Stantec

Woodward 3rd Party Review – Process Risks Review

June 22, 2023

Prepared for:

City of Hamilton

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Executive Summary

Stantec Consulting Ltd. was retained by the City of Hamilton (City) to conduct a 3rd party review of the proposed Phase 2 upgrades at the Woodward WTP. Recently, the City has undertaken a number of studies related to the Phase 2 upgrades project.

This report focuses on the risks associated with the proposed upgrades and preferred alternatives / technologies in terms of their suitability to achieve the desired objectives for the Phase 2 WTP Upgrades. In addition, the proposed construction staging, overall schedule, and potential impact to plant operations during the course of construction were reviewed with respect to maintaining water production and treatment objectives. Stantec's Comprehensive Performance Evaluation (CPE) approach was used to compare proposed technologies and their rated capacity to the overall rated capacity for the WTP to confirm that existing treatment bottlenecks are anticipated to be alleviated with the proposed upgrades.

The report concludes the following:

Table E-1: Risks and Recommendations

Problem / Risk	Recommendation	Report Section
The plant operates with frequent start-stop cycles, resulting in increased peak flows. During construction, these flows will result in elevated loading rates through sedimentation and filtration while trains are offline.	There is an opportunity to evaluate the total plant production requirements in an effort to peak-shave high plant flow operating scenarios to minimize performance and production risks during construction and operate the plant more in line with best practices.	2.1 – 2.3
Tertiary flocculation stage considered unnecessary	Remove tertiary flocculation stage from the Phase 2 upgrades scope.	2.3.1
The capacity risk of having one or two sedimentation basins offline is expected to be moderate. With two sedimentation basins offline, performance is expected to decline at flowrates greater than 130 – 260 MLD, dependent upon temperature. Higher settled water turbidity could result in shorter filter run times and greater risk of turbidity breakthrough.	Perform an extended full-scale stress test at a sedimentation loading rate between 1.2 and 2.0 m/h and filtration loading rate of 12 m/hr, and complete a full-scale trial using a sedimentation polymer aid. The polymer aid may allow sedimentation to operate at a higher loading rate. Additional details for process stress testing are included in Appendix F.	2.3.1
The capacity risk of having one filter quadrant offline during construction is expected to be minimal, however, having two filter quadrants offline could reduce plant capacity to 321 – 386 MLD.	Prioritize upgrades to the filtration process including upgraded underdrains and backwash technology, optimize the filter backwash sequence, and implement FTW infrastructure. Develop an SOP for operating the Woodward WTP with only two (2) filter quadrants (or 10 filters in service with 2 standby) where the potential plant capacity may be limited to approximately 320 MLD.	2.3.2

Problem / Risk	Recommendation	Report Section
At current loading rates, individual filter effluent turbidity goals are not always achieved.	Plant performance is in line with the AWWA Partnership for Safe Water Goals for the most part; however, there exists an opportunity to address the frequency of elevated average hourly filter effluent turbidity.	2.3.2
Disinfection credits may be limited under worst-case conditions during construction when one or two sedimentation basins are offline. Currently, the plant relies on CT through sedimentation for the majority of its disinfection credits.	Raise minimum pre-chlorine residuals through pre-treatment such that sufficient contact time is provided under cold water conditions with reduced sedimentation capacity. UV upgrades could be moved ahead in the schedule.	2.3.3
Concerns were presented regarding potential surcharging of the filter effluent channel access hatch during potential elevated flow scenarios during construction.	Stress testing, conducted in March 2023, with one filter quadrant offline demonstrated an operational bottleneck between 575 – 600 MLD due to chemical dosing restrictions. Surcharging in the filter effluent hatch was not observed during the stress test.	4

A risk matrix was developed to summarize the risks identified in this review, and present potential remediation strategies in Section 5.0.

Table of Contents

LIST OF TABLES

LIST OF FIGURES WITHIN THE REPORT

LIST OF APPENDICES

1.0 INTRODUCTION

1.1 BACKGROUND

The Woodward Water Treatment Plant (WTP) provides potable water for the City of Hamilton and some communities in Halton and Haldimand. The plant was originally constructed in 1931 and expanded in the late 1950s. The treatment process includes intake chlorination for seasonal zebra mussel control and year-round pathogen inactivation, screening, pre-chlorination for pathogen inactivation ahead of pre-treatment, coagulation with polyaluminum chloride (PACl), flocculation, conventional gravity sedimentation, granular activated carbon (GAC) filtration, post-filter chlorination for primary and residual disinfection, ammoniation to form chloramines for residual maintenance, and fluoridation. The current rated capacity of the WTP is 909 MLD, though the current expected maximum capacity is approximately 500 MLD.

In 2016, CH2M HILL (now Jacobs) completed a process unit performance review of the Woodward WTP to identify operational (including water quality), capacity or hydraulic restraints[1]. The review found the following:

- **Pre-Treatment and Sedimentation**: It was expected that process performance could not be maintained or sustained at plant flowrates above 250 MLD or during high raw water turbidity events. Operations' existing strategy is to shut down the plant when raw water turbidity is elevated.
- **Filtration**: based on historical data from 2013, the plant is meeting the regulatory criterion for the filters of ≤ 0.3 NTU 95% of the time in individual filter effluent turbidity readings; however, not all filters are able to meet ≤ 0.1 NTU in 100% of individual filter effluent turbidity readings in a calendar month, suggesting compliance with future regulations may be challenging. Existing plants flowrates were well below the 2041 projected maximum day flows of 650 MLD, and it is anticipated that future higher flow rates (and changing turbidity profile of the source water) will challenge filtered water quality due to the combined risks of declining sedimentation process performance and higher filter loading rates.
- **Disinfection**: year-round pre-chlorination is required to achieve *Giardia* inactivation. Post-filter inactivation alone for primary disinfection is not feasible due to the limited capacity of the existing clearwells.

In general, the 2016 report concluded that that the 2041 target plant production of 650 MLD could be achieved only under low source water turbidity (≤ 5 NTU) conditions. At sustained moderate raw water turbidity levels (5 – 15 NTU), the plant capacity was expected to be 500 MLD or less, and at sustained high raw water turbidity levels (≥ 30 NTU) the plant capacity was expected to be 300 MLD or less.

[1] Woodward Avenue WTP Final Summary Report – WTP Capital Works Implementation Plan. CH2M. April 2016.

1.2 PROBLEM STATEMENT

The proposed construction sequencing associated with Phase 2 upgrades at the Woodward WTP means some process units will experience elevated loading rates for several months. The ability of the WTP to continue to meet water quality and production requirements under high loading conditions requires review.

1.3 OBJECTIVES

This report reviews the proposed upgrades and preferred alternatives in terms of their ability to suit the desired objectives for the Phase 2 Upgrades. In addition, proposed construction staging, overall schedule, and potential impact to plant operations during the course of construction with respect to maintaining water production and achieving treatment objectives are presented.

1.4 APPROACH

An evaluation of flow sequencing and process risks associated with the pre-treatment, filtration, and disinfection upgrades is presented in Section 2.

The possibility of a temporary mobile system for additional sedimentation capacity was reviewed in Section 3.

An evaluation of flow scenarios associated with upgrades, including preliminary stress testing, is provided in Section 4.

A risk matrix was developed and is shown in Section 5.

Recommendations and conclusions are provided in Section 6.

2.0 EVALUATION OF FLOW SEQUENCING AND PROCESS RISKS ASSOCIATED WITH UPGRADES

This section presents a review of three (3) years of flow data (2019 to 2022) for each major WTP process unit, with the aim of evaluating process unit loading rates during future construction activities.

By defining process unit loading requirements during construction, process bottlenecks and associated performance and operational risks associated with the proposed construction sequencing can be identified and flagged for mitigation.

2.1 FLOW ANALYSIS (SCADA DATA)

Stantec reviewed hourly SCADA low lift pumping (LLP) and individual filter flow data from 2019 through 2022 as detailed below.

2.1.1 Determination of WTP Flowrates

Raw water low lift pump flow metering SCADA data and filtered water flow metering SCADA data were reviewed to assess WTP flows.

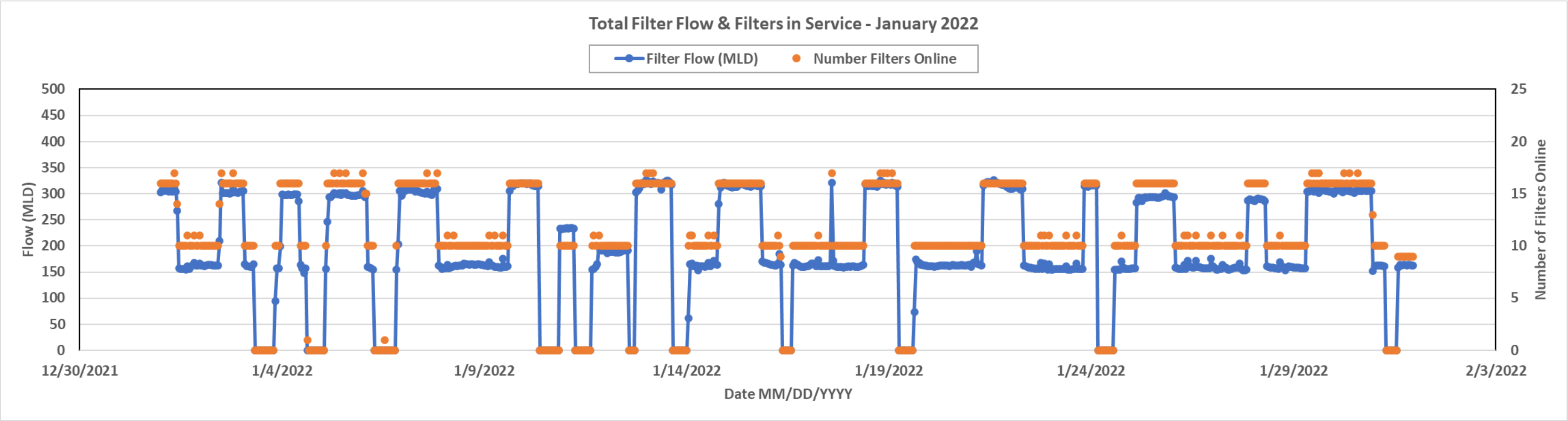
During the data evaluation, a discrepancy between total raw water flow and total filter flow was identified whereby total filter effluent flow values were higher than total raw water flow values. In consultation with the City, it was identified that there are known problems with the accuracy of the raw water flow metering (refer to Appendix B for additional supporting information).

In response to this observation, filter flows were used to evaluate flow conditions and associated process loading rates for all unit processes at Woodward WTP. For this reason, the following review focuses on filtered water SCADA data. Seasonal filter flow data for the period 2019 through 2022 was analyzed to assess the total number of filters online at any one time and the corresponding total filtered flow rate; this data is in Figure 2-1 for one month per season in 2022.

In addition to the data presented in Figure 2-1, the following observations were also noted form the review:

- The WTP was routinely offline, which occurred at a higher frequency in July and October,
- The WTP operates at a series of somewhat fixed flow set-points of 150, 250, 350 and 400 L/s.

Given that the plant operates in frequent start-stop flow sequences suggests that the WTP flow is responding to an equalization feedback signal from downstream storage and demand requirements.


Total Filter Flow & Filters in Service - January 2022
Filter Flow (MLD)
Number Filters Online
Flow (MLD)
Number of Filters Online
500
450
400
350
300
250
200
150
100
50
0
25
20
15
10
5
0
12/30/2021
1/4/2022
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1/14/2022
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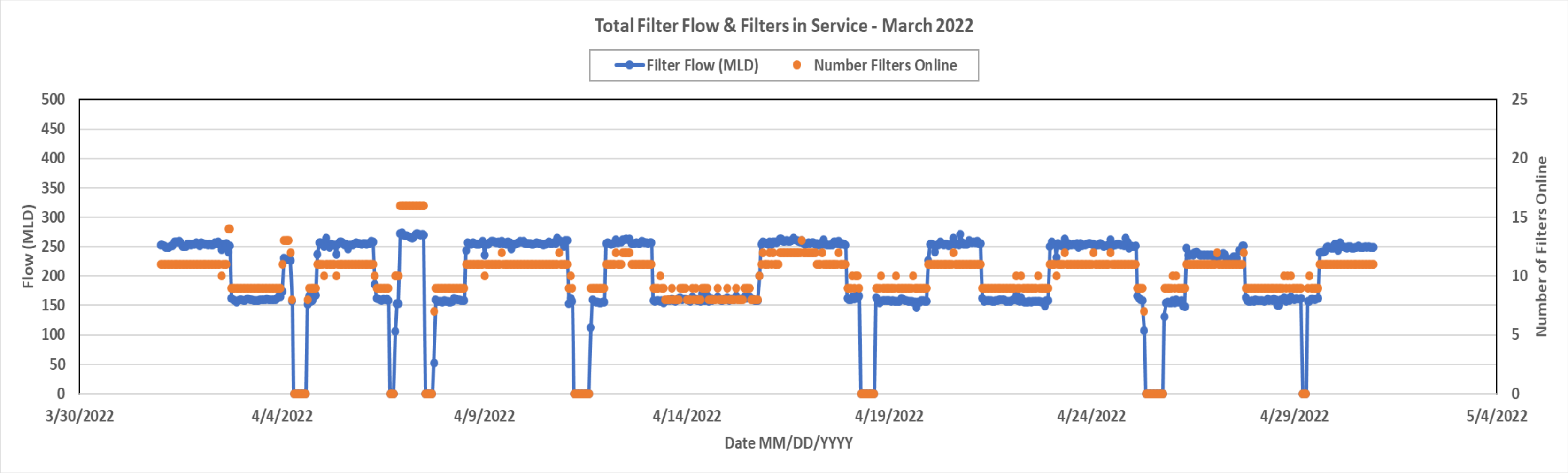
2/3/2022
Date MM/DD/YYYY


Total Filter Flow & Filters in Service - March 2022
Filter Flow (MLD)
Number Filters Online
Flow (MLD)
Number of Filters Online
500
450
400
350
300
250
200
150
100
50
0
25
20
15
10
5
0
3/30/2022
4/4/2022
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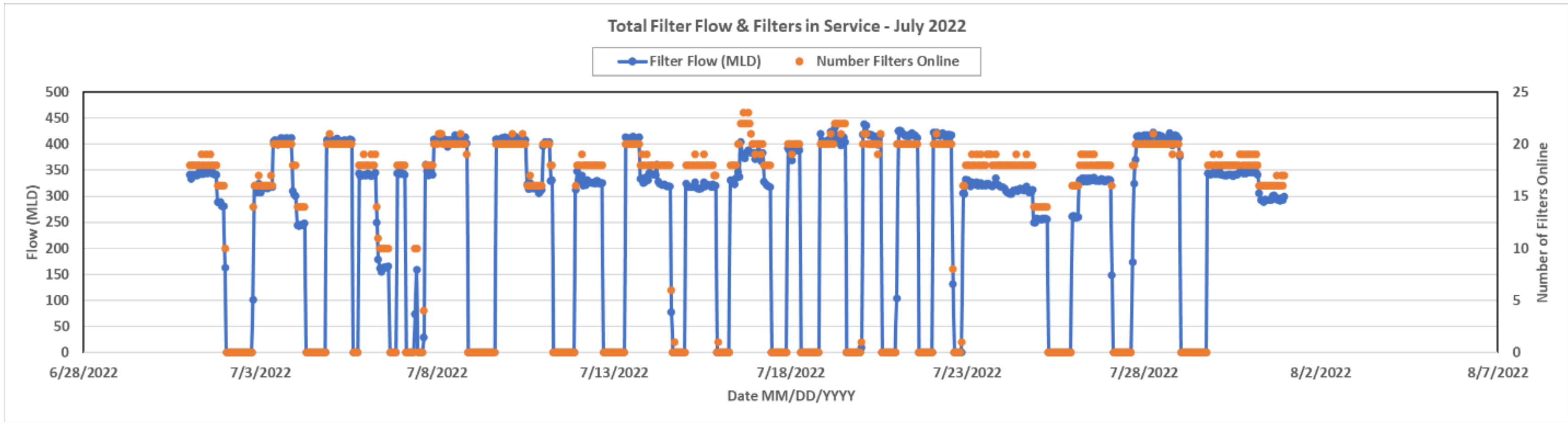

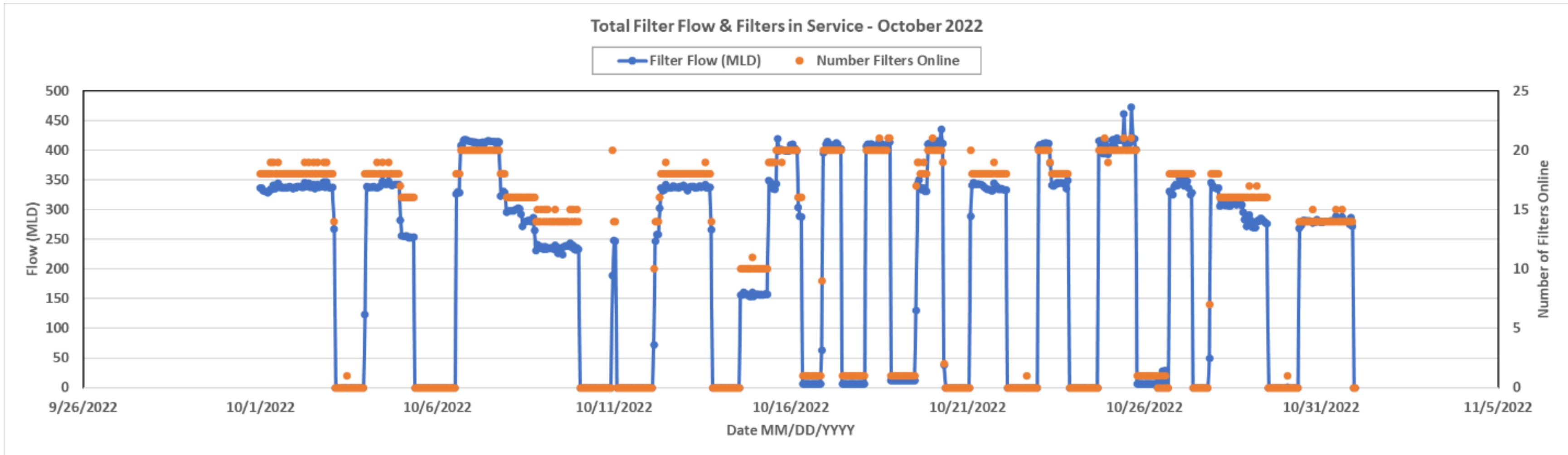

Figure 2-1: Seasonal Total Filter Flow and Number of Filters in Service for January, March, July and October 2022, respectively

To further evaluate seasonal flow operation, a scatter plot of average monthly flows and maximum monthly flows was created against raw water temperature for data provided from 2019 through 2022 as shown in Figure 2-2.

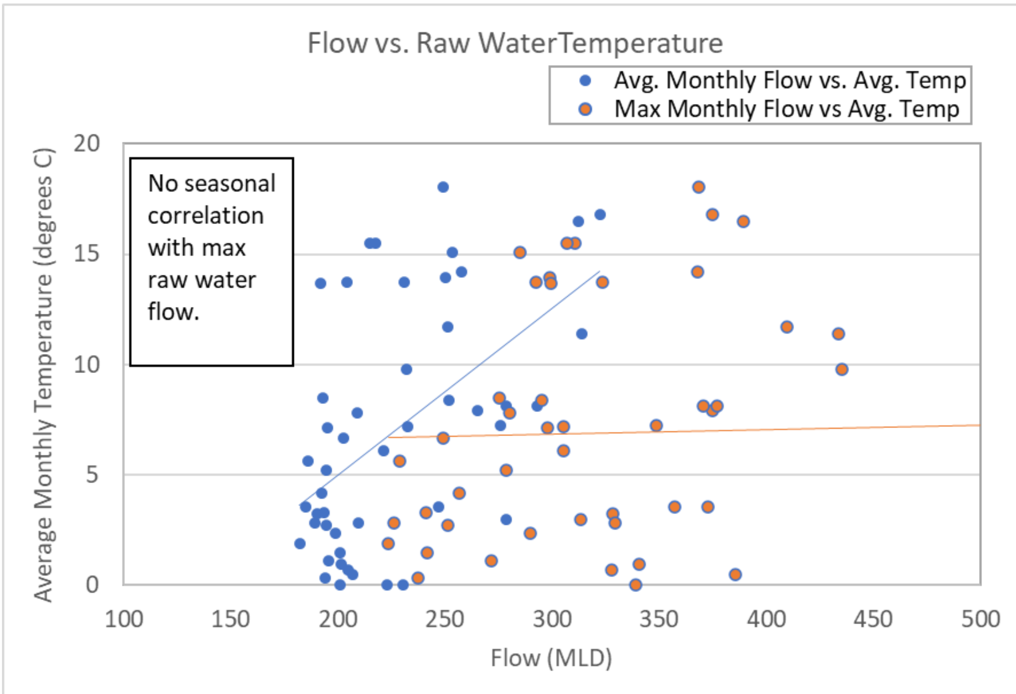

Figure 2-2: Average and Maximum Monthly Flows Relative to Raw Water Temperature (2019 - 2022)

Figure 2-2 suggests that higher average monthly flows are slightly correlated with warmer temperatures, and maximum monthly flows are not correlated with temperature.

In considering future construction sequencing, the flow data indicates that it may be possible to reduce peak production flows and associated peak process loading rates during construction by operating the WTP for longer periods of time at a lower flow rate, to provide the same net production of water over time.

The data also suggests that there may be an opportunity to extend construction activities into the summer months, given higher flows may not be necessary during the months from May through August.

2.1.2 Flow Selection for Risk Evaluation

For the purposes of evaluating process and operational risks during the proposed construction activities, Stantec's aim was to identify a projected peak demand flow.

Initially, the City provided draft projected demands for Woodward WTP showing that the peak historical day was approximately 490 MLD, the historic maximum day demand (MDD) was approximately 400 MLD or less, and the historic average day demand (ADD) was approximately 225 to 250 MLD. Additionally, the projected demands figure shows stabilized demand since 2012.

Stantec understands the WTP operates with frequent on/off cycles due to chloramine residual decay issues within the distribution system that occur when the system runs continuously. Shutting down for long drain cycles was reported to facilitate better mixing and water quality in the distribution system – this strategy has been adopted by Operations within the past few years. The plant also operates in this manner to take advantage of energy tariffs during the summer by shutting down when possible.

It is recommended to further investigate the chloramine residual issues within the distribution system that occur when the system runs continuously. Peak shaving current WTP flows would be beneficial to many aspects of the proposed upgrades, including plant hydraulics, temporary sedimentation measures, and the design approach for the upgrades. Peak shaving would be possible if the system were to be run continuously.

Given the potential opportunity for minimizing peak flows, Stantec used a peak demand flow of 425 MLD for the purpose of the analysis of risks to process performance during construction. This value represents the MDD * 1.25 and the 99th percentile of total filter flow in 2022.

2.2 PLANT PERFORMANCE DESKTOP REVIEW

2.2.1 Risks and Opportunities with Filter Operation

Given filtration is a critical pathogen barrier for the Woodward WTP in addition to downstream disinfection, a focus on risks and opportunities associated with filter operation was conducted. Granular media filtration performs best with consistent operation rather than in a start-stop approach. Therefore, the current operational approach may be hard on the filters and require more backwashing, resulting in higher filter headloss or turbidity breakthrough therefore impacting performance and efficiency, and potential damage to underdrains.

The filter flow observations present an opportunity to evaluate the total plant production needs over a longer time-period in an effort to peak-shave high plant flow operating scenarios to minimize risks during construction and in an effort to operate the plant more in line with best practices.

2.2.2 Plant Performance Review

A desktop evaluation of existing plant performance (process water quality under alternative loading rates) was conducted to baseline how the WTP currently performs at different flow rates. Findings from this review inform considerations for operating the plant at the selected peak demand flow rate of 425 MLD during the construction period.

Stantec reviewed plant performance and applied the American Water Works Association (AWWA) Partnership for Safe Water Goals which primarily focus on turbidity of settled water and filter effluent (refer to Table 2-1). Additionally, Stantec evaluated potential operational factors that may impact turbidity performance to understand performance risks during construction.

Table 2-1: AWWA Partnership for Safe Water Turbidity Optimization Goals

Unit Process	Goal Description	Partnership Optimization Performance Goal
Sedimentation	Continuous, stable performance regardless of variation in raw water quality	• When raw water average ≤10 NTU, <1.0 NTU 95th percentile • (When raw water average >10 NTU, <2 NTU 95th percentile)
Filtration – Combined Filter Effluent (CFE) Turbidity	Continuous, stable performance regardless of variations in raw and settled water quality	• <0.10 NTU, 95th percentile • <0.30 NTU, maximum
Filtration – Individual Filter Effluent (IFE) Turbidity	Continuous, stable performance regardless of variations in raw and settled water quality	• <0.10 NTU, 95th percentile • <0.30 NTU maximum
Filtration – Backwash Recovery	Minimize passage of elevated turbidity water into treated water stream	• Return to service when IFE turbidity <0.1 NTU after filter-to-waste

The goals presented in the table above serve as high-level performance objectives for a well optimized plant to provide reliable treatment and public health protection. It is recommended to strive to maintain these performance objectives even during construction activities.

Raw water turbidity data was reviewed, as presented graphically in Figures 2-3 through 2-6.

A review of raw water turbidity values produced the following general findings:

- Average hourly raw water turbidity recorded at the LLPS was <10 NTU more than 95% of the time.
- Settled water turbidity on side 1 and side 2 were <1 NTU 95% of the time.
- Filter effluent turbidity was <0.1 NTU 85% of the time; however, the 95th percentile was 1.1 NTU and the maximum was 2.0 NTU.

These results confirm that raw water turbidity is low and settled water turbidity is generally low and well managed. However, the occurrence of elevated average hourly filter effluent turbidity is a notable consideration for construction sequencing; specifically, the absence of filter-to-waste (FTW) and optimized filter backwashing infrastructure likely has an impact on average filter effluent turbidity and therefore it is recommended to prioritize these upgrades to filtration to minimize filtration performance risks during construction.

The trendline for raw water turbidity from 2019 through 2022 indicates that elevated turbidity events >50 NTU occur sporadically and are not common for Woodward WTP; they occur approximately four times per year and typically last for less than 5 days. Occasionally, an elevated raw water turbidity event will extend to the 5 – 10 day timeframe. The maximum average hourly raw water turbidity value observed during this timeframe was 180 NTU. This raw water turbidity data suggests that suitable clarification processes for this water type may include enhanced sedimentation with lamella plates (possibly with a settling aid polymer) or dissolved air flotation (DAF).

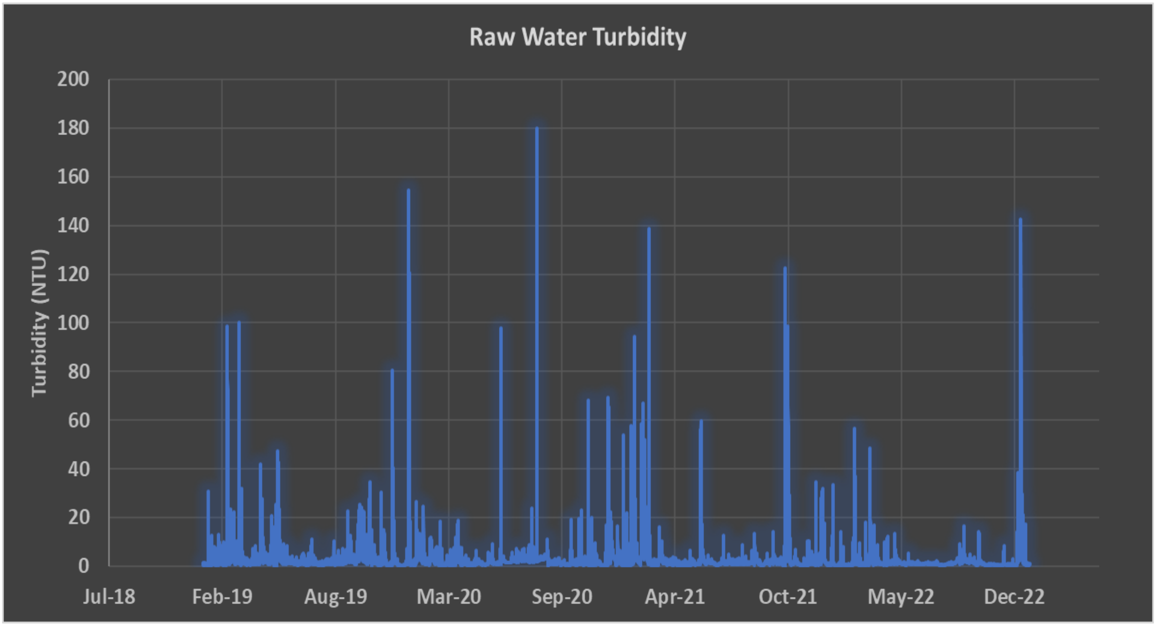

Figure 2-3: Trendline of Raw Water Turbidity (2019 - 2022)

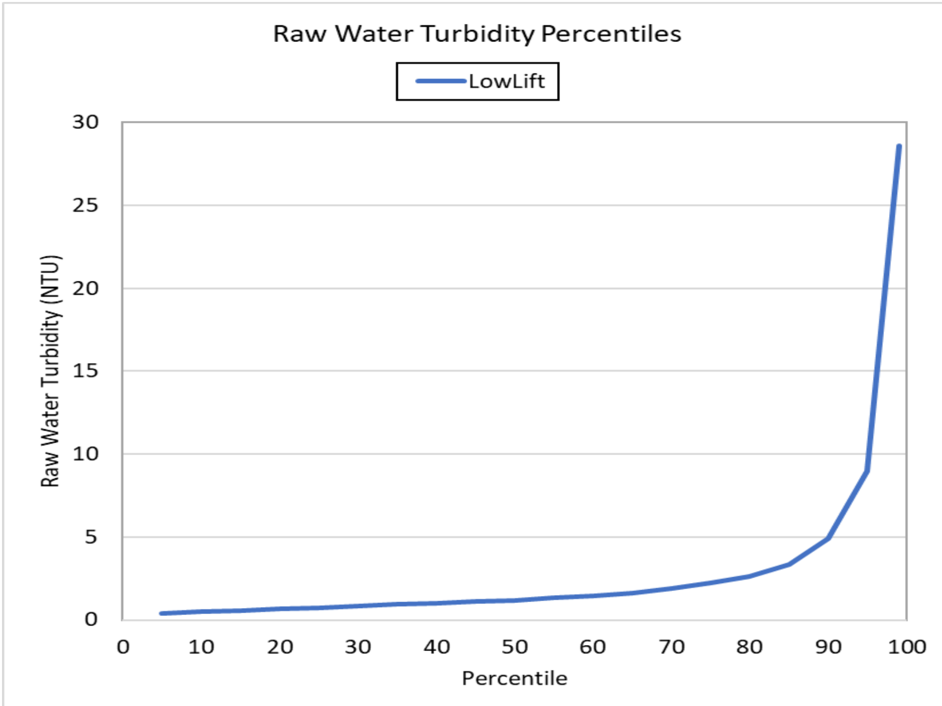

Figure 2-4: Percentile Plot of Raw Water Turbidity (2019 - 2022)

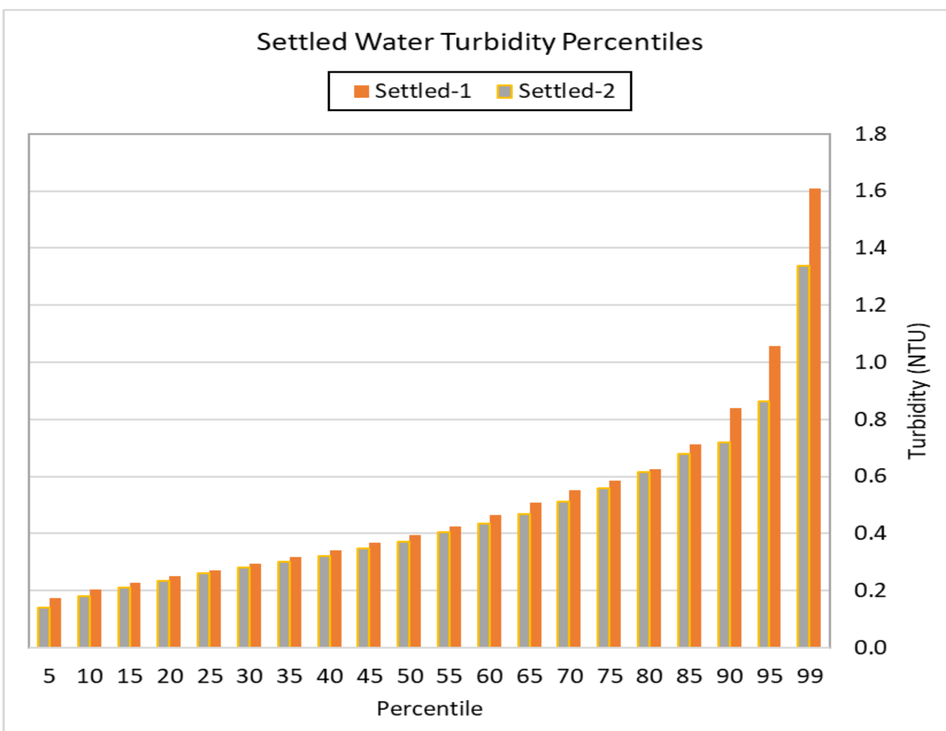

Figure 2-5: Percentile Plot of Settled Water Turbidity (2019 - 2022)

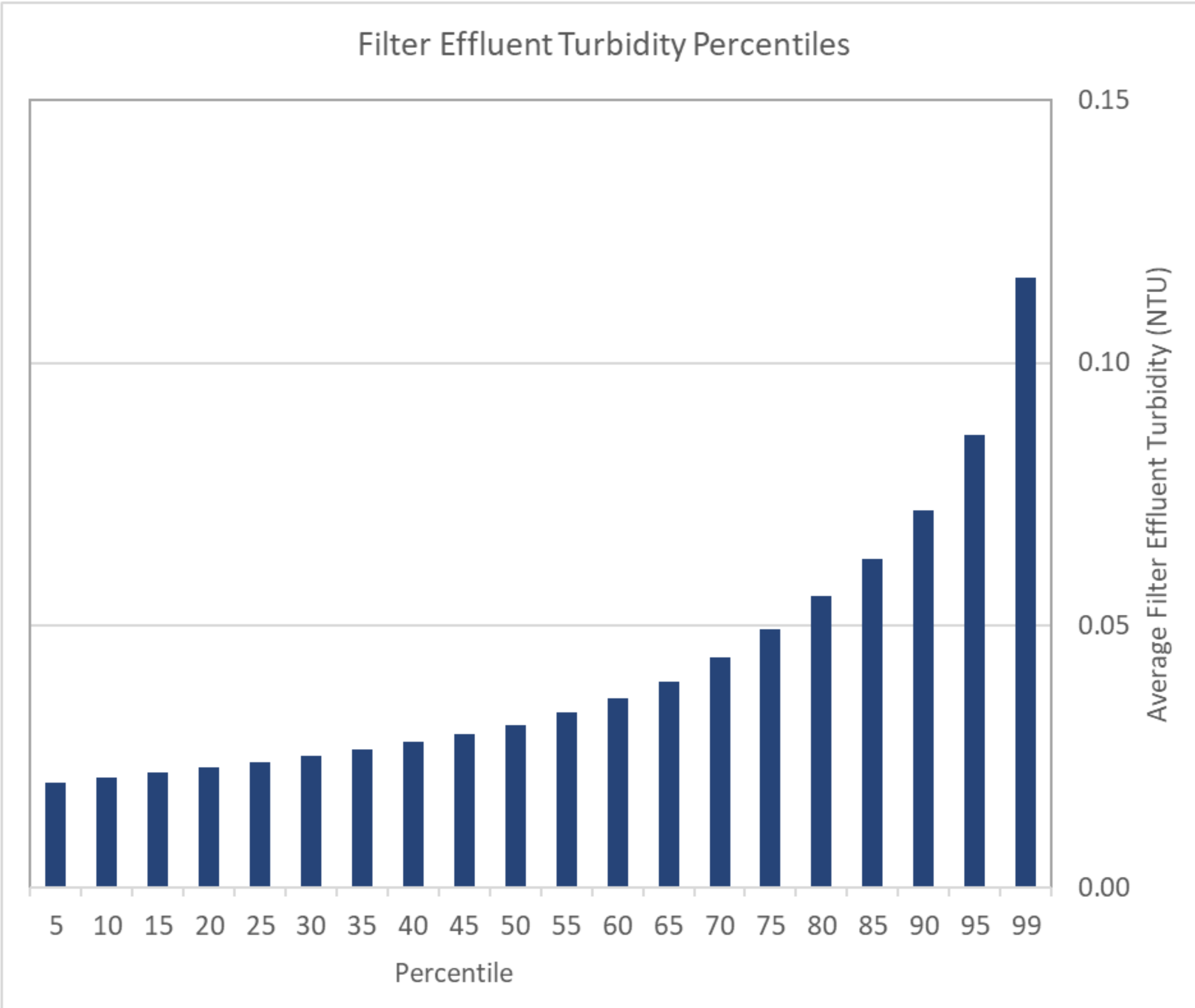

Figure 2-6: Percentile Plot of Filter Effluent Turbidity (2021 - 2022)

A review of the frequency of filter surface overflow rates (SOR) was undertaken, as presented in Figure 2-7. The data presented highlights that the filters have not been operated at loading rates above 9 m/h in the last three years.

In order to operate for extended periods of time at a higher filtration loading rate (e.g., the design loading rate of 12 m/h), it would be recommended to perform an extended full-scale stress test at 12 m/h and to also evaluate a full-scale trial using a sedimentation polymer aid. The polymer aid may allow the sedimentation process to operate at a higher loading rate as well. It is not recommended to operate the filters at a loading rate beyond the design loading rate of 12 m/h under any operating conditions; and in the winter when raw water turbidity is low and sedimentation provides low turbidity removal (i.e., the plant operates similar to a direct filtration plant), it is not recommended to operate the filters at a loading rate >10 m/h unless demonstrated through stress testing.

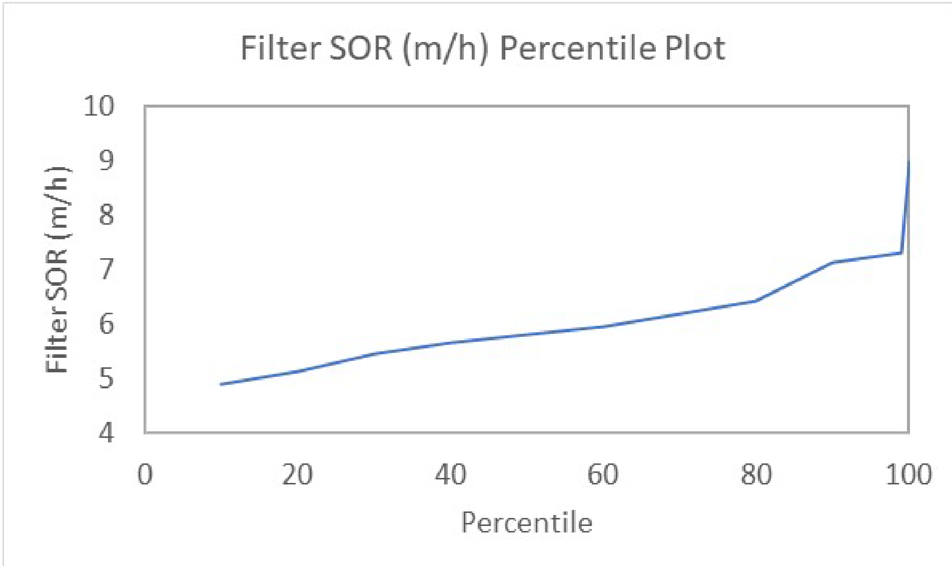

Figure 2-7: Percentile Plot of Filter Surface Overflow Rate (SOR) in Practice (2019 - 2022)

The figures below present an evaluation of potential factors impacting settled water turbidity.

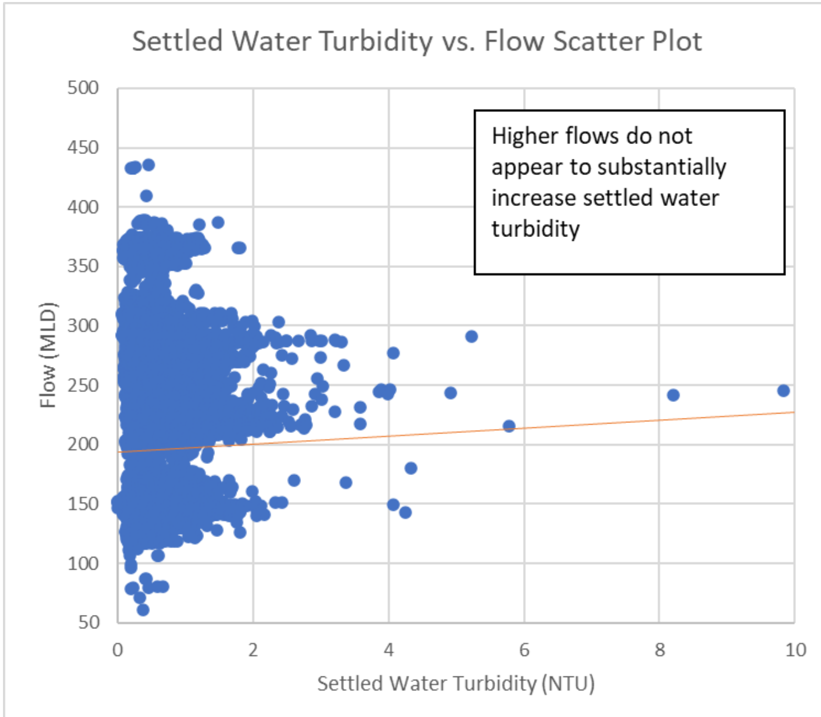

Figure 2-8: Scatter Plot of Settled Water Turbidity and Flow (2022)

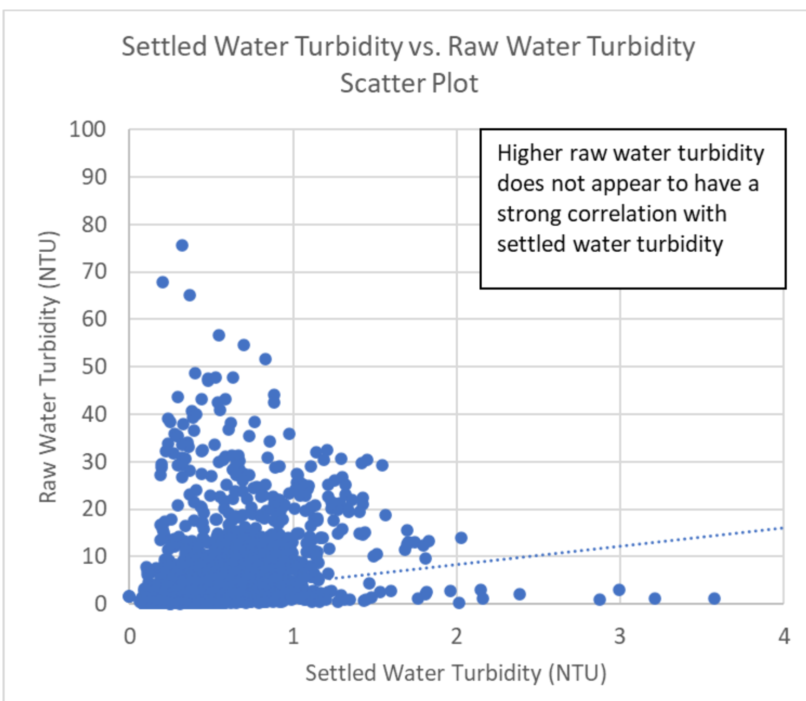

Figure 2-9: Scatter Plot of Settled Water Turbidity and Raw Water Turbidity (2022)

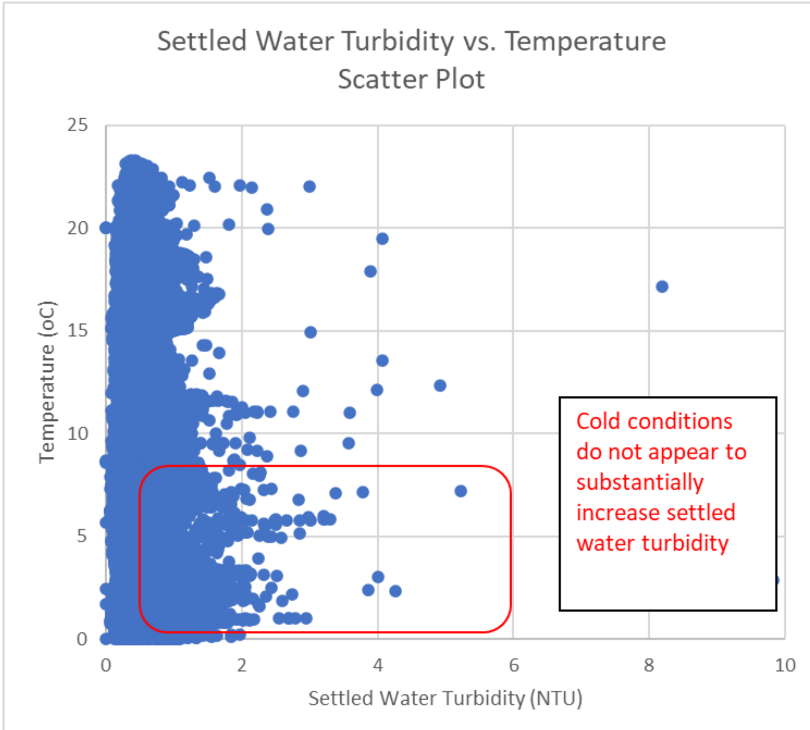

Figure 2-10: Scatt Plot of Settled Water Turbidity and Temperature (2022)

A correlation between higher flows and elevated settled water turbidity was not observed in 2022, with settled water turbidity maintained at <2 NTU at flows up to 425 MLD (Figure 2-8).

Additionally, elevated raw water turbidity was not associated with elevated settled water turbidity, suggesting that the existing sedimentation basins were able to effectively manage raw water turbidity events in 2022 (Figure 2-9).

Finally, settled water turbidity was not found to correlate with raw water temperature or show higher turbidity values during cold water conditions (Figure 2-10).

The above observations suggest that pre-treatment and sedimentation processes are currently operating well at current loading rates, but call into question the limitations on plant operation during high raw water turbidity events.

2.3 PLANT CAPACITY RISKS

To understand the capacity risks during construction, a desktop evaluation of the baseline and future (relating to the construction period) unit process capacities – including consideration for pre-treatment trains being out of service during the construction period – was undertaken. This analysis used guideline values for respective contact times and loading rates provided by the Ontario Ministry of Conservation and Parks (MECP), and the design assumptions for the original construction of Woodward WTP.

The detailed results of this analysis that support the values discussed in the subsequent process summaries are provided in the **Appendix A and B**.

A review of the likelihood and consequence of identified potential process risks during the proposed construction activities is provided in Section 5.0.

It is noted that a full-scale flow stress test was also performed in March 2023 to validate findings from the desktop review. These results are presented in Section 4.0 (4.3 and 4.4), and a review of the unit process performance during this testing is provided in **Appendix D**. To further understand the practical capacity limitations associated with pre-treatment unit processes, an extended full-scale capacity test on one train of the process is recommended.

2.3.1 Pre-Treatment / Sedimentation

Flocculation design and performance is affected by the retention time through flocculation basins. Based on the MECP guidance value of a contact time of 30 minutes, flocculation capacity is expected to be reduced to 402 MLD with two trains offline, and 603 MLD with one train offline. However, Stantec has experience with flocculation basins designed with contact times as low as 15 to 20 minutes in cold water conditions that perform well and therefore this process is expected to be able to meet the rated plant capacity of 909 MLD with a 20-minute contact time. Therefore, it is recommended to defer capital upgrades to increase flocculation capacity as the plant is expected to be able to meet AWWA and MECP performance criteria with the existing flocculation basins. Alternatively, it is recommended that the City invest in opportunities to optimize consistent pre-treatment chemistry such as the use of online streaming current to ensure good charge neutralization is achieved by accurate coagulant dosing through all raw water quality conditions.

Sedimentation performance is affected by the sedimentation area available at a given flow rate – i.e., the sedimentation loading rate. When sedimentation basins are taken offline, the treatment capacity is decreased, as shown in Figure 2-12.

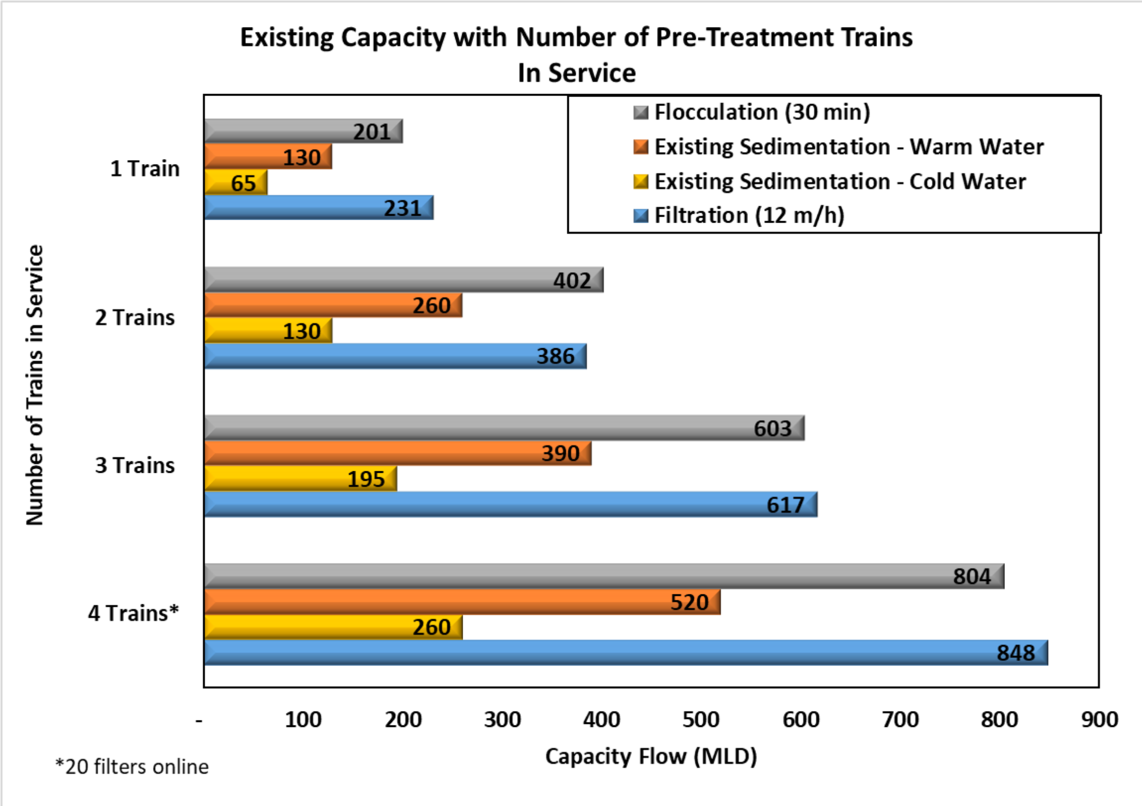

Figure 2-11: Existing Estimated Unit Process Capacities with Number of Trains Out of Service

With all sedimentation basins operating, based on guideline performance criteria, the existing treatment process is expected to be able to perform well up to approximately 520 MLD, which corresponds to an SOR of 2.16 m/hr with all four trains in service. Allowable sedimentation loading rates are generally reduced under cold water conditions, so there is the potential for declining sedimentation performance in cold water conditions at flows >260 MLD (corresponding to 1 m/hr). With one train offline, performance of sedimentation is expected to decline at plant flow rates higher than 390 MLD and 195 MLD for warm water and cold water conditions, respectively.

It should be noted that with two (2) sedimentation basins offline, sedimentation performance is expected to decline at flow rates greater than 260 MLD (1 m/hr) and 130 MLD (2 m/hr) in cold water and warm water conditions, respectively.

Given that sedimentation performance is expected to be negatively impacted by cold water conditions, it may be worthwhile to review the construction schedule to explore opportunities for sedimentation upgrades to occur in the spring and summer months when sedimentation capacity is expected to be higher with one or two trains out of service. Lower water temperatures result in higher viscosity and lower sedimentation velocities. Furthermore, there is an opportunity to complete a coagulation optimization study to determine optimal coagulant doses for varying raw water conditions.

While sedimentation is not a key unit process barrier for Woodward WTP for pathogen control, higher settled water turbidity could result in shorter filter run times as a result of either higher rates of headloss accumulation or greater risk of turbidity breakthrough. This could result in more filters out of service at a given time than anticipated and potentially negatively impact the ability of the WTP to reliably meet demands until sufficient filters can be backwashed and brought back into service. This risk presents further support to evaluate the potential benefits to a settling aid polymer.

An additional evaluation of the plant capacities achieved by alternative clarification technologies is provided in **Appendix C**.

2.3.2 Filtration

It should be noted that Woodward WTP is suspected of operating similarly to a direct filtration plant under certain operating conditions such as when raw water turbidity is very low and water temperatures are cold. Under these conditions, poor flocculation and sedimentation may be achieved with respect to particle removal and therefore the majority of particle loading to the plant must be managed by filtration. When operating under these conditions, a maximum filter loading rate of 10 m/h is recommended to maintain filtration efficiency and acceptable unit filter run volumes (UFRVs).

Based on this desktop evaluation, filtration performance is expected to be acceptable up to a potential plant flow rate of 514 MLD with only 16 filters in service (equivalent to a loading rate of 10 m/h per filter), and this could potentially be increased to 617 MLD with only 16 filters in service if a loading rate of 12 m/h can be demonstrated. This is shown in Table 2-2.

Table 2-2: Filtration Conditions with Number of Filter Quadrants Offline

	Evaluation Scenarios			
No. Filter Beds	**22**	**16**	**10**	**6**
SOR (m/h)	6.31	8.68	13.89	23.14
	9.65	13.27	21.24	35.40
	13.50	18.56	29.70	49.50
Capacity - MLD (10 m/h):	707	514	321	193
Capacity - MLD (12 m/h)	848	617	386	231
Capacity - MLD (15 m/h)	1,060	771	482	289
No. Standby Filters	2	8	14	18
Quads Online	4	3	2	1

The capacity risk of having one of the four filter quadrants (i.e., set of 6 filters) offline during construction is anticipated to be minimal. The capacity risk of having two (2) filter quadrants offline at a given time during construction could reduce plant capacity to 321 MLD (at 10 m/hr), which could potentially be increased to 386 MLD if a filter loading rate of 12 m/h can be demonstrated. It is recommended to develop a standard operating procedure for the construction periods that require two (2) filter quadrants to be offline at a given time.

It should be noted that potentially increasing the filtration loading rate to 12 m/h results in a maximum plant capacity of 848 MLD with 22 filters in service, and the capacity declines to 707 MLD at a loading rate of 10 m/h with 22 filters in service. Therefore, the overall WTP capacity will be limited to approximately 848 MLD long-term provided no expansion to the filtration process. This is not expected to be an issue with respect to projected demands to 2050 (with peak historical day of <800 MLD); however, it is not in line with the current DWWP for a rated capacity of 909 MLD.

Another opportunity to optimize coagulation, flocculation and sedimentation, particularly during construction but also in terms of general optimization, would be to evaluate the use of online streaming current or bench-scale zeta potential measurements to validate adequate coagulation chemistry to optimize filtration run times.

This review demonstrates that flocculation is not a limiting unit process for the Woodward WTP based on projected demands of 425 MLD and 650 MLD under the assumption that a 20-minute contact time would be sufficient and optimized coagulation would be practiced routinely. In general, Stantec does not support prioritizing or capital expenditures associated with additional flocculation capacity at Woodward WTP.

2.3.3 Disinfection

To evaluate the disinfection capacity of the plant, the following criteria were used:

- For a WTP with a surface raw water source, a minimum 2-log removal of *Cryptosporidium*, 3-log removal/inactivation of *Giardia*, and a 4-log removal/inactivation of viruses must be achieved at all times when the plant is supplying water to the distribution system.
- The conventional filtration system of the water treatment plant is capable of providing disinfection removal credits of 2-log for *Cryptosporidium*, 2.5-log for *Giardia* and 2-log removal for viruses. Since *Giardia* requires the longest contact time with chlorine for inactivation (as compared to viruses), a 0.5-log *Giardia* inactivation was used to determine the required chlorine contact time.
- The required concentration multiplied by time (CT) values for inactivation of *Giardia* were calculated from the US EPA equation for free chlorine, $CT_{required}$,

$$CT_{required} = 0.2828(pH)^{2.69} (C_{Cl\ residual})^{0.15} (0.933)^{(T-5)}$$

where:

$C_{Cl\ residual}$ = Free chlorine residual, mg/L

pH = Water pH at Point of Entry into distribution system, S.U.

T = Water temperature, °C

- Consideration is only given to the effective volume of the clearwells.
- Cold water conditions were used to evaluate the disinfection capacity.

- The effective contact volume of the process units was determined by using the target water level and baffling factor used in the Woodward WTP CT calculator. This factor is assigned based on the configuration of the inlet and outlet piping, operating water levels, and the degree of baffling. The baffling factor is multiplied by the operating volume to determine the effective volume for chlorine contact.
- 5^{th} percentile raw and treated chlorine residual, 1^{st} percentile settled water chlorine residual, 95^{th} percentile pH and 5^{th} percentile temperature were selected as the worst-case conditions, reflected through actual operating values.

Table 2-3 presents a summary of the data used for CT calculations.

Table 2-3: Conditions Used for Disinfection Capacity Evaluation at 450 MLD

Parameter	Chlorine Residual (mg/L)	pH	Temperature (degrees C)	Actual CT (mg-min/L) (2)	*Giardia* log-inactivation (2)	Notes(1)
Pre-Chlorination Cold Water Conditions						
Intake Pipe 1	0.51	8.25	0.2	8	0.07	5^{th} percentile LLP intake residual, 95^{th} percentile LLP sample pH, 5^{th} percentile raw water temperature
Intake Pipe 2	0.5	8.4	0.2	12	0.11	5^{th} percentile LLP intake chlorine residual, 95^{th} percentile LLP sample pH, 5^{th} percentile raw water temperature
Pre-Treatment (Module 1)	0.9	7.7	0.2	44	0.45	1^{st} percentile settled water chlorine residual, 95^{th} percentile settled water pH, 5^{th} percentile raw water temperature
Pre-Treatment (Module 2)	0.84	7.8	0.2	41	0.42	1^{st} percentile settled water chlorine residual, 95^{th} percentile settled water pH, 5^{th} percentile raw water temperature
Post-Chlorination Cold Water Conditions						
Clearwell 1	1.2	7.5	0.2	15	0.09	5^{th} percentile clearwell 1 chlorine residual, 95^{th} percentile HWHLP pH, 1^{st} percentile raw water temperature
Clearwell 2	0.9	7.5	0.2	12	0.14	5^{th} percentile clearwell 2 chlorine residual, 95^{th} percentile HWHLP pH, 1^{st} percentile raw water temperature
Sum, excluding post-chlorination				**61**	**0.49**	Intake 1, Module 2 only
Sum, including post-chlorination				**73**	**0.72**	Intake 1, Module 2 only

(1) Daily average SCADA data from January 1, 2019 through December 31, 2022.
(2) CT and *Giardia* inactivation calculated at current peak capacity – 450 MLD.

Based on these conditions, the disinfection process at the Woodward WTP would be able to achieve 0.5-log *Giardia* inactivation (regulatory requirement) at current peak flows of 450 MLD under worst-case conditions with all sedimentation tanks in service. Pre-chlorination contributes 0.49-log *Giardia* inactivation, while post-chlorination contributes 0.23-log *Giardia* inactivated, for a total of 0.72, which meets the 0.5-log *Giardia* inactivation requirement. If CT provided in the clearwells is not counted, then the plant would not be able to achieve 0.5-log *Giardia* inactivation at 450 MLD under worst-case conditions.

The figure below shows *Giardia* inactivation provided through each module based on plant flow and number of sedimentation basins available. It is Stantec's understanding that the current CT calculators do not account for contact time in the clearwells, this figure therefore does not account for CT provided in the clearwells.

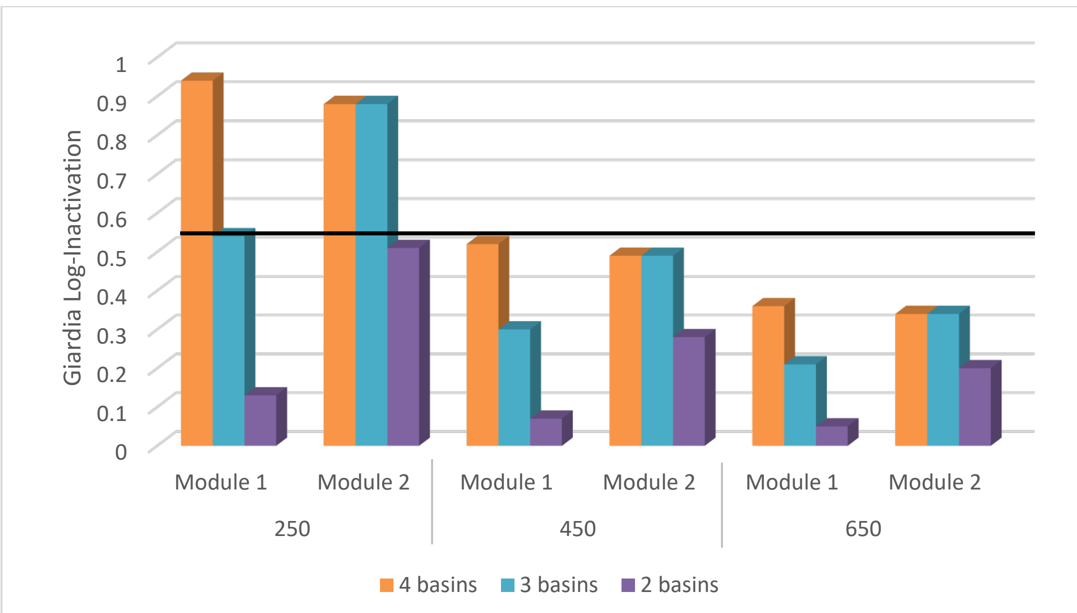

Figure 2-12: Giardia Log-Inactivation with Increasing Flow and Reduced Sedimentation Capacity

Based on the available CT, under worst-case conditions the plant would be limited to the flows shown in **Figure 2-13**, dependent upon the number of sedimentation tanks in service and whether the clearwells are counted.

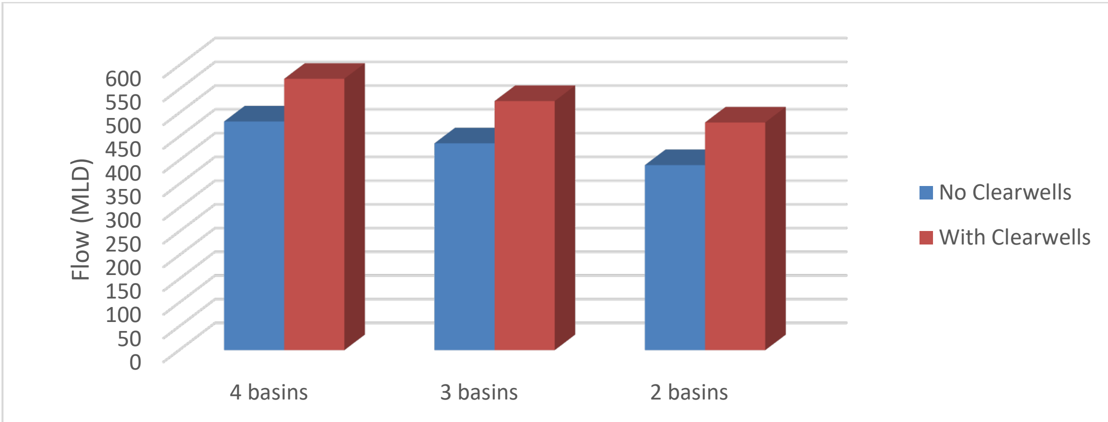

Figure 2-13: Plant Flow Capacity Based on CT Restrictions

3.0 OPPORTUNITIES / OPTIONS FOR POTENTIAL BACKUP SYSTEMS

Stantec contacted Suez to inquire about use of their MPAK mobile system for provision of temporary supplemental treatment capacity during construction works.

The systems offer various treatment technologies including Actiflo^{TM}, ultrafiltration, and ion exchange. Suez offers temporary trailers that can mobilize to site to provide treatment capacity during maintenance and construction activities.

Based on discussions, it was concluded that the Suez mobile systems would not be able to supply sufficient capacity to replace a 95 MLD sedimentation tank and are therefore not a suitable alternative to a temporary 5th sedimentation tank.

4.0 EVALUATION OF FLOW SCENARIOS ASSOCIATED WITH UPGRADES

4.1 FLOW SEQUENCING DURING VARIOUS CONSTRUCTION STAGES

The proposed construction schedule requires the plant to operate in a non-typical flow configuration, which is anticipated to result in higher than typical flowrates in portions of the plant. Stantec has identified two hydraulic increase cases (detailed in Technical Memo #1) as summarized below.

1. Hydraulic Increase #1 – Sedimentation Upgrades.

   Removal of a single sedimentation train will increase the flow to the other trains by 8.3% of the influent plant flow. At a peak flow of 480 MLD, this represents an increase per train of 40 MLD.

2. Hydraulic Increase #2 – Filter Upgrades.

   The proposed schedule shows the filters being upgraded in quadrants (6 filters to be upgraded at once). During this upgrade, the flow will increase to the other filters by 8.3% of the influent plant flow. At a peak flow of 480 MLD, this represents an increase of 40 MLD per filter quadrant.

Given the recommendations within this document and by other firms, Stantec has prioritized hydraulic increase #2 for preliminary assessment and investigation.

4.2 PRELIMINARY HYDRAULIC MODEL

Stantec constructed a preliminary hydraulic model in the Stantec Hydraulic Analysis and Design System (HADeS v. 4.3) using existing hydraulic grade line (HGL) and plant design information for the west (Filters 1 through 12) and east (Filters 13 through 24) filter galleries. We have noted that, due to a bulkhead installed in the filter effluent channels, all of the west side filter effluent flows through the original channel into clearwell 1, while all of the eastern effluent will flow through the larger channel into clearwell 2.

The results of our analysis are shown in **Figure 4-1** and **Figure 4-2**. Our preliminary model predicts that, under typical conditions, the filter effluent channels will operate under a partially filled condition. Under a partially filled condition, filter backpressure at the effluent valve will be effectively decoupled from the clearwell level and hydraulic resistance within the effluent channel. Above certain combinations of clearwell levels and channel flowrates, the water level is predicted to rise to the top of the effluent channel. Beyond this point, the hydraulic resistance of both the effluent channel and clearwell level will add to that of the filter. This will result in further opening of the filter effluent valve for comparable flowrates, which may reduce maximum filter runtimes due to built-up headloss compared to lower flow rates.

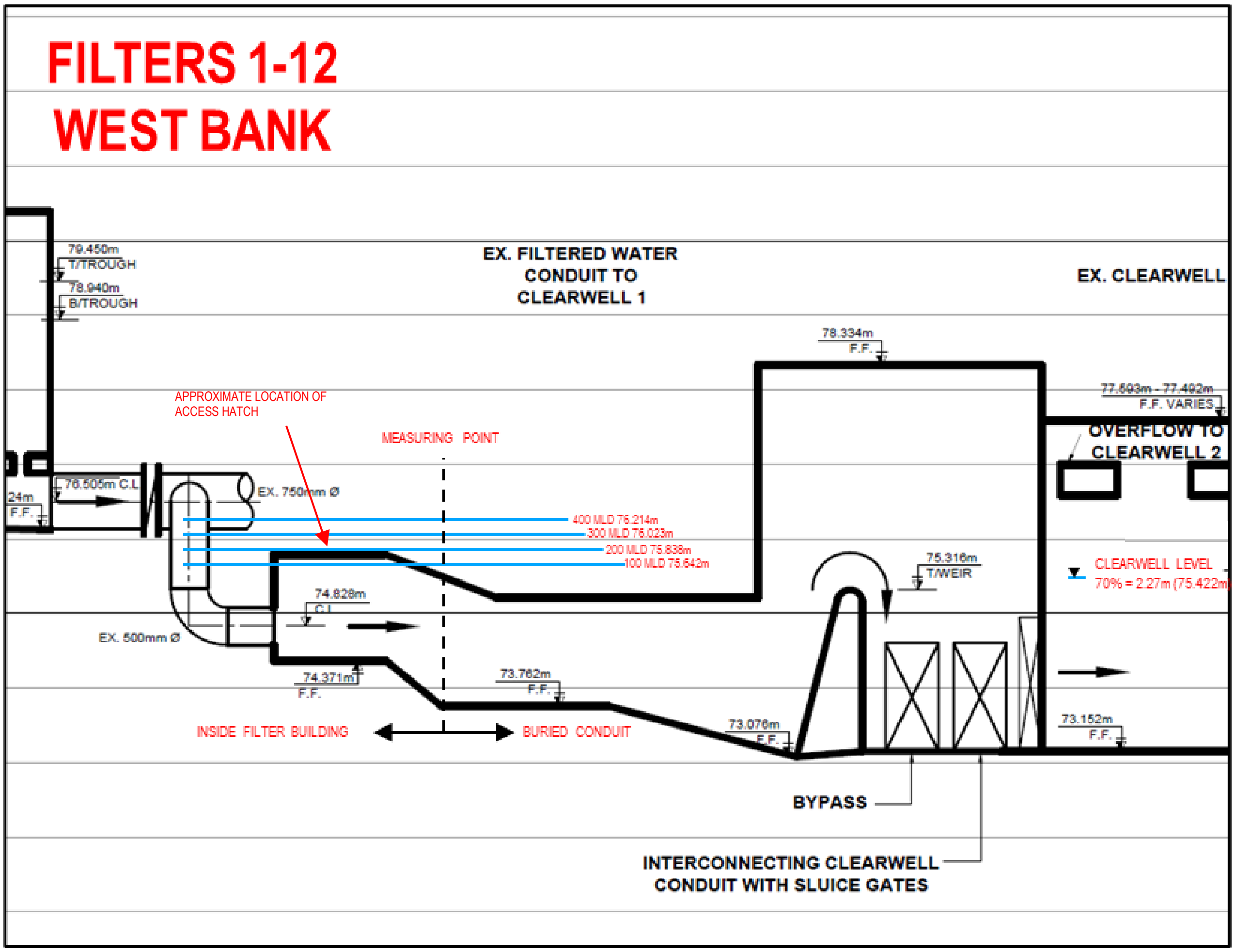

Figure 4-1 Predicted running water depths in the west filter bank (filters 1 through 12) effluent channel under various flowrates with a clearwell depth of 2.27 m.

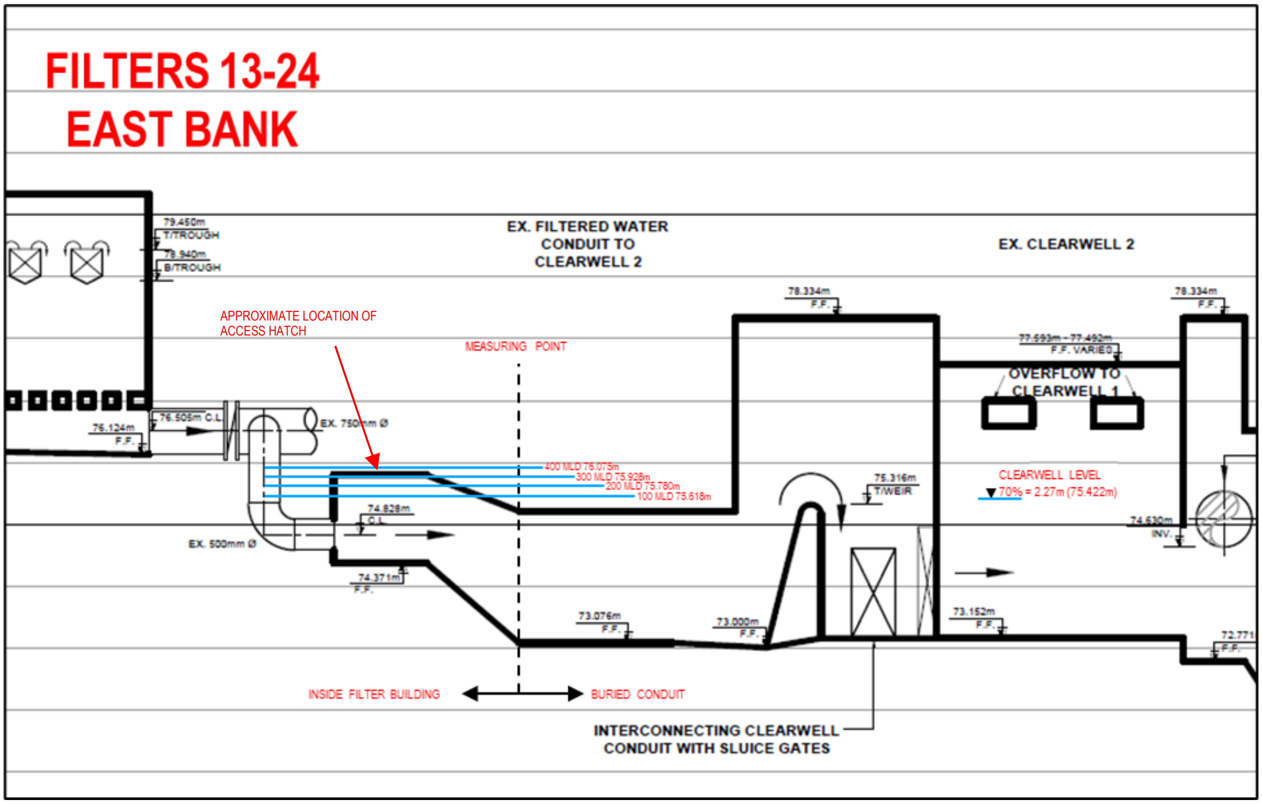

Figure 4-2 Predicted running water depths in the east filter bank (filters 13 through 24) effluent channel under various flowrates with a clearwell depth of 2.27 m.

4.3 HYDRAULIC STRESS TESTING

Stantec participated in plant stress testing on March 27, 2023 at the Woodward WTP, which aimed to:

1. Understand the effect of higher than typical flowrates on the plant with a single filter quadrant out of service.
2. Verify and validate any hydraulic bottleneck within the system, specifically downstream from the filters as described within Section 4.2.

To do this, plant operators adjusted the flow at western and eastern sections of the plant according to **Table 4-1**, which simulated the flow that would be seen in each effluent channel if one quadrant on the west side of the plant was out of service. This is analogous to what is expected during the filter upgrade portions of the proposed construction scope.

Table 4-1: Stress Testing Scenarios

Low Lift pump flowrate (MLD)	Scenario: Western Bank (filters 1-6 of 7-12) out of service		Notes
	Western Effluent Channel Flowrate (MLD)	*Eastern Effluent Channel Flowrate (MLD)*	
250	83	167	
300	100	200	
350	117	233	
400	133	267	
450	150	300	
480	160	320	Filters 1 through 6 placed out of service
500	167	333	Filters 1 through 6 placed out of service
600	200	400	Filters 1 through 6 placed out of service

It should be noted that during the stress test, the flowrate balance between each side was achieved by taking various filters out of service, to keep filters operating at nearly the same loading rate as was seen during the 250 MLD run. Above the 480 MLD influent flowrate run, filters 1 through 6 were taken out of service and the flowrate balanced amongst the remaining filters to simulate conditions expected during the retrofit. Due to existing conditions, filters 21 and 22 were out of service for the duration of the test.

Two filters from each bank were chosen for analysis as these were online for the length of the test. These filters were filter 11 (west bank) and Filter 13 (east bank) and are situated in similar locations with respect to the effluent channel. Graphs of the pressure drop across the effluent valve and the clearwell (for the respective filter) level are shown as

Figure 4-3 and **Figure 4-4**. Pressure drop was calculated using manufacturing Cv versus % open graphs. The pressure drop across the valve is a direct result of the valve open position.

Filter #11, in the west bank, shows two distinct regions of pressure drop, termed **low slope** (loss of 0.124 kPa of headloss per MLD) and **high slope** (0.282 kPa of headloss per MLD). Thus, in the high slope region, the valve must open further than in the low slope region to maintain a desired flowrate. The transition between the regions is thought to occur because of additional resistance downstream of the valve above ~130 MLD and a clearwell #1 level of 2.55 m. This added resistance is likely due to the channel being surcharged, as indicated from the HADeS simulations in **Figure 4-1** described earlier. Note that the flowrates mentioned here refer to the flow within the filter effluent channel, rather than the full plant flowrate.

As a result of these distinct regions, the operation margin to a 100% open valve will be reduced to a greater extent than what may be expected at lower channel flows. For the data shown for filter #11, the reduction in margin is in the order of 7%. Thus, operating in the **high slope** range, the valve for filter #11 is expected to reach 100% open 7% faster than in the low slope range. Filter #11 had a filter age of approximately 25 hours during this test (nearly 50% of the time to backwash). Under these conditions, the effluent valve is expected to be open to 78% with a channel flowrate of 200 MLD. Further, given this filter age, the valve is predicted to be 100% open at a flowrate of 266 MLD in the western effluent channel.

In contrast, filter #13 in the eastern bank (**Figure 4-4**) shows a single slope region for entirety of the flow range studied. It is Stantec's opinion that this is because the filter effluent channel is not surcharged, effectively de-coupling the filter effluent from the hydraulic resistance effects of the effluent channel or clearwell level. Note that the surcharge level for clearwell #2 is predicted to be ~350-375 MLD (**Figure 4-2**). These results suggest that there is no hydraulic impact of running the east side channel to 400 MLD.

Given the age of filter #13 (19.7 hours at the end of the filter test), it is expected that the effluent valve will be 100% open at an eastern channel flowrate of 639 MLD.

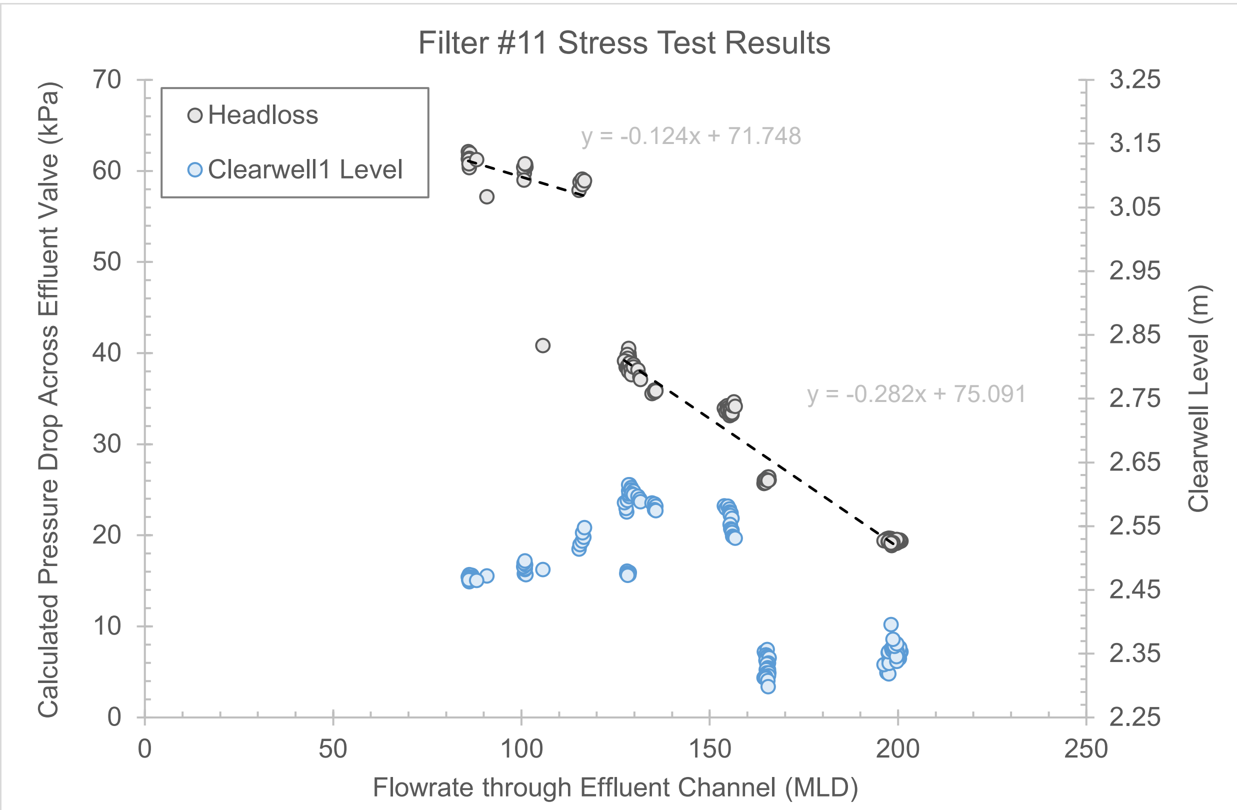

Figure 4-3: Filter 11 (West Bank) Stress Test Results

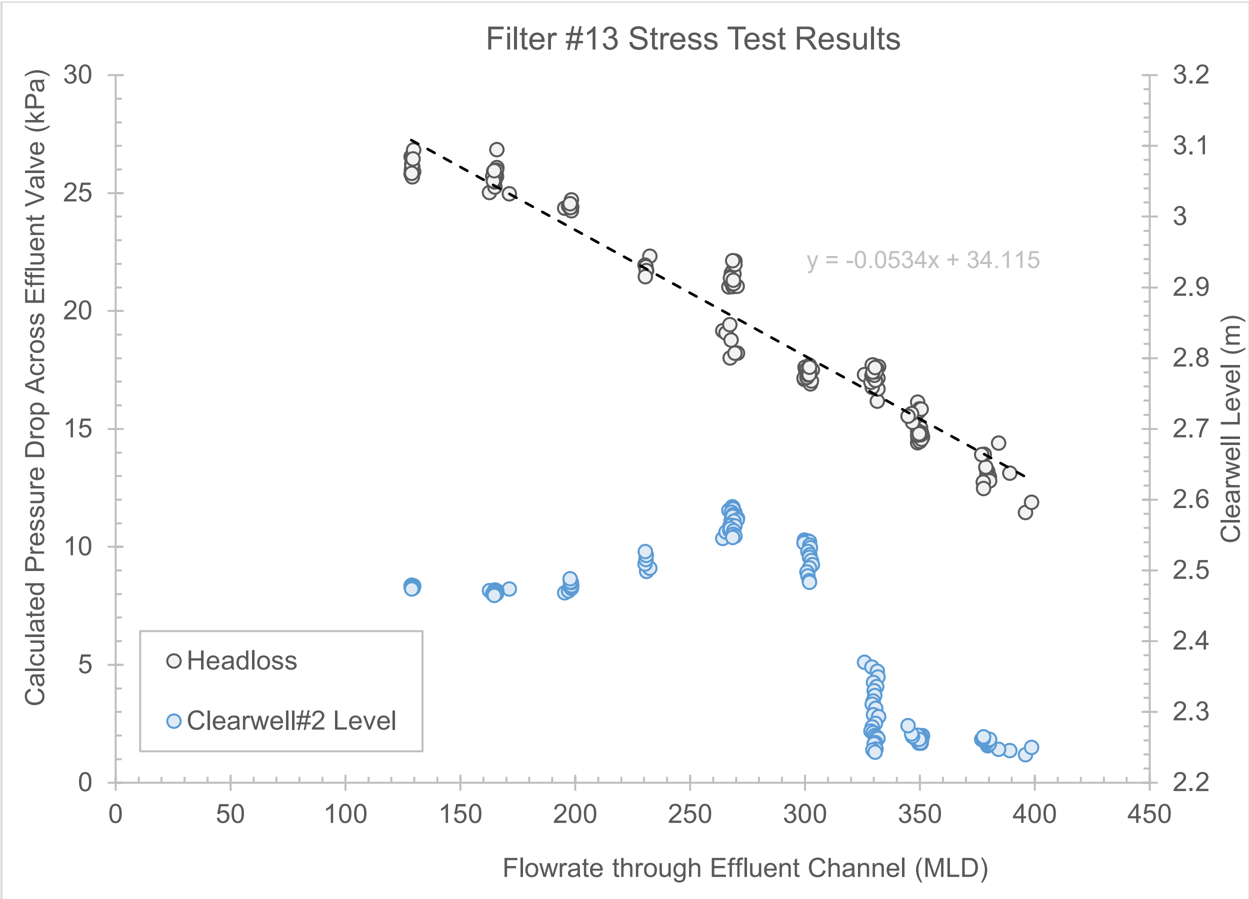

Figure 4-4: Filter 13 (East Bank) Stress Test Results

4.4 SECONDARY STRESS TESTING RESULTS

During the stress test, it was observed that an operational bottleneck occurred between 575 and 600 MLD total plant flow. At these plant flowrates, chemical system high flow alarms were received, suggesting that the chlorine dosing could not be increased without investigation. It was understood that one pre-chlorinator and one post-chlorinator were operating at maximum capacity in this range, precluding further increases in total plant flowrate without sacrificing CT.

Surcharging of the filter effluent channel hatch was not observed. Anecdotally, it is understood that this has happened in the past. Stantec believes that this may have been caused by bolts not tightened to specification, as the watertight hatch is designed to withstand water pressure.

We further understand that the stress test may not have been able to proceed during periods of warmer ambient temperatures. Stantec was informed that the VFD room for the high lift pumps contains a potentially inadequate HVAC system and cannot accommodate high flowrates for extended periods of time due to temperature rejection issues.

Finally, we understand that there have been concerns regarding cavitation of the high lift pumps limiting their capacity. Stantec observed the high lift pumps operating between 550 and 575 MLD during the stress test. On site, staff noted the presence of characteristic sounds of cavitation coming from the intake of the pump, as well as discharge pump pressures oscillating by roughly +/-10 psi(g). Based on operator discussions, we understand that this concern is not present at lower flowrates (below 400 MLD discharge). Although the characteristic sound of cavitation is present, it is most noticeable at the intake of the pump, rather than at the pump casing.

We recommend further testing and investigation on VFD temperature reduction, chemical line flowrates, and cavitation to understand impacts on discharge flowrates.

5.0 RISK MATRIX

A list of potential risks and consequences was identified for the proposed construction activities with respect to plant performance and potential flow rates. The hazardous events were then ranked according to their associated risk. The two main elements considered for ranking were the likelihood of occurrence and the severity of occurrence. **Table 5-1** and **Table 5-2** (from the MECP DWQMS[2] Guide) elucidate the rating system.

Table 5-1: Risk Scoring for Event Likelihood

Description	Likelihood of hazardous event occurring	Rating
Rare	May occur in exceptional circumstances; rarely expected to occur or have an impact.	1
Unlikely	Could occur during certain operating conditions.	2
Possible	Potential to occur or have an impact at one or more times during construction.	3
Likely	Expected to occur on a regular basis (monthly to quarterly) during construction.	4
Very Likely	Expected to have an impact throughout the construction activities.	5

Table 5-2: Risk Scoring for Event Consequence

Description	Consequences of hazardous event occurring	Rating
Insignificant	Insignificant performance impact; little or no health risk	1
Minor	Limited performance impact; minor health risk	2
Moderate	Potential for performance impact at some operating conditions; health impact on small part of the population	3
Major	Large or expected performance impacts through construction schedule; part of population at risk	4
Catastrophic	Major or continuous performance impacts; or potential for complete system failure	5

Risk is the lack of certainty about the outcome of a particular choice. Statistically, the level of negative risk can be calculated as the product of the probability that the harm occurs multiplied by the severity of that harm. In practice, a risk matrix is a useful approach when either the probability or the harm severity cannot be estimated with accuracy and precision. Considering this approach, a risk matrix rating risks according to the likelihood of an event occurring and the consequence of this event occurring was developed as shown in **Table 5-3**.

[2] https://www.ontario.ca/page/ontarios-drinking-water-quality-management-standard-pocket-guide

Table 5-3: Woodward WTP Risk Matrix

		Consequence				
		Catastrophic (5)	Major (4)	Moderate (3)	Minor (2)	Insignificant (1)
Likelihood	Almost Certain (5)	25	20	15	10	5
	Likely (4)	20	16	12	8	4
	Moderate (3)	15	12	9	6	3
	Unlikely (2)	10	8	6	4	2
	Rare (1)	5	4	3	2	1

Risk Rating	
15 - 25	**High** - Constitutes a Significant Risk. Managing this risk is a priority and additional risk control measures are needed. Interim steps may be needed prior to implementing permanent solutions
5 - 14	**Medium** - Constitutes a Moderate Risk with Caution. Investigate if additional measures can reduce risk even further.
1 - 4	**Low** - Constitutes a Tolerable Risk. Monitoring is required to ensure controls are maintained and effective.

Table 5-4 describes the risk rating for the Woodward WTP Phase 2 Upgrades based on the consequence and likelihood of an event. The risk matrix summarizes the likelihood and consequences of risks associated with major component upgrades and existing conditions for the WTP.

Table 5-4: Woodward WTP Phase 2 Upgrades Risk Matrix Results

Item #	Component	Root Cause	Risk	Likelihood	Consequence	Risk Rating	Remediation
1	Typical Operating Flow Regime • Frequent on/off cycles • No equalization of filter flows	Distribution system residual issues	Increased stress on major unit processes; unoptimized filter operation – frequent start-stop is hard on infrastructure and filter underdrains and can minimize filter run-times; without optimization plant required to run at higher peak flows through construction with capacity restrictions	4	3	12	Complete a study to address distribution system residual issues to enable the plant to run continuously at lower flows. Opportunity to operate at lower peak flows during construction activities that require pre-treatment processes to be offline.
2	Flocculation • Existing flocculation capacity appears to be adequate for ≥900 MLD	Design	Flocculation upgrades increases complexity of construction and extend schedule, unsupported capital expenditure. **Financial risk** with no demonstrated performance or regulatory benefit. The AECOM construction cost estimate for the flocculation upgrades is $5M.	4	4	16	Remove tertiary flocculation stage from Phase 2 Upgrades scope

Item #	Component	Root Cause	Risk	Likelihood	Consequence	Risk Rating	Remediation
3a	Sedimentation • 1 – 2 tanks offline for extended period	Capacity limitation	Potential to impact CT calculation with sludge accumulation in sedimentation basins, and potential for floc accumulation and carry-over into filtration at higher flow rates. Potential for overlap of scheduled sedimentation basin maintenance when only 2 trains are in service.	5	3	15	Investigate possibility of implementing DAF and locating in lower stores footprint to expedite clarifier upgrades construction staging and increase sedimentation capacity in smaller footprint. Evaluate opportunities to have sedimentation tanks offline in warm water conditions when sedimentation performance is expected to be more robust.
3b	Sedimentation • Incomplete evaluation for best available technology	Design	Selected technology may be susceptible to organics and algae upsets. Capacity achieved by proposed upgrades will not provide rated capacity with one train offline. Proposed technology could require substantial labor and maintenance for plate cleaning and/or operation and maintenance of an aeration system for plate cleaning which may not reduce labor burden associated with existing maintenance of sedimentation basins.	4	3	12	Potential to improve management of algae and organics with high-rate clarification technology. Potential to increase clarification capacity in smaller footprint making land available for other future potential uses (e.g., treatment of emerging contaminants). Potential to minimize and/or streamline future maintenance and operational procedures associated labor burden relative to existing process.

Item #	Component	Root Cause	Risk	Likelihood	Consequence	Risk Rating	Remediation
3c	Sedimentation • Cost risk regarding potential for significant concrete work	Age	There is a financial risk associated with the potential for significant concrete rehabilitation work within the existing sedimentation basins.	2	3	6	Complete recommended testing to confirm structural integrity of concrete including carbonation testing and pH testing.
3d	Temporary 5th Sedimentation Tank • Reuse of lamella plates	Complexity	Damage to plates in transport preventing reuse; financial	3	2	6	Plan for loss of 10-15% of modules in transport; set aside $240k for replacement.
4a	Filtration • 2 filter quadrants offline for a 1-month period	Capacity limitation	Desktop evaluation suggests capacity could be limited to 320 MLD. Could result in short filter run times or additional capacity restrictions if several filters in two quadrants enter backwashing at the same time.	5	4	20	Modify construction plan to reduce amount of time with two filter quadrants offline. Push filter upgrades ahead in schedule to allow for operation of modern filter beds and backwash systems during filter capacity restrictions. Develop SOP for operating plant at a 320MLD restriction with 2 filter quadrants online.
4b	Filtration • Backwash limitations during filter upgrades	Capacity Limitation	If a backwash is called for while a single quadrant is out of service and the plant is running at a high flowrate, the filter design loading rate may be exceeded.	5	4	20	Monitor operations for periods where this condition is expected to occur, if possible, increase plant throughput to increase supply in clearwells and reduce low lift pump rates to allow backwashing to occur without exceeding filter loading rates.

Item #	Component	Root Cause	Risk	Likelihood	Consequence	Risk Rating	Remediation
5	Disinfection • Plant relies on pre-chlorination disinfection for CT	Capacity limitation	Reduced disinfection capacity due to sedimentation upgrades	4	5	20	Increase minimum chlorine residuals, count disinfection credits from filtration and clearwells. Push UV upgrades ahead in schedule.
6a	High lift pumps • Cavitation occurs at flows over 450 MLD	Reported to be influent pipe size	Inability for plant to pump expected flows. Note flow testing was conducted 03/27/2023 and pumps were able to pump 600 MLD though cavitation was occurring.	4	4	16	Confirm root cause is size of influent pipes and correct as part of upgrades. Address on/off cycles, allowing the plant to run consistently at lower flow rates. Understand nature and location of noise – perform risk and maintenance analysis for continued and extended operation.
6b	High lift pumps • High lift VFDs unable to operate at top capacity during summer months	Inadequate HVAC	Potential forced reduction in high lift capacity during warmer months	5	2	10	Investigate temperature effects within VFD room and upgrade the HVAC system if determined cause. Potentially use temporary air conditioners if required. It is Stantec's understanding that this is currently in design with a consultant.
7	Complexity of Overall Conceptual Design	Construction plan and schedule	Delays to schedule, financial risk	4	3	12	Separate construction into two phases, prioritizing protection of public health.

6.0 RECOMMENDATIONS AND CONCLUSIONS

The Stantec team has evaluated the process risks associated with the current proposed Phase 2 upgrades.

Raw water and filtered water flow rates were reviewed. It was noted that there was a significant flow discrepancy between raw water and filtered water flow, likely due to the Module 1 raw water flow meter issues. Design for the replacement of the flow meter is in progress. Frequent start-stop cycles were observed in the flow data. Granular media filtration performs best with consistent operation rather than in a start-stop approach. This type of operation may be hard on filters and require more backwashing, resulting in higher filter headloss or turbidity breakthrough impacting performance and efficiency. The flow evaluation presents an opportunity to evaluate the total plant production needs in an effort to peak-shave high plant flow operating scenarios to minimize risks during construction and operate the plant more in line with best practices.

Plant performance using the AWWA Partnership for Safe Water Goals was reviewed. The results indicate that raw water turbidity is low and settled water turbidity and filtered water turbidity are generally low and well managed. However, there is an opportunity to minimize risks of potentially elevated filter effluent turbidity events by constructing FTW piping and optimizing filter backwashing to minimize filter ripening spikes and improve filter cleaning during backwashing. It was noted that filtration has not been operated at a loading rate > 9 m/hr in the past three years; in order to operate for extended periods at higher loading rates during construction, an extended full-scale stress test at 12 m/hr is recommended. It may be of interest to approach this stress testing in stepwise manner, by initially testing 10 m/h, followed by 11 m/h and finally 12 m/h should the first two tests demonstrate the ability to maintain unit filter run volumes at greater than 250 m^3/m^2.

The existing sedimentation treatment process is expected to perform well up to approximately 520 MLD, with the potential for declining performance in cold water conditions at flows greater than 260 MLD. With two sedimentation basins offline, performance is expected to decline at flowrates greater than 130 MLD and 260 MLD in cold and warm water conditions, respectively. Higher settled water turbidity could result in shorter filter run times as a result of higher headloss accumulation rates and greater risk of turbidity breakthrough. Filtration performance is expected to be robust to a potential plant flow rate of 514 MLD with only 16 filters in service; this could potentially be increased to 617 MLD with only 16 filters in service if a loading rate of 12 m/hr can be demonstrated. The capacity risk of having one filter quadrant offline during construction is expected to be minimal, however, having two filter quadrants offline could reduce plant capacity to 321 MLD – or potentially 386 MLD if a filter loading rate of 12 m/hr can be demonstrated. The sedimentation basins provide the majority of the CT required for 0.5-log *Giardia* inactivation. With the potential for two sedimentation basins offline during construction, CT could limit plant production under worst-case conditions. It was noted that CT provided through the clearwell is not included in the current CT calculator.

Plant stress testing was conducted on March 27, 2023 to understand the hydraulic limitations associated with higher flowrates with one quadrant out of service, and verify and validate any hydraulic bottlenecks within the system downstream of the filters. The results of the stress test demonstrated an operational bottleneck between 575 – 600 MLD due to chemical dosing high flow alarms; the final chlorinator was operating at maximum capacity precluding further increases in plant flowrate. Surcharging in the filter effluent channel hatch was not observed during the stress test. Some characteristic sounds of cavitation were observed at the high lift pump intake when operating at these flows. Additional analysis of the treatment performance response during this stress testing is provided in **Appendix D**.

A risk matrix was developed to evaluate the likelihood and consequence of the risks identified in this evaluation. The following recommendations have been developed:

- Backwashing during filter upgrades may result in design filter loading rate exceedances. Operations should be monitored for periods where this condition is expected to occur.
- Raise minimum pre-chlorine residuals through pre-treatment such that sufficient contact time is provided under cold water conditions with reduced sedimentation capacity. UV upgrades could be moved ahead in the schedule.
- Prioritize upgrades to the filtration process including upgraded underdrains and backwash technology, optimize the filter backwash sequence, and implement FTW infrastructure ahead of sedimentation upgrades.
- Perform an extended full-scale stress test at a filtration loading rate of 12 m/hr, and complete a full-scale trial using a sedimentation polymer aid. The polymer aid may allow sedimentation to operate at a higher loading rate, which will be beneficial for the construction period when capacities are limited.
- Develop an SOP for operating the Woodward WTP with only two (2) filter quadrants (or 10 filters in service with 2 standby) where the potential plant capacity may be limited to approximately 320 MLD.
- Remove tertiary flocculation stage from the Phase 2 upgrades scope.
- Conduct further testing and investigation of VFD temperature reduction, chemical flowrates, and cavitation to understand impacts on discharge flowrates.
- Evaluate the use of online streaming current or bench-scale zeta potential measurements to validate adequate coagulation chemistry to optimize filtration run times.
- Given the City is considering DAF as an alternative clarification process, evaluate the feasibility and cost-benefit relative to sedimentation with lamella plates, and conduct pilot testing to validate design loading rate.
- Complete a detailed evaluation of sedimentation/clarification technologies. Investigate the possibility of implementing DAF and locating in the lower stores footprint. Stantec understands this is currently under review with a consultant, including structural integrity of the sedimentation tanks and soil bearing capacity.

- Review the construction schedule to explore opportunities for sedimentation upgrades to occur in the spring and summer months when sedimentation capacity is expected to be higher with one or two trains out of service.
- Investigate opportunities to equalize total filter flow rates to reduce high WTP flow conditions, and minimize plant shut-downs and filter start-stop operation. With flow peak shaving, the construction schedule could be modified if higher capacity is not required through the summer as has been observed in recent years.
- Replace Module 1 Flow Meter (underway) and validate that SCADA total raw water flows are in line with total filter flows.
- Complete recommended testing to confirm structural integrity of concrete including carbonation testing and pH testing.
- Plan for loss of 10-15% of plate modules in transport between temporary sedimentation tank and tank 2; set aside $240k for replacement.

APPENDIX A
PLANT CAPACITY ANALYSIS WORKBOOK

WOODWARD – FULL-SCALE WATER TREATMENT PLANT STRESS TESTING

Objectives

The objective of the full-scale stress testing is to evaluate capacity limitations associated with the existing filtration process in its pre-construction condition to understand potential flow restrictions during Phase II upgrades. The objective of this testing is not to optimize filter UFRV although this could be investigated using a similar protocol / approach, following filter upgrades with modern underdrains and air scour equipment, in concert with optimize coagulation chemistry.

Each stress test will be trialed with all existing four (4) clarification trains in service- but only two filter quadrants of the process (i.e. 12 filters).

The preferred filter quadrants for testing are at the discretion of plant operations. It is recommended to test quadrants that have representative performance of the filtration process and no known filter condition or operating issues. The other quadrants can either be taken offline, maintained at a low flow-rate or other configuration as pre-determined by the City and operations to accommodate distribution demands and storage levels, clearwell levels, or other supply considerations.

The full-scale flow capacities planned to be tested at Woodward WTP include the following:

1. **370 MLD** (185 MLD per quadrant), representing current predicted process potential performance limitation for filtration with two filter quadrants out of service and a target loading rate of 11 m/hr.
    - **To achieve these target filtration loading rates, it is recommended to run the testing with 11 filters online and 1 in standby.**

2. **405 MLD** (202.5 MLD per train), representing a filter loading rate of 12 m/h (with 11 filters online and 1 in standby); to be tested should Trial 1 at 370 MLD be successful.
    - **To achieve these target filtration loading rates, it is recommended to run the testing with 11 filters online and 1 in standby.**

Stress testing at approximately 370 MLD and 405 MLD

This component of the stress test requires that the plant is operated at a constant flow rate of 370 MLD for a duration of as long as possible (e.g., until 2 of the 11 filters enter backwash), or for a minimum period of 24 hours, whichever is shorter. Prior to initiating the test, filters in the test quadrants should be backwashed to allow for the most robust testing conditions possible. Should one filter enter backwash during the testing, the standby filter in the test quadrant could be brought online in an effort to extend the testing.

Should testing at 370 MLD with two filter quadrants prove successful in terms of maintaining filter UFRV > 200 m^3/m^2, then the testing is to be repeated at a flow condition of 405 MLD.

It is preferred to conduct the testing during typical raw water quality conditions and not during a raw water quality event (e.g., lake turnover, elevated turbidity). All monitoring and performance evaluations are to be repeated for this set of testing as described below.

Protocol for Full-Scale Testing

Guidance for Operations and Conditions for Terminating the Test:

- Submission of a Form 2 to the MECP is recommended prior to testing to notify the MECP of the intent to test a higher flow condition on one train than current average day flows but well within the DWWP flow rate. If additional testing is completed with a filter aid polymer, the Form 2 will be required to notify the MECP of a process change to be trialed on two filter quadrants of the full-scale process with the addition of the polymer to the stage-2 flocculation basin (dose to be informed by jar-testing).

- Cleaning of sedimentation basins is recommended prior to the test.
- Calibration of instrumentation (turbidity meters, temperature probes, pH probes) to be completed prior to testing.
- Filter effluent turbidity set-point programming could be increased to 0.20 NTU
    - This will allow for an evaluation of the rise in headloss accumulation and/or filter effluent turbidity during the test to 0.15 NTU (half the MAC of 0.3 NTU).
- The test is to be initiated with 11 filters online and one (1) filter on stand-by
    - All filters to be backwashed prior to initiating testing
    - The stand-by filter is to be brought online should one (1) filter go out of service.
- Target flow rates should be achieved in a step-wise approach (e.g., by increasing plant flows by 50 MLD at a time before achieving steady state operation at the given test flow rate) so as not to disrupt process performance due to a flux in plant flow rate
- The test is to be terminated should one of the following conditions arise:
    - If two (2) of the initial in-service filters are offline (or three [3] filters offline in total) / backwashing AND the filter effluent turbidity reaches 0.15 NTU
    - CT calculations are not met

Zeta-Potential Monitoring and Coagulant Dose Adjustments to be Completed by Operations Staff

It is also recommended to use zeta-potential to uphold appropriate coagulation chemistry through sedimentation during testing.

During the testing, zeta-potential parameters should be monitored three times a day (e.g. every 4 hours at 8 am, 12PM, and 4 PM) in the post-coagulated water (downstream of flash mixing) of the Test Train. A set point of >-8 mV is recommended to be upheld during testing.

During the testing, coagulant doses should be adjusted to maintain the optimal post-coagulation zeta potential set-point.

Response action:

- Should zeta potential measurements in the raw water decline, or post-coagulation decline to become more negative than the set-point or approximately -5 mV, coagulant dose should be increased.
- Should zeta potential measurements in the raw water increase, or post-coagulation increase to become more positive than the set-point, or approximately +3 mV, coagulant dose should be decreased.

Evaluation of Results

Following the testing, Stantec will submit a request for SCADA data including the following parameters:

- Raw water

  - Turbidity
  - Temperature
  - pH
- Coagulation
  - Chemical Doses
  - pH
- Settled water turbidity
- Filtration (for filters in service):
  - Flows
  - Runtime
  - UFRV
  - Effluent Turbidity
  - Headloss
- Operations log containing observations made during the course of each trial and particularly during backwashing events – a description of the reason for terminating each filter run (e.g., headloss, turbidity breakthrough, time, other).

The preferred increment for SCADA data will be determined following observations made during full-scale testing.

Laboratory parameters to be requested include:

- Grab sampling for raw water, settled water, and filter effluent UVA

Reliable performance will be evaluated against the following criteria:

- UFRVs greater than 200 m^3/m^2 while maintaining filter effluent turbidity <0.1 NTU.

Should the stress test need to be terminated prior to achieving the target UFRV condition, a review of the rate of filter headloss accumulation, and increased settled water turbidity conditions will be completed.

APPENDIX B
FLOW ANALYSIS

APPENDIX B

The City communicated that the accuracy of the Module 1 Raw Water Flow Meter is poor at high flow rates. Operations staff have observed that this flow meter it is often off by 10 to 40 MLD due to heavy turbulence upstream of the flowmeter; accuracy is improved at lower flow rates. This magnetic flow meter has a butterfly valve and a proximal pipe elbow which are known to be problematic for accurate flow readings. It is understood that the Module 2 flow meter is a Venturi and has better accuracy, and that there is an ongoing project to replace the Module 1 Raw Water Flow Meter.

Table B-1: Seasonal Maximum and Average Raw Water and Total Filter Flow Rates (2022)

Process Flows (MLD)		Raw Water (MLD)		Filtration (MLD)	
Year	**Month**	**Maximum**	**Average**	**Maximum**	**Average**
2022	January	340	201	326	194
2022	March	241	194	274	199
2022	July	433	314	439	243
2022	October	370	293	472	206

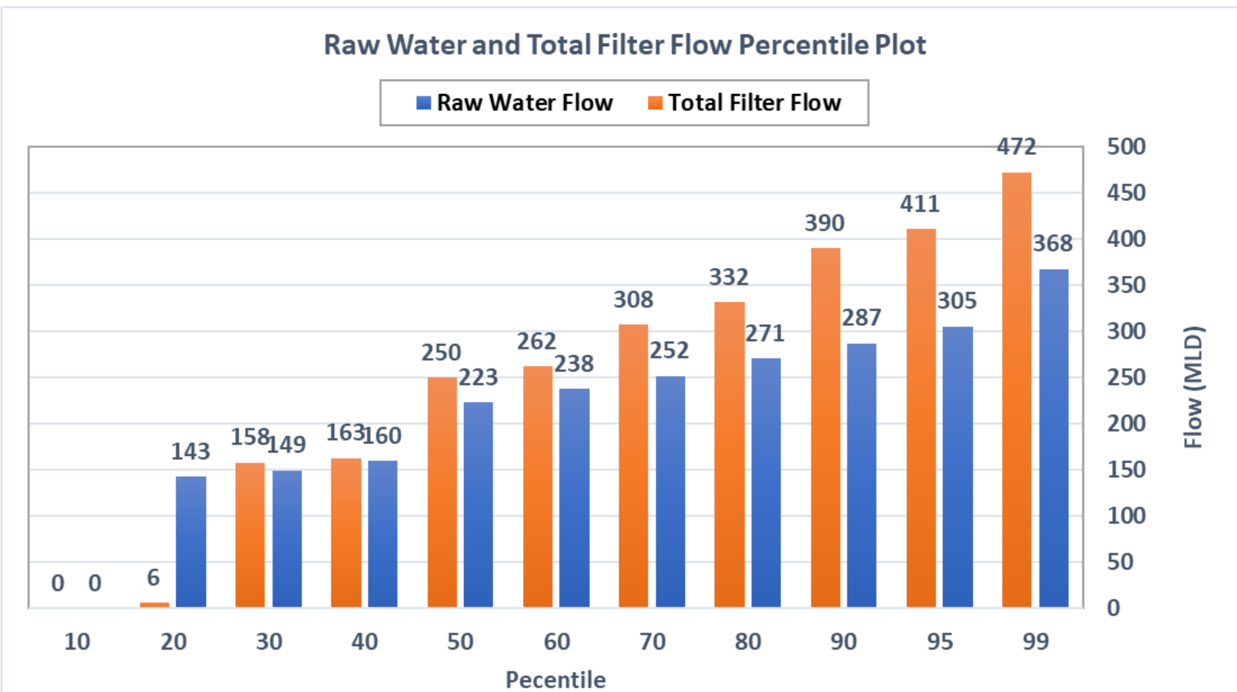

Figure B-1: Raw Water Flow and Total Filter Flow Percentile Plot Demonstrating Discrepancy Between SCADA Flow Values

APPENDIX C
DISSOLVED AIR FLOTATION EVALUATION

APPENDIX C

PRELIMINARY REVIEW OF ALTERNATIVE CLARIFICATION TECHNOLOGIES FOR WOODWARD WTP

Stantec reviewed the potential unit process capacity that could be achieved by upgrades for either enhanced sedimentation basins with lamella plates or dissolved air flotation (DAF).

Enhanced Sedimentation with Lamella Plates

The proposed upgrades for sedimentation with lamella plates were assumed to have a plate coverage area of 45% (conservatively). With two (2) or three (3) upgraded trains in service, the estimated capacity would increase to approximately 572 MLD and 859 MLD, respectively. This is expected to meet projected demands beyond 2050. However, upgrading only two (2) trains, as planned for the Phase 2 Upgrades, will not enable the plant to achieve the targeted 650 MLD maximum capacity.

If the goal of the upcoming construction activities is to achieve a reliable process capacity of 909 MLD long-term, then the capital costs for sedimentation upgrades with lamella plates may be misplaced. As the capacity graph below indicates, with one train out of service (e.g., for maintenance), the plant capacity would be reduced to 286 MLD after the Phase 2 upgrades, or 859 MLD long-term, which may not meet the objective of the construction activities. There may be other, high-rate, technologies that can achieve the same or higher capacity in a lower footprint.

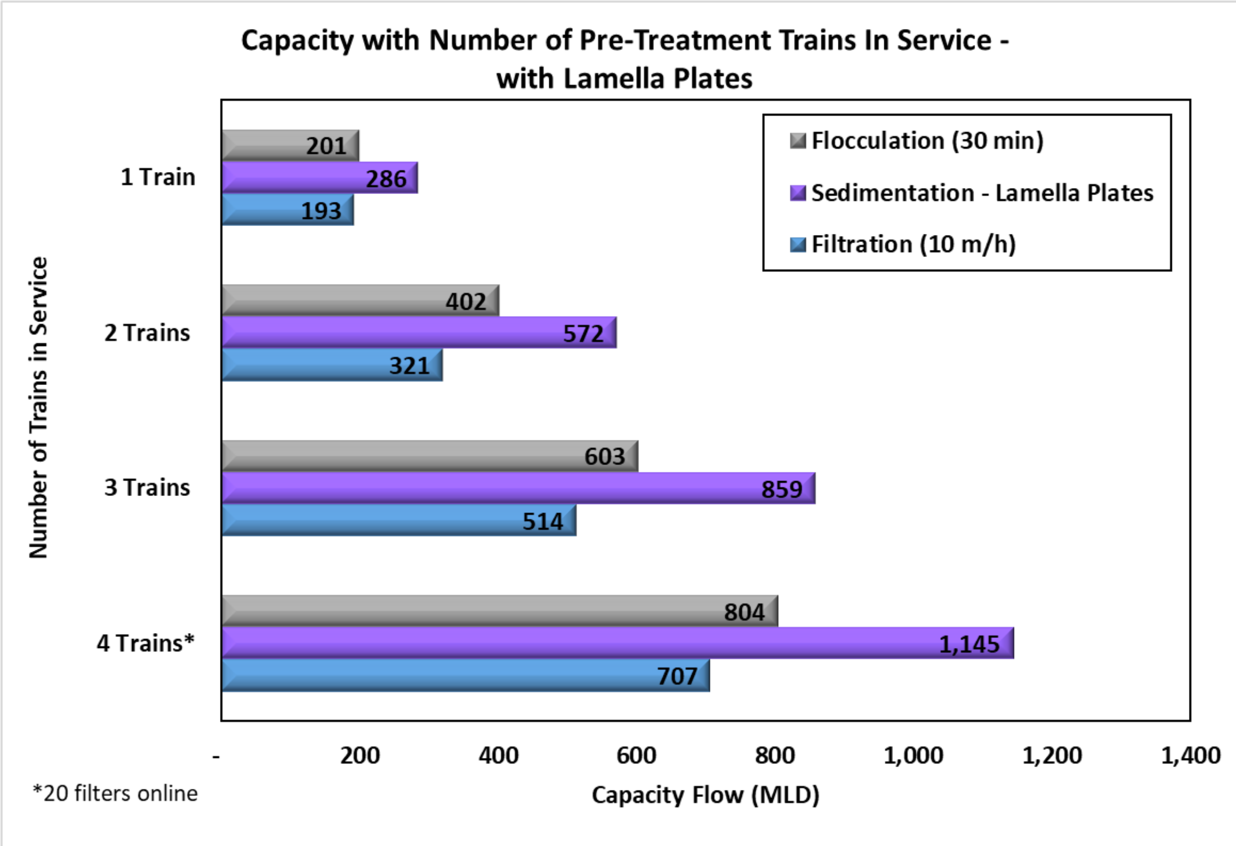

Figure C-1: Unit process capacity potential with number of pre-treatment trains out of service with Woodward WTP upgraded sedimentation with lamella plates

Table C-1: Unit process capacity potential and risks for sedimentation upgrades with lamella plates

Sedimentation Evaluation - Lamella Plates - Plate Coverage Area Calculation					Sedimentation - Lamella Plates: Evaluation Scenarios			
Flow Condition	Flow Rate (m^3/d)		Flow (MLD)	No. Trains:	4	3	2	1
PEAK (2022)	459,000	m^3/d	425	SOR (m/h) - Plate Coverage SA	3.92	5.23	7.84	15.68
PHASE 1 (PHD GROWTH)	702,000	m^3/d	650		6.00	8.00	11.99	23.99
Rated Capacity	981,720	m^3/d	909		8.39	11.18	16.77	33.54
Downstream Losses:	8%			Capacity - MLD (5 m/h):	1,145	859	572	286

Dissolved Air Flotation Retrofit

A preliminary conceptual evaluation of the potential unit process capacity for DAF at Woodward required a preliminary markup of alternative process unit configurations. Understanding that typically 11 m is the maximum approximate acceptable width of a DAF basin, the following conceptual layouts were prepared to either consider DAF upgrades within the existing sedimentation basins or in the footprint of the lower stores. This preliminary evaluation assumed a conservative DAF loading rate of 18 m/h, although many installations with comparable raw water quality have demonstrated good performance at loading rates of 26 m/h or higher.

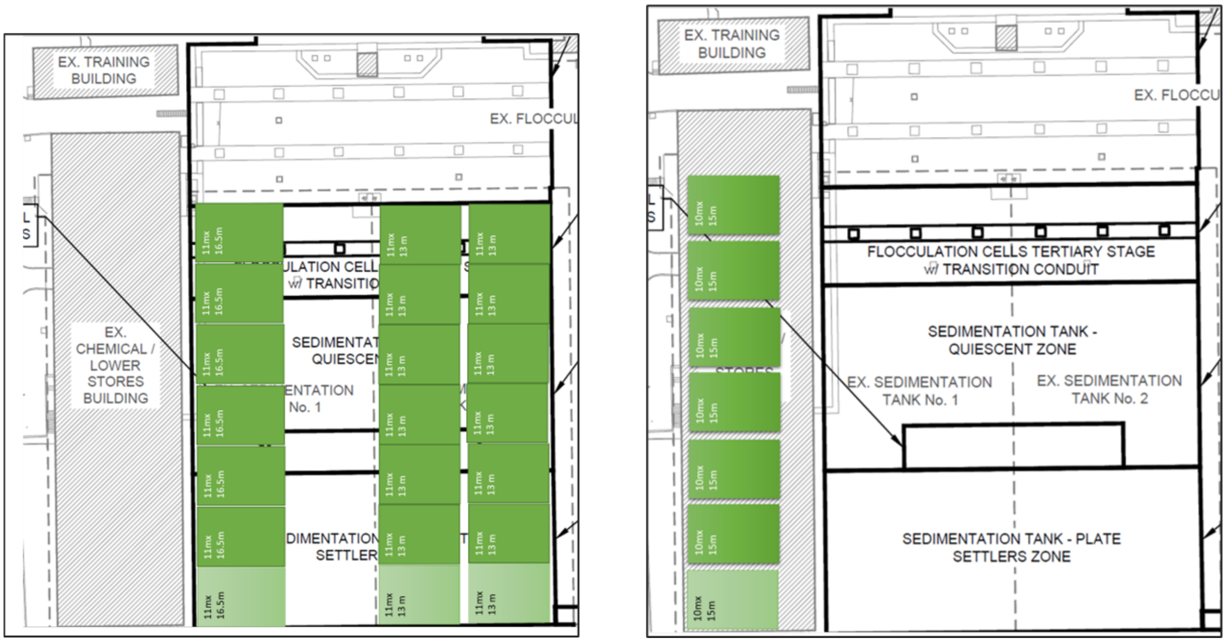

Figure C-2: Preliminary conceptual schematic of DAF unit process layouts; retrofit into existing sedimentation basins (LEFT) and greenfield construction in location of existing lower stores (RIGHT).

The results of this review suggest that, conservatively, 13 DAF units (11x16 m each with 1 standby) could achieve the plant rated capacity of 909 MLD, while nine (9) units could achieve the capacity of 608 MLD, and seven (7) units could achieve 456 MLD. Higher loading rates could reduce these estimates by 20% or more.

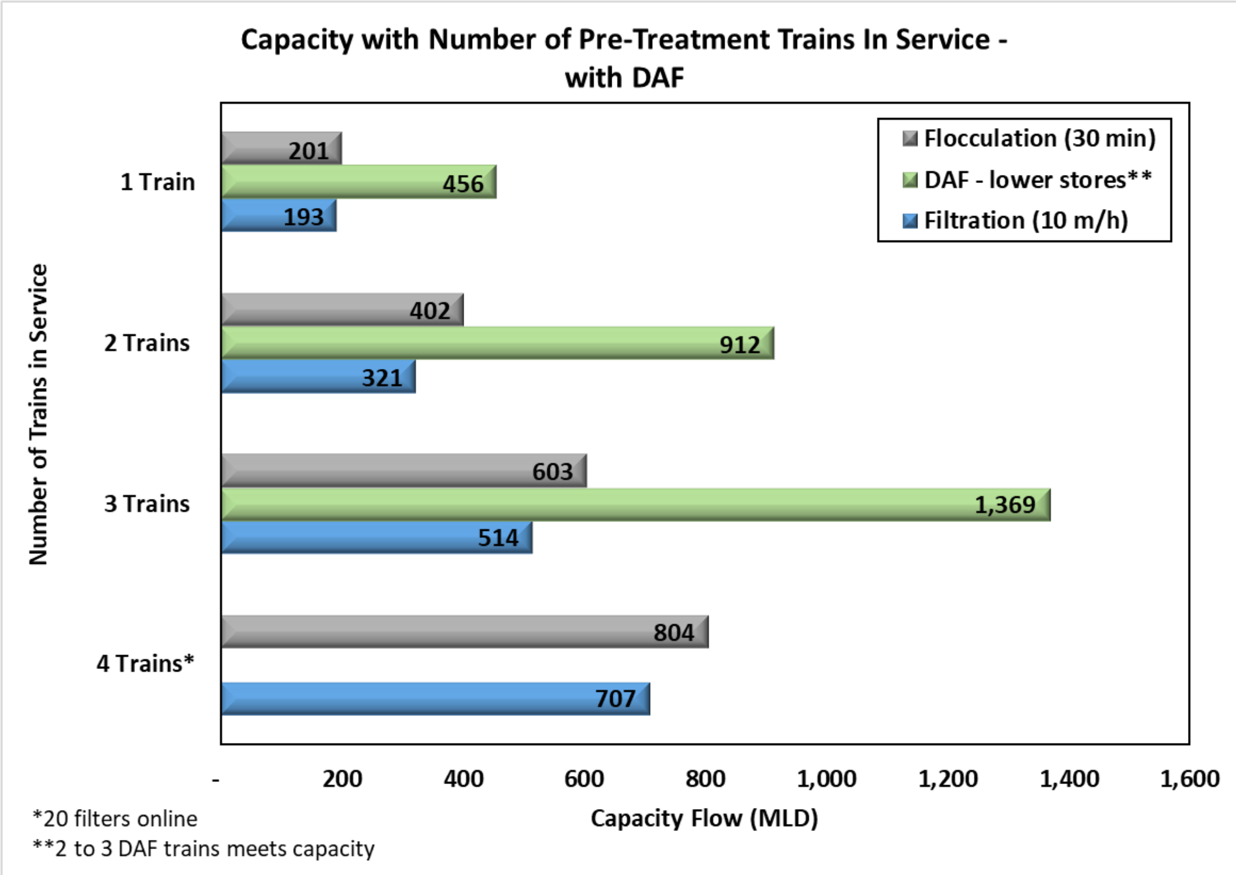

Figure C-3: Conceptual unit process capacity potential for dissolved air flotation upgrades at Woodward WTP (6 units per train)

EVALUATION OF ALTERATIVE CLARIFICATION TECHNOLOGIES

To evaluate the best available technology for upgrading the clarification process at Woodward WTP with respect to the existing treatment processes in place (coagulation, flocculation, filtration) and the raw water quality, Stantec conceptually reviewed and scored evaluation criteria associated with sedimentation upgrades with lamella plates and DAF upgrades (either retrofit or at the lower stores). The details of that analysis are summarized in Table C-2 and Figure C-4 below.

Overall, the results of this conceptual review suggest that DAF is expected to provide operational and performance benefits over enhanced sedimentation with lamella plates. The potential advantages for a DAF upgrade at Woodward WTP may include:

- Higher rate process able to achieve a higher loading rate and capacity in a given footprint, potentially minimizing construction activities and leaving land available for potential future uses (e.g., treatment for emerging contaminants, filter backwash recycle holding tanks)
- A more robust technology process for the management of potential algae blooms

- Potential for minimizing chemical consumption where the use of a sedimentation polymer aid would not be required, but could benefit operation of enhanced sedimentation
- Potential for more streamlined operations and maintenance burden. While DAF would have higher energy costs and maintenance associated with saturators and compressors which require annual maintenance shut-downs, lamella plates could require routine washing of the plate and/or operation of an automated aeration cleaning system which would also require maintenance and operation in itself.

It is understood that the City has plans underway to conduct pilot testing for DAF at Woodward WTP and conceptual layouts for DAF retrofitting, and Stantec is in support of this approach to understanding the best approach to addressing sedimentation shortfalls for Woodward WTP.

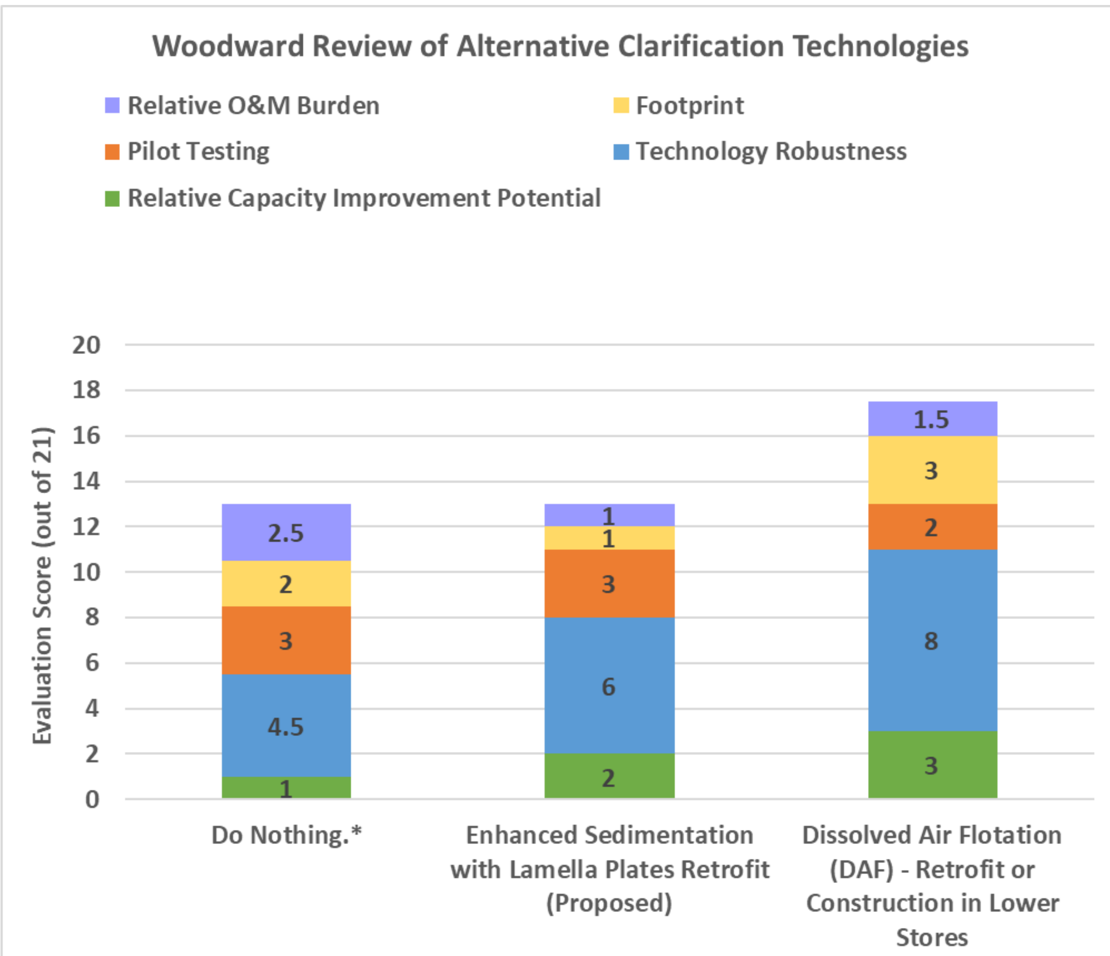

Figure C-4: Conceptual evaluation of alternative clarification technologies for Woodward WTP.

Table C-2: Summary of results of conceptual evaluation of alternative clarification technologies for Woodward WTP.

Evaluation Scores	Alternatives			
	1	**2**	**3**	
Evaluation Criteria	**Do Nothing.***	**Enhanced Sedimentation with Lamella Plates Retrofit (Proposed)**	**Dissolved Air Flotation (DAF) - Retrofit or Construction in Lower Stores**	**Total Potential score**
Relative Capacity Improvement Potential	1	2	3	3
Technology Robustness	4.5	6	8	9
Turbidity	2	2.5	3	
Organics	1.5	2	2	
Algae	1	1.5	3	
Pilot Testing	3	3	2	3
Footprint	2	1	3	3
Relative O&M Burden	2.5	1	1.5	3
GRAND TOTAL SCORE	**13**	**13**	**17.5**	**21**

APPENDIX D
STRESS TESTING ANALYSIS

APPENDIX D

SUMMARY OF PROCESS PERFORMANCE DURING STRESS TESTING

Introduction

As described in Sections 4.3 and 4.4, a brief stress test was performed at Woodward WTP in March 2023. A review of the pre-treatment unit process performance in response to that testing is provided below. It is noted that during the testing, Filters 1 through 6, 21, and 22 were offline. SCADA data was provided in 1 minute increments to support this analysis.

A summary of the raw water temperature and pH conditions through the plant is provided below in **Table D-1**. In general, the test was performed at cold water conditions which are theorized to produce more challenging conditions for sedimentation performance.

Table D-1. Summary of Raw Water Temperature and Plant pH Values During Testing

Test Conditions	Value	Stdev	Count (*n*)
Temperature, Raw Water (degrees C)	2.15	0.007	10
pH, Raw Water	8.11	0.039	20
pH, Settled Water (1)	7.52	0.018	300
pH, Settled Water (2)	7.48	0.022	300
pH, HLPS (1)	7.37	0.037	300
pH, HLPS (2)	7.29	0.007	300

Raw Water Turbidity

Raw water turbidity was found to increase during the test as flow rate was increased as shown in **Figure D-1**., and a correlation between plant flow (total filter flow as this is known to be more accurate) and raw water turbidity was identified as shown in **Figure D-2**.

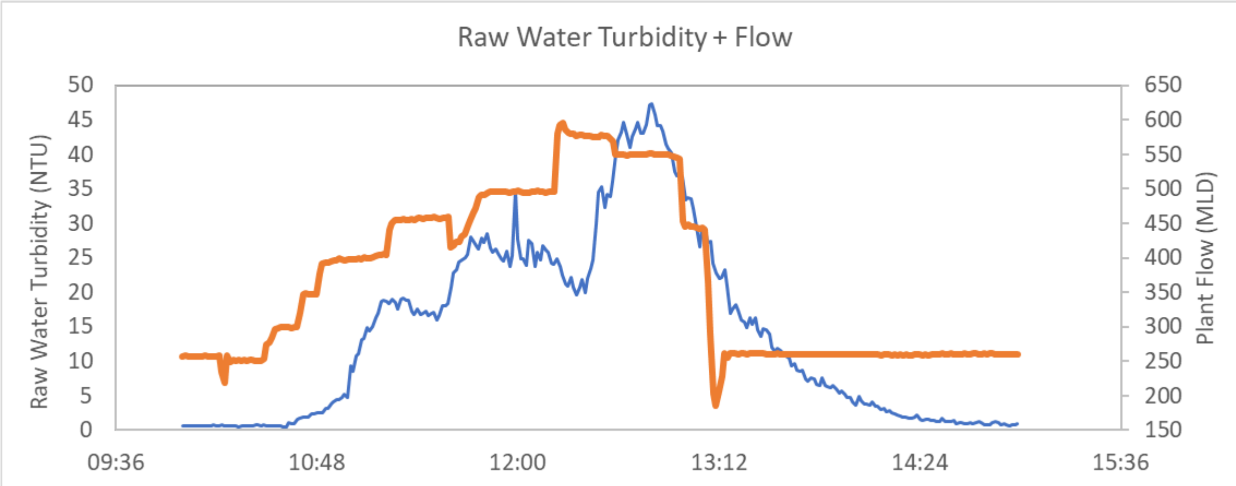

Figure D-1. Trendline of raw water turbidity and plant flow during stress testing.

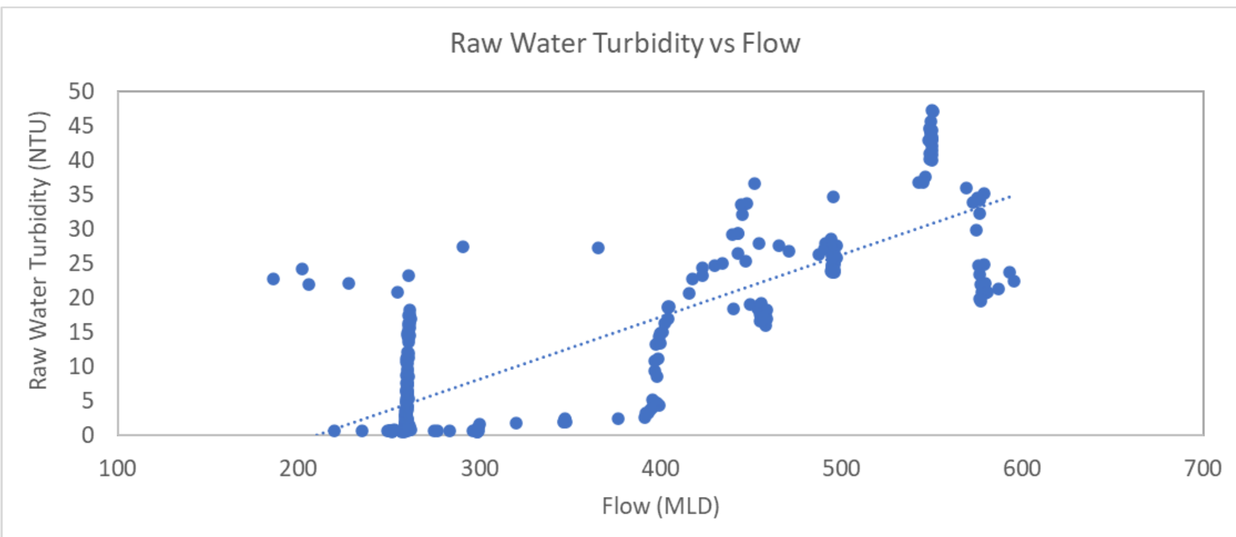

Figure D-2. Relationship between raw water turbidity and total plant flow during testing.

PACl Dosing

During testing, operators reported that there were issues with the coagulant pumps maintaining the target flow pacing for continuous, sustained coagulant dosing. The trend for the ratio of plant flow rate to PACl pump discharge flow during the testing is presented in **Figure D-3**. This demonstrates that the ratio significantly declined once the plant was running above about 400 MLD and all four (4) PACl pumps followed the same declining trend at the higher flow rates. Additionally, the maximum PACl pump speed feedback approached 80% once flows were greater than or equal to 550 MLD (**Figure D-4**).

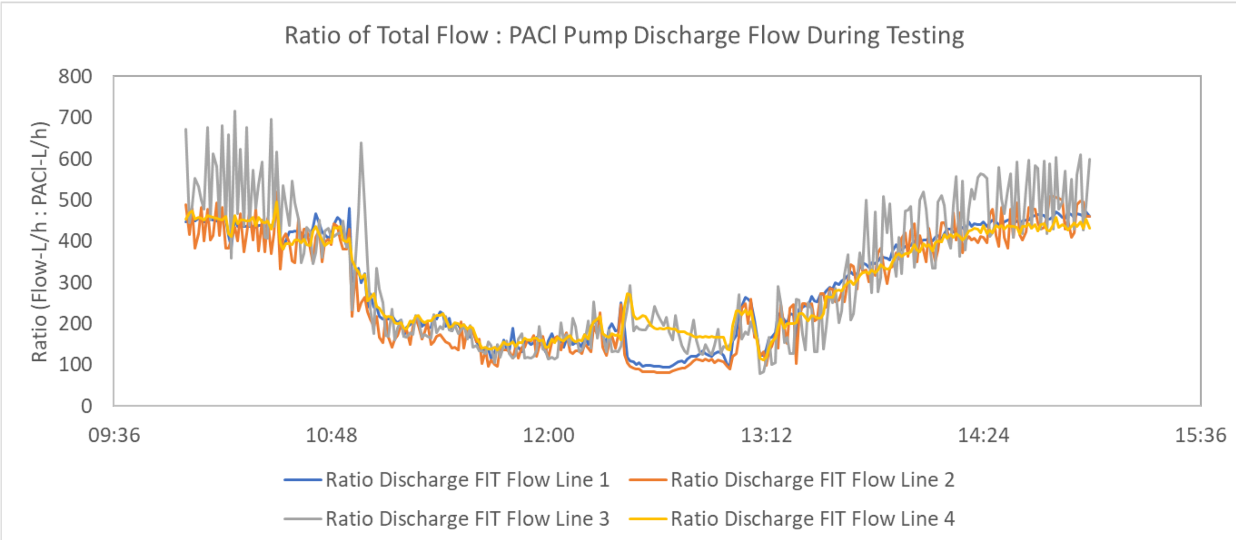

Figure D-3. Ratio of Plant Flow to PACl Pump Flow during stress testing.

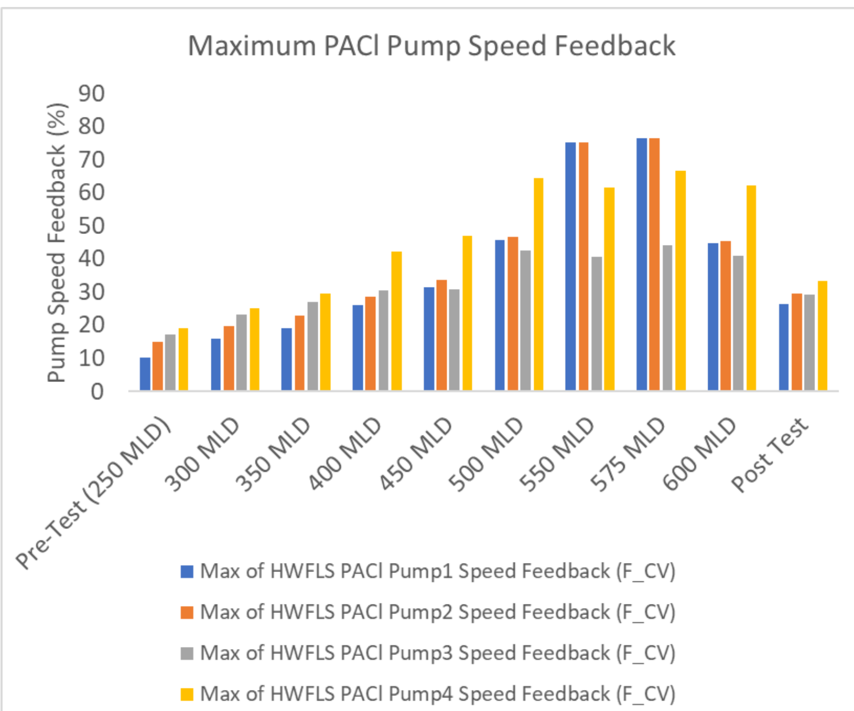

Figure D-4. Maximum PACl pump speed feedback during stress testing.

Sedimentation

Throughout the testing, the loading rate of sedimentation was increased in a step-wise approach from approximately 1.0 m/h to briefly above 2.0 m/h which is the maximum sedimentation surface overflow rate

(SOR) recommended by the MECP (**Figure C-5**) (based on the value of a surface area of 2,710 m^2 per train).

While average settled water turbidity did rise for both sedimentation basins over the course of the brief test, the maximum turbidity value observed was <0.8 NTU as shown in **Figure D-6**. The scatter plot in Figure C-5 shows a gradual increase in the trend of settled water turbidity at higher plant flows. Therefore, extended operation at future projected demands anticipated during construction is recommended to understand the longer term robustness of sedimentation when one or more trains are scheduled to be offline.

Finally, higher settled water turbidity was observed on Side 2 than on Side 1 which may be the result of the accuracy of the instrumentation sample line, instrument maintenance (e.g., potential clogging of the line), a difference in sludge blanket at the test initiation, or represent a true difference in performance between the two sides (**Figure D-7**).

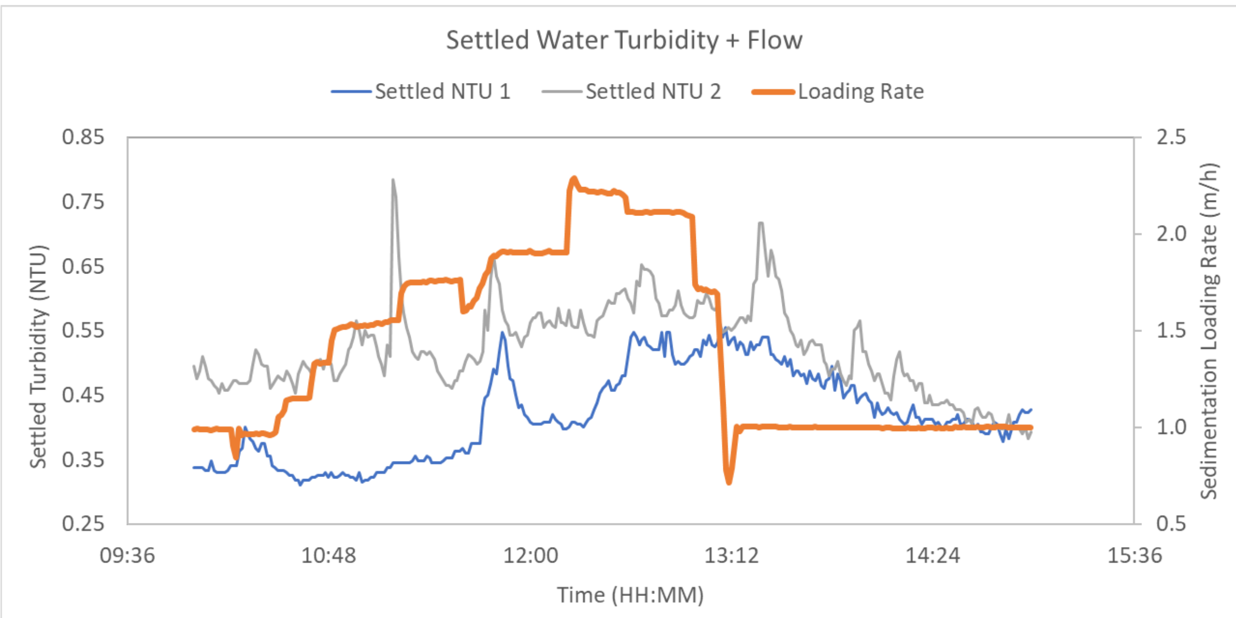

Figure D-5. Settled water turbidity trends during testing while increasing plant flow and sedimentation loading rate.

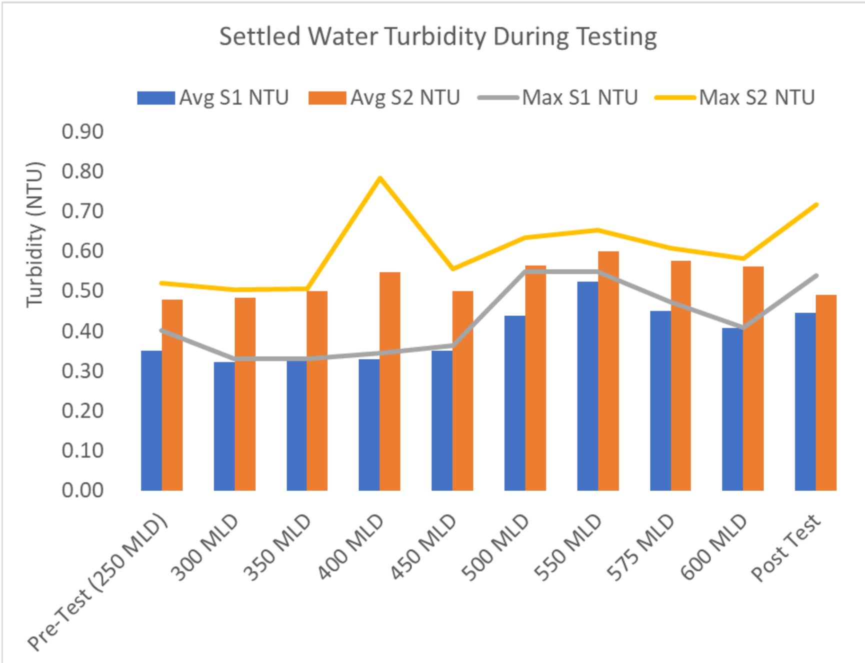

Figure D-6. Average and maximum settled water turbidity observed during brief stress test modes.

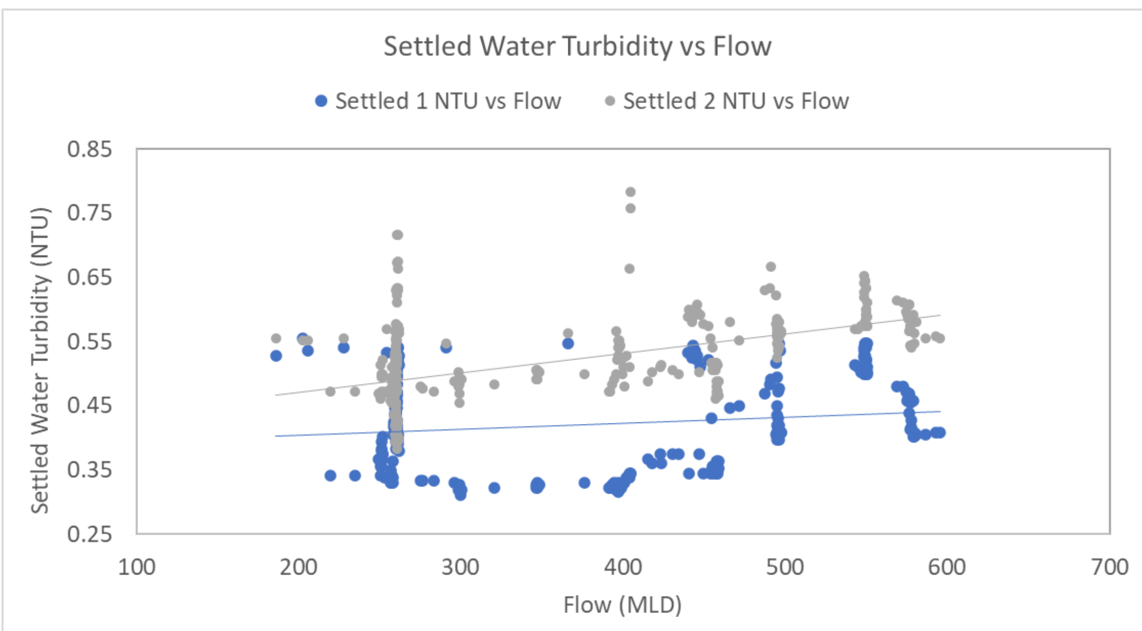

Figure D-7. Scatter plot of settled water turbidity and plant flow during stress testing.

Filtration

Due to the short duration of this stress testing, an evaluation of filter efficiency, robustness, or unit filter run volume (UFRV) is not practical. To further evaluate these process capabilities, a longer and sustained stress test is recommended. Overall, due to filtration programming controls, filter effluent turbidities were maintained below 0.1 NTU (radar **Figure D-8** showing the results only for even numbered filters in service).

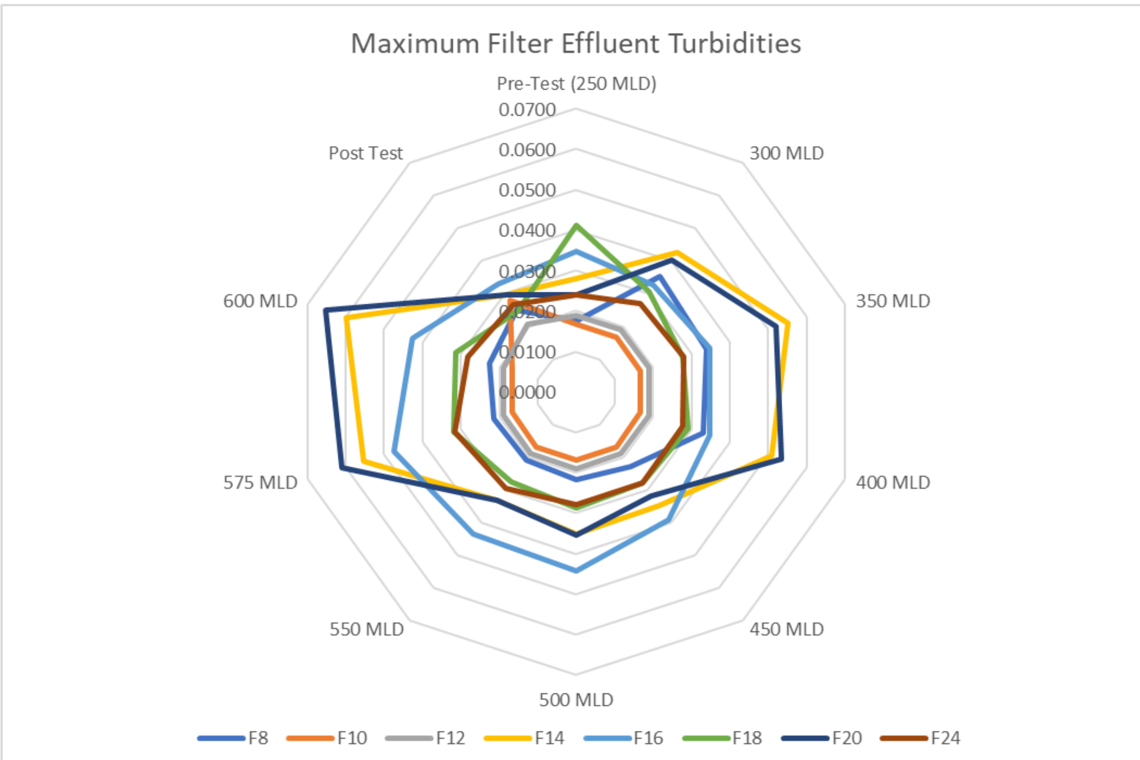

Figure D-8. Maximum Filter Effluent Turbidity During Stress Testing (even numbered filters in service only)

A marked increase in filter effluent turbidity was observed particularly for Filters 14 16, 19, 20, and 23, when flow was transitioned from 500 MLD to 600 MLD (**Figure D-9**).

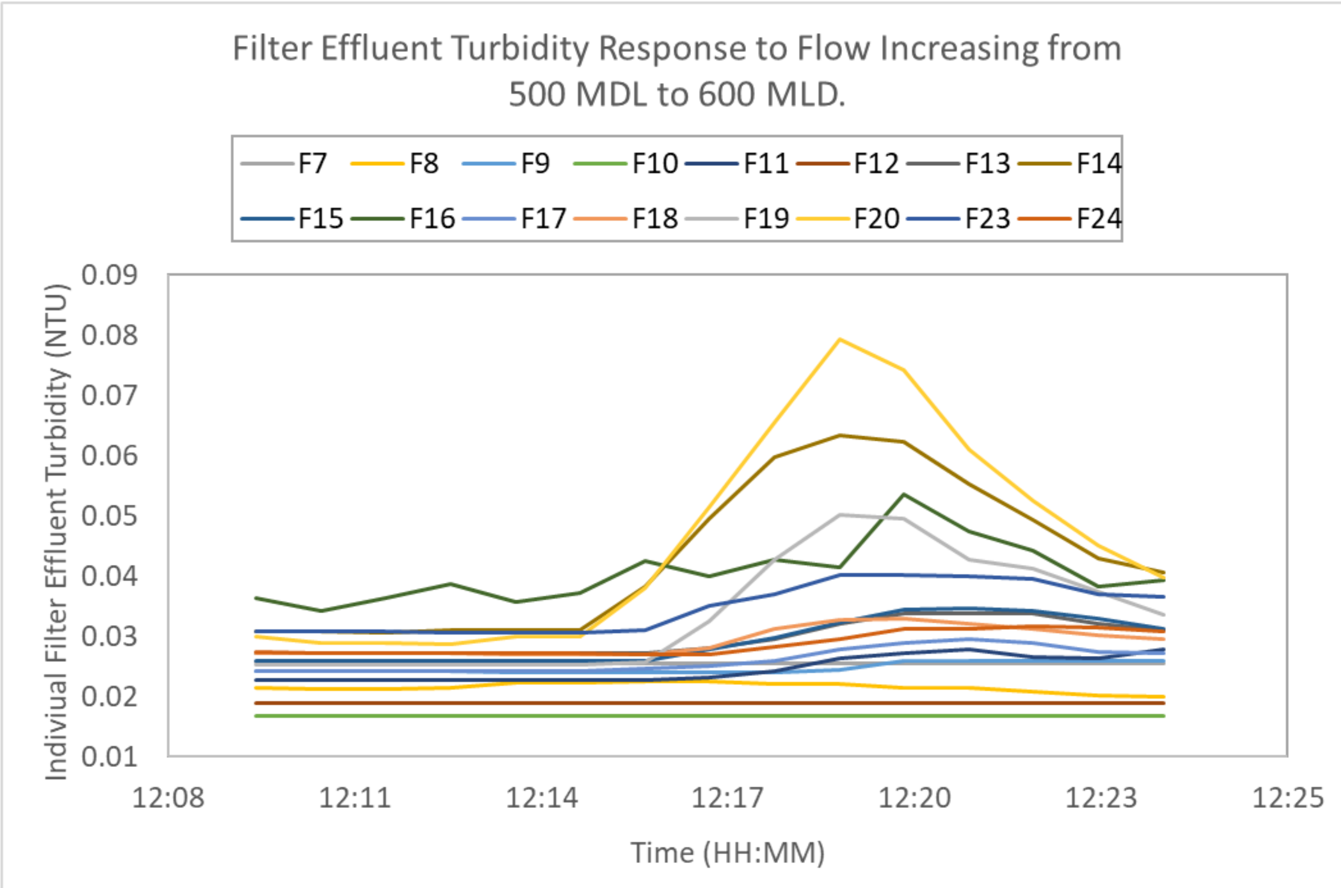

Figure D-9. Individual filter effluent turbidity response to flow increasing from 500 MLD to 600 MLD.

Finally, a review of filter loading rates practiced during the stress testing was conducted based on the total filter flow, the number of filters in service and the individual filter bed surface area (134 m^2). The maximum filter loading rate testing at full-scale was 11.6 m/h for a duration of approximately 12 minutes (**Figure D-10**).

A scatter plot of the correlation between average and maximum filter effluent turbidity against filter loading rate is provided in **Figure D-11**. This data suggests a potential trend of higher maximum filter effluent turbidity and higher filter effluent turbidity variability at higher flow rates.

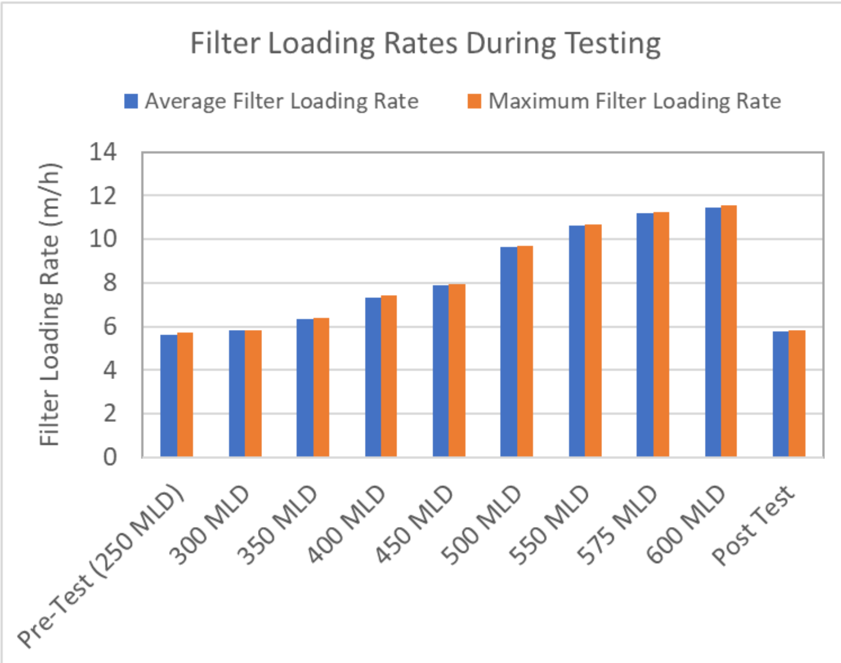

Figure D-10. Filter Loading Rates Experienced During Stress Testing

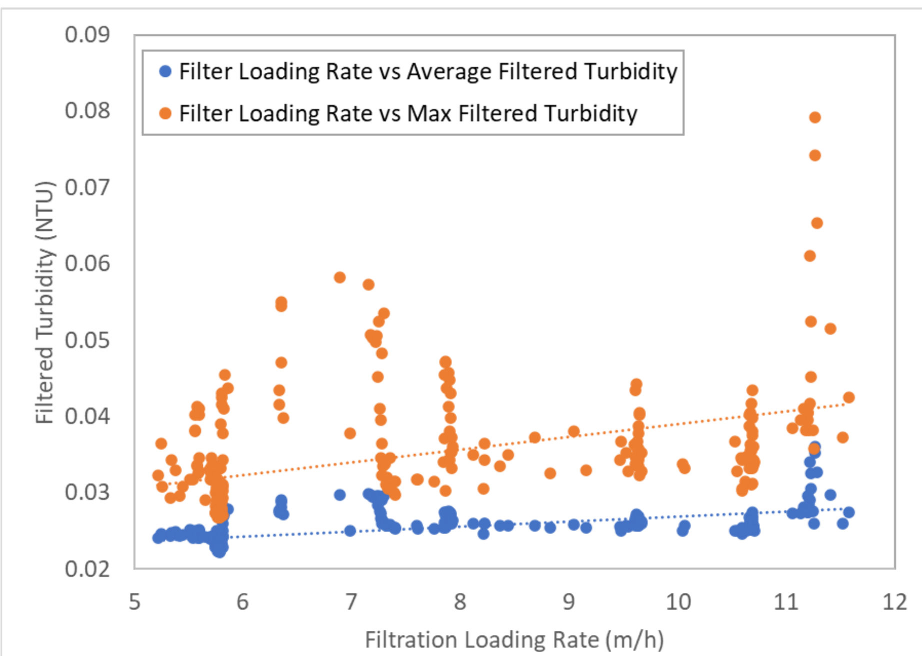

Figure D-11. Scatter plot of average (blue) and maximum (orange) filter effluent turbidity and filter loading rate.

Based on these observations, a sustained stress test could further elucidate the potential capacity for the filtration process to maintain good unit filter run volume performance values at higher flows.

SUMMARY OF OBSERVATIONS AND RECOMMENDATIONS

A summary of the process performance observations during stress testing is provided below:

1. Raw water turbidity was found to increase with increasing plant flow rate.
   a. It is recommended to investigate the cause of this observation.
   b. Potential causes could be uptake of sand off of the bottom of the lake near the intake; sloughing of biofilm from within the intake pipe; natural raw water turbidity event.
   c. Potential remediation could involve an SOP or programming to minimize flux at the intake when increasing the plant flow rate; routinely clean intake pipe walls.
2. PACl pumps were unable to maintain flow-pacing at higher flows.
   a. Recommend to review programming and pump sizing.
3. Consider repeating sedimentation loading rate test for an extended duration at an elevated flow rate representative of future projected demands during construction to understand potential performance limitations with extended operation at higher loading rates.
4. There is a potential trend of higher maximum filter effluent turbidity and higher filter effluent turbidity variability at higher flow rates.
   a. Consider conducting a sustained stress test at a higher plant capacity to elucidate the expected UFRV that can be maintained at higher flow rates and identify the practical process capacity limitation with respect to the current filters.

APPENDIX E
PRELIMINARY REVIEW OF BACKWASH OPTIMIZATION

APPENDIX E

REVIEW OF OPTIMIZED FILTER BACKWASHING

Woodward WTP operates 24 filters in the absence of filter-to-waste (FTW) and optimized backwash equipment. Stantec has reviewed the filer design and media specifications to provide a recommended backwash sequence incorporating an Extended Terminal Subfluidization Wash (ETSW) to minimize filter-to-waste and optimize filter out of service time. The aim of this recommendation is to provide a framework for which to design filter backwash pump upgrades for optimized filter backwashing.

It is recommended to initially add an ETSW step after the high-rate wash step. The recommended ETSW wash settings are as follows:

- ETSW Step: 10 MLD for a duration of 15 minutes.

No media fluidization (suspension) should be observed during this step if performed correctly.

Success of this testing would be determined based on minimizing the filter ripening spike. Should the filter ripening spike persist with the implementation of the ETSW step, then lengthening the ETSW step to a duration of 17 minutes or increasing the ETSW flow rate up to a maximum of 70 MLD could be trialed. An effective ETSW rate for Woodward WTP based on the media specifications available should not exceed 70 MLD.

To further optimize this step, the ETSW step could be reduced to a duration of 10 minutes at temperatures greater than 15 degrees C.

Further backwash optimization can be achieved by optimizing the low-rate and high-rate wash steps to the following settings:

- Low-Rate Wash Step: 70 MLD for 0.5 minutes (or 1 minute if programming does not allow less than 1 minute)
- High-Rate Wash Step: 125 MLD for 3 minutes.

The recommended ETSW Backwash Sequence is as follows:

Initial Recommended Backwash Sequence with ETSW Step.

Step	Description	Rate (MLD)	Duration (min)
1	Close Filter Inlet Valve		
2	Drain water to low level (16" or 1.5 ft from top of filter media) through filter to waste valve (FTW).		
3	Close FTW valve.		
4	Open outlet valve, backwash pump starts		
5	Low Wash (from filter wash inlet)	72	0.5

Initial Recommended Backwash Sequence with ETSW Step.

Step	Description	Rate (MLD)	Duration (min)
6	High Wash (aka FLUIDIZATION) - transition occurs within 10 seconds	125	3
7	ETSW (Low wash) - transition occurs immediately; within 10 seconds	10	15
8	Wash outlet valve closes and low wash fills the filter up to normal operating level.		
9	Low wash turns off (backwash pump off) and wash inlet valve closes		
10	Filter sits for stratification time	0	10
11	Filter Inlet valve opens (and FTW valve opens if available)	200	5
12	FTW valve closes, if available.		
13	Filter effluent opens to return filter to service.		

Summary of assumptions:

Parameter	Description	Value	Units
Effective Size (**ES**)	sand	**0.50**	mm
Uniformity Coefficient (**UC**)	sand	**1.70**	d60/d10
Media Density	sand	**2.65**	g/cm^3
Media Depth **(D)**	sand	**1.65**	feet
Effective Size (**ES**)	gac	**1.00**	mm
Uniformity Coefficient (**UC**)	gac	**2.10**	d60/d10
Media Density	gac	**1.55**	g/cm^3
Media Depth **(D)**	gac	**2.30**	feet
Freeboard (top of media to overflow)	filter at rest	**2.80**	feet
Surface Area of Filter (or one side)	basis for flows	**720**	sq. ft.

APPENDIX F
PROCESS STRESS TESTING
PRELIMINARY GUIDE

WOODWARD – FULL-SCALE WATER TREATMENT PLANT STRESS TESTING

Objectives

The objective of the full-scale stress testing is to evaluate capacity limitations associated with the existing filtration process in its pre-construction condition to understand potential flow restrictions during Phase II upgrades. The objective of this testing is not to optimize filter UFRV although this could be investigated using a similar protocol / approach, following filter upgrades with modern underdrains and air scour equipment, in concert with optimize coagulation chemistry.

Each stress test will be trialed with all existing four (4) clarification trains in service- but only two filter quadrants of the process (i.e. 12 filters).

The preferred filter quadrants for testing are at the discretion of plant operations. It is recommended to test quadrants that have representative performance of the filtration process and no known filter condition or operating issues. The other quadrants can either be taken offline, maintained at a low flow-rate or other configuration as pre-determined by the City and operations to accommodate distribution demands and storage levels, clearwell levels, or other supply considerations.

The full-scale flow capacities planned to be tested at Woodward WTP include the following:

1. **370 MLD** (185 MLD per quadrant), representing current predicted process potential performance limitation for filtration with two filter quadrants out of service and a target loading rate of 11 m/hr.
    - **To achieve these target filtration loading rates, it is recommended to run the testing with 11 filters online and 1 in standby.**

2. **405 MLD** (202.5 MLD per train), representing a filter loading rate of 12 m/h (with 11 filters online and 1 in standby); to be tested should Trial 1 at 370 MLD be successful.
    - **To achieve these target filtration loading rates, it is recommended to run the testing with 11 filters online and 1 in standby.**

Stress testing at approximately 370 MLD and 405 MLD

This component of the stress test requires that the plant is operated at a constant flow rate of 370 MLD for a duration of as long as possible (e.g., until 2 of the 11 filters enter backwash), or for a minimum period of 24 hours, whichever is shorter. Prior to initiating the test, filters in the test quadrants should be backwashed to allow for the most robust testing conditions possible. Should one filter enter backwash during the testing, the standby filter in the test quadrant could be brought online in an effort to extend the testing.

Should testing at 370 MLD with two filter quadrants prove successful in terms of maintaining filter UFRV > 200 m^3/m^2, then the testing is to be repeated at a flow condition of 405 MLD.

It is preferred to conduct the testing during typical raw water quality conditions and not during a raw water quality event (e.g., lake turnover, elevated turbidity). All monitoring and performance evaluations are to be repeated for this set of testing as described below.

Protocol for Full-Scale Testing

Guidance for Operations and Conditions for Terminating the Test:

- Submission of a Form 2 to the MECP is recommended prior to testing to notify the MECP of the intent to test a higher flow condition on one train than current average day flows but well within the DWWP flow rate. If additional testing is completed with a filter aid polymer, the Form 2 will be required to notify the MECP of a process change to be trialed on two filter quadrants of the full-scale process with the addition of the polymer to the stage-2 flocculation basin (dose to be informed by jar-testing).

- Cleaning of sedimentation basins is recommended prior to the test.
- Calibration of instrumentation (turbidity meters, temperature probes, pH probes) to be completed prior to testing.
- Filter effluent turbidity set-point programming could be increased to 0.20 NTU
  - This will allow for an evaluation of the rise in headloss accumulation and/or filter effluent turbidity during the test to 0.15 NTU (half the MAC of 0.3 NTU).
- The test is to be initiated with 11 filters online and one (1) filter on stand-by
  - All filters to be backwashed prior to initiating testing
  - The stand-by filter is to be brought online should one (1) filter go out of service.
- Target flow rates should be achieved in a step-wise approach (e.g., by increasing plant flows by 50 MLD at a time before achieving steady state operation at the given test flow rate) so as not to disrupt process performance due to a flux in plant flow rate
- The test is to be terminated should one of the following conditions arise:
  - If two (2) of the initial in-service filters are offline (or three [3] filters offline in total) / backwashing AND the filter effluent turbidity reaches 0.15 NTU
  - CT calculations are not met

Zeta-Potential Monitoring and Coagulant Dose Adjustments to be Completed by Operations Staff

It is also recommended to use zeta-potential to uphold appropriate coagulation chemistry through sedimentation during testing.

During the testing, zeta-potential parameters should be monitored three times a day (e.g. every 4 hours at 8 am, 12PM, and 4 PM) in the <u>post-coagulated water</u> (downstream of flash mixing) of the Test Train. A set point of >-8 mV is recommended to be upheld during testing.

During the testing, coagulant doses should be adjusted to maintain the optimal post-coagulation zeta potential set-point.

Response action:

- Should zeta potential measurements in the raw water decline, or post-coagulation decline to become more negative than the set-point or approximately -5 mV, coagulant dose should be increased.
- Should zeta potential measurements in the raw water increase, or post-coagulation increase to become more positive than the set-point, or approximately +3 mV, coagulant dose should be decreased.

Evaluation of Results

Following the testing, Stantec will submit a request for SCADA data including the following parameters:

- Raw water

  - Turbidity
  - Temperature
  - pH
- Coagulation
  - Chemical Doses
  - pH
- Settled water turbidity
- Filtration (for filters in service):
  - Flows
  - Runtime
  - UFRV
  - Effluent Turbidity
  - Headloss
- Operations log containing observations made during the course of each trial and particularly during backwashing events – a description of the reason for terminating each filter run (e.g., headloss, turbidity breakthrough, time, other).

The preferred increment for SCADA data will be determined following observations made during full-scale testing.

Laboratory parameters to be requested include:

- Grab sampling for raw water, settled water, and filter effluent UVA

Reliable performance will be evaluated against the following criteria:

- UFRVs greater than 200 m^3/m^2 while maintaining filter effluent turbidity <0.1 NTU.

Should the stress test need to be terminated prior to achieving the target UFRV condition, a review of the rate of filter headloss accumulation, and increased settled water turbidity conditions will be completed.