too soon, as the city continues to face similar challenges in other areas where existing infrastructure is struggling to keep up with the growing demands.

By stretching the limits of conventionality and thinking creatively, the City of London and Stantec were able to find a better solution for water treatment needs that can now serve as a model for many of Ontario's wastewater treatment plants, particularly those that are considering expansions or changes to meet more stringent effluent limits.

Conclusion

Construction of the MBR retrofit at the Oxford Pollution Control Plant was successfully completed in the summer of 2008.

To date, the Section 2 MBR retrofit has performed beyond expectations and has been the subject of many published papers including:

i. WAS thickening using ultra-filtration membranes – Preliminary results at Oxford water pollution control plant – Presented at the WEAO Conference in Toronto, 2009

ii. MBR at Oxford water pollution control plant – How is it working? - Presented at the WEAO Conference in Toronto, 2009

iii. Disinfection after MBR ultra-filtration membranes – Is it needed? - Presented at the WEAO Conference in Toronto, 2009

iv. How to retrofit a plant using MBR technology – Presented at the WEAO Conference in Ontario in 2007

v. Sludge thickening using MBR technology for sludge thickening – Presented at the WEAO (Ontario), MWEA (Michigan) and WEF international (California) conferences in 2007

vi. Article in Environmental Science and Engineering (January 2008)

The "learning" arising from this project have advanced the general state of knowledge for MBR technology and paved the way for faster adoptions by others in similar situations.