

APPENDIX C-4
TREATMENT PROCESS OPTIONS



**POINT PLEASANT
WATER TREATMENT PLANT EXPANSION**

**TECHNICAL MEMORANDUM NO. 4
TREATMENT PROCESS EXPANSION**

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1.0 INTRODUCTION

Utilities Kingston retained J.L. Richards & Associates Limited, in association with CH2M HILL Canada Limited, to complete a Class Environmental Assessment (EA) to expand the treatment capacity at the Point Pleasant Water Treatment Plant (WTP), previously referred to as the Kingston West WTP, in order to implement the June, 2007 Master Plan for Water Supply for the City of Kingston Urban Area. This Master Plan identified works that would be required to meet existing and future demand increases within the urban area of Kingston resulting from growth. The Master Plan EA determined that the expansion of the Point Pleasant WTP is of high priority. Therefore the purpose of this Class EA study is to identify the preferred strategy for meeting future water treatment needs at the Point Pleasant WTP.

The Point Pleasant WTP, located at 80 Sunny Acres Road, supplies water to the Kingston West water distribution system, and currently has a rated capacity of 45.5 megaliters per day (ML/d). This Class EA study will examine alternative strategies to increase the functional capacity of the WTP to 80 ML/d by the year 2012 in order to accommodate demand. With ever more stringent treated water quality requirements, and an expanding Kingston population, there may be a need to improve on both the capacity and treated water quality of the existing facility.

A number of important issues are being reviewed and addressed through five Technical Memoranda prepared as part of the Class EA process, as summarized below:

Technical Memorandum No. 1	Source Water Quality and Drinking Water Treatment Objectives
Technical Memorandum No. 2	Existing Facility Condition Assessment and Treatment Limitations
Technical Memorandum No. 3	Low Lift Pump Station Upgrade/Expansion
Technical Memorandum No. 4	Treatment Process Expansion
Technical Memorandum No. 5	Treated Water Pumping and Storage Upgrade/Expansion

This Technical Memorandum (TM No. 4) provides an overview of the available treatment technologies for the upgrade to the Point Pleasant WTP, and the preferred selection that will best meet the requirements of the expansion. TM No. 4 does not provide details associated with expansion requirements of either the low lift pumping or high lift pumping areas, and what effects, if any, each of the treatment alternatives will have on these areas. This information is presented in Technical Memorandum No. 3 – Low Lift Pump Station Upgrade/Expansion and

Technical Memorandum No. 5 – Treated Water Pumping and Storage Upgrade/Expansion. Similarly, since they are considered common to all options, the evaluation does not take into account:

- Raw water transmission piping upgrades
- Upgrades to the existing water treatment plant
- Interconnecting piping upgrades
- Chlorine facility upgrades
- Standby power requirements

2.0 DESIGN CRITERIA

The following section summarizes the design criteria used to develop the alternative treatment technologies that have been evaluated in TM No. 4.

2.1 Design Capacity

The rated capacity of the current Point Pleasant WTP is 45,965 m³/d (based on the Certificate of Approval). As noted in the Master Plan, the WTP is considered to have a “functional” capacity of only 41 ML/d¹. The objective of the project is to increase the net water production from the WTP to 80 ML/d to satisfy the projected water demand to the year 2026. Therefore, the WTP expansion being considered as part of this project is approximately 40 ML/d (net).

Consideration has also been given to the potential future consolidation of the Point Pleasant WTP and the Kingston Central WTP. This could potentially increase the water production requirement at the Point Pleasant WTP from 80 ML/d to an ultimate capacity of 200 ML/d. Regardless of the treatment technology selected for expansion, additional land beyond the current property owned by the City will be required to allow expansion to 200 ML/d. As such, the selection of the treatment technology will not be affected by the requirement for future consolidation.

2.2 Treated Water Quality Basis

The treated water quality objectives have been discussed in general in Technical Memorandum No. 1., Table 1 (an excerpt from TM No. 1) summarizes the recommended water quality objectives:

¹ This is due to an additional 4.5 ML loss due to filter off-line time, backwash volume, filter to waste volume and clearwell recovery of backwash water, when the system runs at rated capacity for an extended period of time (i.e. 1 – 2 days).

Table 1 – Selected Regulations For Water Treatment Plants

Parameter		Current MOE Requirements	Current US EPA Requirements	Recommended Design Objectives for Expansion of the Kingston West WTP
Pathogen Control	<i>Giardia</i>	≥ 3.0-log (99.9%) reduction, where at least 0.5-log (68%) reduction must be from disinfection portion of treatment process	Not specifically required under LT2ESWTR (governed by Cryptosporidium removal)	Minimum 3.0-log (99.9%) reduction
	<i>Cryptosporidium</i>	≥ 2.0-log (99%) reduction	3.0 – 5.5-log (99.9% to 99.99968) reduction, depending on source water Cryptosporidium concentrations ¹ 1-log (90%) reduction must be provided by alternative technologies (depending on source water) ¹	Minimum 3.0-log(99.9%) reduction
	<i>Viruses</i>	≥ 4.0 log (99.99%) reduction, where at least 2-log (99%) reduction must be from disinfection portion of treatment process	≥ 4.0-log (99.99%) reduction	Minimum 4.0-log (99.99%) reduction
Turbidity Removal	<i>Filter Effluent Turbidity</i>	< 0.3 NTU in 95% of CFE* measurements, in order to achieve approved pathogen removal credits ²	< 0.3 NTU in 95% of CFE measurements in order to achieve approved pathogen removal credits Additional 0.5-log (68%) removal credit can be achieved if CFE < 0.15 in 95% of measurements Additional 1.0-log (90%) removal credit can be achieved if IFE < 0.15 NTU in 95% of measurements	0.1 NTU in 95% of IFE ⁺ measurements
Organics	<i>Total Organic Carbon</i>	Not currently regulated, but aesthetic objective of < 5 mg/L	15 – 50% removal based on source water alkalinity ³	Enough reduction to allow disinfection by-products to meet regulations

Table 1 – Selected Regulations For Water Treatment Plants

Parameter	Current MOE Requirements	Current US EPA Requirements	Recommended Design Objectives for Expansion of the Kingston West WTP
Taste and Odour	Not currently regulated, but aesthetic objective is "inoffensive"	3 TON (threshold odor number) ⁴	Inoffensive
Lead	0.01 mg/L	0.015 mg/L in the 90 th percentile of all samples	0.01 mg/L
Copper	1.0 mg/L	1.3 mg/L in the 90 th percentile of all samples	1.0 mg/L
Aluminum Residuals	0.1 mg/L ⁵	0.05 mg/L ⁵	0.05 mg/L
Disinfection By-Products	<i>Total Trihalomethanes</i>	0.100 mg/L	0.08 mg/L
	<i>Total Haloacetic Acids (HAA)</i>	Not currently regulated	0.06 mg/L

Notes:
 * CFE = Combined Filter Effluent
 + IFE = Individual Filter Effluent
¹ The Bin classification system that outlines the Cryptosporidium removal requirements is summarized in the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) fact sheet in Appendix C of TM No. 1.
² New MOE Design Guidelines for Drinking-Water Systems adapted in 2008 has a new design target of 0.1 NTU IFE.
³ This requirement is governed by the EPA's Stage 2 Disinfectants/Disinfection By-Product Rule to reduce the THMs in finished water.
⁴ This corresponds to a "rotten-egg", musty or chemical smell
⁵ This value is a recommended objective by the mentioned governing body, not a regulation.

2.2.1 Existing Plant Water Quality Review

Reviewing the treated water quality of the existing filtration plant in conjunction with the water quality table above, it is expected that the existing filtration plant will not be able to consistently meet the 0.1 NTU individual filter effluent (IFE) turbidity objective, especially during peak flow operation when the plant is operating at rated capacity. As such, any treatment option that will continue to use the existing filtration plant as part of the expansion will likely require optimization to the existing process and a reduction in the functional capacity in order to consistently meet this target.

The reduction in the functional capacity through the existing facility requires the new facility to be designed to handle the expansion requirements plus the reduction in flow from the existing facility. Currently, the surface area of the existing 3 media filters results in a filter loading rate of approximately 12 m/hr (5 gpm/ft²) at full plant capacity. This loading rate is expected to be too high to achieve the required 0.1 NTU IFE target. However, by lowering this value to a more conservative value of approximately 8.1 m/hr (3.3 gpm/ft²), it is expected that the 0.1 NTU IFE turbidity design target could be consistently achieved. This would reduce the capacity of the existing facility from 45.5 to approximately 32 ML/d.

Another potential modification is to optimize the coagulation/flocculation process by increasing the coagulant dose and adding pH control capability. This may allow the existing filters to operate at higher loading rates, which would not require these filters to be de-rated as much. Currently, the coagulant is dosed at 0.8 to 1.2 mg/L without any pH correction of the feed water, which is typically in the range of 7.8 to 8.2. However, the optimum pH for coagulation with PACl (polyaluminium hydroxychloride) is typically 6.5 to 7.0, and operating outside that pH range can significantly reduce the effectiveness of the PACl and can lead to higher aluminum residuals in the treated water. Adding pH correction with an acid upstream of coagulant addition could significantly improve the effectiveness of the coagulation process, resulting in a reduction in filter effluent turbidity and organics, and reduce the amount of residual aluminum. Also, as mentioned in Technical Memorandum No. 2, jar testing has shown that a PACl dose of approximately 2.5 to 5.0 mg/L could significantly improve the treated water quality.

The addition of acid to lower the pH for coagulation would also result in the need for a caustic dosing system to raise the pH before the treated water enters the distribution system in order to inhibit pipe corrosion.

Final design loading rates and the need for optimization of the coagulation and filtration process will be determined during design with jar and pilot testing. For the purpose of TM No. 4, we have assumed that optimization to the filter loading rate and coagulation process would allow the existing treatment plant to achieve the target effluent turbidity of 0.1 NTU IFE, improve removal of organics, and would likely reduce aluminium residuals.

2.3 Site Considerations

The existing WTP occupies approximately 20% of the area at the City-owned property, which has a total area of approximately 3.9 Ha. The WTP expansion alternatives developed in TM No. 4 were based on construction within the City's property boundaries.

The site is generally flat with a gentle slope towards Lake Ontario. Bedrock is assumed to be very shallow (approximately 1 m below grade), based on conditions encountered during previous construction. Ground water is likely to be slightly higher than the lake level.

3.0 TREATMENT TECHNOLOGY ALTERNATIVES

There are currently many treatment technologies available that can meet the capacity and water quality demands of the expansion to the Point Pleasant Water Treatment Plant. Each technology offers a unique treatment method, and has advantages and disadvantages based on the requirements of this particular project. Table 2 provides a brief summary of the long-list of available alternatives that could be applied for the expansion of the existing Point Pleasant WTP. Advantages and disadvantages tabulated here are specific to the application of the treatment technologies to this expansion.

Table 2 – List Of Available Treatment Technologies For The Expansion Of The Point Pleasant WTP

Individual Treatment Process	Available Water Treatment Plant Design Options	Advantages	Disadvantages	Carried Forward for Further Evaluation for Point Pleasant WTP Expansion?
Conventional Filtration (Coagulation, Flocculation, Sedimentation, Filtration)	<i>Dissolved Air Flotation (DAF) Clarification or Actiflo Clarification or Gravity Settling + Media Filtration</i>	<ul style="list-style-type: none"> - Excellent total organic carbon/turbidity removal for good quality water sources - Lower disinfection requirement (higher pathogen removal credit) - Increased filter loading rates, leading to possibly smaller media filters 	<ul style="list-style-type: none"> - Larger overall footprint - Higher capital and operating costs due to multiple technology approach - Change from existing treatment process - Additional chemical systems (polymer for Actiflo) - More complex process - Expansion to residual treatment required 	NO
Direct Filtration	<i>Coagulation + Flocculation + Media Filtration</i>	<ul style="list-style-type: none"> - Consistent with existing treatment process - Very similar to existing design - Lower operating costs - Taste and odour removal possible with GAC 	<ul style="list-style-type: none"> - Less flexibility for meeting future regulations - “Medium” footprint - Higher disinfection requirement (lower pathogen removal credit) - Expansion to residual treatment required 	YES
	<i>Membrane Filtration</i>	<ul style="list-style-type: none"> - Smaller footprint - Excellent turbidity removal - No additional coagulation chemicals required - Likely no additional waste treatment facilities required - Higher flexibility to meet future water quality regulations 	<ul style="list-style-type: none"> - Different technologies for each half of the plant - No significant total organic carbon removal - Higher operating costs - No additional pathogen removal credits available due to blending with existing plant effluent - Does not address taste and odour 	YES

Table 2 – List Of Available Treatment Technologies For The Expansion Of The Point Pleasant WTP

Individual Treatment Process	Available Water Treatment Plant Design Options	Advantages	Disadvantages	Carried Forward for Further Evaluation for Point Pleasant WTP Expansion?
Disinfection	<i>Chlorination</i>	<ul style="list-style-type: none"> - Consistent with existing treatment process - Can maintain existing chlorine gas equipment - Lower operating costs 	<ul style="list-style-type: none"> - Less flexibility for meeting future regulations - May require more chlorine contact to achieve required CT - Potential for disinfection by-products 	YES
	<i>UV Disinfection</i>	<ul style="list-style-type: none"> - Lower chlorine dose for disinfection - Higher flexibility to meet future water quality regulations - No additional treated water storage for CT - Lower potential for disinfection by-products - Taste and odour removal available 	<ul style="list-style-type: none"> - Higher capital and operating costs - Energy intensive process - Operators unfamiliar with technology - Booster pump likely required - Higher footprint - Additional standby power required 	YES
Advanced Treatment Processes	<i>Ozone + Biologically Activated Carbon Contactors + Membrane Filtration</i>	<ul style="list-style-type: none"> - Superior multiple barrier approach - Addresses any taste and odour - Excellent turbidity removal - Lower chlorine dose - No coagulation chemicals required - High level of flexibility to deal with future regulations 	<ul style="list-style-type: none"> - Very high capital and operating costs - Additional safety requirements due to ozone - Change from existing treatment process - Higher energy requirements - “Overkill” for low total organic carbon/turbidity source water 	NO

3.1 Selected Treatment Technologies

While there are many treatment technologies available to meet the requirements of the treatment plant expansion, many of them are not considered to be economically, spatially, or practically feasible for the expansion of the Point Pleasant WTP. Based on a mainly qualitative review of the options presented above, there are three main treatment technologies that are potentially suitable and will be considered further for the expansion of the Point Pleasant Water Treatment Plant.

3.1.1 Option 1 – Direct Filtration with Chlorine Disinfection

As described in previous technical memoranda, the existing plant currently uses direct filtration (coagulation-flocculation-filtration) with chlorine disinfection as the treatment process. One of the proposed viable options for the expansion is to keep the existing system, and provide an additional, new direct filtration system that will essentially be a duplicate of the existing direct filtration treatment system to provide the increased plant capacity. This would involve providing additional rapid mix tanks, flocculation tanks, media filters, process waste residuals handling facilities, and possibly additional treated water storage, to allow the entire WTP to reliably treat 80 ML/d. Figure 1 provides a simplified flow schematic for this treatment option.

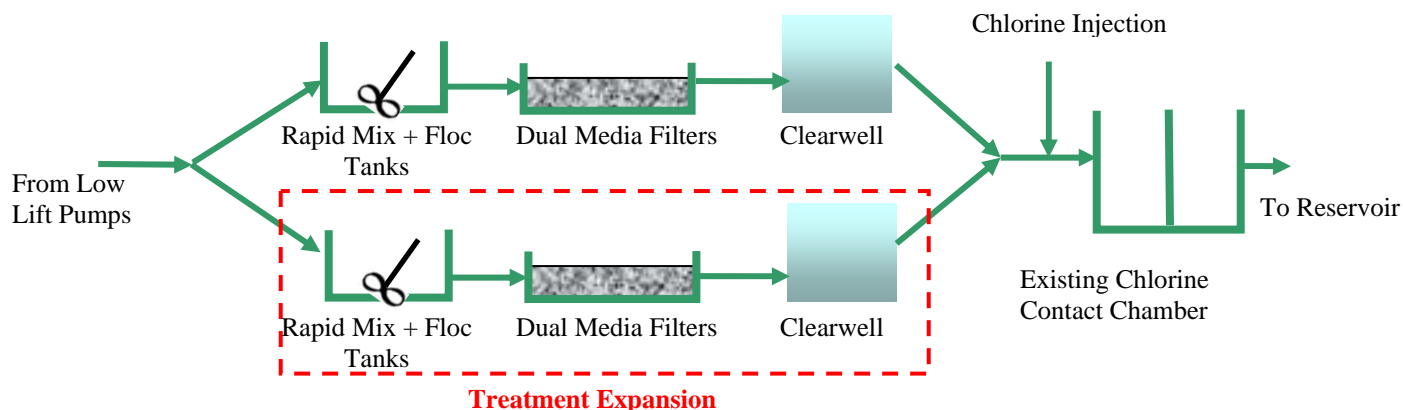


Figure 1 – Simplified Schematic Of The Point Pleasant Water Treatment Plant Expansion Using Direct Filtration With Chlorination.

Direct Filtration Expansion

The design of a new direct filtration facility would allow for simple design changes regarding rapid mix and flocculation retention times, filter media configuration and depth, filter underdrain style and hydraulic profile that would result in optimized process performance. This would provide optimum turbidity and organics removal while maximizing flow through the facility. It has the added advantage that a system of similar flow and effluent water quality requirements is already present at the water treatment plant.

Upgraded processes upstream of the direct filtration system would be used to move the 80 ML/d of raw water to the existing and new direct filtration treatment areas (a detailed description of the modifications to the existing raw water pumping process is provided in Technical Memorandum No. 3). Once the coagulant has been injected, the total raw water flow would be split amongst the two direct filtration processes. The filter effluent from each direct filtration process would then recombine and flow to the chlorine contact tank and reservoir.

Disinfection

Completing the expansion using direct filtration process will provide water that meets filter effluent turbidity requirement that will allow the plant to achieve the 2.0-log (99%) removal of *Giardia* and *Cryptosporidium*, and 1.0-log removal (90%) removal of viruses. To achieve the remaining *Giardia* and virus log removal requirements, chlorine disinfection will continue to be used. The level of disinfection achieved using chlorine depends on both the concentration of chlorine used, and the amount of time the chlorine has to work on pathogens in the water. A common measure of this combination of concentration and time used in the water treatment industry is CT, which is simply the concentration multiplied by the contact time. Using the existing chlorine contact tank as the means of achieving the required CT for the additional 1-log inactivation of *Giardia* and 3-log (99.9%) inactivation of viruses, the chlorine residual at the exit of the chlorine contact tank would have to be maintained at a minimum of 1.6 mg/L, at the total expanded plant flow of 80 ML/d (under worst case temperature and pH conditions). This increased chlorine dose requirement for CT is not expected to result in any additional equipment associated with primary disinfection, as the existing chlorinator currently used for chlorination in the chlorine contact tank has enough capacity to provide a chlorine dose of 2.3 mg/L at 80 ML/d.

It also must be noted that this chlorine dose requirement of 1.6 mg/L is under the worst-case conditions of full plant capacity at the minimum temperature. This is traditionally not experienced at the Point Pleasant WTP, as the maximum plant flow is mostly only required in the summer during peak water demand season. A typical chlorine dose for the plant expansion would be in

the range of 0.4 to 0.6 mg/L, to meet the CT requirement at 20°C of approximately 25 to 27 mg/L-min. This would be easily achievable with the existing chlorination and chlorine contact tank system.

Water Quality

As with the existing direct filtration process, in order to meet the 0.1 NTU effluent turbidity objective, a new direct filtration facility would be subject to the same design constraints of a modified coagulation process, including an 8.1 m/hr (3.3 gpm/ft²) loading rate, a higher coagulant dose, and a pH control system. The new media filters would also need to be designed to account for the reduction in the existing plant capacity rating. This would require the new facility to be designed for a net capacity of 48 ML/day, allowing for a total plant capacity of 80 ML/day.

Process Waste Residuals

The addition of new media filters for the increase in plant flow will result in more process waste from filter backwashing. Since the backwash wastewater will contain coagulated solids (as with the existing treatment process), it will need to be treated to allow the water to be sent back to the lake. Sludge from this wastewater will be disposed of in the sanitary sewer system. Although backwash waste treatment facilities are currently available, they are inadequately sized to handle the combined backwash waste that will be generated by the existing and new filters. As such, additional waste handling facilities, as well as transfer piping and pumping, will need to be constructed as part of the expansion.

3.1.2 Option 2 – Direct Filtration with Ultraviolet Disinfection

Another option available for the plant expansion is to provide a duplicate direct filtration system for the expanded plant flow (as in Option 1), but supplement the existing chlorine disinfection system with an ultraviolet disinfection system for the entire 80 ML/d expanded plant flow. This would involve the same equipment modifications outlined in Option 1, except that the primary disinfection would be provided through ultraviolet (UV) light and chlorination. Once the process water exits the media filters, it will pass through the UV disinfection system prior to entering the chlorine contact tank and reservoir. Chlorination would still be used for virus inactivation and distribution system residual maintenance.

Ultraviolet disinfection is a process that involves subjecting treated water to moderate doses of ultraviolet light in order to inactivate pathogens. Although the pathogens are often not destroyed outright, their ability to reproduce is destroyed, rendering them harmless. The UV light is

administered to the treated water directly in the process piping, with the use of UV lamps and detection equipment. The UV dose is controlled by the number and intensity of the UV lamps, and is generally modulated in response to the change in flow.

Figure 2 provides a simplified flow schematic for direct filtration and UV disinfection treatment option.

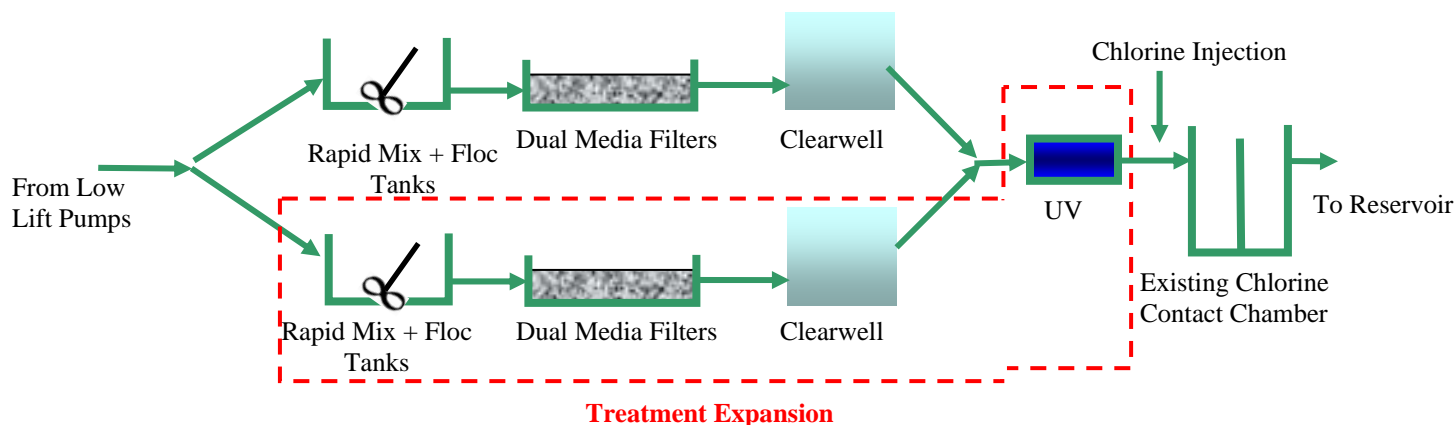


Figure 2 – Simplified Schematic Of The Point Pleasant Water Treatment Plant Expansion Using Direct Filtration And UV Disinfection.

Direct Filtration Expansion

The direct filtration details of this system are identical to those outlined in the previous section for Option 1.

Disinfection

Primary disinfection for the inactivation of *Giardia* would be achieved with the UV disinfection system. Chlorination would still be required to provide virus inactivation, and to maintain a disinfectant residual in the distribution system for secondary disinfection. However, the chlorine dose for inactivation would be significantly lowered as it would only be required to provide the CT for the additional 3-log virus inactivation. This could allow some of the chlorine contact tank to be used as on-site storage. The UV system would also provide the flexibility to provide additional pathogen inactivation if degraded water quality is experienced in the future, or if more stringent pathogen removal regulations are enacted.

The UV units could be installed on either the effluent piping from each individual filter, or to the combined filter effluent piping, resulting in a smaller number of large diameter UV reactors.

Anticipated headloss through the UV reactors would likely prevent gravity flow from the filters to the clearwell, through the UV units. As such, it is likely that in-line booster pumping would need to be installed in order to allow 80 ML/d to flow from the clearwell to the chlorine contact tank.

To achieve the additional 3-log (99.9%) removal of viruses, a CT of 9 mg/L-min would be required, resulting in a required chlorine dose of 0.12 mg/L. This is significantly lower than the 1.6 mg/L chlorine residual currently maintained at the exit of the chlorine contact tank, and is therefore easily achievable with the existing disinfection system. The existing chlorine dosage is based on providing the disinfection requirements and maintaining adequate residuals throughout the distribution system. If the distribution system chlorine residual requirements could be lowered, the UV disinfection option would result in a significant reduction in the chlorine dosing requirements for the entire expanded treatment plant.

Water Quality

The main water quality details for this treatment option are identical to those outlined in the Water Quality section for Option 1. However, UV disinfection could allow for the use of an Advanced Oxidation process to further enhance the taste and odour removal currently provided by the granular activated carbon (GAC) media in the filters. UV disinfection can be combined with an oxidizing chemical, such as hydrogen peroxide, to eliminate many of the taste and odour causing compounds. This method will require the addition of an oxidizing chemical, along with a storage and feed system, which could easily be added in the future.

Process Waste Residuals

The details surrounding the process waste residuals of this system are identical to those outlined in the Process Waste Residuals section for Option 1.

3.1.3 Option 3 – Membrane Filtration with Chlorine Disinfection

Another available option for the expansion of the Point Pleasant WTP is to keep the existing direct filtration process and install a new membrane filtration facility to handle the additional flow required to meet the 80 ML/d expansion. Membrane filtration is a technology that uses a pressure differential (either pressure or vacuum) to force water through a microporous (very small openings) membrane filter to remove organics, turbidity, and waterborne pathogens. For pressurized systems, feed water is pumped into the membrane housing, where the pressure forces the water from the outside of the membrane to the inside, leaving behind the

contaminants on the membrane surface. For vacuum systems, the water is sucked through the membrane, leaving the contaminants on the outside surface of the membrane.

Raw water would be pumped to the filtration area using upgraded low lift pumping, where the flow would be split (prior to coagulant addition), with a portion going to the existing filtration building and the remainder going to the new membrane filtration facility. After the clean water passes through the membrane, it must be disinfected, as membranes do not provide the required disinfection. The membrane filtered water exits the filtration area, recombines with the media filtration effluent, and flows into the chlorine contact tank and reservoirs. Figure 3 provides a simplified flow schematic for the membrane filtration and chlorine disinfection treatment option.

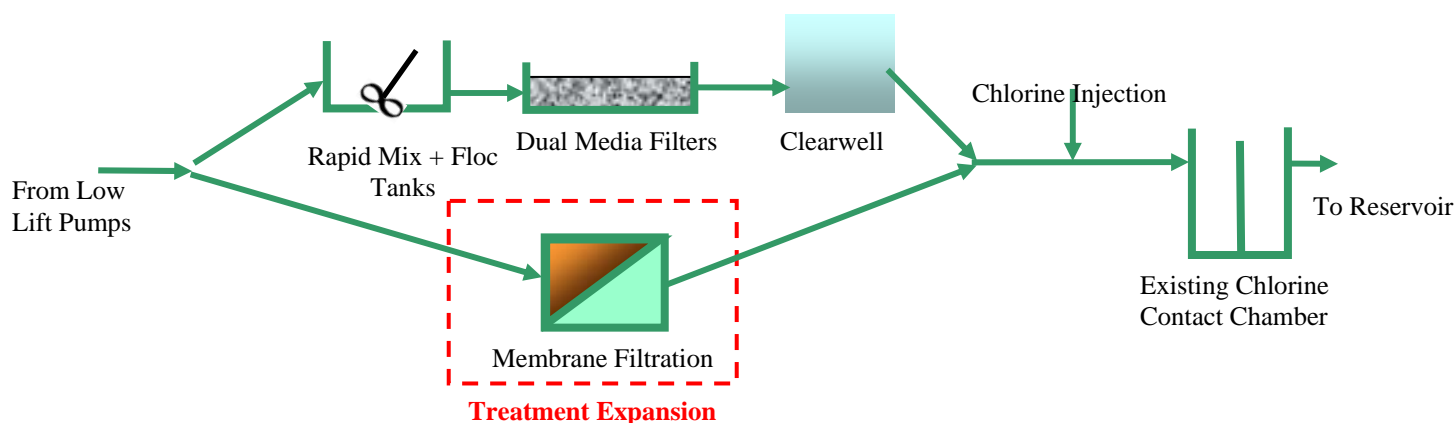


Figure 3 – Simplified Schematic Of The Point Pleasant Water Treatment Plant Expansion Using Membrane Filtration And Chlorine Disinfection.

There is less benefit of a UV disinfection system for this option than with direct filtration, since the primary disinfection requirements are much lower due to the higher removal credit achieved with membranes. Therefore, only the chlorine disinfection was considered.

Membrane Filtration

The effective surface water contaminant removal capability of a microfiltration (MF) or ultrafiltration (UF) membrane is related to the small pore size associated with the membranes. As shown in Figure 4, depending on the specific manufacturer, MF has a membrane pore size of approximately 0.1 to 1.0 μm , and UF has a membrane pore size of approximately 0.01 to 0.1 μm . This is 10 to 100 times smaller in magnitude compared to what typical media filtration can provide. While this does provide limited improvement in turbidity and organics removal, it significantly increases the pathogen removal capabilities compared to a conventional filtration system.

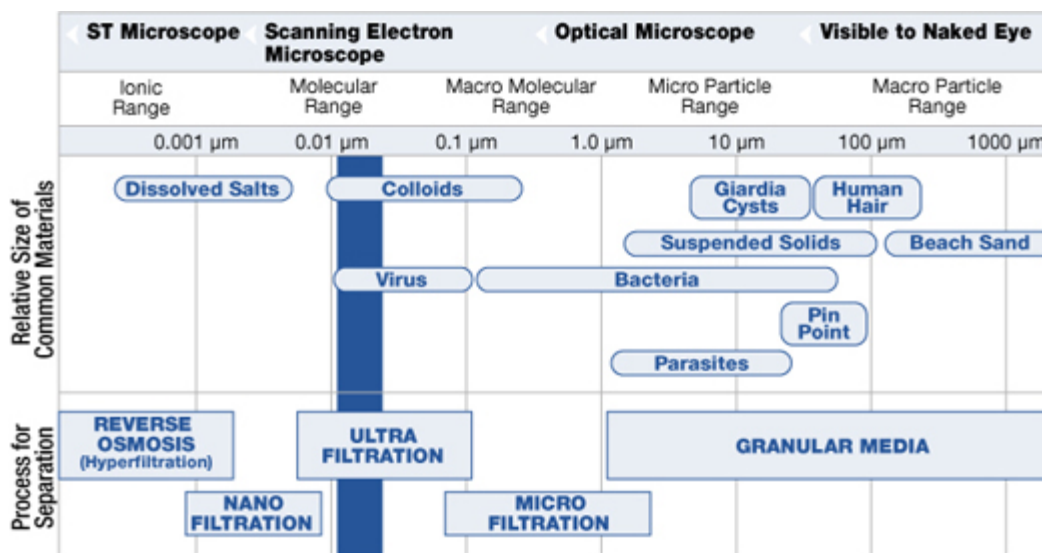


Figure 4 – Pore Size Range For Various Membrane Filtration Technologies.

Membrane filtration systems operate at relatively high liquid loading rates, making them a high efficiency, high rate filter, allowing for a greater treated water capacity within a smaller footprint. However, as membrane filters are high efficiency filters, they typically operate at a higher headloss (2 to 40 psi vacuum or pressure), commonly referred to as transmembrane pressure, and require frequent backwashing (typically every 30 to 60 minutes). The backwash waste contains only concentrated feed water contaminants, will most likely not require any additional treatment, and can be sent directly back to Lake Ontario².

Membrane filtration systems also require additional ancillary equipment for verification of membrane integrity. Any leaks, breaks, or defects in the membrane that are larger than the membrane pore size must be readily identified. This is accomplished using pressure decay-based air testing with a compressed air system.

Periodically, chemical cleaning is used to remove stubborn cake layer fouling on the surface of the membrane, and cumulative pore fouling not removed by backwashing alone. Typically, every 30 to 60 days, the membrane system undergoes a two step chemical soaking/recirculation cleaning regime with high pH and low pH chemicals (typically chlorine and citric acid).

² This will require discussion with the MOE. However since the solids level is expected to be less than 25 mg/L, and there is no pre-treatment, it is expected that the MOE will allow this.

Disinfection

Membrane filtration can provide up to 4.0-log (99.99%) removal of *Cryptosporidium* and *Giardia*. However, Ontario regulations require that regardless of the filtration technology, at least 0.5-log (68.4%) removal/inactivation of *Giardia* must be provided by disinfection. In addition, the Ontario Ministry of the Environment (MOE) does not credit membrane filtration with any virus removal. In order to provide the required level of disinfection, chlorination will continue to be used for the membrane filtration expansion option. Currently, the disinfection system is designed to provide a CT of 122 mg/L-minute at 1 mg/L of chlorine and a flow 45.5 ML/d. Considering the flow from the membrane system alone, to achieve the 0.5 log (68.4%) removal of *Giardia* (which will also provide much more than the required 4-log (99.99%) removal of viruses), the required CT at 1 mg/L of chlorine is 51 mg/L-minute. Unfortunately, the effluent from the membrane system cannot be considered alone, as it will be combined with the effluent from the existing media filters. Since the media filters are only credited with 2-log (99%) removal of *Giardia*, a 1-log (90%) inactivation of *Giardia* would still be required; and since this water is blended with the membrane effluent, the entire 80 ML/d of expanded WTP flow must have a chlorination CT associated with 1-log (90%) removal of *Giardia*. As outlined in Option 1, with the existing chlorine contact tank, this will require an increase in the chlorine dose to 1.5 mg/L, and essentially eliminates the higher log removal credit achievable with membrane filtration.

Water Quality

As mentioned, membranes provide excellent suspended organics and turbidity removal due to their small pore size. As such, membrane filtration can provide treated water effluent turbidity that will easily meet the 0.1 NTU effluent turbidity target outlined in Technical Memorandum No. 1. However, since the membrane system will only be used to treat the additional water required for the expansion, the membrane effluent will be blended with the effluent from the media filters. As mentioned in the previous sections, there are a number of modifications required to the existing facility in order to achieve the 0.1 NTU IFE (Individual Filter Effluent) target for the existing system, including a reduction in the capacity of the existing filters. Although the membrane filtration option would limit the loading rate and pH dosing modifications to the existing facility, it would also require a membrane filtration system designed to handle the expanded plant flow along with the loss in capacity of the existing filters. This would require the membrane filtration system to be designed to have a capacity of 48 ML/day.

While membrane filtration provides suspended organics and turbidity removal, the lack of any pre-treatment upstream of the membranes means membrane filtration is not expected to provide any significant removal of dissolved organic carbon (DOC).

Organic carbon removal has an effect on the formation of disinfection by-products in the distribution system. Since the membrane filtration option is not expected to provide any significant dissolved organic carbon removal, it is possible that there would be an increase in the disinfection by-products in the distribution system, even when the membrane filtration water is blended with the existing media filter effluent. However, since the raw water DOC is quite low, averaging only 2.1 mg/L in 2007, the lack of additional DOC removal provided by the membranes is not expected to raise the disinfection by-product levels in the distribution system beyond the current regulations outlined in Technical Memorandum No. 1.

Taste and odour issues will also not be addressed with a membrane filtration system. Without a pre-treatment system or polishing treatment, traditional taste and odour compounds pass through membrane pores and into the distribution system, leading to possible taste and odour problems. Additional pre-treatment chemicals such as an oxidant or powder activated carbon (PAC) would be required if taste and odour issues are experienced, adding additional cost, waste, and complexity to the membrane system.

Process Waste Residuals

The addition of a membrane filtration system for the water treatment expansion would result in more process waste from backwashing. However, as outlined earlier, if there is no pre-treatment chemical addition, the backwash waste is comprised only of concentrated feed water solids. Assuming that the membrane system is operated at 95% recovery, the waste will be approximately 20 times higher in solids than the feedwater. Historical feed turbidity suggests that this concentrated waste would be around 20 mg/L of Total Suspended Solids (TSS) (assuming 1 mg/L of TSS per NTU of turbidity, a common comparison for Lake Ontario water). Most water treatment plants discharging to Lake Ontario are allowed to discharge 25 mg/L TSS, as long as the discharge is away from the shoreline. The membrane filtration facility would, therefore, not require any modifications to the existing waste handling facility, and may only require a means of conveyance further away from the shoreline than the existing piping provides.

4.0 EVALUATION OF SELECTED TREATMENT TECHNOLOGY ALTERNATIVES

The three treatment technology alternatives outlined in Section 3 provide distinct advantages and disadvantages for the expansion of the Point Pleasant Water Treatment Plant. In order to determine the best option for Utilities Kingston, the advantages and disadvantages in five (5) distinct areas will be examined, including:

- Capital and overall lifecycle costs
- Constructability and integration with existing plant
- Flexibility of the process to meet future needs
- Treated water quality
- Operability and Maintenance

Table 3 outlines a summary of these five evaluation criteria for each of the three proposed treatment options, based on the design parameters outlined in Section 3.0.

Table 3 – Summary Of The Short-List Treatment Options For The Expansion Of The Point Pleasant WTP

Treatment Option	Lifecycle Costs ^{1,2}	Advantages	Disadvantages
Option 1: Direct Filtration + Chlorine Disinfection	Capital³: \$20 – 26 million Total O&M: \$350,000 – 500,000/yr Total NPV: \$24 - 32 Million	<ul style="list-style-type: none"> - Easy to integrate with existing direct filtration plant compared to membrane filtration option - Allows for re-use of existing backwash equipment - Provides moderate level of total organic carbon removal, reducing DBP precursors - Operators are familiar with existing process - Lower operations and maintenance requirements compared to other two options 	<ul style="list-style-type: none"> - May require excavation for a new clearwell - Limited inherent flexibility to meet potential future pathogen removal and effluent turbidity requirements - Larger footprint compared to membrane filtration option - Requires significant process optimization to achieve effluent turbidity and aluminum targets - Requires expansion of existing residuals handling facilities - Higher chlorine dose required to achieve pathogen inactivation requirements compared to UV option
Option 2: Direct Filtration + UV Disinfection	Capital⁴: \$22 - 28 Million Total O&M: \$400,000 – 550,000/yr Total NPV: \$26.5 - 34 Million	<ul style="list-style-type: none"> - Similar to Option 1 (easy to integrate, backwash equipment re-use, operator familiarity with filters) - Provides flexibility to increase pathogen inactivation to meet possible future regulations - Adds an additional “barrier” available for the treatment process - Possibility of advanced oxidation for additional taste and odour control - Lower chlorine requirement for disinfection, decreasing potential for DBPs. 	<ul style="list-style-type: none"> - Similar to Option 1 (excavation, larger footprint, process optimization, residuals facilities) - Requires additional space for UV reactors and control panels within the filter effluent pipe gallery - Requires additional standby power compared to Option 1 - May require additional booster pumping on filter effluent
Option 3: Membrane Filtration + Chlorine Disinfection	Capital⁵: \$15.5 – 22 Million Total O&M⁵: \$360,000 – 530,000/yr Total NPV: \$20 - 28 Million	<ul style="list-style-type: none"> - Smaller footprint compared to media filter option - No additional clearwell excavation - Much less, if any, additional residual handling facilities required - Membrane facility will meet effluent turbidity requirements regardless of feedwater quality - Membrane facility provides flexibility to meet potential future pathogen removal requirements 	<ul style="list-style-type: none"> - More difficult to integrate with existing DF facility compared to media filter option - Requires significant chemical and process optimization for existing DF facility - No significant DOC removal with membrane filtration process - Higher operation and maintenance requirements and more instrumentation and control intensive compared to media filters - Requires additional standby power compared to media filtration - Operations staff are not familiar with membrane filtration, and requires much more involvement than media filtration

¹ These costs are an estimate of the opinion of probable costs and are intended to serve only as order of magnitude pricing for the purposes of comparing options. The range represented is a -10%/+30% range. These do not include any low lift or high lift pumping upgrade costs.

² All lifecycle costs are based on a 20 year lifecycle at a 6% discount rate and running the plant at 80 MLD continuously. These do not include any low lift or high lift pumping costs.

³ These costs include pre- and post-treatment pH control systems (entire plant), media filters, a flocculation system, a clearwell, and waste handling facilities. Backwash pumping costs are not included.

⁴ These costs include pre- and post-treatment pH control systems (entire plant), media filters, a flocculation system, a clearwell, waste handling facilities, and a UV disinfection system. Backwash pumping costs are not included.

⁵ These costs include the membrane filtration system and the pre- and post-treatment pH control system for the de-rated existing filtration plant only. Backwash pumping, additional standby power costs and any possible backwash waste conveyance systems are not included

4.1 Capital and Life Cycle Costs

When examining the overall NPV, the costs for the three options are similar, considering these as economy of scale estimates. The capital costs associated with equipment and construction are higher for the media filters, due to the clearwell needs, pretreatment chemical dosing, and additional waste handling facilities (the costs for the media filters alone are significantly less than the membrane system). Although the membrane system will not require any of this equipment, there are a number of systems that could be required (such as feed and treated water equalization, or waste equalization) that are not included in the costs outlined. These systems could significantly increase the capital costs of the membrane system.

The power costs for the membrane system are also much higher than for the media filters alone, due to the requirements associated with the additional pumping needed for the membrane system. However, the yearly chemical costs associated with the pH control system surrounding the media filters nearly offsets the negligible power costs of the media filters.

The increased chlorine dose for the chlorination option requires no capital investment. As such, the costs associated with the increased chlorine usage are negligible, less than \$5000 per year, compared to the UV system, which has an O&M cost of approximately \$53,000 per year.

Examining the above information, the NPV costs for each of the systems are similar, resulting in no clear advantage for any option regarding overall costs.

4.2 Constructability and Integration

The existing treatment facility is a direct filtration system that has been in operation for nearly 40 years. Upgrading the system with more of the same technology of nearly the same capacity could provide a substantial advantage regarding system design requirements and integration. The previous plant expansion, completed in 1985, added a new direct filtration train that was integrated into the overall plant design, which could provide additional insight for this proposed expansion project if filters were the technology used for the expansion.

Installing a membrane system would allow for a smaller footprint for the expansion (as the membrane building would be smaller and no additional waste residual handling would be required), and would not require any significant excavation costs, potentially an advantage for construction given the expectation of the presence of rock at shallow depths. However, there is not a shortage of land required at the Point Pleasant WTP for the expansion to 80 ML/d, leaving plenty of area for any technologies to be feasible from a required footprint standpoint. The

membrane filtration system would also require moving the chemical dosing point from the existing location, resulting in added costs and longer chemical dosing lines.

Since membrane systems often have large and rapid fluctuations in treated water flow (due to the frequent backwash requirement), hydraulic integration of the membrane system with the existing plant could also prove to be difficult.

The installation of a UV system could pose some constructability challenges, as the reactors would be installed directly in-line of the existing (and new for the expansion) filter effluent piping. Since this area is constricted, it could prove to be difficult installing the reactors in this area. However, an arrangement of the three UV reactors could be installed to disinfect the combined effluent flow (the existing and new filtration combined), which would not be as space constrictive as the individual filter effluent option. The three UV reactors would require booster pumping. Increasing the existing chlorine dose for the required disinfection for the expansion would have no appreciable effect on any system or construction activities.

Examining the information presented above, media filters with chlorination is likely to be a better choice for the expansion of the Point Pleasant Water Treatment Plant in regards to constructability and integration. While membrane filtration provides some footprint advantages, these advantages are not significant driving forces for the Point Pleasant Water Treatment Plant, and the added complexity of unique and separate treatment trains is not desirable. UV disinfection will also have many spatial integration challenges, but should still be considered for future expandability to provide flexibility in the event of water quality or regulatory changes. Integration and design of the same as existing media filtration and disinfection technology will provide for an easier transition to higher plant capacity.

4.3 Flexibility

As water treatment facilities tend to be in service for many years, flexibility to deal with any future water quality and pathogen reduction requirements is a key consideration. As water quality demands increase, source water quality becomes worse, and effluent water quality regulations become more stringent, the ability of a technology to deal with these issues is an advantage. While media filtration and chlorination are well established technologies, they have limited options available to easily deal with such changes. While filter depth, filtration area, media type, and under-drain type can be modified, these modifications can require additional capital cost investment, depending on how the system is designed. However, chlorine dosages can be increased easily, as long as the chlorination system is sized to handle such increases.

Membrane filtration is a fairly new technology that provides relatively consistent pathogen removal and effluent water quality, regardless of source water quality. Since these systems are relatively new, they are inherently designed with future considerations in mind, making flexibility one of their key components. Since membrane systems have many associated operational strategies (backwashing, aeration, and chemical maintenance and recovery cleaning), there are many parameters that can be quickly and cost effectively modified and optimized to deal with unexpected changes or potential future requirements.

UV systems also fall into this category, as space and infrastructure remain the same, and only the internal lamp components change to deal with increased pathogen reduction requirements. Pathogen inactivation capabilities can be increased with a change of lamp types and intensity of UV light, having little effect on the overall design of the plant.

While a media filtration system with either chlorine or UV disinfection does provide flexibility, the membrane system provides a higher level of flexibility. However, this flexibility is somewhat diminished as the membrane effluent will be combined with the existing media filter effluent. For this reason, there is only a small, if any, advantage to the membrane filtration option.

4.4 Treated Water Quality

The treated water quality available from either the direct filtration process or the membrane filtration process will meet the current Ontario guidelines. As mentioned earlier in the report, both the membrane filtration system and the media filtration system can achieve the 0.1 NTU effluent turbidity target. However, the increased chemical dosing requirements and de-rating of the existing plant for the media filtration option negate the cost advantage that would be achieved with media filters alone.

A membrane system will not provide any significant DOC removal, whereas the coagulation/flocculation that would be part of the direct filtration option would continue to provide a moderate level of DOC removal, ensuring a consistently low level of disinfection by-products in the distribution system. This, however, is only a limited advantage to the media filtration option, as the historical raw water DOC is fairly low, suggesting that the membrane filtration option would most likely not result in an increase in the disinfection by-products beyond the current regulations.

Examining the expected water quality provided by each option, there is no distinct advantage for either option, as all three are capable of providing water quality that will meet the required 0.1 NTU design target.

4.5 Operability and Maintenance

As with any water treatment system, the ease of operation and maintenance is of key importance to the operations staff responsible for operating the system, and is a very important consideration for the Point Pleasant WTP expansion. The existing direct filtration system has been in operation for many years, allowing the operations staff to become very familiar with the overall operation and optimization of a direct filtration facility for this water source. Completing the expansion with the same basic technology is an attractive option, as WTP staff are already familiar with the system operation. A direct filtration system with chlorination also has less components and less functionality than a membrane or UV system, resulting in less overall maintenance for a direct filtration system for the operators. Extensive training would also be required in order for the operators to become as familiar with these new treatment processes as they are with the existing treatment process.

The advantage to a membrane filtration system and UV disinfection systems is that nearly all of the operations are completely automated. Membrane systems also provide automated data logging of a number of process parameters required for not only operation, but verification of proper membrane process optimization (such as permeability recovery, membrane fouling rates, chemical consumption, etc.). However, since the system has such a high level of automation, there are many components on the system (valves, pumps, compressors, etc.), resulting in a higher risk of component failure. Membrane systems also require fibre repairs as part of the regular maintenance schedule, an activity that can have significant time requirements; something not required for media filters.

The membrane filtration option will result in two different treatment technologies at the water treatment plant. This could result in operational challenges that would not be experienced if there was only one treatment technology throughout the plant. Common systems, such as backwash pumps and blowers, will likely not be able to be used between the two different systems. Since this option would involve the implementation of two distinct technologies, there would be a reduced degree of redundancy, as compared to a system comprised of one technology.

The direct filtration with chlorination option would have an advantage over others, due to the familiarity of the operations staff with the direct filtration process and lower operations and maintenance requirements for a membrane filtration system and a UV disinfection system.

5.0 SELECTED TREATMENT ALTERNATIVE

A review of the three short-listed options has been presented in this Technical Memorandum. Based on the information outlined, the recommended choice for the expansion to the Point Pleasant Water Treatment Plant is Direct Filtration with Chlorine Disinfection. As discussed, this treatment option is the most favourable overall selection regarding cost, constructability and integration, flexibility, water quality, and operability.