# Appendix C

# Technical Memorandum #3 – Development and Evaluation of Alternative Solutions – Treatment and Residual Management

# New Dundee Water Supply System – Iron and Manganese Upgrades Class Environmental Assessment

## Technical Memorandum #3

Development and Evaluation of Alternative Solutions

Final

Prepared for:

Region of Waterloo



**RVA 194591**

September 27, 2022

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**Attention: Kaoru Yajima**

Dear Mr. Yajima:

Re: Technical Memorandum #3 – Development and Evaluation of Alternative Solutions - Draft 3 New Dundee Water Supply Iron and Manganese Upgrades Class Environmental Assessment

Please see enclosed Technical Memorandum #3 revised to reflect the revised design flow values per TM #1 for the New Dundee Water Supply Iron and Manganese Upgrades Class Environmental Assessment (EA).

Yours very truly,

**R.V. ANDERSON ASSOCIATES LIMITED**

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Process Engineer

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## Technical Memorandum #3

## Develop and Evaluate Alternative Solutions

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# 1.0 Introduction

The Region of Waterloo has embarked upon a Class Environmental Assessment (EA) for the New Dundee Water Supply System in the Community of New Dundee, in the Township of Wilmot, in accordance with the requirements of the *Municipal Class Environmental Assessment* which is an approved process under the *Ontario Environmental Assessment Act*. The New Dundee Water Supply facility is located on 156 Alderview Dr., Township of Wilmot.

The Region is completing this Class EA to address water treatment upgrades that have been identified based on anticipated changes to the Ontario Drinking Water Standards (ODWS). In June 2019, Health Canada issued the *Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Manganese*, which established an aesthetic objective of 0.02 mg/L. It can be noted that aesthetic objectives are intended to address non-health related items such as odour, taste, and colour. To be in line with Health Canada recommendations, it is anticipated the provincial objective for manganese will be reduced from 0.05 mg/L to 0.02 mg/L, with a design operating objective of 0.015 mg/L. The New Dundee Well Supply System was identified for potential treatment upgrades to consistently meet the anticipated new standard.

In September 2019, the Region retained R.V. Anderson Associates Limited (RVA) to complete the Class Environmental Assessment for the Iron and Manganese Treatment Upgrades.

This technical memorandum (TM) is the third of four technical memoranda to be released as part of the Class EA. The objective of TM #3 is to describe the treatment and residual management alternatives being considered, and their evaluation using the criteria identified in **TM #2 – Evaluation Criteria** to reach a preferred alternative for the treatment technology and residual management strategy.

# 2.0 Summary of Existing Conditions and Recommendations

Existing site conditions and background information were reviewed and summarized as part of **TM #1 – Project Background and Existing Conditions**. Also included in **TM #1 – Project Background and Existing Conditions** was a recommendation about the inclusion of pilot testing in this Class EA based off other similar pilot testing studies. The key points of **TM #1 – Project Background and Existing Conditions** are summarized below:

- The New Dundee Water Supply System is in the community of New Dundee, in the Township of Wilmot, in the Regional Municipality of Waterloo. The system supplies the community only and is not connected to any larger water supply system in the Region. The Region owns the water supply facility located on 156 Alderview Drive, and the Township owns the linear infrastructure in the community, which consists of watermains and storm sewer system.
- The well house was constructed in 1977, with additional inground storage cells being constructed in 1986 and 1990.
- The New Dundee Water Supply System was identified in a Region wide report (Stantec, 2017) as requiring facility upgrades to meet the anticipated ODWS manganese concentration objective. This was confirmed in TM #1.
- A Natural Sciences Existing Conditions Report was completed of the Study Area. The report found the Grand River Conservation Authority mapping of the area and floodplain limits to be in close proximity to the site, being found in the north of the site.
- A Stage 1 Archaeological Assessment (AA) was completed of the Study Area. The Assessment found archaeological potential in the area and suggested a Stage 2 AA be completed prior to any construction works, through either a pedestrian survey or a test pit survey.
- If the preferred treatment alternative is oxidation and conventional filtration, pilot testing for this system is not required. The Region and RVA have completed pilot testing in prior Region projects (Shingletown Schedule C Class EA and Middleton Schedule A Class EA) for iron and manganese removal through oxidation and conventional filtration, and the water quality

at the New Dundee system is similar to the water quality of those systems. RVA recommends using a filter loading rate of 14.4 m/hr.

# 3.0 Review and Selection of Treatment Alternatives

There are many options to treat for iron and manganese in water supply systems, and these options are laid out in the *Health Canada Guidelines for Canadian Drinking Water Quality – Manganese* and in the *AWWA Iron and Manganese Removal Handbook*. RVA has selected nine treatment or mitigation options for review. These options have been selected due to their possible suitability for the New Dundee Water Supply system.

## 3.1 Review of Treatment Alternatives

The treatment alternatives selected for review were as follows:

- **Alternative 1**: Do Nothing
- **Alternative 2**: Watermain Extension from Region Integrated Urban System in Kitchener
- **Alternative 3**: In Situ Removal
- **Alternative 4**: Iron and Manganese Sequestration
- **Alternative 5**: Oxidation and Filtration
- **Alternative 6**: Biological Filtration
- **Alternative 7**: Membrane Filtration
- **Alternative 8**: Lime and Soda Softening
- **Alternative 9**: Ion Exchange Softening

A summary and preliminary evaluation of these alternatives is provided below. As part of the preliminary evaluation the residuals of each treatment system were evaluated for volumes and types of residuals produced, and the associated processing of these residuals. However, the residual management alternatives in Section 4.0 only pertain to the preferred alternative as selected in this Section.

### 3.1.1 Alternative 1: Do Nothing

Per the Class EA requirements, a Do Nothing alternative was required for evaluation. This option represents the existing conditions and maintaining them going forward. As the objective of the Class EA is to reduce manganese concentrations to the future Health Canada Aesthetic Objectives, this alternative does not meet the objective and was not shortlisted.

### 3.1.2 Alternative 2: Watermain Extension from Region Integrated Urban System in Kitchener

The cities of Kitchener-Waterloo are serviced by the Region's Integrated Urban Systems (IUS). Currently, IUS extends to approximately 10 kilometres by roadways from the community of New Dundee. While a watermain expansion may be possible to implement to extend the IUS into the New Dundee water supply system, this addition has not been considered in the Kitchener Growth Management Plan as of 2019. As such, this alternative was not be considered further.

### 3.1.3 Alternative 3: In Situ Removal

In situ removal of manganese from the water supply system means removing the manganese before it is pumped from the ground. To achieve this, aerated water is injected into the target aquifer to precipitate the manganese out of the water, prior to being pumped out by the wells. This alternative has only seen limited installations in the worldwide and raises concerns about possible clogging of the aquifer and altering the aquifer geochemistry. As a result, this alternative was not considered for the shortlist.

### 3.1.4 Alternative 4: Iron and Manganese Sequestration

Iron and manganese sequestration is the process of adding chemicals to the water supply system such that iron and manganese do not precipitate out of the water in the distribution system. This alternative is employed as a temporary measure usually, and the manganese is not removed in this process, so the objective of lowering manganese concentrations is not met. As a result, this alternative was not considered for the shortlist.

### 3.1.5 Alternative 5: Oxidation and Filtration

This alternative consists of oxidizing the raw water to precipitate the iron and manganese out of solution, and then removal the precipitated particles via filtration and adsorption. A list of possible oxidants for use is provided below:

1. Permanganate: Either potassium permanganate ($KMnO_4$) or sodium permanganate ($NaMnO_4$). The permanganate is injected into the raw water upstream of the filtration process. Dosing of the permanganate requires careful consideration, as an overdose of the chemical could result in turning the water a pink colour.

2. Chlorine Dioxide: Chlorine dioxide has been proven to effectively oxidize manganese at concentrations that are present in the New Dundee system. Operational issues arise with chlorine dioxide however, as it is unstable and must be either produced on site or shipped in specialized containers at low temperatures. Storage of the chlorine dioxide must be carefully coordinated, as the solution is explosive if it is able to evaporate.

3. Ozone: Ozone can be used as an oxidizer for manganese, however per *Health Canada-Guidelines for Canadian Drinking Water Quality-Manganese* is considered less effective than other oxidants for achieving levels below 0.02 mg/L, the proposed AO. Limited pilot studies have been completed on this subject, and onsite production of ozone requires significant capital and operating cost requirements, to store the oxygen, produce the ozone, bubble the ozone through the raw water, and neutralize off gases.

4. Chlorine: Chlorine, in the form of sodium hypochlorite solution (NaOCl) is capable of oxidizing manganese in raw water, however, under standard pH conditions (pH 7-8) requires long contact times to completely oxidize the manganese. However, when combined with filtration and adsorption, the filtration and adsorption make up the deficit of not fully oxidizing the raw water by removing the manganese through other methods. The Region uses sodium hypochlorite in a liquid solution very frequently throughout its drinking water treatment and distribution systems, and one such system already exists at New Dundee.

The second aspect of the treatment process is the filtration process. When using the term "conventional filtration" two types of filtration are referenced. Gravity filtration using a sand and anthracite media, and pressure filtration using sand and anthracite, manganese greensand, or manganese dioxide ore filter media. For groundwater that is non-GUDI, the *AWWA Iron and Manganese Removal Handbook* recommends that pressure filtration be employed, because of the smaller footprint of the system, and not requiring the filter to remove pathogens that would be present in surface water. For filter media, manganese greensand and manganese dioxide ore have both been pilot tested in previous Region of Waterloo projects, with very similar filter effluent quality results. Therefore, we recommend both media as they serve an equivalent technical standard.

For this system, the oxidation and conventional filtration best suited is a chlorine oxidation using sodium hypochlorite followed by a pressure filtration system with manganese greensand or manganese dioxide ore filter media. This alternative was taken to the shortlisted options.

### 3.1.6 Alternative 6: Biological Filtration

Biological filtration uses naturally occurring bacteria to convert manganese from its aqueous form Mn (II) to an insoluble form Mn (IV) where the insoluble form is then removed in the backwash process. The bacteria would grow on gravity filtration media, and the filters would require air to be pumped in to keep the redox potential at optimal levels. Air is required as other forms of oxidation would kill the bacteria required for the manganese and iron removals. While the process has been used in installations worldwide and in some parts of Canada, the process is not in use currently in the Region. Additionally, an extensive pilot testing study is required to ensure the raw water is properly conditioned to facilitate removals and that the bacteria is kept alive. The bacteria may also take a long time to cultivate, extending the start-up and commissioning process and increasing construction and operational costs. Due to the long pilot study time and high cost associated such a pilot study, and because this process would also require a gravity filtration system, this alternative was not considered for further analysis.

### 3.1.7 Alternative 7: Membrane Filtration

Membrane filtration is the process of using a semi-permeable membrane to remove the manganese and iron from the raw water stream while allowing the water to flow through uninhibited. Per the *AWWA Iron and Manganese Removal Handbook*, membranes are most frequently applied when the source water contains high levels (>5 mg/L) of iron and manganese, for GUDI wells, or for surface wells. Use of a membrane filtration system still requires oxidation prior to the filtration, and the most common form of oxidant used in for this application is permanganate, however chlorine may also be used. One other important factor with membrane filtration is the possibility of fouling, where if the manganese or iron is oxidized in the membrane it may clog the membrane pores, increasing head loss through the membrane and decreasing the efficiency of future removals. A pilot test study would be required, and the membrane technology would require a pre-selection process. The treatment process is also considered very energy intensive, resulting in higher energy consumption rates and increased greenhouse gas (GHG) emissions. However, membrane filtration is often considered to have the smallest of footprints compared to the other treatment processes. As public perception and minimizing additional land purchasing is one of the objectives of the Class EA, this option was considered further for a shortlisted review.

### 3.1.8 Alternative 8: Lime and Soda Softening

Lime and soda softening is the process which uses calcium hydroxide and sodium carbonate to increase the pH of the water to 11, to allow for precipitation of the dissolved iron and manganese ions. Iron and manganese removal is oftentimes not the goal of lime and soda softening, but more of a by-product. Lime and soda softening is principally used for large scale water softening, and requires silos for lime storage, feed equipment, clarifiers, gravity filters, and residue management systems. In the case of New Dundee, the water hardness is not a concern and the system flow rates are relatively small, so employing a lime and soda softening that has a large footprint and produces a large amount of residuals is not reasonable. As such, this alternative was not considered further.

### 3.1.9 Alternative 9: Ion Exchange Softening

Ion exchange uses zeolite beads to allow iron and manganese to exchange with the ions located on the zeolite beads (like sodium or potassium) for the purposes of removing the iron and manganese. As with Alternative 8, removing iron and manganese is more of a by-product of this treatment process, as the ion exchange would also decrease the water hardness. As part of the maintenance process, a brine solution is required to backwash the filters. This brine would need to be dealt with as a residual and disposed of accordingly. Additionally, sodium levels in the treated water would be increased, which presents a health risk to those that have risk factors such as hypertension. Due to the operational and health factors coupled with no need to decrease the water hardness, this option was not considered further.

## 3.2 Treatment Alternatives Evaluation

From the list of treatment technologies available and reviewed above, two alternatives were short-listed for a detailed review:

- **Alternative 5: Conventional Oxidation and Filtration using Chlorine Oxidation and Pressure Filtration**
- **Alternative 7: Membrane Filtration using Chlorine Oxidation**

One aspect of the evaluation was determining facility footprint sizing. To compare the facility footprint sizes, RVA has drawn upon past experience and projects in order to determine the approximate sizes for comparison purposes, and has concluded that the membrane treatment alternative would be a smaller footprint compared to the conventional oxidation and filtration process.

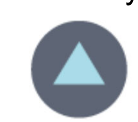
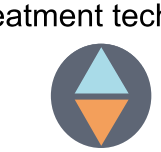
For comparison of lifecycle costs, a high-level cost comparison was conducted based on a Water and Wastewater Asset Cost Study completed by R.J. Burnside corrected to present day for capital costs, and historical data from past projects. These values are not intended to be used as construction cost estimates, and do not include any land acquisition costs, they are only intended for use to compare the alternatives against each other in this TM. The cost comparisons may be found in Appendix A of this report.

These short-listed alternatives were evaluated based on criteria as discussed in **TM #2 – Evaluation Criteria** in Table 3.2 to 3.5 and summarized in Table 3.6. They were scored based on Table 3.1, as given in **TM #2 – Evaluation Criteria**.

**Table 3.1 – Legend of Symbols for Evaluation**

|  |  |  |  |  |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| Low Alignment with Criteria | Not Well Aligned with Criteria | Somewhat Aligned with Criteria | Well Aligned with Criteria | Very Well Aligned with Criteria |

**Table 3.2 – Evaluation of Alternative Treatment Solutions – Technical Category**

| | | | Alternative 5 | Alternative 7 |
|---|---|---|---|---|
| **Evaluation Category** | **Criteria** | **Percentage** | **Chlorine Oxidation + Pressure Filtration** | **Membrane Filtration** |
| Technical | **Provides Reliable Service** | 3.57% | • Technology will reliably provide drinking water that meets the future proposed standard.  | • Technology will reliably provide drinking water that meets the future proposed standard.<br>• Complex to operate and monitor the treatment process with multiple chemicals required.  |
| Technical | **Meets Existing and Future Needs** | 3.57% | • Technology meets existing and futures needs for drinking water.  | • Technology meets existing and futures needs for drinking water.  |
| Technical | **Aligns with Existing and Planned Infrastructure** | 3.57% | • Treatment technology is currently in use in the Region for iron and manganese removal.<br>• Chlorine currently in use in the existing facility  | • Treatment technology is not currently in use in the Region for iron and manganese removal.<br>• Additional chemicals are required for backwash and maintenance purposes.  |
| Technical | **Aligns with Existing and Future Land Use** | 3.57% | • Treatment will require medium sized property acquisition partially or fully outside the Rural Settlement Area Boundary.  | • Treatment will require a small sized property acquisition partially or fully outside the Rural Settlement Area Boundary  |
| Technical | **Aligns with Approval and Permitting Process** | 3.57% | • Standard permits and approvals are required to construct this treatment technology.  | • Standard permits and approvals are required to construct this treatment technology.  |

| | | | Alternative 5 | Alternative 7 |
|---|---|---|---|---|
| **Evaluation Category** | **Criteria** | **Percentage** | **Chlorine Oxidation + Pressure Filtration** | **Membrane Filtration** |
| **Technical** | **Manages and Minimizes Construction Risks** | 3.57% | • Treatment technology will not adversely affect or increase construction risks. | • Treatment technology will not adversely affect or increase construction risks. |
| **Technical** | **Ability to Adapt to Climate Change** | 3.57% | • Treatment technology is fully indoors and will be resilient to extreme weather events. | • Treatment technology is fully indoors and will be resilient to extreme weather events.<br>• Increased energy consumption associated with this technology would lead to more GHG emissions. |
| **Overall Technical Score** | | **25%** | | |

**Table 3.3 – Evaluation of Alternative Treatment Solutions – Natural Environment Category**

| | | | Alternative 5 | Alternative 7 |
|---|---|---|---|---|
| **Evaluation Category** | **Criteria** | **Percentage** | **Chlorine Oxidation + Pressure Filtration** | **Membrane Filtration** |
| **Natural Environment** | **Protects Environmental Features** | 6.25% | • No additional chemicals are required over what is currently being used at the site.<br>• Treatment requires a medium sized footprint facility. | • Additional chemicals are required over what is currently being used at the site, creating additional spill risks to the environment.<br>• Treatment requires a small sized footprint facility. |
| **Natural Environment** | **Protects Wildlife and Species at Risk** | 6.25% | • Medium treatment footprint site will impact wildlife habitats. | • Small treatment footprint site will impact wildlife habitats. |
| **Natural Environment** | **Protects Groundwater, Streams and Rivers** | 6.25% | • Treatment process will have minimal impact to GRCA Regulated Floodplains and local streams and rivers. | • Additional chemical storage and deliveries present increased risks of spills to the environment. |
| **Natural Environment** | **Minimizes Climate Change Impacts** | 6.25% | • No relative difference between alternatives with respect to possible climate change impacts. | • No relative difference between alternatives with respect to possible climate change impacts. |
| **Overall Natural Environment Score** | | **25%** | | |

**Table 3.4 – Evaluation of Alternative Treatment Solutions – Social Category**

| Evaluation Category | Criteria | Percentage | Alternative 5<br>Chlorine Oxidation + Pressure Filtration | Alternative 7<br>Membrane Filtration |
|---|---|---|---|---|
| Social | **Minimizes Impacts to Residents Related to Noise, Odour, Traffic, and Aesthetics** | 4.17% | • Treatment facility will visually change the existing suburban landscape<br>• Minimal effects on noise, odour, and traffic in the area. | • Treatment facility will visually change the existing suburban landscape<br>• Negative effects on traffic in the area due to increased chemical deliveries and additional operator personnel for maintenance purposes. |
| Social | **Minimizes Impacts to Businesses** | 4.17% | • Treatment technology will improve water quality for local businesses. | • Treatment technology will improve water quality for local businesses. |
| Social | **Manages and Minimizes Construction Impacts** | 4.17% | • Construction of facility with proper measures will have minimal impacts on the surrounding area. | • Construction of facility with proper measures will have minimal impacts on the surrounding area. |
| Social | **Protects Cultural Heritage Features** | 4.17% | • Cultural Heritage features will not be impacted by the treatment technology. | • Cultural Heritage features will not be impacted by the treatment technology. |
| Social | **Protects Archaeological Features** | 4.17% | • Treatment technology may impact existing archaeological features.<br>• An archaeological assessment will be completed in the EA/Design phase to determine if archaeological impacts will be affected. | • Treatment technology may impact existing archaeological features.<br>• An archaeological assessment will be completed in the EA/Design phase to determine if archaeological impacts will be affected. |

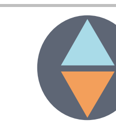
| | | | Alternative 5 | Alternative 7 |
|---|---|---|---|---|
| **Evaluation Category** | **Criteria** | **Percentage** | **Chlorine Oxidation + Pressure Filtration** | **Membrane Filtration** |
| **Social** | **Protects Health and Safety** | 4.17% | • Region operations will not be negatively affected by the treatment technology.<br>• Public health and safety will not be affected by treatment technology.<br> | • Region operations working with additional chemicals will require additional health and safety precautions and increase risk to the staff.<br>• Public health and safety will not be affected by treatment technology.<br> |
| **Overall Social Score** | | |  |  |

**Table 3.5 – Evaluation of Alternative Treatment Solutions – Financial Criteria**

| | | | Alternative 5 | Alternative 7 |
|---|---|---|---|---|
| **Evaluation Category** | **Criteria** | **Percentage** | **Chlorine Oxidation + Pressure Filtration** | **Membrane Filtration** |
| **Financial** | **Provides Low Lifecycle Costs** | 25% | • The treatment technology has a lifecycle cost of $4,000,000  | • The treatment technology has a lifecycle cost of $9,000,000  |
| **Overall Financial Score** | | |  |  |

## 3.3 Preferred Treatment Alternative

Based on the detailed evaluation completed in Tables 3.2 – 3.5, a preferred alternative technology has been identified. Conventional oxidation using chlorine and filtration using either manganese dioxide coated media or pure manganese dioxide media is the preferred alternative for iron and manganese removal at the New Dundee Water Supply System. The key reasons are as follows:

- It is a familiar and well proven technology for the Region.
- It will not require any additional chemicals over what is already in use at the site
- The treatment technology has a relatively small footprint, which is ideal for the location in a suburban neighbourhood, and will reduce land acquisition costs for the Region

**Table 3.6: Summary of Treatment Technology Evaluation Criteria**

| | | Alternative 5 | Alternative 7 |
|---|---|---|---|
| **Evaluation Criteria** | **Percentage** | **Chlorine Oxidation + Pressure Filtration** | **Membrane Filtration** |
| **Technical** | 25% | ▲ | ▲▼ |
| **Natural Environment** | 25% | ▲▼ | ▼ |
| **Social** | 25% | ▲ | ▲▼ |
| **Financial** | 25% | ▲ | ▼ |
| **Overall** | 100% | ▲ | ▼ |

## 3.4 Sensitivity Analysis for Treatment Alternatives

During the first PCC completed in June and July of 2020; data collection was completed in the form of comments sheets. These comment sheets were analyzed to determine stakeholder preferences with respect to evaluation criteria weighting up to this point. In this case, the social evaluation criteria have some greater weight than the others as the facility is located in a small town and suburban neighbourhood. Changing the weighting to:

- Technical 20%, Natural Environment 20%, Social 40%, Financial 20%

still yielded that Alternative 5 was the preferred alternative. As such, the weighting will remain equal.

# 4.0 Review and Selection of Residual Management Alternatives

Estimates for residual production were calculated based on the preferred alternative, and a list of residual management strategies was developed for evaluation, using the same criteria as was included in **TM #2 – Evaluation Criteria**

## 4.1 Residuals Produced

The residuals produced from the conventional filtration and oxidation are as follows:

- Filter backwash wastewater
- Filter run to waste generated after a backwash cycle
- Filter run to waste generated prior to a pump start cycle
- Wastewater generated by chlorine and turbidity analyzers

The following sections list the assumptions and design parameters used in evaluating the waste stream volumes.

The filter suppliers AdEdge, Napier-Reid, and Kurita Water were contacted for filter sizing and backwash requirements. The filter suppliers specified either a manganese coated media or a solid manganese dioxide media.

#### 4.1.1 Filter Sizing

Filter sizing is integral to determining the backwash volumes for said filters. The backwash volumes are often based on a backwash loading rate and filter cross-sectional area. Conceptual Basis of Design calculations may be found in Appendix B, and a summary of the calculations may be found below:

- **Number of filters:** Good industry design standards for filtration systems show it is prudent to have a level of redundancy in the filtration system, meaning the filter system is capable of handling the full design flow if one of the filters is offline. As such, two vertical pressure filters were selected, each capable of treating the full plant design flow, so that the system may operate fully with one filter out of service. Vertical pressure filters were selected because of their small footprint in comparison with other horizontal pressure filter options.

- **Filter Sizing:** As discussed in **TM #1 – Project Background and Existing Conditions,** because of recent past pilot testing of similar raw water concentrations, pilot testing was excluded from this scope, and a filter loading rate of 14.4 m/hr is to be applied in preliminary sizing of the filters. The PTTW flow of the system is 11.4 L/s, or 0.98 MLD. Historical data however shows the pumps at the facility not reaching this PTTW limit in the past five years. As part of **TM #1 – Project Background and Existing Conditions** therefore, a more detailed analysis was completed to determine a treatment design capacity based on the existing and anticipated future flows. This treatment design capacity is 8.0 L/s, or 0.69 MLD. Per standard manufacturer sizing, the closest filter size to meet this design loading rate at the PTTW flow is a 1.68 m Ø (5'6") vertical pressure filter, yielding a filter area of 2.21$m^2$ and a filter loading rate of 13.1 m/hr, and up to 14.3 m/hr with a supernatant recycle rate of 1.3 to 2.9 $m^3$/hr, depending on the raw water flow rate More information on supernatant recycling values can be found in Section 4.6.

#### 4.1.2 Filter Purge

As mentioned in Section 4.1.1, the pumps at the existing facility operate on a start/stop basis, with pump runtimes ranging from 3 – 24 hours, and downtimes of up to 8 hours. Therefore, before a filter may be run to the system, a purge is required. The Region has stated that historically a purge consists of running the well pumps for a period of two minutes through the filters and discharging this stream into the backwash equalization tank (BET).

#### 4.1.3 Filter Backwash

The filter backwash loading rate was given by one manufacturer as 60 m/hr for a period of ten minutes for each filter. This was the most conservative backwash loading rate value, so it was used for subsequent calculations This rate yields a backwash volume of 22.1 $m^3$ per filter, and 44.2 $m^3$ for both filters. The backwash is supplemented by an air scouring process, with air blowers. Based on past iron and manganese removal projects, recent pilot testing data within the Region with similar raw quality characteristics, and discussions with filter manufacturers, filter backwash would be recommended once every 48 hours of accumulated filter run time. In Alternatives B, C, and E, the filter backwash would be directed to a Backwash Equalization Tank (BET), where it would settle out into the supernatant and the settled solids.

- **Supernatant:** As stated in **TM #1 – Project Background and Existing Conditions**, pilot testing had been conducted at a groundwater supply station within the Region for iron and manganese removal in the past three years, with similar water characteristics as New Dundee. The supernatant in the Shingletown study was tested against the Ministry of Environment, Conservation, and Parks' (MECP) Provincial Water Quality Objectives (PWQO) which are set at a level which is protective of all forms of aquatic life and recreational water uses. Chlorine levels in the pilot testing study were above the PWQOs, and the same is anticipated at New Dundee. These elevated concentrations would mean dechlorination is required prior to discharge to the environment. Additionally, copper levels greater than the PWQO were noted in the pilot testing supernatant, and it is possible that this will also be an issue at New Dundee, given the similar raw water quality data and raw water copper concentrations. While these copper concentrations are well below the ODWS, the PWQO is a more stringent standard as copper is quite toxic to aquatic flora and fauna. The similarities in the copper concentrations can be seen in **Table 4.1.** It can be seen that the majority of the concentrations have tested below the detectable limit, however this is the raw water concentration, and as was shown in the

Shingletown pilot testing, these low concentrations have still resulted in higher than allowable PWQO limits in the supernatant. For reference, the PWQO limit for copper being discharged into the environment is 5 µg/L.

**Table 4.1: Raw Water Copper Concentrations at New Dundee and Shingletown**

| Source | Sample Date | Concentration (µg/L) |
|---|---|---|
| New Dundee ND04 | 1992-04-21 | <10 |
| New Dundee ND04 | 1992-07-20 | 40 |
| New Dundee ND04 | 1994-03-14 | <10 |
| New Dundee ND04 | 1995-12-18 | <10 |
| New Dundee ND04 | 2001-04-04 | <1 |
| New Dundee ND04 | 2002-05-21 | <1 |
| New Dundee ND04 | 2002-05-24 | <1 |
| New Dundee ND04 | 2019-12-10 | 0.51 |
| New Dundee ND05 | 2019-12-10 | 0.911 |
| Shingletown K50 | 1994-01-26 | <10 |
| Shingletown K50 | 1995-05-29 | 1 |
| Shingletown K50 | 1996-10-23 | <10 |
| Shingletown K50 | 1999-04-13 | <10 |
| Shingletown K50 | 2000-11-28 | <1 |
| Shingletown K50 | 2000-11-28 | <1 |
| Shingletown K50 | 2000-11-28 | <1 |
| Shingletown K50 | 2001-03-07 | 4 |
| Shingletown K50 | 2001-03-30 | <1 |
| Shingletown K50 | 2001-06-19 | <1 |
| Shingletown K50 | 2001-07-23 | 0.7 |
| Shingletown K50 | 2001-09-10 | <1 |
| Shingletown K50 | 2001-12-05 | <1 |
| Shingletown K50 | 2002-06-12 | <1 |
| Shingletown K50 | 2003-05-26 | <1 |

- **Settled Solids:** Based on past project experience and prior supplier correspondence, a solids concentration of 0.05% to 0.1% is achieved when terminal head loss is reached. These settled solids sludge can reach a concentration of 5000 mg/L. Using the highest recorded iron and manganese concentrations of 79 µg/Land 38 µg/L respectively, and assuming a settled sludge concentration of 1000 mg/L, it was calculated that a solids volume of approximately 29.5 $m^3$ would be produced per year.

### 4.1.4 Filter to Waste

As part of the filter backwash process, the filters should be run to waste for a period of three to five minutes after every backwash. Assuming a five-minute run to waste, this yields a waste volume of 1.2 $m^3$ per filter, and 2.4 $m^3$ for both filters, all of which would be directed to the BET in Alternatives B, C, and E.

### 4.1.5 Chlorine Analyzer Flows

Chlorine analyzers are required on the filter inlet header downstream of chlorine injection, and at the end of the chlorine contact tank, totalling two analyzers. The analyzers would be equipped with solenoid valves on their inlets, such that water would flow through them only while the well pumps are operating, to keep the pipes the samples are being taken off of full at all times. While running, each analyzer flows at approximately 0.05 $m^3$/hr. However, at the current plant these flows are directed to the storm sewer system after they are dechlorinated. The new facility will incorporate this same design concept, with the chlorine analyzer flow being directed to the storm sewer.

### 4.1.6 Turbidity Analyzer Flows

Turbidity analyzers are required on the raw water supply, and on the discharge of the filters totalling two analyzers. As with the chlorine analyzers, the turbidity analyzers are required to run at all times the wells are running, and each analyzer flows at approximately 0.018 $m^3$/hr. Again, as with the chlorine analyzers, a solenoid valve will be installed on the analyzer inlet so that water only flows through them while the well pumps are flowing.

**Table 4.2: Summary of Estimated Process Residual Volumes per Backwash Cycle.**

| Source | Rate per Unit ($m^3$/hr) | Number of Units | Time (hr/cycle) | Frequency (Cycles/week) | Volume/week ($m^3$/week) |
|---|---|---|---|---|---|
| Filter Purge | 14.4 | 2 | 0.033 | 3.5 | 3.4 |
| Filter Backwash | 132.4 | 2 | 0.17 | 3.5 | 154.7 |
| Filter to Waste | 14.4 | 2 | 0.083 | 3.5 | 8.4 |
| Chlorine Analyzers | 0.05 | 2 | 48 | 3.5 | 16.8 |
| Turbidity Analyzers | 0.018 | 2 | 48 | 3.5 | 6.1 |
| Total | | | | | 189.4 |

Waste stream sources that are not process residuals include:

- Sample Sink
- Eyewash Station
- Safety Shower
- Floor Drains
- Washrooms (if required)

Management of these waste streams will be confirmed in later stages of this project and may include discharge to surface or septic systems, depending on the characteristics of the waste stream.

## 4.2 Residual Management Alternatives

After the pre-screening of the treatment alternatives, residual management strategies and technologies were considered for use. These were tailored to suit the preferred treatment technology:

- **Alternative A:** Do Nothing

- **Alternative B:** Backwash Equalization Tank (BET) with pumping of all residuals and supernatant to an existing sanitary sewer
- **Alternative C:** BET with supernatant discharged to the storm sewer system, and solids hauled off to a septage receiving station
- **Alternative D:** Lagoon for backwash equalization and solids storage (all residuals) with supernatant discharged to the storm sewer system
- **Alternative E:** BET with supernatant recycled into the raw water supply, upstream of the filters, and solids hauled to a septic receiving station

A summary of each alternative is given below:

### 4.2.1 Alternative A: Do Nothing

This alternative would only be applicable if no residuals are produced, and since there will be residuals, this alternative was not considered further.

### 4.2.2 Alternative B: Backwash Equalization Tank (BET) with pumping of all residuals and supernatant to an existing sanitary sewer

The community of New Dundee does not have a local sanitary sewer system. The nearest sanitary sewer system is approximately 9 km away following major roadways, at the south-west corner of Kitchener. As this would effectively manage the residuals, this alternative will be further considered in the detailed evaluation. For the purposes of estimating the scope, it was assumed two pumping stations will be required to move the flows to the existing sanitary system in addition to the pumping from the facility. If this solution were selected as the preferred solution, additional analysis would need to be conducted on the existing Kitchener sewer capacity, and also on the new sewage pumping stations, including their design flow rates, configuration, and associated forcemain alignment.

### 4.2.3 Alternative C: BET with supernatant released to the storm sewer system, and solids hauled off to a septage receiving station

As discussed in Section 4.1.2, the supernatant that remains after a settling time contains higher than the Provincial Water Quality Objective (PWQO) values of chlorine and may contain higher values of copper. The PWQOs govern the concentration of a discharge into the environment or a watercourse. While the supernatant will not be directly discharged into the environment, the storm sewer discharges into the environment, so the backwash flows may still be governed by the PWQOs. Additionally, chlorine will need to be dechlorinated prior to being released, requiring additional chemical handling and a dechlorination system. Therefore, this alternative was not considered further.

#### 4.2.4 Alternative D: Lagoon for backwash equalization and solids storage (all residuals) with supernatant released to the storm sewer system

This option would require settled solids to be stored on site in a lagoon, which would amount to additional property acquisition, and the presence of a semi-full pool of settled solids sludge year-round. The supernatant being released to the storm presents the same issues as detailed in Alternative C, with respect to high concentrations of chlorine and possibly copper, requiring additional treatment to treat the water prior to discharge. Due to additional land acquisition requirements, supernatant treatment, and unpleasant view of the site, this option was not considered further.

#### 4.2.5 Alternative E: BET with supernatant recycled into the raw water supply, upstream of the filters, and solids hauled to a septic receiving station

This option would allow for the supernatant to be used effectively and not require any additional dechlorination, while only marginally increasing loading rates on the filters from 13.3 m/hr at PTTW Design rates to 14.5 m/hr at PTTW plus 3.6 $m^3$/hr recycle rates. The settled solids would be pumped out into a septage truck, resulting in periodic truck traffic in the area. Due to the minimal construction works requirements compared to the other options, and effective reuse of backwash supernatant on site, this alternative was evaluated further.

## 4.3 Residual Management Evaluation

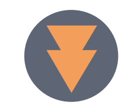
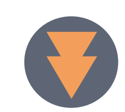
Based on the preliminary evaluation completed in Section 4.2, the two alternatives selected for a more detailed evaluation are:

- **Alternative B -** BET with pumping of all residuals and supernatant to an existing sanitary sewer; and
- **Alternative E:** BET with supernatant recycled into the raw water supply, upstream of the filters, and solids hauled to a septic receiving station

As with the treatment technology review in Section 3, the residual management strategies will be evaluated based on the evaluation criteria as highlighted in **TM #2 – Evaluation Criteria**, in the following tables.

As with the treatment technology evaluation, a high-level cost comparison was conducted based on past RVA experience with sewage pumping station costs. These values are not intended to be used as construction cost estimates, and do not include any land acquisition costs, they are only intended for use to compare the alternatives against each other in this TM. This comparative cost information can be found in Appendix C of this report.

**Table 4.3 – Evaluation of Alternative Residual Management Solutions – Technical Criteria**

| | | | Alternative B | Alternative E |
|---|---|---|---|---|
| **Evaluation Category** | **Criteria** | **Percentage** | **BET and new Sewage Pumping Stations** | **BET + Supernatant Recycle + Solids Hauling** |
| Technical | **Provides Reliable Service** | 3.57% | • Will reliably manage and handle residuals.<br>• New sewage pumping stations will increase operational complexity and odour control issues with low forcemain usages.<br> | • Will reliably manage and handle residuals.<br> |
| Technical | **Meets Existing and Future Needs** | 3.57% | • Will meet the current and future residual management needs of the facility.<br> | • Will meet the current and future residual management needs of the facility.<br> |
| Technical | **Aligns with Existing and Planned Infrastructure** | 3.57% | • No existing sanitary sewer system.<br>• Existing sanitary system not designed for these additional flows.<br> | • Residual management currently in use by the Region and other municipalities.<br> |
| Technical | **Aligns with Existing and Future Land Use** | 3.57% | • Sewage pumping stations will have impacts on existing land use, and future land uses.<br> | • BET and solids tank will have a low impact on the existing and future land uses.<br> |
| Technical | **Aligns with Approval and Permitting Process** | 3.57% | • Additional approvals and permits are required for linear construction, and for construction of new sewage pumping stations.<br> | • Standard permits and approvals are required to construct this residual management.<br> |

| | | | Alternative B | Alternative E |
|---|---|---|---|---|
| **Evaluation Category** | **Criteria** | **Percentage** | **BET and new Sewage Pumping Stations** | **BET + Supernatant Recycle + Solids Hauling** |
| **Technical** | **Manages and Minimizes Construction Risks** | 3.57% | • Residual management will greatly increase construction risks, due to the large scope of construction required, along existing and operational roadways.  | • Residual management will not adversely affect construction risks.  |
| **Technical** | **Ability to Adapt to Climate Change** | 3.57% | • Residual management strategy will require additional standby power or emergency storage requirements in the event of a power outage.  | • Residual management strategy is fully indoors, and is resistant to extreme weather events, with usable existing standby power.  |
| **Overall Technical Score** | | |  |  |

**Table 4.4– Evaluation of Alternative Residual Management Solutions – Natural Environment Criteria**

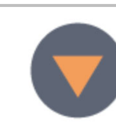
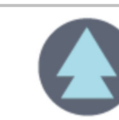
| | | | Alternative B | Alternative E |
|---|---|---|---|---|
| **Evaluation Category** | **Criteria** | **Percentage** | **BET and New Sewage Pumping Stations** | **BET + Supernatant Recycle + Solids Hauling** |
| **Natural Environment** | **Protects Environmental Features** | 6.25% | • Alternative will have a negative impact on sensitive environmental features due to creek crossings.  | • Residual management strategy will have no impact on environmentally sensitive areas.  |
| **Natural Environment** | **Protects Wildlife and Species at Risk** | 6.25% | • Alternative will have negative impacts to possible species at risk in environmentally sensitive areas, such as the aforementioned creek crossing.  | • Alternative will have little impact on wildlife.  |
| **Natural Environment** | **Protects Groundwater, Streams and Rivers** | 6.25% | • Forcemain will cross under one creek, and through wetlands, increasing chance of breaks.  | • Facility location will be outside of a GRCA regulated area, minimizing adverse effects against local watercourses and sources.  |
| **Natural Environment** | **Minimizes Climate Change Impacts** | 6.25% | • Construction of forcemains and sewage pumping stations will result in the release of greenhouse gas (GHG) emissions.  | • Hauling away of settled solids will result in the release of GHG emissions  |
| **Overall Natural Environment Score** | | **25%** |  |  |

**Table 4.5 – Evaluation of Alternative Residual Management Solutions –Social Criteria**

| | | | Alternative B | Alternative E |
|---|---|---|---|---|
| **Evaluation Category** | **Criteria** | **Percentage** | **BET and New Sewage Pumping Stations** | **BET + Supernatant Recycle + Solids Hauling** |
| **Social** | **Minimizes Impacts to Residents Related to Noise, Odour, Traffic, and Aesthetics** | 4.17% | • Sewage pumping stations will impact the suburban landscape of the area.<br>• Sewage pumping stations will increase risk of odour impacts<br> | • Residual management facility will visually change the existing suburban landscape<br>• Negative effects on traffic in the area due to increased solids hauling requirements<br> |
| **Social** | **Minimizes Impacts to Businesses** | 4.17% | • Roadway construction will have negative impacts on local businesses<br> | • Truck hauling will have minimal impacts on residents<br> |
| **Social** | **Manages and Minimizes Construction Impacts** | 4.17% | • Construction of forcemain will have large impact along its route on the surrounding area.<br> | • Construction of facility with proper measures will have minimal impacts on the surrounding area.<br> |
| **Social** | **Protects Cultural Heritage Features** | 4.17% | • Cultural Heritage features have a greater risk of being impacted by this residual management strategy.<br> | • Cultural Heritage features will not be impacted by the residual management strategy.<br> |

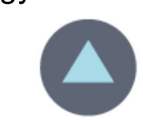
| | | | Alternative B | Alternative E |
|---|---|---|---|---|
| **Evaluation Category** | **Criteria** | **Percentage** | **BET and New Sewage Pumping Stations** | **BET + Supernatant Recycle + Solids Hauling** |
| **Social** | **Protects Archaeological Features** | 4.17% | • Archaeological features have a greater risk of being impacted by this residual management strategy.<br>• An archaeological assessment will be completed in the EA/Design phase to determine if archaeological impacts will be affected. Due to length of forcemain, additional area will need to be captured<br> | • Residual management strategy may impact existing archaeological features.<br>• An archaeological assessment will be completed in the EA/Design phase to determine if archaeological impacts will be affected.<br> |
| **Social** | **Protects Health and Safety** | 4.17% | • Region operations will require additional PPE and confined space entry equipment to service the sewage pumping stations.<br>• Public health and safety will not be affected by treatment technology.<br> | • Construction and operation will have minimal impacts on residents and Region staff.<br>• Public health and safety will not be affected by treatment technology.<br> |
| **Overall Social Score** | | |  |  |

**Table 4.6 – Evaluation of Alternative Residual Management Solutions –Financial Criteria**

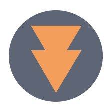
| | | | Alternative B | Alternative E |
|---|---|---|---|---|
| **Evaluation Category** | **Criteria** | **Percentage** | **BET and New Sewage Pumping Stations** | **BET + Supernatant Recycle + Solids Hauling** |
| **Financial** | **Provides Low Lifecycle Costs** | 25% | • The residual management alternative has a lifecycle cost of $6,400,000.  | • The residual management alternative has a lifecycle cost of $1,100,000.  |
| **Overall Financial Score** | | |  |  |

## 4.4 Preferred Residual Management Alternative

After the detailed evaluation conducted above, the preferred residual management alternative was **Alternative E –** BET with supernatant recycled into the raw water supply, upstream of the filters, and solids hauled to a septic receiving station. The principal reasons for this selection are:

- Efficient use of the backwash supernatant to be re-incorporated into the supply system.
- Minimal capital and lifecycle costs to implement.
- This residual management strategy has been effectively used in prior projects.

**Table 4.7 – Summary of Residual Management Evaluation Criteria**

| | | Alternative B | Alternative E |
|---|---|---|---|
| **Evaluation Criteria** | **Percentage** | **BET and New Sewage Pumping Stations** | **BET + Supernatant Recycle + Solids Hauling** |
| **Technical** | 25% |  |  |
| **Natural Environment** | 25% |  |  |
| **Social** | 25% |  |  |
| **Financial** | 25% |  |  |
| **Overall** | 100% |  |  |

## 4.5 Sensitivity Analysis for Residual Management Alternatives

As with the treatment technology evaluation, the short-listed residual management alternatives were subject to a sensitivity analysis. Due to the suburb surrounding the existing well supply facility, the social criteria have been increased per the following:

- Technical 20%, Natural Environment 20%, Social 40%, Financial 20%

In this case, Alternative E was still shown as the preferred alternative.

## 4.6 Supernatant Recycle Analysis

An integral part of this preferred residual management strategy is the effective recycling of supernatant from the BET back through the filters.

Historically, the Region has kept a recycle flowrate of less than or equal to 10% of the raw water flows into the filter on existing systems. Additionally, as determined in previous pilot testing studies, a period of 4 hours is given to allow the supernatant and the settled solids in the BET to sufficiently settle out. Therefore, supernatant recycle cannot occur for these four hours. Per historical operation information of other facilities as obtained through Region staff, it is common practice that recycle streams are not started until 30 minutes after the wells have been flowing through the filter, so this was also been considered in the below cases. Given this operational information of existing systems in the Region of Waterloo, a volume balance was completed on two possible operational scenarios to see that the recycle of supernatant is sufficient to fully reuse the flows into that BET as identified in Section 4.1.

### 4.6.1 Operational Case 1: Treatment Capacity Design Flows

In operational case 1, PTTW flows were assumed, with the additional parameters listed below:

- Filter Flowrate: 8.0 L/s
- Filters in operation: 2
- Filter Run-Time: 48 hours
- Equivalent hours in time elapsed: 48 hours
- Pump Start/Stops: 1
- Filter Purges: 1
- Supernatant Recycle Rate: 10% of 8.0 L/s = 0.8 L/s

- Supernatant Recycle Run time: 48 hours – 4 hours settling time = 44 hours

The volume balance is summarized in the Table below:

**Table 4.8 – Operation Case 1: PTTW Flows Volume Balance**

| **Flows into BET** | | | | |
|---|---|---|---|---|
| **Source** | **Flowrate ($m^3$/hr)** | **Units** | **Duration/Filter Runtime (hr)** | **Volume /Cycle ($m^3$)** |
| **Filter Backwash** | 132.4 | 2 | 0.17 | 44.2 |
| **Filter to Waste** | 28.8 | 1 | 0.083 | 2.4 |
| **Filter Purge** | 28.8 | 1 | 0.033 | 1.0 |
| **Analyzers Flows** | 0.07 | 2 | 48 | 6.7 |
| | | | **Volume In** | **54.3** |
| **Flows out of BET** | | | | |
| **Source** | **Flowrate ($m^3$/hr)** | **Units** | **Duration/Filter Runtime (hr)** | **Volume/Cycle ($m^3$)** |
| **Supernatant Recycle** | 2.9 | 1 | 44 | 126.7 |
| | | | **Volume Out** | **126.7** |
| | | | **Volume In – Volume Out** | **-72.4** |

After completing the volume balance, the result was that if the system were to run per the treatment design capacity and on the basis of the Region's best practices with regards to operating supernatant recycle streams, the system would run at a net deficiency, which means the supernatant recycle system could adequately recycle all the supernatant in between backwash cycles.

### 4.6.2 Operational Case 2: Historical Flows from 2020

In Operation Case 2, the historical flows that were used were taken from supplied SCADA data from January 2020 to September 2020. During this nine-month period, it was observed that the pumps were running for approximately 2483 hours.

The 48-hr filter runtime value was applied to this, to determine the number of backwash cycles that would be required in this period, which was about 51 backwash cycles. Considering that there are 274 days in in January – September 2020, this leaves us with one backwash occurring every 5.3 days. Other parameters such as filter purges and pump starts and stops were taken from data snapshots, of looking at a typical backwash cycle length, and counting the pump starts/stops, which also equals the filter purges required. Finally, the four hour settling time was excluded from this scenario because there are on average longer than four hour periods between pump starts and stops, so it can be coordinated to backwash the filters after a run period, giving the settling time while the well pumps are off. The other parameters are below:

- Filter Flowrate: 6.78 L/s (average flows while pumps were on)
- Filters in operation: 2
- Filter Run-Time: 48 hours
- Equivalent hours in time elapsed: 127 hours
- Well Pump Start/Stops: 18
- Filter Purges: 18
- Supernatant Recycle Rate: 10% of 6.78 L/s = 0.68 L/s
- Supernatant Recycle Run time: 48 hours – 18*0.5 hrs = 39 hours

The volume balance is summarized below:

**Table 4.9 – Operational Case 2: 2020 Historical Data Flows Volume Balance**

| Flows into BET | | | | |
|---|---|---|---|---|
| **Source** | **Flowrate ($m^3$/hr)** | **Units** | **Duration/Filter Runtime (hr)** | **Volume /Cycle ($m^3$)** |
| **Filter Backwash** | 132.4 | 2 | 0.17 | 44.2 |
| **Filter to Waste** | 28.8 | 1 | 0.083 | 2.4 |
| **Filter Purge** | 28.8 | 1 | 0.6 | 1.0 |

| | | | | |
|---|---|---|---|---|
| **Analyzers Flows** | 0.07 | 2 | 48 | 6.5 |
| | | | **Volume In** | **54.1** |
| **Flows out of BET** | | | | |
| **Source** | **Flowrate ($m^3$/hr)** | **Units** | **Duration/Filter Runtime (hr)** | **Volume/Cycle ($m^3$)** |
| **Supernatant Recycle** | 2.45 | 1 | 39 | 95.5 |
| | | | **Volume Out** | **95.5** |
| | | | **Volume In – Volume Out** | **-41.4** |

In this historical operational scenario, it can be noted that a deficiency would be produced every cycle, which means that the supernatant would be recycled sufficiently. Some other points to note from this analysis:

- In Operational Case 2, the four hour shutdown was not included in the supernatant pump runtime, because it would be assumed that the filters would be operationally set to not run for four hours after backwash.
- Other options to mitigate backwash volumes would be a reduction of well pump start/stops, discharging the chlorine and turbidity analyzer flows into the storm system as is done currently at the facility, or reducing the delay between the well pump start and supernatant pump start from 30 minutes to fifteen minutes.

# 5.0 Preferred Treatment Alternative and Residual Management Strategy

The objective of this TM was to determine the preferred treatment and associated residual management strategy for removal of iron and manganese at the New Dundee Water Supply Facility. After an evaluation using criteria as recorded in **TM #2 – Evaluation Criteria,** the preferred treatment technology was found to be conventional oxidation using chlorine, and conventional pressure filtration using either manganese dioxide coated filter media or solid manganese dioxide, with an N+1 redundancy. The preferred residual management strategy is to hold residual flows in a BET, recycle the supernatant back into the raw water supply header, and pump and haul the settled solids as required.

# 6.0 References

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# Appendix A – Treatment Alternatives Comparative Cost Information

**New Dundee Iron and Manganese Removal Upgrades Class EA- Waterloo, ON**

**TM #3 - Captial and O&M Cost - Appendix A**

Updated: 2021-08-24

New Dundee Capacity 8.0 L/s

## Alternative 5: Chlorine + Pressure Filter+ Catalytic Media

CAPITAL COST

The comparative capital cost of the conventional oxidation and filtration alternative was estimated based on the Water and Wastewater Asset Cost Study (R.J. Burnside, 2005) Iron and Manganese Removal cost estimation curve. Applied to the curve were a 1.33 general multiplier for items such as engineering, permits, approvals, construction overhead, building and site works, field investigations and water source development, 1.24 multiplier for building costs, 1.03 regional multiplier, 1.05 for SCADA and 1.02 for flowmeters. These curves were adjusted to 2020 costs based on the RS Means Construction Cost Index with 20% contigency and a 6% COVID cost realized by other municipalities, rounded up to nearest million. The relative costs between alternatives was compared against previous project experience. These curves did not include the cost for secondary disinfection, contact tank, reservoir, well pumps or residual management equipment and tankage. A detailed cost estimate will be prepared at a later date in the project for the preferred alternative.

| CAPITAL COST | Cost |
|---|---|
| | $ |
| Estimated Capital Cost | $ 1,000,000.00 |
| **Total** | $ 1,000,000 |

OPERATION AND MAINTENANCE

A high level comparative cost estimate was prepared, considering only the primary components associated with this technology. This does not include the common O&M costs associated with HVAC, lighting, and other ancilliary equipment, and residual management costs. A detailed construction cost estimate for the entire facility will be prepared at a later date in the project.

| ANNUAL COSTS | Unit | Quantity | Price per unit | Yearly Cost | Discount Rate | Present Cost of 50 years | **Assumptions** |
|---|---|---|---|---|---|---|---|
| | | | $ | $ | % | $ | |
| Backwash Pump | kWh/yr | 167 | $ 0.13 | $ 22 | 4% | $ 467 | 109.5 m³/hr, 5 m TDH, 2.5 kW, 11 minute runs, two runs / 2 days. Electrical price per Waterloo North Hydro rates, June 2020. |
| Backwash Air Blowers | kWh/yr | 681 | $ 0.13 | $ 88 | 4% | $ 1,901 | 7.5 kW, 15 minute runs, two runs / 2 days. Electrical price per Waterloo North Hydro rates, June 2020 |
| Operation & Maintenance Labour | hr/year | 780 | $100.00 | $78,000 | 4% | $ 1,675,610 | 15 hours/week to maintain system |
| **Total** | | | | **$ 100,000** | | **$ 1,700,000** | Rounded up to nearest one hundred thousand. |

| LIFE CYCLE | 2020 Price | Years to perform | Discount Rate | Present Cost | **Assumptions** |
|---|---|---|---|---|---|
| | $ | | % | $ | |
| Replace Media Every 10 Years | $ 21,029 | 10 | 4% | $ 14,207 | Estimate for GreensandPlus and anthracite media replacement. |
| Replace Media Every 10 Years | $ 21,029 | 20 | 4% | $ 9,598 | Estimate for GreensandPlus and anthracite media replacement. |
| Replace Media Every 10 Years | $ 21,029 | 30 | 4% | $ 6,484 | Estimate for GreensandPlus and anthracite media replacement. |
| Replace Media Every 10 Years | $ 21,029 | 40 | 4% | $ 4,380 | Estimate for GreensandPlus and anthracite media replacement. |
| Replace Media Every 10 Years | $ 21,029 | 50 | 4% | $ 2,959 | Estimate for GreensandPlus and anthracite media replacement. |
| Filter Underdrain Replacement | $ 50,000 | 20 | 4% | $ 22,819 | 5% of capital cost for both filters. |
| Filter Underdrain Replacement | $ 50,000 | 40 | 4% | $ 10,414 | 5% of capital cost for both filters. |
| Valves Overhaul Every 10 Years | $ 43,300 | 10 | 4% | $ 29,252 | 50% of original cost of 3 valves and 2 motorized actuators per filter (2 filters) |
| Valves Overhaul Every 10 Years | $ 43,300 | 20 | 4% | $ 19,762 | 50% of original cost of 3 valves and 2 motorized actuators per filter (2 filters) |
| Valves Overhaul Every 10 Years | $ 43,300 | 30 | 4% | $ 13,350 | 50% of original cost of 3 valves and 2 motorized actuators per filter (2 filters) |
| Valves Overhaul Every 10 Years | $ 43,300 | 40 | 4% | $ 9,019 | 50% of original cost of 3 valves and 2 motorized actuators per filter (2 filters) |
| Valves Overhaul Every 10 Years | $ 43,300 | 50 | 4% | $ 6,093 | 50% of original cost of 3 valves and 2 motorized actuators per filter (2 filters) |
| **Total** | | | | **$ 200,000** | Rounded up to nearest one hundred thousand. |

## OVERALL COST

| | | | | |
|---|---|---|---|---|
| Capital Costs | $ 1,000,000 | $ 1,150,000 | Annual Operating Costs | $ 100,000 |
| Present Value O&M | $ 1,900,000 | $ 2,185,000 | | |
| Subtotal | $ 2,900,000 | | | |
| | $ 435,000 | add | 15% | Safety Factor |
| **TOTAL COST FOR ALTERNATIVE** | **$ 4,000,000** | Rounded up to nearest million | | |

**New Dundee Iron and Manganese Removal Upgrades Class EA- Waterloo, ON**

**TM #3 - Captial and O&M Cost - Appendix A**

Updated: 2021-08-24
New Dundee Capacity 8.0 L/s

## Alternative 7: Membrane Filtration

CAPITAL COST

The comparative capital costs were estimated based on the Water and Wastewater Asset Cost Study (R.J. Burnside, 2005) Iron and Manganese Removal cost estimation curve with 1.33 general multiplier for items such as engineering, permits, approvals, construction overhead, building and site works, field investigations and water source development, 1.24 multiplier for building costs, 1.03 regional multiplier, 1.05 for SCADA and 1.02 for flowmeters. These curves were adjusted to 2020 costs based on the RS Means Construction Cost Index with 20% contigency and a 6% COVID cost realized by other municipalities, rounded up to nearest million. The relative costs between alternatives was compared against previous project experience. These curves did not include the cost for secondary disinfection, contact tank, reservoir, well pumps or residual management equipment and tankage. A detailed cost estimate will be prepared at a later date in the project for the preferred alternative.

| CAPITAL COST | Cost |
|---|---|
| | $ |
| Estimated Capital Cost | $ 4,000,000.00 |
| **Total** | $ 4,000,000 |

OPERATION AND MAINTENANCE

A high level cost estimate was prepared for comparison purposes only. A more detailed cost estimate will be prepared at a later date in the project. This cost comparison does not include the O&M costs associated with all alternatives including the energy consumption from the high lift pumps and HVAC . The costs for residual management will be reviewed at a later date.

| ANNUAL COSTS | Unit | Quantity | Price per unit | Yearly Cost | Discount Rate | Present Cost of 50 years | Assumptions |
|---|---|---|---|---|---|---|---|
| | | | $ | $ | % | $ | |
| Energy Consumption - Membrane System | kWh/yr | 16,000 | $ 0.13 | $ 2,080 | 4% | $ 44,683 | From previous project estimate. Includes membranes, feed pumps, and ancillary equipment. |
| Operation & Maintenance Labour | hr/yr | 1040 | $ 100.00 | $ 104,000 | 4% | $ 2,234,147 | 20 hours/week to maintain system |
| Chemical Costs for Sodium Hypochlorite | L/year | 600 | $ 1.37 | $ 825 | 4% | $ 17,719 | Cost of chemical and dosages from previous project estimate, pro-rated to design flow. |
| Chemical Costs for Citric Acid | L/year | 100 | $ 3.64 | $ 364 | 4% | $ 7,817 | Cost of chemical and dosages from previous project estimate, pro-rated to design flow. |
| Chemical Costs for Hydrochloric Acid | L/year | 100 | $ 1.23 | $ 123 | 4% | $ 2,646 | Cost of chemical and dosages from previous project estimate, pro-rated to design flow. |
| Chemical Costs for Sodium Bisufite | L/year | 200 | $ 1.38 | $ 276 | 4% | $ 5,935 | Cost of chemical and dosages from previous project estimate, pro-rated to design flow. |
| Chemical Costs for Sodium Hydroxide | L/year | 100 | $ 2.85 | $ 285 | 4% | $ 6,119 | Cost of chemical and dosages from previous project estimate, pro-rated to design flow. |
| **Total** | | | | **$ 200,000** | | **$ 2,400,000** | Rounded up to nearest one hundred thousand. |

| LIFE CYCLE | 2020 Price | Years to perform | Discount Rate | Present Cost | Assumptions |
|---|---|---|---|---|---|
| | $ | | % | $ | |
| Membrane Replacement | $ 320,000 | 10 | 4% | $ 216,181 | 20% of equipment cost based on previous project (~$1,600,000 for equipment, 40% capital cost) |
| Membrane Replacement | $ 320,000 | 20 | 4% | $ 146,044 | 20% of equipment cost based on previous project (~$1,600,000 for equipment, 40% capital cost) |
| Membrane Replacement | $ 320,000 | 30 | 4% | $ 98,662 | 20% of equipment cost based on previous project (~$1,600,000 for equipment, 40% capital cost) |
| Membrane Replacement | $ 320,000 | 40 | 4% | $ 66,652 | 20% of equipment cost based on previous project (~$1,600,000 for equipment, 40% capital cost) |
| Membrane Replacement | $ 320,000 | 50 | 4% | $ 45,028 | 20% of equipment cost based on previous project (~$1,600,000 for equipment, 40% capital cost) |
| **Total** | | | | **$ 600,000** | Rounded up to nearest one hundred thousand. |

## OVERALL COST

| | | | | |
|---|---|---|---|---|
| Capital Costs | $ 4,000,000 | $ 4,600,000 | Annual Operating Costs | $ 200,000 |
| Present Value O&M | $ 3,000,000 | $ 3,450,000 | | |
| Subtotal | $ 7,000,000 | | | |
| | $ 1,050,000 add | | 15% Safety Factor | |
| **TOTAL COST FOR ALTERNATIVE** | **$ 9,000,000** | | | |

# Appendix B –Filter Design and Preliminary Residual Management Calculations

**New Dundee Iron and Manganese Removal Class EA - Waterloo, ON**
**TM #3, Appendix B - Filter Design and Preliminary Residual Management Calculations**
**August 24, 2021**

## Basic Design Parameters

| Parameters | L/s | $m^3/hr$ |
|---|---|---|
| Current PTTW Capacity | 8 | 28.8 |
| Current PTTW Capacity plus Supernatant Recycle | 8.80 | 31.68 |

## Filtration

| Parameters | | | |
|---|---|---|---|
| Number of Filters | 2 | | |
| Filter Diameter | 1.68 | m | |
| Filter Area | 2.21 | $m^2$ | |
| Filter Loading Rate (1 Filter offline) | 13.05 | m/hr | |
| Filter Loading Rate (1 Filter offline, recycle) | 14.35 | m/hr | |
| | | | |
| Backwash Loading Rate (water) | 60.0 | m/hr | |
| Backwash Duration per Filter | 10 | minutes | |
| Backwash Volume per Filter (water) | 22.10 | $m^3$/filter | |
| | | | |
| Filter Purge Flowrate (water) | 28.80 | $m^3$/hr | |
| Filter Purge Time Length | 2 | minutes | *Both filters purged at the same time, each seeing 50% flow.* |
| Filter Purge Volume (water) | 0.96 | $m^3$/backwash cycle | |
| | | | |
| Filter to Waste Loading Rate | 6.5 | m/hr | *Both filters run to waste at the same time, each seeing 50% flow.* |
| Filter to Waste Run per Filter | 5 | minutes | |
| Filter to Waste Run per Filter | 1.200 | $m^3$ | |
| | | | |
| Waste Volume per Filter | 23.30 | $m^3$/filter | |
| Waste Volume for all Filters | 47.56 | $m^3$/backwash cycle | |

## Alternative B: BET + Pumping of Solids and Supernatant to Sanitary Sewer

| Supernatant and Solids Produced | | | |
|---|---|---|---|
| Filter Run Time | 2 | Days Runtime Backwash/Filter | *Filter run time for Napier Reid filters, MD-80 filter media.* |
| Backwash Frequency | 182.5 | Days/year | |
| Chlorine and Turbidity Analyzer Waste | 1191.36 | $m^3$/year | |
| Backwash Volume Produced per year | 9871.06 | $m^3$/year | |
| Pumping Rate of Supernatant and Solids | 15 | L/s | |
| Hours of Pump Operation | 183 | hrs/year | |
| Hours of Pump Operation (per day) | 30 | minutes/day | |

## Alternative E: BET + Recycling of Supernatant + Settled Solids Holding Tank + Settled Solids Haulage

| Solids Produced | | | |
|---|---|---|---|
| Percent of Solids | 0.1% | | |
| Concentration of Solids | 1000 | mg/L | |
| Mn in Raw Water | 0.038 | mg/L | *Max. recorded Mn raw water concentration* |
| Fe in Raw Water | 0.079 | mg/L | *Max. recorded Fe raw water concentration* |
| Mn & Fe Removed per year | 29.52 | kg/year | |
| Volume of Solids per year | 29.52 | $m^3$/year | |
| Design Flowrate of Sludge Pumps | 18.00 | $m^3$/hr | |
| Pump Run time per year | 2.00 | hrs/year | |
| Volume of Haulage Truck | 6 | $m^3$ | |
| Frequency of Haulage Truck Required | 5 | trips/year | |
| Length of Haulage Time per Trip | 4 | hrs/trip | |
| Haulage Time per year | 20 | hrs/year | |

# Appendix C – Residual Management Alternatives Comparative Cost Estimate

**New Dundee Iron and Manganese Removal Upgrades Class EA- Waterloo, ON**

**TM#3- Residual Cost Comparison - Appendix C**

Updated: 2021-08-24 JPR

## Alternative B: BET + Pumping of Solids and Supernatant to Sanitary Sewer

CAPITAL COST

| CAPITAL COSTS | Unit | Quantity | Price per unit | Cost | |
|---|---|---|---|---|---|
| | | | $ | $ | |
| Supernatant/ Solids Pumps | per unit | 2 | $ 40,000.00 | $ 80,000 | Pumps located at the facility. |
| Forcemain Installation | per m | 9000 | $ 300.00 | $ 2,700,000 | Estimate of pipe material, excavation, bedding, backfill and asphalting. |
| Pumping Station | per station | 2 | $ 700,000.00 | $ 1,400,000 | Construction of wet well, building, equipment, standby generator. Does not include property acquistion. Two SPSs located along FM route. |
| Backwash Equalization Tank | | N/A | $ - | $ - | Both alternatives require a backwash equalization tank. Will not be considered in comparative cost estimate. |
| **Total** | | | | **$ 4,200,000** | Rounded up to nearest one hundred thousand. |

OPERATION AND MAINTENANCE

| ANNUAL COSTS | Unit | Quantity | Price per unit | Yearly Cost | Discount Rate | Present Cost of 50 years | |
|---|---|---|---|---|---|---|---|
| | | | $ | $ | % | $ | |
| Energy Consumption - Supernatant and Solids Pumps | kWh/yr | 6964 | $ 0.13 | $ 905 | 4% | $ 19,449 | 6 pumps (2 stations + facility) operating at 90 m³/hr, 20 min/ day, 30 m TDH, 10.6 kW. Electrical price per Waterloo North Hydro rates, June 2020. |
| Operation & Maintenance Labour | hr/yr | 520 | $ 100.00 | $ 52,000 | 4% | $ 1,117,074 | 10 hrs/week to maintain system and pumping station |
| **Total** | | | | **$ 100,000** | | **$ 1,200,000** | Rounded up to nearest one hundred thousand. |

| LIFE CYCLE | 2019 Price | Years to perform | Discount Rate | Present Cost | |
|---|---|---|---|---|---|
| | $ | | % | $ | |
| Equipment Replacement | $ 32,000 | 10 | 4% | $ 21,618 | 40% of capital equipment cost (pumps) |
| Equipment Replacement | $ 32,000 | 20 | 4% | $ 14,604 | 40% of capital equipment cost (pumps) |
| Equipment Replacement | $ 32,000 | 30 | 4% | $ 9,866 | 40% of capital equipment cost (pumps) |
| Equipment Replacement | $ 32,000 | 40 | 4% | $ 6,665 | 40% of capital equipment cost (pumps) |
| Equipment Replacement | $ 32,000 | 50 | 4% | $ 4,503 | 40% of capital equipment cost (pumps) |
| **Total** | | | | **$ 100,000** | Rounded up to nearest one hundred thousand. |

## OVERALL COST

| | | | | | |
|---|---|---|---|---|---|
| Capital Costs | $ 4,200,000 | $ 4,830,000 | | Annual Operating Costs | $ 100,000 |
| Present Value O&M | $ 1,300,000 | $ 1,495,000 | | | |
| Subtotal | $ 5,500,000 | | | | |
| | $ 825,000 | add | 15% | Contingency | |
| **TOTAL COST FOR ALTERNATIVE** | **$ 6,400,000** | Rounded up to nearest hundred thousand | | | |

**New Dundee Iron and Manganese Removal Upgrades Class EA- Waterloo, ON**

**TM#3- Residual Cost Comparison - Appendix C**

Updated: 2021-08-24 JPR

## Alternative E: BET + Recycling of Supernatant + Settled Solids Holding Tank + Settled Solids Haulage

CAPITAL COST

| CAPITAL COSTS | Unit | Quantity | Price per unit | Cost | Assumptions |
|---|---|---|---|---|---|
| | | | $ | $ | |
| Supernatant Recycling Pumps | per unit | 2 | $ 25,000.00 | $ 50,000 | Estimate for metering pump with medium TDH, low flow. |
| Settled Solids Sludge Pumps | per unit | 2 | $ 25,000.00 | $ 50,000 | Estimate for pump with low TDH, medium flow. |
| Decanter | per unit | 2 | $ 35,000.00 | $ 70,000 | From supplier correspondence on past projects. |
| Settled Solids Holding Tank | per m³ concrete | 25 | $ 1,850.00 | $ 46,250 | Sized for 29 m³ of sludge |
| Backwash Equalization Tank | | N/A | $ - | $ - | Both alternatives require a backwash equalization tank. Will not be considered in comparative cost estimate. |
| **Total** | | | | **$ 300,000** | Rounded up to nearest one hundred thousand. |

OPERATION AND MAINTENANCE

| ANNUAL COSTS | Unit | Quantity | Price per unit | Yearly Cost | Discount Rate | Present Cost of 50 years | Assumptions |
|---|---|---|---|---|---|---|---|
| | | | $ | $ | % | $ | |
| Energy Consumption - Supernatant Recycling Pumps | kWh/yr | 1139 | $ 0.13 | $ 148 | 4% | $ 3,180 | 2.9 m³/hr, 12 hrs/day, 20 m TDH, 0.26 kW. Electrical price per Waterloo North Hydro rates, June 2020. |
| Energy Consumption - Settled Solids Sludge Pumps | kWh/yr | 1.1 | $ 0.13 | $ 0.14 | 4% | $ 3 | 18 m³/hr, 3 hrs/year, 5 m TDH, 0.35 kW. Electrical price per Waterloo North Hydro rates, June 2020. |
| Operation & Maintenance Labour | hr/yr | 104 | $ 100.00 | $ 10,400 | 4% | $ 223,415 | 2 hrs/week to maintain system |
| Haulage Costs | per hour | 20 | $ 300.00 | $ 6,000 | 4% | $ 128,893 | 5 trips/year, 4 hours per trip. Based on 2020 Hydrovac trucking rates. |
| **Total** | | | | **$ 100,000** | | **$ 400,000** | Rounded up to nearest one hundred thousand. |

| LIFE CYCLE | 2019 Price | Years to perform | Discount Rate | Present Cost | |
|---|---|---|---|---|---|
| | $ | | % | $ | |
| Equipment Replacement | $ 68,000 | 10 | 4% | $ 45,938 | 40% of capital equipment cost (pumps and decanter) |
| Equipment Replacement | $ 68,000 | 20 | 4% | $ 31,034 | 40% of capital equipment cost (pumps and decanter) |
| Equipment Replacement | $ 68,000 | 30 | 4% | $ 20,966 | 40% of capital equipment cost (pumps and decanter) |
| Equipment Replacement | $ 68,000 | 40 | 4% | $ 14,164 | 40% of capital equipment cost (pumps and decanter) |
| Equipment Replacement | $ 68,000 | 50 | 4% | $ 9,568 | 40% of capital equipment cost (pumps and decanter) |
| **Total** | | | | **$ 200,000** | Rounded up to nearest one hundred thousand. |

## OVERALL COST

| | | | | |
|---|---|---|---|---|
| Capital Costs | $ 300,000 | $ 345,000 | Annual Operating Costs | $ 100,000 |
| Present Value O&M | $ 600,000 | $ 690,000 | | |
| Subtotal | $ 900,000 | | | |
| | $ 135,000 | add | 15% | Safety Factor |
| **TOTAL COST FOR ALTERNATIVE** | **$ 1,100,000** | Rounded up to nearest hundred thousand | | |