TOWN OF OSOYOOS

Water and Wastewater Engineering Services

Source Water and Treatment Feasibility Study

FINAL / March 2025

Osoyoos
Canada's warmest welcome ®*

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PROFESSIONAL
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Abbreviations

°C	degrees Celsius
2023 WSIP	2023 Osoyoos Water System Infrastructure Plan
AACE	Association for the Advancement of Cost Engineering
ADD	average daily demand
ASTM	American Society for Testing and Materials
BC	British Columbia
$CaCO_3$	calcium carbonate
cells/mL	cells per milliliter
CFU	colony forming unit
DAF	dissolved air flotation
DBP	disinfection byproduct
DOC	dissolved organic carbon
DWOG	Drinking Water Officers' Guide (Ministry of Health 2023)
EBCT	empty bed contact time
GAC	granular activated carbon
GARP	Groundwater at Risk of Containing Pathogens
GCWDG	Guidelines for Canadian Drinking Water Quality (Health Canada 2022)
GSP	Greensand Plus
GST	goods and services tax
HAA_{FP}	haloacetic acid formation potential
HP	horsepower
HVAC	heating, ventilation, and air conditioning
IX	ion exchange
km	kilometers
kW/m^2	kilowatt hours per square meter
L/s	liters per second
m	meters
m/hour	meters per hour
m^2	square meters
m^3	cubic meters
MAC	maximum acceptable concentration
MDD	maximum daily demand
mg/L	milligrams per liter
mJ/cm^2	millijoules per square centimeter
MLD	million liters per day
mm	millimeters

N	nitrogen
ng/L	nanograms per liter
NTU	nephelometric turbidity unit
PAC	powdered activated carbon
PACl	polyaluminum chloride
PFAS	per-and polyfluoroalkyl substances
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid
psi	pounds per square inch
TCU	true colour unit
TDS	total dissolved solids
THM_{FP}	trihalomethane formation potential
TOC	total organic carbon
Town	Town of Osoyoos
USEPA	United States Environmental Protection Agency
UV	ultraviolet
UVT	ultraviolet transmittance
VFD	variable frequency drive

SECTION 1 INTRODUCTION

The Town of Osoyoos (Town) is located in southern British Columbia (BC), bordering Washington State to the south, and located adjacent to Osoyoos Lake. The Town supplies drinking water to consumers using a series of groundwater wells that are located within the developed areas around Osoyoos Lake. Water from these wells is chlorinated and pumped directly into the distribution system. The capacity of the existing groundwater supply wells and distribution network is not sufficient to meet the anticipated future water demands in the region, per the 2023 Osoyoos Water System Infrastructure Plan (2023 WSIP). In addition, the quality of the groundwater requires additional treatment to meet both aesthetic and health based drinking water quality objectives set out by the BC Ministry of Health.

The purpose of this report is to evaluate the available source water supply alternatives and provide recommendation of the preferred long term solution for the Town to meet domestic water demands while meeting provincial drinking water guidelines. This report has been updated to reflect updated design criteria and project objectives developed through value engineering efforts completed subsequent to the original submission in April, 2024. These changes represent refinement in the design parameters and can be carried forward into preliminary design. As such, several of the references included in the appendices are directed towards the 2024 version of this report.

SECTION 2 BACKGROUND DATA REVIEW

2.1 Existing Water System

The Town's six production wells collectively pump into the primary pressure zone, which operates with at a hydraulic grade line of approximately 340 m (Figure 1). Water storage in the 340 system is handled by two concrete reservoirs, the 340 reservoirs, which are fed by the distribution system. Booster pumps supply two additional pressure zones at 402 and 452 m. These zones are serviced by the 402 and Dividend reservoirs which are filled via the 340 reservoirs and the Fairway Hills Booster Station, respectively. The Town has a separate irrigation system which supplies water to agricultural users using Osoyoos Lake, with one intake in the North Basin and another in the Central Basin. Irrigation is chlorinated but the intakes are shallow and not suitable for drinking water supply because of pathogen exposure risk.

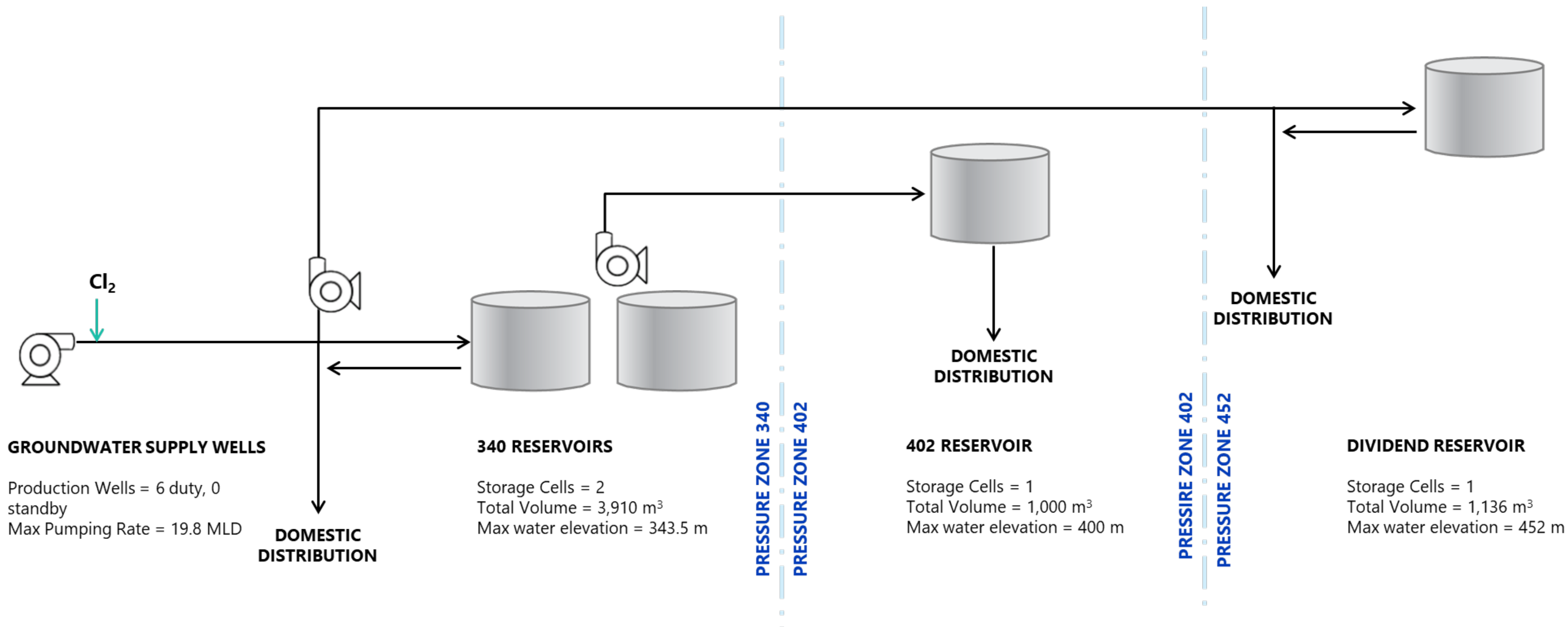

Figure 1 Process Flow Diagram for the Town's Existing Water Supply System

2.2 Current and Future Water Demands

Domestic water demand projections for the Town were developed by TRUE Consulting Ltd. (TRUE) in the 2023 WSIP (Martins and Underwood 2023). The report demonstrates that the historical maximum daily demand (MDD) was 19.7 million liters per day (MLD) in 2021, while the average daily demand was calculated at 1083 L/day/capita based on five year averaging.

The 2023 WSIP presents a range of future demand forecasts for the year 2050 using an anticipated 1 percent, 2 percent and 3 percent growth rates both with accounting for water conservation measures and without. With projected MDD under the moderate growth scenario of 2 percent was forecasted to be 25 MLD with conservation and 32 MLD without conservation.

Average daily demand was estimated for the summer months (May to August) to assess the needs and impacts on infrastructure system for sustained peak flow periods, as is typical for water supply and treatment system planning in the Okanagan Interior. Data presented in the 2023 Annual Water Report (McDonald and Brounstein 2023) identified the ADD in 2023 to be 11.9 MLD. This results in a 2050 summer ADD of 15.9 MLD with conservation and 20.3 MLD without conservation (Table 1).

As part of the value planning effort, the forecasted water demand estimates were further refined in 2024 to reflect target conservation values, updated current and maximum daily demands values, and revised planning horizons. The following assumptions were applied to establish the forecasted water consumption rates for use in planning the future water infrastructure needs:

- Average daily demand (ADD) per capita calculated to be 1083 L/day/capita (TRUE 2024) base on the previous five years average.
- Use of the moderate growth rate of a 2 percent population growth rate, starting from the 2021 census population of 5556.
- Average demand reduced by 10 percent over the first 5 years to account for water conservation efforts.
- The MDD calculated as 2.55 times the ADD.

This projection agrees with the demand projection presented in the 2023 WSIP, with a 2050 MDD of 24.5 MLD (Figure 2).

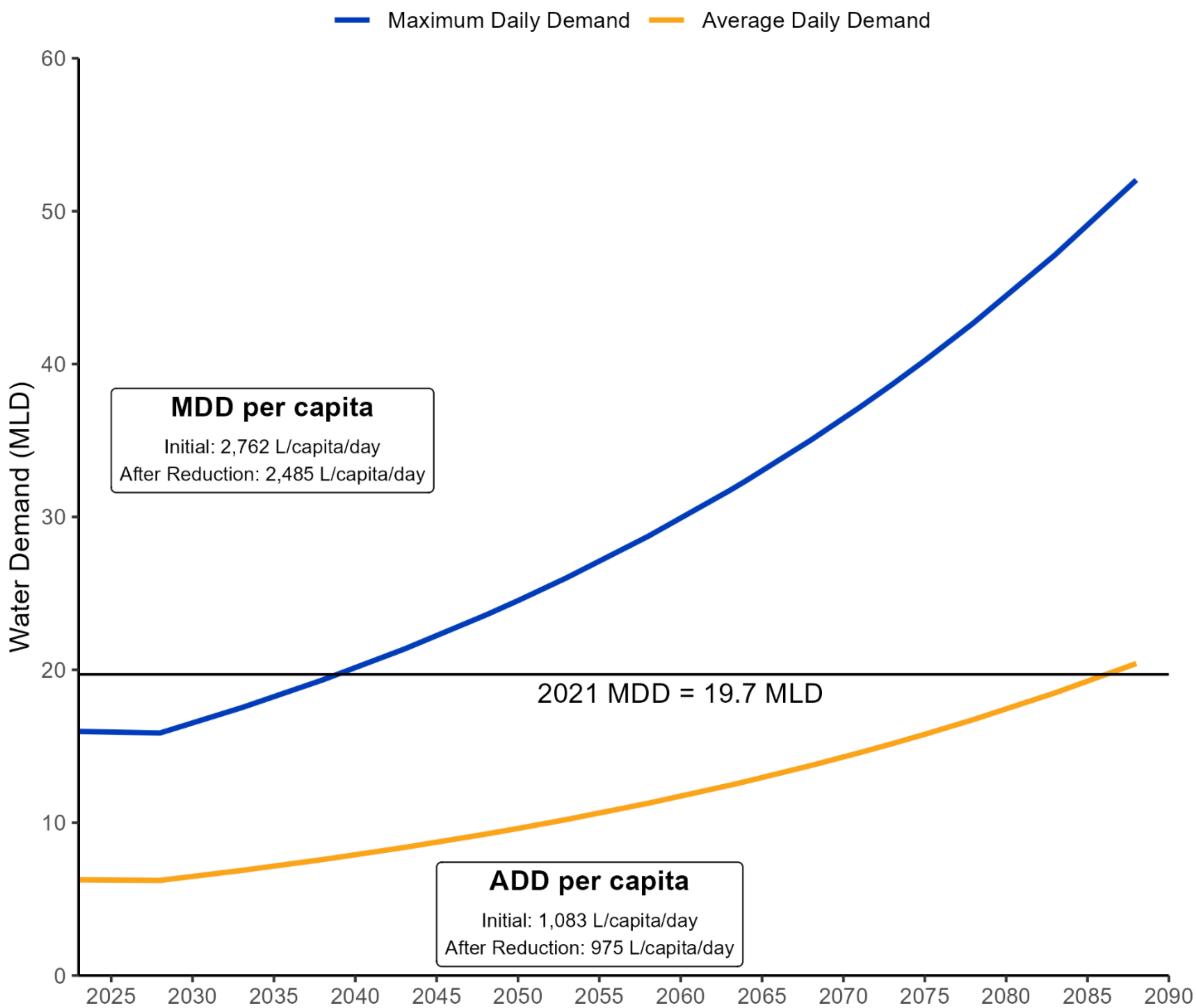

Figure 2 ADD and MDD Projections Based on Value Engineering Inputs

2.3 Water Licences

Yearly water consumption projections suggest that the Town's Conditional Water Licence, authorized by the Province of British Columbia via the Water Sustainability Act, will eventually require restructuring. Currently, 3,043,000 cubic meters (m^3) are allotted for drinking water consumption and 6,366,000 m^3 are allotted for irrigation, with the licence stipulating that water can be supplied from either Osoyoos Lake or the adjacent aquifers 193 and 194. The 2023 Annual Water Report states that the well network supplied 2,430,397 m^3 for drinking water consumption, an increase of 7 percent over 2022, and the irrigation system supplied 4,704,504 m^3, which has been steadily decreasing year over year (McDonald and Brounstein 2023). Applying a 2 percent growth rate, the annual domestic consumption is expected to increase to 4,150,000 m^3 with conservation and 3,240,00 m3 without conservation by 2050. In both cases the drinking water portion (i.e. domestic) of the license may be exceeded. However, provided that the irrigation consumption remains at or below 2023 levels, the combined water consumption will not exceed the combined volume provided in the licence within the study period. Provided the water licence can be restructured to shift allotment from irrigation to drinking water supply, the existing licenced capacity is adequate to meet the 2050 project water demands.

Table 1 Current and 2050 Domestic Water Demands Using 2 percent Growth Rate

Year/Conditions	Maximum Daily Demand MLD	Average Summer Daily Demand MLD	Yearly Consumption m^3	Water License (Domestic) m^3
2023	19.7	11.9	2,430,397	3,043,000
2050 (with conservation)	25	15.9	3,240,000	
2050 (without conservation)	32	20.3	4,150,000	

The Conditional Water Licence also stipulates that Osoyoos Lake must be maintained at elevations between 276.9 and 280.1 meters (m). Osoyoos Lake is large, containing 327 million m^3 when full, and has historically been more prone to flooding than drought conditions. However, the possibility of reduced withdrawal capacity from the Lake due to low levels should be considered when selecting an intake location and treatment system.

2.4 Groundwater

2.4.1 Groundwater Capacity

The Town currently has 6 production wells, labelled 1, 3, 4, 5, 6, and 8, located across the municipality and are all within developed areas (Figure 3). These wells have a combined capacity of 23.0 MLD, however, the measured pumping rates indicate that only 19.8 MLD can actually be withdrawn based on wells 1 and 3 pumping above capacity and wells 4, 5, 6, and 8 pumping under capacity (Martins and Underwood 2023). The existing well pumping capacity is roughly equivalent to the 2021 maximum daily demand of 19.7 MLD but according to Martins and Underwood (2023) cannot support the peak system flows and do not achieve the recommended well redundancy. In addition, several of the existing production wells (i.e. Wells 3, 4, 5, and 6) are aging and likely require rehabilitation or replacement in the near future based on a typically useful service life of 50 years (Western Water Associates Ltd., personal correspondence). Additional groundwater supply well capacity would be required to satisfy redundancy requirements and meet future water demands. Further analysis would be needed to confirm rehabilitation well yields and land availability for siting of new groundwater wells.

Source: 2023 Water System Infrastructure Plan

Figure 3 Locations of Production Wells

All production wells draw from unconfined sand and gravel aquifers 193 and 194 between elevations 272.5 m and 253.5 m (Table 2). Wells 1 and 8 are adjacent to the Central Basin, which has a minimum elevation of approximately 248 m, while wells 4, 5, and 6 are adjacent to the North Basin, which has a minimum elevation of approximately 218 m. Well 3 is located further from the shore and draws from aquifer 194. Osoyoos is an arid region, with an average annual precipitation of 320 millimeters (mm), of which only 16 mm is expected to recharge the aquifer (Rathfelder and Gregory, 2019). This recharge is well below the sustainable yield of the aquifer and there are no permanent streams in the area. In addition, aquifer recharge was shown to be greatest during the irrigation season and groundwater flows into Osoyoos Lake. Therefore, aquifer recharge is primarily driven by land irrigation (Rathfelder and Gregory, 2019).

Table 2 Production Well Log Data

	Date Drilled	Elevation (m)	Casing Diameter (mm)	Screen Depth (m)	Simplified Lithology
Well 1	Jan. 1995	279.3	300	6.8 to 9.2	Clay – Gravel with Sand – Sand with Gravel – Clay
Well 3	May 1971	280.6	300	9.8 to 15.2	Sand and Silt – Sandy Gravel – Silt
Well 4	Aug. 1979	280.0	200	16.0 to 23.7	Silt – Sand and Gravel – Gravel with Sand – Silt
Well 5	Jul. 1986	280.0	400	18.9 to 26.5	Assumed same as Well No. 4
Well 6	Sept. 1986	283.0	250	10.3 to 13.4	Silty Sand and Gravel – Gravel with Sand - Clay
Well 8	Apr. 1995	280.0	300	8.8 to 13.0	Sand – Sand with Gravel – Gravel with Sand – Clay

2.4.2 Groundwater Quality

Groundwater pathogen risk in BC is accessed using the Groundwater at Risk of Containing Pathogens (GARP) approach, detailed by the Ministry of Health (2023). This approach considers several potential factors that can indicate pathogen risk. Using this framework, it is likely that all production wells would be considered GARP for the following reasons:

1. All wells draw from a highly vulnerable, unconfined aquifer.
2. All wells except well 3 are located within 150 m of Osoyoos Lake and have intake depths that are above the lake depth.
3. All wells are located within 300 m of a probable source of enteric virus and do not have a barrier to prevent viral transport.
4. Well 1 is located adjacent to a large sanitary lift station.

Additional details on the GARP screening assessment are included in the value planning technical memorandum 1, which is attached to this report in Appendix A.

The well system is currently treated with single barrier chlorination via sodium hypochlorite added at the well pumpstations. Moving forward, this approach will only be permitted if virus-only pathogen status can be demonstrated for the wells, otherwise an additional disinfection barrier would be required. The lack of manganese treatment at some wells also causes aesthetic challenges during the summer, when all wells are in service.

When all wells are operating, the system experiences elevated manganese concentrations which approach the maximum acceptable concentration of 0.12 milligrams per liter (mg/L) set by Interior Health (Ministry of Health 2023). Concentrations above the aesthetic objective of 0.02 mg/L are common and cause water discolouration and manganese accumulation within the distribution system. It is also noted that wells 4 and 5 have ammonia concentrations exceeding 0.5 mg/L and all wells have total organic carbon concentrations above 3 mg/L. This leads to a high potential for disinfection byproduct (DBP) formation, which is currently managed by carefully adjusting the chlorine dose for each well and routine flushing. Water quality analysis of test wells 9 and 10 show similar results to the production wells, with both containing moderate to high manganese, high ammonia, and high disinfection byproduct formation potential (McDonald and Brounstein 2023).

Well 4 was sampled for 22 Per-and polyfluoroalkyl substances (PFAS) three times in 2023, with one sample having a total PFAS concentration above 40 nanograms per liter (ng/L). These concentrations are above the Health Canada objective for PFAS. Another potential concern is the municipal landfill, located in the North-West portion of the aquifer. Landfills are known sources of PFAS and other contaminants to water systems, and this landfill had unlined liquid waste disposal lagoons that may contribute to aquifer contamination (Rathfeld and Gregory 2019). The risk posed by the landfill was identified by Rathfeld and Gregoy (2019), but their report did not detail how it may affect future water supply. Further study is required to determine the impacts of landfill operation on water quality.

Overall, additional treatment is needed for the groundwater to meet water health and aesthetic quality guidelines.

Table 3 Groundwater Quality Parameters and Supply Flowrate for Production (Wells 1 through 8) and Test Wells (Wells 9 and 10) in 2023

Parameter	Production Wells						Test Wells[3]		Blended Value[1][2]	MAC (AO)[4]
	Well 1	Well 3	Well 4	Well 5	Well 6[5]	Well 8	Well 9	Well 10		
Alkalinity (mg/L as $CaCO_3$)	233 ± 18	230 ± 77	252 ± 15	213 ± 19	281 ± 11	174 ± 5	-	-	187 (162 – 206)	-
Hardness (mg/L as $CaCO_3$)	306 ± 26	294 ± 15	234 ± 6	196 ± 4	309 ± 134	172 ± 17	201	212	240 (230 – 253)	(80-100)*
Ammonia (mg/L as N)	0.03 ± 0.03	0.07	**0.66 ± 0.17**	**0.61 ± 0.12**	0.05	**0.18**	**0.47**	**0.34**	0.35 (0.31 – 0.40)	0.1*
Chloride (mg/L)	50.9 ± 15.4	18.3 ± 2.0	6.3 ± 1.5	11.9 ± 4.4	23.0 ± 6.8	13.4 ± 2.3	13.5	15.6	17.3 (14.2 – 23.1)	(250)
Iron (mg/L)	< 0.01	< 0.01	**0.30 ± 0.01**	0.14 ± 0.01	0.02 ± 0.03	0.01 ± 0.01	< 0.01	< 0.01	0.08 (0.08 – 0.09)	(0.3)
Manganese (mg/L)	0.002 ± 0.001	**0.042 ± 0.003**	**0.130 ± 0.006**	**0.140 ± 0.003**	**0.068 ± 0.024**	**0.140 ± 0.022**	**0.101**	**0.044**	0.096 (0.086 – 0.109)	0.12 (0.02)
Nitrate (mg/L as N)	5.45 ± 0.61	2.95 ± 0.32	0.02 ± 0.02	0.011 ± 0.002	2.82 ± 0.91	0.45 ± 0.23	< 0.01	< 0.01	1.19 (0.94 – 1.56)	10
Nitrite (mg/L as N)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.03 ± 0.04	< 0.01	< 0.01	0.01 (0.01 – 0.02)	1.0
Turbidity (NTU)	0.09 ± 0.03	0.12 ± 0.03	0.84 ± 0.04	0.76 ± 0.43	< 0.10	0.21 ± 0.12	0.11	0.22	0.39 (0.28 – 0.55)	1.0
TDS (mg/L)	433 ± 34	391 ± 34	300 ± 12	260 ± 4	415 ± 13	241 ± 20	274	293	323 (311 – 343)	(500)*
TOC (mg/L)	**3.94±0.82**	**4.47**	**4.19 ± 1.19**	**4.52 ± 0.54**	2.53 ± 0.75	**3.62 ± 0.91**	3.18	3.13	3.87 (3.39 – 4.33)	4.0
pH (mg/L)	7.8 ± 0.2	7.7 ± 0.6	8.1 ± 0.1	7.9 ± 0.2	7.9 ± 0.1	7.8 ± 0.3	7.9	7.8	8.1 (7.8 – 8.2)	(7.0-10.5)*
THM_{FP} (mg/L)	-	0.06	< 0.01	0.16	0.08	0.17 ± 0.07	-	-	-	0.1*
HAA_{FP} (mg/L)	-	0.07	< 0.01	0.11	0.04	0.13 ± 0.01	-	-	-	0.08*
PFOA (ng/L)	-	-	2.9 ± 2.1	-	-	-	-	-	-	30 as total PFAS[6]
PFOS (ng/L)	-	-	0.5 ± 0.7	-	-	-	-	-	-	30 as total PFAS[6]
Total PFAS (ng/L)	-	-	25.2 ± 11.0	-	-	-	-	-	-	30 as total PFAS[6]
Supply Flowrate[7] (MLD)	2.2	3.3	4.1	6.5	3.1	3.8	2.2	3.7	28.9	-

Notes:
(1) Mean +/- standard deviation for individual wells. Minimum, mean, and maximum for blended values, weighted by supply flowrate.
(2) Blended value includes test wells 8 and 9.
(3) Test wells 9 and 10 only have one observation.
(4) Values with asterisk from Canadian Drinking Water Quality Guidelines (Health Canada 2022), otherwise values from the B.C. Drinking Water Officers' Guide (Ministry of Health 2023). Values above the guideline value are bolded except for THM_{FP} and HAA_{FP} because these parameters are regulated in the distribution system and formation potential is a worst-case scenario.
(5) Well 6 used only sparingly and increased use causes higher manganese concentrations.
(6) Health Canada objective for the sum of 25 PFAS 30 ng/L, which includes PFOA and PFOS. USEPA maximum concentration limits for PFOA and PFOS are 4 ng/L.
(7) Flowrate shown as production capacity, reported by Martins and Underwood (2023).

$CaCO_3$ - calcium carbonate; DOC - dissolved organic carbon; HAA_{FP} - haloacetic acid formation potential; MAC - maximum acceptable concentration; N - nitrogen; NTU - nephelometric turbidity unit, PFOA - perfluorooctanoic acid; PFOS - perfluorooctanesulfonic acid; TDS - total dissolved solids, THM_{FP} - trihalomethane formation potential; TOC - total organic carbon; USEPA - United States Environmental Protection Agency.

2.5 Groundwater Pilot Testing

The Town conducted pilot groundwater treatment testing during December 2023 and February 2024 in partnership with the University of British Columbia and Community Circle (formerly RESEAU), using a pilot system supplied by BI Pure Water Canada, Inc. The pilot tested catalytic manganese removal using Greensand Plus (GSP), manganese adsorption using a manganese dioxide media (Filox), biofiltration, and ion exchange. The GSP, Filox, and biofilter were fed aerated groundwater from well 4, while the ion exchange resin was fed effluent water from the Filox filter. The biofilter was operated continually from December to mid-February, while the other pilot systems were not operated during January.

A variety of parameters were measured in the influent and effluent water of each treatment, including ammonia, sulfate, TOC, and turbidity. The manganese concentration across the GSP and Filox filters was also measured. During the first phase of the pilot, in December, there was removal of ammonia, manganese, and turbidity across the GSP filter, while the Filox filter removed manganese and turbidity, the biofilter only removed turbidity and the ion exchange resin only removed TOC (Figure 4).

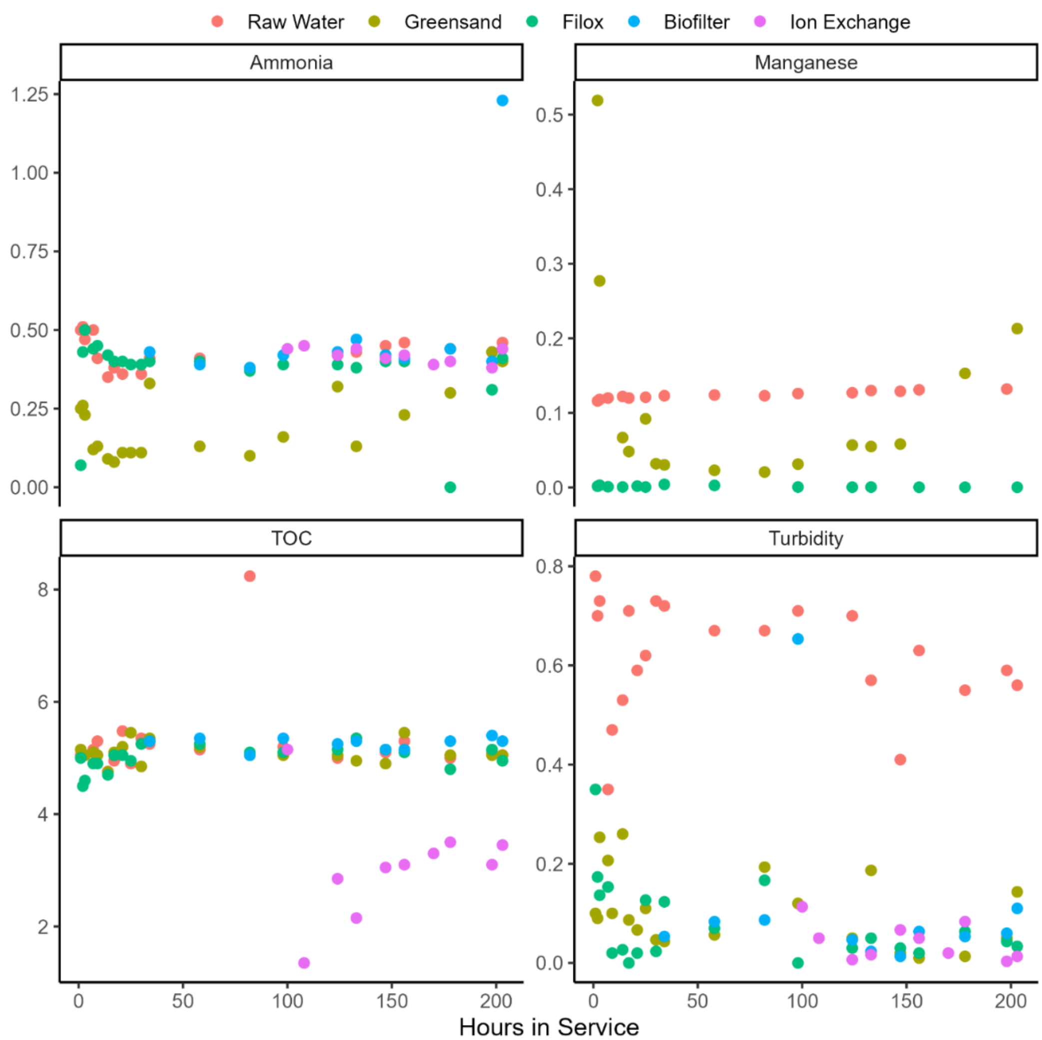

Figure 4 Groundwater Pilot Results for December 4 to 15, 2023

Unit for ammonia is mg/L as N, sulfate and TOC are mg/L, while turbidity is NTU.

During the second phase of pilot testing there was again some removal of ammonia and turbidity across the GSP filter (sulfate was not observed), turbidity removal by biofilter, and TOC removal by the ion exchange resin (Figure 5). However, the ion exchange resin released turbidity and had lower removal efficiency for TOC. Note that the resin was not regenerated between experiments, was described as operating in "biological mode", and was operated at an empty bed contact time of 7 minutes. The GSP filter was able to remove some manganese initially, but then later released manganese to concentrations above the allowable concentration of 0.12 mg/L.

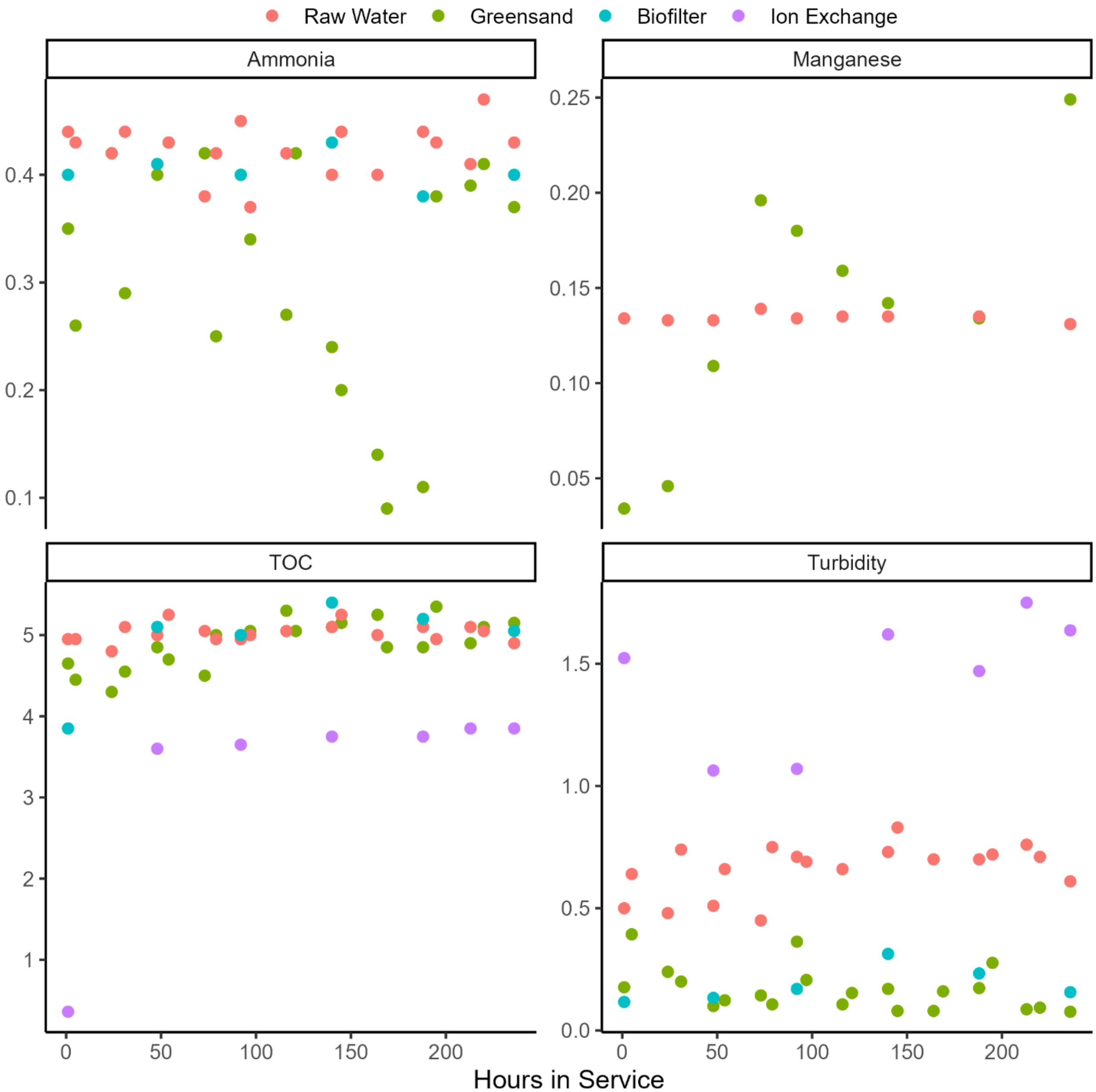

Figure 5 Groundwater Pilot Results for January 31 to February 10, 2024

Unit for ammonia is mg/L as N, manganese and TOC are mg/L, while turbidity is NTU. Note that the biofilter was operating continuously from December 4, 2023 to February 10, 2024.

2.6 Surface Water

2.6.1 Osoyoos Lake Water Quality

The water quality of Osoyoos Lake and considerations for intake location were extensively investigated by Larratt Aquatic in 2020 and are detailed in their report titled "Source Assessment of the Town of Osoyoos Intake No. 8" (Self and Larratt 2020). The following summarizes the details relevant for water quality and water treatment analysis, specifically focusing on the North Basin because it is the preferred withdrawal point for the proposed treatment system.

2.6.1.1 Physical Characteristics

Osoyoos Lake consists of three basins separated by shallow ridges, North, Central, and South, containing a combined 327 million m^3 of water when full. The North Basin is the head of the lake and is also the deepest section, with a maximum depth of approximately 65 m. This basin currently contains Intake #8 at a depth of 14 m which is used to supply irrigation water (Figure 6). This intake sits 1 m above the sediment and is protected by an octagonal screen. The Lake is fed by the Okanagan River and is regulated by Zosel Dam, located at the Lake's Southern end within Washington State, and flows into the Okanogan River. The Okanagan water system has several communities upstream of Osoyoos which use it for water supply and discharge treated wastewater. The watershed area is developed for agricultural and residential use and the Lake has experiences significant recreational use during the summer. There is also an outfall for the agricultural drainage system adjacent to Intake No. 8 (Rathfeld and Gregory, 2019).

Source: 2023 Water System Infrastructure Plan

Figure 6 Osoyoos Lake Water Intake Locations in the North and Central Basins

2.6.1.2 Water Quality Characteristics

A summary of the key water quality parameters sampled for Osoyoos Lake are presented in Table 4. The Osoyoos Lake water quality can be generally categorized as a high quality surface water with low turbidity, moderate organics and low microbial levels. The lake is prone to seasonal algae events, with manageable levels encountered at the recommended surface water intake depth of 30 m.

Table 4 Osoyoos Lake Water Quality Parameters

Parameter	Units	Average at Intake	Average at 20 m	Average at 30 m	MAC (AO)(2)
Alkalinity	mg/L as $CaCO_3$	124(3)			-
Temperature	°C	10.3	8.1	7.5	(15)
Dissolved oxygen	mg/L	8.1	7.6	7.3	-
pH		8.11	8.03	8.03	(7.0-10.5)*
Manganese	mg/L	0.0017	0.0014	0.0010	0.12 (0.02)
Total Nitrogen	mg/L	0.272 ± 0.105	0.331 ± 0.289		-
Total Phosphorous	mg/L	0.014 ± 0.013	0.023 ± 0.019		-
Turbidity	NTU	0.99	0.645	**1.16**	1.0
UV Transmittance		82.10%	81.60%	82.30%	-
TOC	mg/L	**4.6**	**4.3**	**4.4**	4.0
Colour	TCU	6.5	6.6		15
E. coli	CFU/100 mL	1	<1	1	10
Algae	cells/mL	2988	1089	1558	-
PFOS	ng/L	TBD(4)	TBD(4)	TBD(4)	30 as total PFAS (4)
PFOA	ng/L	TBD(4)	TBD(4)	TBD(4)	30 as total PFAS(4)
Total PFAS	ng/L	TBD(4)	TBD(4)	TBD(4)	30 as total PFAS(4)

Notes:
(1) Values with asterisk from Canadian Drinking Water Quality Guidelines (Health Canada 2022), otherwise values from the B.C. Drinking Water Officers' Guide (Ministry of Health 2023). Values above the guideline value are bolded.
(2) Alkalinity measured by the Town in 2019. The remaining values are sourced from Self and Larratt (2020).
(3) Samples have been collected but analysis is pending.
(4) Health Canada objective for the sum of 25 PFAS 30 ng/L, which includes PFOA and PFOS. USEPA maximum concentration limits for PFOA and PFOS are 4 ng/L.
°C - degrees Celsius; cells/mL - cells per milliliter; CFU - colony forming unit.; TUC - true colour unit; UV - ultraviolet.

The North Basin of Osoyoos Lake was classified as mesotrophic based on its moderate nutrient concentrations. Total nitrogen in the epilimnion averaged 0.272 ± 0.105 mg/L as N from 1976 to 2020 (2019 values have been reported in Table 4 for comparison to other parameters) and has remained stable from 2000-2020, but the proportion of ammonia has decreased, limiting the bioavailability of nitrogen. Total phosphorous in the epilimnion averaged 0.014 ± 0.013 mg/L over the same period, significantly decreasing from 1975-2000 but then remaining stable from 2000-2020. Concentrations in the hypolimnion were higher, at 0.331 ± 0.289 mg/L as N and 0.023 ± 0.019 mg/L respectively, but the lack of light, oxygen, and lower temperatures limited microbial activity at depth.

Seasonal temperature fluctuation cause Osoyoos Lake to stratify during the spring and summer months. Above 20 m of depth the temperature varied from a peak of 25 degrees Celsius (°C) in August to 4°C in late December. Below 20 m the temperature was more consistent, ranging between 4 and 7°C. The epilimnion extended to approximately 20 m depth and remained well oxygenated throughout the study year whereas below 20 m depth the hypolimnion decreased to below 3.5 mg/L in early fall. While this is not anaerobic, the concentration was low enough to result in metal dissolution from sediment on the Lake bottom. The pH of the Lake was consistent, ranging between 7.9 and 8.3. These conditions resulted in some manganese at 60 m depth, with a maximum concentration of 0.03 mg/L observed in a 60 m depth sample taken in September 2019, but concentrations were generally below levels where treatment would be required. Concentrations for other metals were not reported.

The conditions in the epilimnion allowed for substantial algae growth, with diatoms dominating in spring following spring overturn and cyanobacteria dominating the remainder of the growing season because of the lack of bioavailable nitrogen. The concentrations algae decrease with depth, with samples taken below 20 m usually below 2000 cells/mL in 2019. Cyanobacteria blooms have occurred in the Lake, with the last observed bloom occurring in the Central Basin in 2013. However, it is possible that the bloom risk is decreasing because of reduced nutrient loading in the Lake (Rathfeld and Gregory, 2019). There was limited bacterial activity in the lake, with 64 percent of *E. coli* samples below detection in 2019. Oocysts *Giardia* and *Cryptosporidium* had no available data for Intake No. 8.

Microbial activity in the Lake drove the remaining parameters relevant for water treatment. TOC was above 4 mg/L regardless of depth, exceeding the guidelines set by Interior Health (Ministry of Health 2023), and will likely result in high DBP formation potential, without further treatment. The average turbidity was below 2 NTU at all depths, while turbidity increased when microbial growth was high and increased with depth, likely because of settling algae cells and bacterial decomposition of organic matter. UV transmissivity averaged 81.6 ± 1.7 percent and varied little by depth. Colour was generally very low averaging 6 ± 2 TCU in 2019. No taste and odour issues were reported. Self and Larratt (2020) report recommends siting a new drinking water intake at 30 m depth to access the optimal water quality and to avoid periodic mixing due to temperature variation and wind is conditions.

2.6.2 Irrigation Pump Station 8

The Town owns and operates Irrigation Pump Station 8, located in the Regional District of Okanagan-Similkameen (PID 008-393-826). The lot is approximately 52 by 11 m, with an area of 630 m^2, with existing infrastructure using less than 200 square meters (m^2). Three phase power is already available on-site. The pumpstation feeds a distribution system independent of the domestic water system, and a 480 m^3 concrete reservoir. The condition of Intake No. 8, located in the North Basin, is very poor and requires replacement. The pumpstation for this intake consists of five vertical turbine pumps ranging from 50 to 200 horsepower (HP). All pumps draw from the same wet well. Water is disinfected by chlorine gas addition via pipe, but disinfection is not designed to meet drinking water standards.

SECTION 3 DESIGN CRITERIA

3.1 Treatment Requirements

Design criteria for the treatment system were based on guidelines established by the BC Ministry of Health and Health Canada. Specifically, the 4-3-2-1-0 objectives must be followed: 4-log (99.99 percent) reduction in enteric viruses, 3-log (99.9 percent) reduction of protozoa, 2 forms of treatment for pathogen log reduction, turbidity below 1 NTU, and 0 detectable *E. coli*, total coliform, and fecal coliform (Table 5).

Table 5 Design Criteria for Groundwater and Surface Water Treatment Systems

Goal	Guideline	Relevant to Groundwater Source	Relevant to Surface Water Source
4-log (99.99%) reduction in viruses	DWOG	✓	✓
3-log (99.9%) reduction in protozoa	DWOG	✓	✓
2 treatment barriers	DWOG	✓	✓
Turbidity less than 1 NTU(1)	DWOG	✓	✓
0 detections *E. coli* and coliforms	DWOG	✓	✓
TOC reduction to below 4 mg/L	DWOG	✓	✓
Ammonia reduction to below 0.05 mg/L	GCDWG	✓	
Manganese reduction to below 0.02 mg/L	DWOG	✓	
Iron reduction to below 0.3 mg/L	DWOG	✓	
Total microcystins below 0.0015 mg/L	DWOG		✓
Geosmin and MIB below threshold limit of 4 and 9 ng/L, respectively	-		✓

Notes:
(1) Measured prior to disinfection.
DWOG - Drinking Water Officers' Guide (Ministry of Health 2023); GCWDG - Guidelines for Canadian Drinking Water Quality (Health Canada 2022)

3.2 Design Flowrates

A design horizon of 2050 using water demand estimates based on value engineering inputs was used for conceptual sizing of treatment infrastructure (Table 6). This provides a conservative assessment for budget and planning purposes (e.g. site selection) and should be further refined during subsequent design phases. Stage 1 is based on the estimated 2050 demand and was targeted as the initial build conditions. Stage 2 represents the addition of another treatment train, with Stage 3 having another train again.

Table 6 Design Criteria for Water Supply and Treatment Infrastructure Sizing

Parameter	Groundwater Source		Surface Water Source	
	Basis	Value (MLD)	Basis	Value (MLD)
Stage 1 - Initial Build				
Raw Water Supply Capacity	MDD+3%	25.8	MDD+5%	26.3
Treated Water Supply Capacity	MDD	25.0	MDD	25.0
Recycle Rate	N/A	-	< 5%xMDD	< 1.3
Stage 2 - Additional Treatment Train				
Raw Water Supply Capacity	MDD+3%	33.0	MDD+5%	33.6
Treated Water Supply Capacity	MDD	32.0	MDD	32.0
Recycle Rate	N/A	-	< 5%xMDD	< 1.6
Stage 3 - Additional Treatment Train				
Raw Water Supply Capacity	MDD+3%	38.6	MDD+5%	39.4
Treated Water Supply Capacity	MDD	37.5	MDD	37.5
Recycle Rate	N/A	-	< 5%xMDD	< 1.9

3.3 Equipment Configurations and Redundancy

We propose the following assumptions for the basis of design:

- Raw Water Supply:
  - N+1 with capacity based on largest unit not in service.
  - Single common water supply pipeline.
  - Capacity to meet raw water supply capacity run with or without 5 percent recycle of treated waste flows.
- Treatment System:
  - Primary Treatment:
    - At least two parallel trains for primary treatment infrastructure with each train sized to accommodate having a single unit or basin out of service.
  - Chemical systems:
    - N+1 for pumping or chemical generation equipment with capacity based on largest unit not in service.
    - Minimum of 2 storage tanks sized to hold a combined minimum volume of 30 days at peak month demand plus 1.2 safety factor.
  - Residuals:
    - Minimum of two trains sized to treat at least 50 percent of the waste production from the treated water design capacity.
    - Dewatering bin storage of three days during MDD conditions.
    - Recycle up to 5 percent of the raw water supply capacity.

SECTION 4 GROUNDWATER SUPPLY AND TREATMENT OPTION ANALYSIS

The groundwater available for treatment in the Town contains high concentrations of manganese, ammonia, and TOC. Additionally, the existing well network accesses an unconfined aquifer characterized as highly vulnerable and are expected to be classified as GARP (see Appendix A). The following sections describe various treatment technologies that could collectively achieve water quality goals, treatment plant siting, and raw water conveyance.

4.1 Groundwater Treatment Technologies

Based on the pilot testing results for the groundwater supply wells completed in 2016 and 2023/2024, a single treatment stage will not satisfy the water quality goals detailed in Section 3.1. The following describes suitable technologies that were considered within this study for treating the groundwater.

4.1.1 Biofiltration

Parameter	Treatment Capability
Turbidity	Moderate
Organics (TOC)	Minimal
Ammonia	Moderate
Iron	Good
Manganese	Good

Biofiltration is a granular media process where microorganisms colonize filter media and remove contaminants through various mechanisms. This process can effectively remove multiple contaminants with variable effectiveness, including ammonia, iron, manganese, and TOC. To remove these contaminants it is critical that high dissolved oxygen concentrations are achieved, typically either through aeration or liquid oxygen injection. Research demonstrates that manganese removal does not usually occur until nitrification is complete (see Appendix B for more details). TOC removal by biofilters is usually low, depending on how biodegradable the organic carbon is, but reductions in DBP concentrations are usually observed and distribution system biological stability is improved by the reduction in biodegradable carbon.

The primary disadvantages to biofiltration are long start-up times (months), limited process control, and the potential for increased head loss. Start-up times for biofilters vary but are expected to be long for this water source because nitrifying bacteria grow slowly. In addition, there is a perceived loss of control compared to chemical treatments, but advances in engineered biofiltration have made improvements, particularly for head loss control. Nutrient addition, hydrogen peroxide addition, and backwashing procedures have been shown to prevent excess head loss accumulation.

Groundwater biofilters are typically constructed as enclosed steel vessels filled with media, often operated as a pressure filter. Empty bed contact times (EBCTs) of 15 minutes or longer are common, but lower EBCTs are possible (see Appendix B). These vessels can be supplied by various companies. Typically, anthracite, GAC, or quartz sand is used as media. A backwash system, which often uses production water from other vessels, and a tank for storing wash water are required in addition to the vessel itself. Backwash supply water should be taken prior to chlorination or dechlorinated. Backwashing frequency is controlled by a combination of head loss, turbidity breakthrough, and runtime. Wash water can likely be discharged to sewer, but an equalization tank is recommended to avoid surcharging the sewer collection system. Typical analytical systems for groundwater biofilters include inline DO, pH, and turbidity sensors, a benchtop spectrophotometer for measuring ammonia, iron, and manganese concentrations, flowmeters, and pressure transducers for measuring head loss.

The following is a summary of the benefits, challenges and specific relevance for consideration by the Town.

- **Benefits:**
  - Removal/degradation of multiple contaminants.
  - Little to no chemical dosing.
  - Improved biological stability of finished water.
- **Challenges:**
  - Uncertain contact time requirements, causing high capital costs.
  - Requires raw water aeration.
  - Potential for long start-up period.
  - Potential for high head loss.
- **Relevance to Osoyoos:**
  - Targets ammonia, iron, and manganese.
  - Required for ammonia removal when TOC is high.

4.1.2 Catalytic Manganese Removal

Parameter	Treatment Ability
Turbidity	Limited
Iron	Good
Manganese	Good

Catalytic manganese removal is a technology often used to remove dissolved manganese from water. This method uses either media coated in manganese oxides (e.g., Greensand) or media composed of manganese oxides (e.g., Pyrolox) to first adsorb Mn^{2+} ions, which are then catalytically oxidized by free chlorine. This results in a continually growing manganese surface that is a robust barrier for concentrations below 0.2 mg/L if free chlorine is available and pH is above 6.0. However, without the presence of free chlorine the adsorption sites on the media will eventually deplete, resulting in no removal and, depending on the water chemistry, the manganese surface may begin to dissolve, sometimes resulting in concentrations above the influent level.

Catalytic manganese removal does not appear to be suitable for this source by itself because of high concentrations of TOC in all wells and high ammonia concentrations in some wells. Ammonia consumes chlorine to produce chloramines, which can be used to sustain manganese removal, but for this source water it will make consistent manganese removal using this method challenging, as demonstrated by pilot results. Due to the high TOC levels, breakpoint chlorination to remove the ammonia prior to catalytic manganese removal is not feasible because it may result in high DBP concentrations, as shown by the DBP formation potential of the groundwater. That said, the pilot did show excellent manganese removal by adsorption to manganese dioxide, therefore, it is likely that a manganese contactor will be effective if the ammonia can be removed prior.

Media for catalytic manganese removal is typically housed in enclosed steel vessels, similar to those used for biofiltration, which are operated at loading rates of 10-20 meters per hour (m/hour). Chlorine can be supplied using either chlorine gas, liquid sodium hypochlorite, or on-site chlorine generation.

Catalytic manganese oxidation causes head loss accumulation, therefore, vessels require occasional backwashing. Backwash frequency is often dictated by head loss and manganese removal performance. Accordingly, a backwash system is required, which often uses production water from other vessels. Backwash water for this system should be chlorinated to help regenerate the media. Wash water should be safe to discharge to sewer, but an equalization tank is recommended to reduce the potential impacts of a large discharge. Typical analytical systems for catalytic manganese treatment include inline pH and free chlorine sensors, a benchtop spectrophotometer for measuring manganese concentration, flowmeters, and pressure transducers for measuring head loss.

The following is a summary of the benefits, challenges and specific relevance for consideration by the Town.

- **Benefits:**
  - Reliable dissolved manganese removal.
  - Can be operated at a high rate, reducing capital costs.
- **Challenges:**
  - Consumes chlorine.
  - Chlorine dose must be optimized to limit wastage (excess chlorine will be removed by UV) and DBP production.
- **Relevance to Osoyoos:**
  - Raw water manganese is an ideal range for this technology.
  - Pilot study demonstrated potential effectiveness.

4.1.3 Organics Adsorption

Parameter	Treatment Ability
Organics (TOC)	Excellent
PFAS	Good to Excellent

Organics removal by adsorption is typically accomplished using either granular activated carbon (GAC) or ion exchange (IX) resin. Both technologies work by attracting the negatively charged organic compounds to their positively charged surfaces. From there, the compounds adhere to the GAC surface by electrostatic forces, whereas for IX the compounds exchange places with OH^- and Cl^- ions. In both cases the removal capacity is limited, with GAC requiring heat treatment and IX resin requiring a sodium chloride and sodium hydroxide brine solution regenerate capacity. GAC regeneration occurs offsite at a supplier facility, requiring shipping and significant energy, whereas IX resin regeneration occurs onsite, generating a concentrated liquid waste stream. In some cases, it is more cost effective to replace the IX resin instead of regenerating it.

In our experience, GAC often has lower capital costs than IX and has the advantage of not producing a concentrated contaminant stream, but it requires a larger footprint. Alternatively, IX has the advantage of being tailored for specific contaminant removal, typically either anions or cations, whereas GAC typically only adsorbs anions. Therefore, regardless of the technology chosen, adsorption will only effectively remove either organics or Mn^{2+} and NH_4^+ because they are both cations while most organic compounds are anions.

One potential advantage of organics adsorption is removal of PFAS. These manmade compounds are common in consumer products and were previously used in some firefighting foams. They are persistent in the environment, and they impact human health. In August 2024, Health Canada finalized a PFAS objective, which is intended to be used as a guideline until the GCDWQ are updated. This objective recommends limiting the sum of 25 specific PFAS compounds to 30 ng/L. These compounds include perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS), which previously had guidelines in the GCDWQ, and other compounds which can be quantified following a specific analytical method. Given the sampling results conducted in 2023, the groundwater system has a high risk of requiring PFAS treatment if this objective is adopted by the BC Ministry of Health. The proposed GAC or IX reactors could remove some PFAS, depending on what compounds are present, while simultaneously removing TOC. However, the removal capacity for PFAS may be limited due to the high TOC concentrations.

Adsorptive contactors, whether using GAC or IX resin, are typically housed in steel vessels and operated under pressure. GAC contractors must be backwashed before commissioning to remove fines. Additional backwashing is required as head loss accumulates. This accumulation is slow because particle loading is low and contactors typically use larger media sizes, but over time the GAC bed will compact and require "fluffing" to reduce head loss. GAC contactors are backwashed less frequently than a granular media filter, but a backwash tank, backwash pump, and spent wash water tank are still required. Wash water is typically dewatered by settling in the holding tank. The settled water can either be recycled at the head of the treatment train or discharged to sewer, while the solids can be combined with other residual solids for disposal. Typical monitoring equipment for GAC contactors includes inline pH measurement, flowmeters, and pressure transducers for measuring head loss.

IX resin is not backwashed but is instead regenerated using sodium chloride and sodium hydroxide brine. Therefore, that system will require storage for the brine, a transfer pump, and storage for the spent solution which is contaminated with PFAS and other anions that the resin releases. Disposal of spent brine may be complicated. It is anticipated that destructive technologies will be available for removing PFAS from brine in the future, but commercial availability is currently limited. Therefore, the spent brine must be disposed of as a hazardous waste. Typical monitoring equipment for IX resin contactors include inline pH measurement, conductivity meters, flowmeters, and pressure transducers for measuring head loss.

Table 7 presents a summary of the benefits, challenges and relevance of the various organic absorption options discussed above.

Table 7 Comparison Between Organic Adsorption Options

Technology	Benefits	Challenges	Relevance to Osoyoos
GAC Contactors	▪ Reliable removal of dissolved organic carbon and PFAS. ▪ Lower equipment capital costs. ▪ Simple operation.	▪ High footprint requirements, increasing building capital costs. ▪ General sorbent that does not target specific contaminants. ▪ Pilot testing required to establish PFAS removal effectiveness. ▪ Media requires periodic replacement.	▪ Can help meeting TOC/DBP guidelines. ▪ Can provide protection against potential PFAS contamination.
IX Contactors	▪ Reliable removal of dissolved organic carbon and PFAS. ▪ Can selectively target specific compounds. ▪ On-site regeneration possible. ▪ Lower footprint requirements, reducing building capital costs.	▪ High equipment capital costs. ▪ Pilot testing required to select optimal resin. ▪ Either concentrated regenerate solution or contaminated resin need to be periodically disposed of. ▪ Operation more complex.	

4.1.4 Disinfection

The groundwater production wells may be at risk of containing pathogens (see Appendix A). Therefore, treatment requirements may be equivalent to surface water, according to the Drinking Water Officer's Guide. Disinfection requirements can be achieved through a combination of primary disinfection and other treatment processes, but generally groundwater treatment plants must rely on a combination of primary disinfection processes. Secondary disinfection is also required to ensure that distributed water remains safe to consume. Primary disinfection can be accomplished using chemical disinfectants, including chlorine (as gas or liquid hypochlorite), chlorine dioxide, and ozone, or using UV radiation. Secondary disinfection can be provided either by residual free chlorine or chloramines.

4.1.4.1 Chemical Disinfectants

Chemical disinfection requires direct contact with the disinfectant for a period of retention time depending on the disinfectant characteristics and concentration, and the flow path of water. This contact allows the disinfectant to damage the microorganisms, typically through an oxidation reaction, directly disabling them. Accordingly, most treatment plants require contact tanks to achieve sufficient disinfection prior to distribution.

Parameter	Treatment Ability
Protozoa	Varies (Minimal to Excellent)
Bacteria	Excellent
Virus	Excellent

Typical chemical disinfectants used in drinking water treatment include chlorine gas, sodium hypochlorite (low or high strength), chlorine dioxide, and ozone. Chlorine gas is a strong oxidant and was commonly used for both primary and secondary disinfection, however, it has become less prevalent due to the health and safety risks associated with transport and handling of chlorine gas. Sodium hypochlorite, both low and high strength solutions, are commonly used and have been products of choice for water utilities in recent years. Low strength sodium hypochlorite can be generated onsite using electrolysis, where the main inputs include electricity, water and salt. High strength sodium hypochlorite can be delivered in bulk, with several product suppliers actively operating in the Okanagan Valley. Chlorine dioxide can be delivered as a bulk liquid or produced on-site using chlorine gas and sodium chlorite, however, that it is considered a poor option due to the hazards associated with using chlorine gas. Ozone could also be used and can be generated on-site using either dried ambient air, oxygen-enriched air, or high-purity oxygen. Accordingly, ozonation requires generation equipment and a contact tank. Ozone is considered to have a higher level of operational complexity when compared to other disinfectants. That said, ozone has the secondary benefit of being a strong oxidant, which can degrade organic matter, including algal byproducts such as Geosmin and 2-Methylisoborneol (MIB). Each of these chemical disinfectants will produce DBPs. Chlorine can produce THMs, HAAs, and other chlorinated byproducts, chlorine dioxide can produce chlorite and chlorate, and ozone can produce bromate when bromide is present.

Table 8 presents a summary of the benefits, challenges and relevance of the various chemical disinfectants discussed above.

Table 8 Comparison of the Chemical Disinfectants

Technology	Benefits	Challenges	Relevance to Osoyoos
Chlorine Gas	▪ Inexpensive. ▪ Storage footprint is low. ▪ Does not degrade. ▪ Provides primary and secondary disinfection. ▪ Familiar to the Town.	▪ Not effective for killing protozoa. ▪ More hazardous than liquid chlorine. ▪ Produces chlorinated DBPs.	▪ Primary (virus and *Giardia*) disinfection ▪ Secondary disinfection ▪ One of the two barriers required.
Sodium Hypochlorite	▪ Less hazardous than chlorine gas. ▪ Provides primary and secondary disinfection.	▪ Not effective for killing protozoa. ▪ More expensive than chlorine gas. ▪ Storage footprint is high. ▪ Degrades over time. ▪ Produces fumes that must be managed. ▪ Produces chlorinated DBPs.	▪ Primary (virus and *Giardia* only) disinfection ▪ Secondary disinfection ▪ One of the two barriers required.
On-Site Chlorine Generation	▪ Least hazardous chemical disinfection option. ▪ Uses inexpensive salts. ▪ Provides primary and secondary disinfection.	▪ Not effective for killing protozoa. ▪ Complicated operation compared to gas or liquid chlorine. ▪ High capital costs. ▪ Produces chlorinated DBPs.	▪ Primary (virus and *Giardia* only) disinfection ▪ Secondary disinfection ▪ One of the two barriers required.
Chlorine Dioxide	▪ Strong oxidant that can also degrade other contaminants.	▪ Only provides primary disinfection. ▪ Produces chlorite and chlorate.	▪ Primary (virus, *Giardia* and Cryptosporidium) disinfection ▪ One of the two barriers required
Ozone	▪ Strong oxidant that can also degrade other contaminants. ▪ Can be generated on-site without chemicals. ▪ Does not produce DBPs when reacting with organics.	▪ Only provides primary disinfection. ▪ High capital costs and operational complexity. ▪ Produces bromate when bromide is present.	▪ Primary (virus and *Giardia*, Cryptosporidium to lesser extent) disinfection ▪ One of the two barriers required

4.1.4.2 Ultraviolet Radiation

Parameter	Treatment Ability
Protozoa	Excellent
Bacteria	Excellent
Virus	Moderate

UV disinfection requires a clear path for irradiation to interact with microorganisms, meaning that water must have limited turbidity and high ultraviolet transmittance (UVT). UV disinfection does not directly disable microorganisms at treatment doses, rather it damages DNA and prevents them from reproducing. This method is effective at inactivating protozoa and bacteria but not viruses. The primary options for UV disinfection are low pressure and medium pressure lamps. They work by running electricity across mercury which is under pressure. Both types of lamps can be effective, but in general medium pressure lamps require a lower footprint but have higher capital and operating costs. UV systems require reactors which house mercury lamps. These reactors are usually configured as flow-through pipes for drinking water systems.

The following is a summary of the benefits, challenges, and specific relevance for consideration by the Town.

- **Benefits:**
  - Very effective for disabling protozoa and bacteria.
  - No DBPs produced.
- **Challenges:**
  - Only provides primary disinfection.
  - Less effective at disabling viruses.
  - Potential for mercury release.
  - Requires low turbidity (i.e. normally less than 1 NTU).
- **Relevance to Osoyoos:**
  - Highly effective primary disinfection for protozoa (greater than 3 log *Cryptosporidium* and *Giardia*).
  - One of the two barriers of treatment.

4.1.4.3 Secondary Disinfection Considerations

Secondary disinfection can be achieved using either free chlorine or chloramines. Chlorine is the most common type of secondary disinfection, and the Town already uses chlorine for residual disinfection. Chloramines are less powerful oxidants and are typically only used when source waters contain free ammonia or when the concentrations of chlorinated DBPs are above acceptable concentrations. While some wells in the production system do have free ammonia, this ammonia must be removed to allow for manganese removal. Additionally, while DBP formation potential is high for the wells in practice it can be controlled while still maintaining effective chlorine residual. Therefore, chloramines are not suitable for this system.

4.2 Recommended Treatment System

An effective groundwater treatment system must target several contaminants. None of the four treatment processes considered can meet the treatment goals alone, therefore, the recommended treatment system is a combination of processes (Table 9). The proposed treatment system has three processes with an option to buildout for an additional process (Figure 7).

Table 9 Treatment Performance for Groundwater Technologies

Goal	Biofiltration	Catalytic Manganese Removal	Organic Absorption GAC Filters (Future)	UV Disinfection	Chlorine Disinfection
4-log (99.99%) reduction in viruses					✓
3-log (99.9%) reduction in protozoa				✓	✓ (*Giardia*)
2 treatment barriers				✓	✓
Turbidity less than 1 NTU	✓				
0 detections *E. coli* and coliforms				✓	✓
TOC reduction to below 4 mg/L			✓		
Ammonia reduction to below 0.05 mg/L	✓				
Manganese reduction to below 0.02 mg/L	✓	✓			
Iron reduction to below 0.3 mg/L	✓				

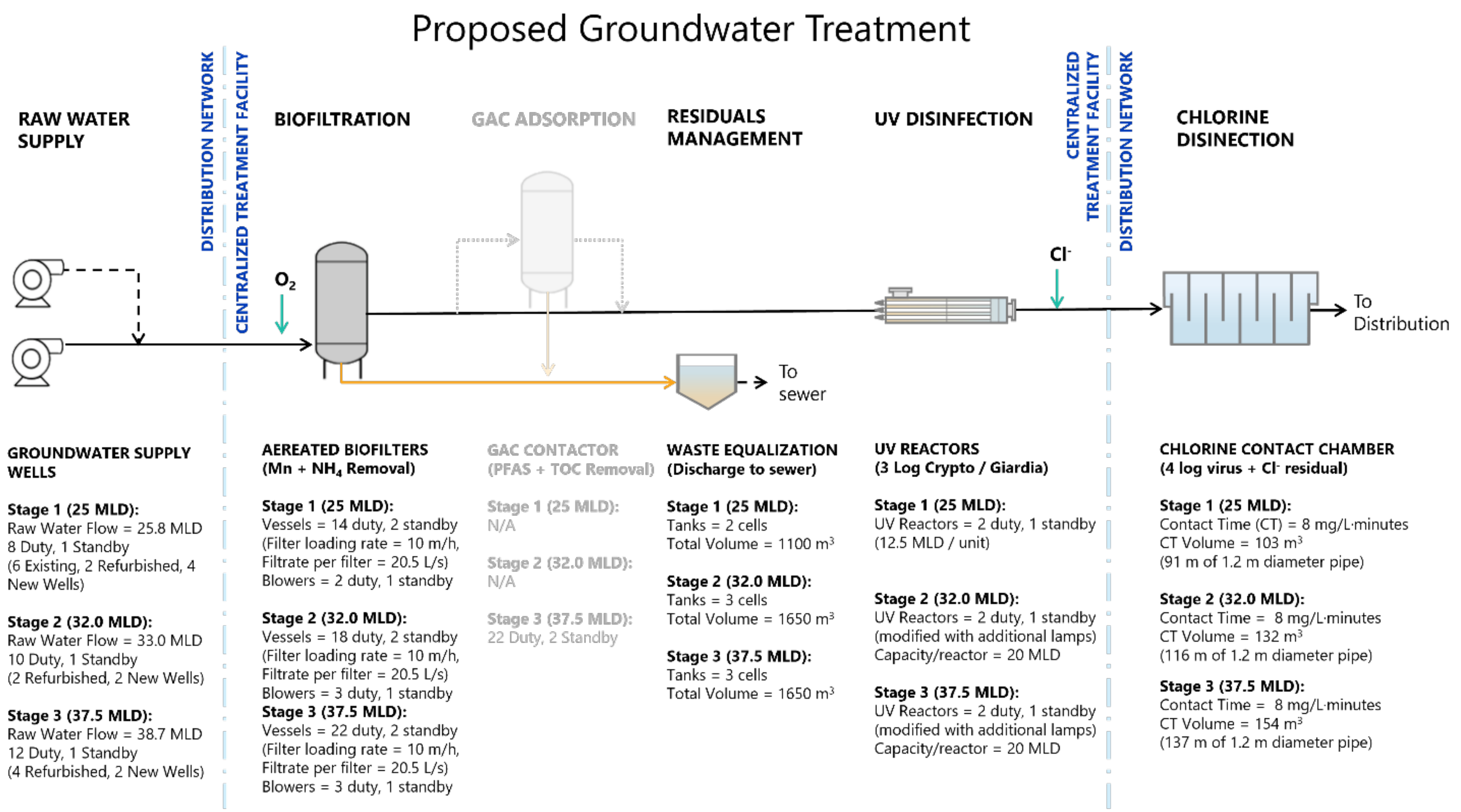

Figure 7 Proposed Groundwater Process Flow Diagram

The treatment train begins with anthracite biofiltration, which targets reduction of ammonia, iron, manganese, TOC, and turbidity. This system requires the water to be aerated and is expected to effectively control ammonia, iron, manganese, and turbidity once the filter has matured. Reduction of TOC is expected but additional treatment may be required. Without pilot testing a conservative contact time of at most 15 minutes and a filtration rate of 10 m/hour is assumed to be required.

After biofiltration there is the option to have adsorptive contactors, either using GAC or ion exchange. These contactors may be required to meet TOC goals and potentially to remove PFAS. These contactors have been excluded from the cost estimation described later.

Finally, the treatment system requires dual disinfection processes based on Ministry of Health treatment credit assignment criteria. Water will first be disinfected by a UV system to achieve a 3-log reduction in protozoa and bacteria, then it will be disinfected with chlorine to achieve a 4-log reduction in viruses. This chlorine dose will also provide secondary disinfection. Secondary disinfection can either be provided by a large diameter pipeline or a designated chlorine contact chamber. Design criteria for the entire system are listed in Table 10. The estimated footprint area of the Stage 1 treatment building is 960 m^2, not including setbacks, roads, or other external infrastructure.

Table 10 Groundwater Treatment Process Design Criteria

Design Criteria	Unit	Stage 1	Stage 2	Stage 3
Treated Water Demand	MLD	25.0	32.0	37.5
Recovery	%	97	97	97
Raw Water Flow	MLD	25.8	33.0	38.7
Biofiltration				
EBCT	minutes	15	15	15
Loading Rate	m/hour	10.1	9.7	9.9
Vessel Diameter	m	3.0	3.0	3.0
Media Depth	m	2.4	2.4	2.4
Media Type	-	Anthracite	Anthracite	Anthracite
Duty Vessels	-	14	18	22
Standby Vessels	-	2	2	2
UV Disinfection				
Minimum UVT	%	85	85	85
UV Dose	mJ/cm^2	40	40	40
Duty Reactors	-	2	2	2
Standby Reactors	-	1	1	1
Chlorine Disinfection				
Chlorine Type	-	Sodium Hypochlorite	Sodium Hypochlorite	Sodium Hypochlorite
Chlorine Concentration	%	12	12	12
Chlorine Dose	mg/L	1.5	1.5	1.5
Contact Time Required	mg/L/minute	8	8	8
Contact Volume Required for 0.9 Baffle Factor	m^3	103	132	154

Design Criteria	Unit	Stage 1	Stage 2	Stage 3
Residuals				
Backwash Rate	m/hour	50	50	50
Backwash Duration	minutes	10	10	10
Filter-to-waste Rate	m/hour	10	10	10
Filter-to-waste Duration	minutes	2	2	2

Notes:
mJ/cm^2 - millijoules per square centimeter.

4.3 Treatment Plant Siting

Various locations were original considered for siting the groundwater treatment option, including a lot near Cottonwood Park on the east side of the Town and Jack Shaw Park on the West side of the Town. These sites within the Town have the advantage of shorter raw water conveyance systems, but they were both ultimately eliminated by the Town because of limited expandability and a preference not to locate infrastructure in residential areas.

We propose siting the treatment facility within the golf course property, immediately east of the reservoir site 340 (Figure 8). This site will require an approximately 6 km raw water transmission main to be installed across the Town to transfer the groundwater from the existing individual wells to the site. Being situated adjacent to the 340 Reservoir, it offers centralized treatment for the entire system and has ample space for the proposed treatment facility and future expansion.

Figure 8 Proposed Treatment Site at Reservoir 340

Approximate available area of 22,400 m², 260 x 80 m

4.4 Raw Water Conveyance

New water main will be required to convey raw groundwater to the proposed treatment plant location (Figure 9). Starting on the East side of the Town, 310 m of 300 mm diameter pipe will be required to convey water from Well 3 and proposed Wells 9 and 10 to Wells 4 and 5. Next, 1,300 m of 450 mm pipe will connect the East wells to Well 8, travelling along the shoreline, across the narrows, and then down Kingfisher Drive. Continuing along Kingfisher drive 410 m of 500 mm pipe will connect the system to Well 1. Next, 1,200 m of 600 mm pipe will be installed along 89th street and then 74th Avenue, where it then intersects with supply from Well 6. Well 6 has 2,100 m of 200 mm pipe along 92nd Avenue, Crowsnest highway, and Meadowlark drive connecting it to the system. After all wells are connected, 500 m of 600 mm pipe connect the network to the groundwater treatment plant. The proposed water conveyance system has inherent challenges because:

1. It would be constructed throughout the Town, resulting in replacement of pavement in addition to disrupting Town activities.
2. The segment between Wells 4/5 and Well 8 is to be installed partially in Osoyoos Lake, which will require special permitting and special construction techniques.
3. The pipe diameter must be oversized to allow for additional wells to be added at any point in the system.

Figure 9 Proposed Raw Water Pipeline Connecting Well Network to Treatment Plant at the Reservoir Site

yellow = 200 mm diameter, blue = 300 mm diameter, green = 450 mm diameter, orange = 500 mm diameter, and red = 600 mm diameter

SECTION 5 SURFACE WATER TREATMENT OPTIONS ANALYSIS

Water from Osoyoos Lake has high TOC concentrations, moderate turbidity, and moderate to high algae concentrations. The following sections describe treatment technologies that may achieve water quality goals, a recommended treatment system, treatment plant siting, and raw water conveyance.

5.1 Surface Water Treatment Technologies

5.1.1 Clarification

Osoyoos Lake is characterized by low turbidity, low colour, moderate organics, and algae. BC water quality guidelines require the 4-3-2-1-0 objectives described in Section 3.0 to be followed. Accordingly, treatment is required to meet water quality guidelines. Clarification is usually one of the first unit processes in a surface water treatment plant. These processes use chemicals to remove particles from raw water.

5.1.1.1 Conventional Clarification

Parameter	Treatment Ability
Turbidity	Good
TOC	Good
Algae	Poor

A conventional clarification system consists of a rapid mix chamber, a series of flocculation basins, and a settling basin. Coagulants, such as aluminum sulphate or polyaluminum chloride (PACl), are added to the mixing chamber, which is usually the pipe segment prior to the flocculation basins. Various polymers may also be added at this stage to improve floc formation and settling. Water is mixed at various speeds in the flocculation basin, which forms agglomerations of particles called flocs. Typically, conventional clarification uses three flocculation basins with mechanical mixers. After the final basin water flows into a long basin without mixing, where flocs are able to settle to the bottom of the basin, where they are removed by periodically draining the basin. Sludge collected in the settling basin would be drained to the wash water system. Water is removed from the top of the basin and flows into subsequent processes.

Conventional clarification requires chemical dosing equipment, basins for flocculation and settling, and mechanical mixers. It can be effective for removing turbidity and TOC but can struggle to remove algae cells because they float. Conventional clarification is best suited for waters with elevated turbidity, which forms heavy flocs that settle faster, allowing for shorter basins.

5.1.1.2 Dissolved Air Flotation

Parameter	Treatment Capability
Turbidity	Good
TOC	Good
Algae	Excellent

A dissolved air flotation (DAF) system consists of a rapid mix chamber, a series of flocculation basins, and a DAF basin. Coagulants and polymers and usually dosed similarly to conventional clarification, but coagulant doses are usually higher because smaller floc sizes are desired. DAF systems typically have two flocculation basins with mechanical mixing. Flocculated water flows under a weir where it is mixed with air saturated recycled water. When the air saturated water enters the chamber microbubbles form, which then float the flocs to the surface of the basin where they are periodically removed by a mechanical skimmer. Sludge collected in the DAF basin would be drained to the wash water system. Clarified water exits at the bottom of the basin and flows into subsequent processes.

DAF clarification requires chemical dosing equipment, basins for flocculation and clarification, mechanical mixers, and a recycle system that includes compressors, saturation tanks, and recycle pumps. These systems are good at removing turbidity and TOC and excellent at removing algae cells. DAF systems are ideal for clarifying water with low turbidity and high organics because organic material is low density compared to inorganic material and therefore is easier to remove by floating instead of sinking.

Table 11 Comparison Between Clarification Options

Technology	Benefits	Challenges	Relevance to Osoyoos
Conventional Clarification	▪ Simple to operate. ▪ Lower operational costs.	▪ Large footprint required, increasing capital costs. ▪ Poor algae removal performance.	▪ Will effectively reduce TOC/DBPs and turbidity. ▪ Must limit risk of filter clogging due to algae.
DAF	▪ Excellent algae removal performance. ▪ Ideal option for low turbidity, high organics. ▪ Smaller footprint required.	▪ Higher capital costs for mechanical equipment. ▪ Higher operational costs. ▪ More complex operation and maintenance.	

5.1.2 Filtration

Filtration removes particles from water which improves finished water quality and reduces disinfectant doses while also directly removing some protozoa and bacteria. Filtration is not strictly required by Interior Health, but to be exempt turbidity must consistently be below 1 NTU before disinfection, which is unlikely for Osoyoos Lake due to algal activity. Filtration for water treatment usually is either granular media filtration, which follows clarification, or membrane filtration, which is usually operated without clarification.

5.1.2.1 Granular Media Filtration

Parameter	Treatment Capability
Turbidity	Good
TOC	Moderate
Algae	Minimal

Granular media filtration is a fixed bed media process where water flows through the pore spaces of sand-sized particles. When operated at a high flow rate it is also called rapid sand filtration. Water is often clarified prior to filtration to remove some particles and stabilize them, allowing easier removal of the remaining particles through the filter bed. Without clarification the filter will require more frequent backwashing and is vulnerable to algae, which can cause extreme head loss. Filter media is usually anthracite or GAC overlaying sand. If the filter is operated as a biofilter additional removal of dissolved contaminants may be possible. Particles trapped in the filter are removed by periodic backwashing.

Granular media filters consist of a filtration basin, filter media, underdrains, and a backwash system that consists of a tank to store water to wash with, backwash pumps, troughs to collect dirty wash water, and a wash water treatment system. The wash water must be further treated to separate reduce solids concentration, usually by high-rate clarification. Solids collected from this process should then be dewatered and disposed of, usually by landfill. Clarified wash water and water collected during the dewatering process can be recycled at the head of the treatment system. An equalization tank is recommended to evenly distribute flow because this recycled water will have higher concentrations of contaminants compared to raw water. Equalization will also allow using a much smaller clarifier to treat wash water.

Granular media filters are good at removing turbidity and TOC when paired with a clarifier. They have limited ability to remove dissolved contaminants but can reduce the concentration of some contaminants such as ammonia, iron, manganese, and TOC when operated as a biofilter (i.e., without a chlorine residual across the filter).

5.1.2.2 Membrane Filtration

Membranes can be used to remove a wide variety of contaminants, including turbidity, TOC, and microorganisms including algae. This can be accomplished using multiple mechanisms and various form factors, but the general principle is that contaminants are rejected, and water passes through the membrane. This results in a concentrated residual stream of contaminated water which must be disposed of. This process requires a hydraulic pressure gradient, which is produced by pumping. This pressure reduces over time as solids accumulate as a thin layer on the membrane surface, which is removed by periodic backflushing. The wastewater produced by backflushing is added to the concentrate stream.

Parameter	Treatment Capability
Turbidity	Excellent
TOC	Moderate
Algae	Minimal

The key advantages to membrane filtration are the small footprint when compared to granular media filtration, disinfection of protozoa and bacteria, and relatively simple operation. However, membrane filtration is mechanically complex and therefore requires highly trained operators, has very high energy use, and has high asset renewal costs because membranes require replacement, typically after 10 years of service. Critically, membranes tend to foul quickly in waters with elevated concentrations of natural organic matter, accordingly clarification will likely be required which negates most of the advantages that membrane filtration has over granular media filtration. Taken together, membrane filtration is unlikely to be an effective option for treating water from Osoyoos Lake.

Table 12 Comparison Between Filtration Options

Technology	Benefits	Challenges	Relevance to Osoyoos
Granular Media Filtration	▪ Low equipment capital costs. ▪ Low operating costs. ▪ Good TOC removal when paired with clarification.	▪ Large footprint, increasing capital costs. ▪ Require chemical pretreatments.	▪ Will effectively reduce turbidity. ▪ Effects of algae should be considered.
Membrane Filtration	▪ Excellent removal of turbidity, protozoa, and bacteria. ▪ Low footprint possible. ▪ Chemical pretreatments may not be required.	▪ High equipment capital costs. ▪ High operating and maintenance costs. ▪ High algae loading and organics can lower performance. » Clarification may be required. ▪ Membranes require replacement after 10 years.	

5.1.3 Activated Carbon

Osoyoos Lake has elevated concentrations of algae during the warm weather months. Algae may produce compounds that degrade water aesthetics, such as Geosmin or MIB, or toxins that are health risks, such as microcystins. These compounds are not effectively removed by conventional treatment processes because they are tiny molecules that are not easily oxidized and are not attracted to coagulants. Fortunately, they can be removed by adsorption to activated carbon.

Parameter	Treatment Capability
TOC	Excellent
Geosmin/MIB	Good
Microcystins	Excellent

Activated carbon for control of algal byproducts can be provided either as powdered activated carbon (PAC) or packed-bed GAC. Both approaches removed contaminants through direct contact, but their application is different. PAC is a consumable added to water early in the treatment process to maximize contact time and is then removed during clarification to limit filter loading, whereas packed-bed GAC is a fixed treatment process located at the end of the treatment process just prior to chlorination in contactor vessels, as described in Section 4.1.3.

The advantages to a PAC system include lower capital costs, lower footprint requirements, and the ability to change the dose as needed. However, PAC creates hazardous dust that must be mechanically controlled, is flammable, increases treatment solids, and has high operational costs if used for extended periods. Taken together, PAC is a useful tool when taste and odour or toxin events are rare but packed-bed GAC is optimal for continual treatment. These treatments may be unnecessary for Osoyoos Lake because of the decreasing risk of algal blooms.

Table 13 Comparison Between Activated Carbon Options

Technology	Benefits	Challenges	Relevance to Osoyoos
PAC	▪ Small footprint, reducing capital costs. ▪ Can scale dose to meet demand. ▪ Low operational costs for short period of use.	▪ Hazardous dust, flammable. ▪ Increases solid waste generated. ▪ High operational costs for long period of use. ▪ Operation and maintenance more complex.	▪ Activated carbon may be useful on-demand for controlling taste and odour compounds and algal toxins. ▪ Technology selection depends on expected risk of these events occurring.
GAC	▪ Simple to operate and maintain. ▪ Effective for continually removing contaminants. ▪ Low operating costs for long periods of use.	▪ Large footprint, increasing capital costs. ▪ High operating costs for short periods of use.	

5.2 Recommended Treatment System

The proposed treatment system for Osoyoos Lake is DAF clarification followed by granular media filtration, UV disinfection, and chlorine disinfection (Figure 10). These processes can effectively meet surface water treatment goals while simultaneously removing algal cells (Table 14). The DAF clarifiers will reduce TOC and turbidity and the filter will remove any remaining particles. If the filter is operated as a biofilter it may further reduce TOC concentration and reduce disinfection byproduct precursors. The system has includes PAC for control of intermittent exposure to algal toxins, taste and odour compounds, and PFAS. PAC can be added upstream of the DAF and removed through the DAF float. The risk of algal toxins and taste and odour compounds has been reducing over time because of decreasing nutrient concentrations in Osoyoos Lake. This makes PAC the ideal option because it can operate intermittently during water quality events and requires a footprint. Similar to the groundwater treatment train, provision for future addition of GAC considered within the siting footprint to address the potential for PFAS exposure in the source water. The treatment process ends with UV[1] and chlorine disinfection, which provides two effective barriers against protozoa, bacteria, and viruses. UV disinfection is not required by current BC guidelines because the DAF and filtration system provide disinfection credit. However, it was included because it was recommended by IHA for this water source as an additional barrier. This assumption should be further evaluated during detailed design. The approximate area of the Stage 1 treatment plant is 1,200 m^2.

Table 14 Treatment Performance for Surface Water Technologies

Goal	DAF Clarification and Granular Media Filtration	PAC or GAC (Future)	UV Disinfection	Chlorine Disinfection
4-log (99.99%) reduction in viruses			✓	✓
3-log (99.9%) reduction in protozoa	✓		✓	✓ (*Giardia*)
2 treatment barriers	✓		✓	✓
Turbidity less than 1 NTU	✓			
0 detections *E. coli* and coliforms			✓	✓
TOC reduction to below 4 mg/L	✓			
Total microcystins below 0.0015 mg/L		✓		
Geosmin and MIB below the threshold limit of 4 ng/L and 9 ng/L, respectively		✓		

[1] UV disinfection is recommended by IHA but is not required to meet the pathogen log reduction credit assignments. For the purposes of this analysis, it is assumed to be included within the surface water treatment solution.

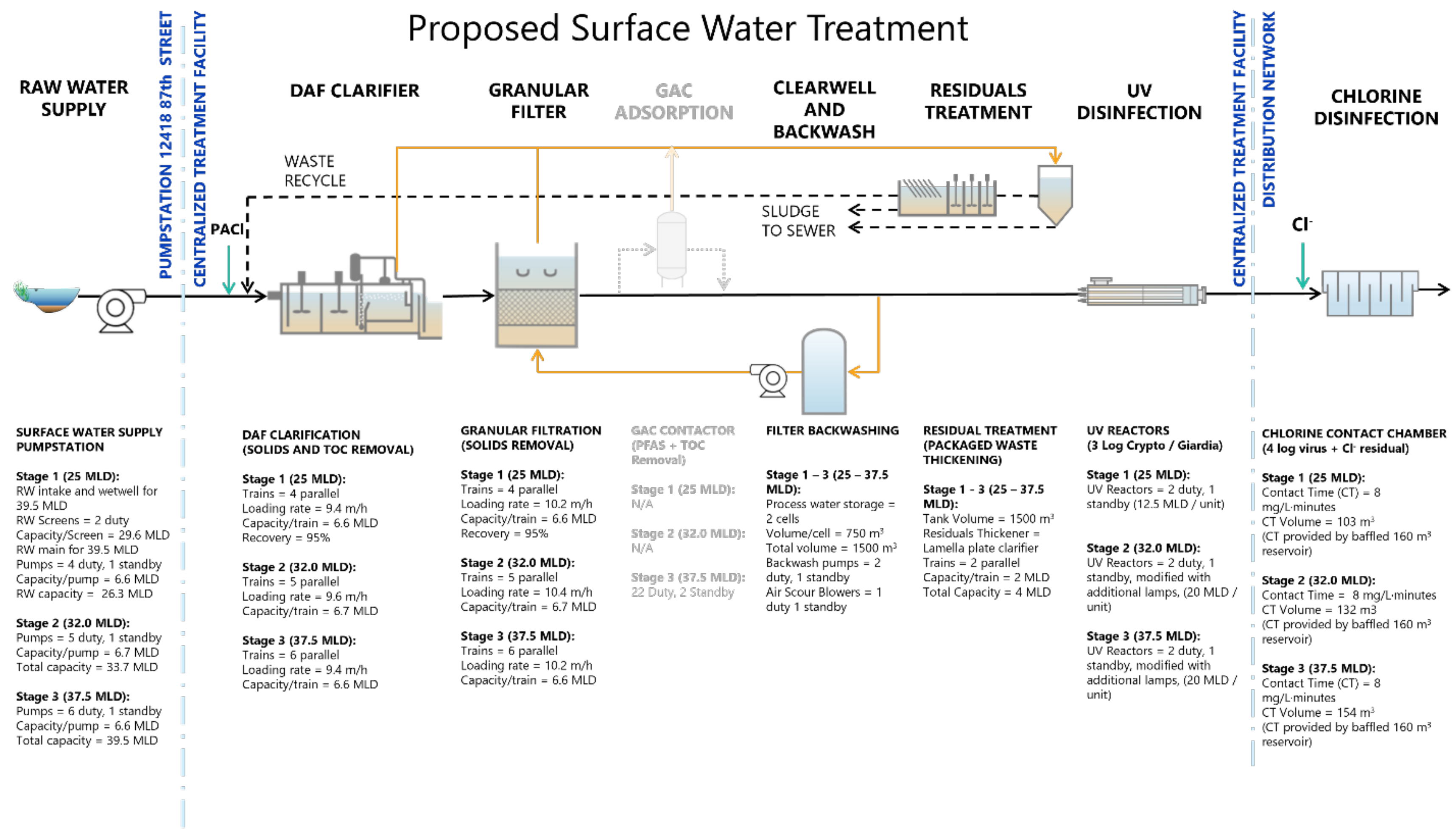

Figure 10 Proposed Surface Water Process Flow Diagram

The surface water plant begins with the addition of pre-treatment chemicals directly to the raw water line. These chemicals include coagulant, a coagulant aid polymer, and a flocculant aid polymer. We propose using PACl as a coagulant because of its proven effectiveness in the region with for TOC removal using DAF. A PACl dose of 20 mg/L has been estimated based on water quality data and similar systems in the region. It is also possible that coagulant and flocculant aid polymers will be required. We propose dosing a polyquaternary amine (epiamine) at 1 mg/L neat and a cationic polyacrylamide at 0.2 mg/L diluted to 0.3 percent concentration to improve flow. Storage and dosing systems are required for these chemicals.

Water will then enter the mechanically mixed flocculation basins. This two-stage system has high mixing speeds when compared to conventional clarification, which results in small flocs that are easily floated. The flocculated water then flows over an angled plate into the DAF basin. Flocs are floated to the surface of the basin using microbubbles. These bubbles are formed by feeding air saturated water to the basin, therefore, a saturation tank and compressor system are required. The floated flocs form a layer of sludge which is periodically removed by a mechanically driven skimmer. This sludge is expected to have a low solids concentration of 2 percent or less because the raw water turbidity is expected to be of organic origin. Accordingly, sludge will be sent to the backwash water holding tanks. A small portion of flocs will sink to the bottom of the basin and will be removed periodically and sent to the backwash water holding tanks.

The clarified water exits the DAF basin at the bottom to avoid loading flocs onto the filter bed. The filter is dual media with anthracite overlaying sand. Filters will require periodic backwashing, therefore, a reservoir for backwash water, backwash pumps, and a system for processing wash water will be required. Wash water will flow into a storage tank from which it will be further clarified using a packaged system. This system is needed because the wash water volume produced will be too large to store and decant. The clarified wash water will be recycled at the head of the treatment plant while the clarified solids will be further dewatered using a centrifuge. Dewatered solids will be disposed of by landfill.

After filtration, water will be disinfected. For this system UV disinfection is not required because DAF combined with granular media filtration provides some disinfection. However, the Drinking Water Officer has indicated their preference for UV disinfection, therefore the design includes UV reactors. Additional primary disinfection and secondary disinfection will be provided by sodium hypochlorite. Storage and a dosing system are required. A baffled contact chamber will be used to achieve disinfection. Design criteria for the entire system are listed in Table 15.

Table 15 Surface Water Treatment Process Design Criteria

Criteria	Unit	Stage 1	Stage 2	Stage 3
Treated Water Demand	MLD	25.0	32.0	37.5
Recovery	%	95	95	95
Raw Water Flow	MLD	26.3	33.7	39.5
Flocculation				
Retention time	minutes	16.4	16.0	16.4
Stages		2	2	2
Duty Basins		3	4	5
Standby Basins		1	1	1

Criteria	Unit	Stage 1	Stage 2	Stage 3
DAF				
Loading Rate	m/hour	9.4	9.6	9.4
Duty Tanks		3	4	5
Standby Tanks		1	1	1
Granular Media Filtration				
Loading Rate	m/hour	10.2	10.4	10.2
Media Type		Anthracite and Sand	Anthracite and Sand	Anthracite and Sand
Duty Filters		3	4	5
Standby Filters		1	1	1
UV Disinfection (Optional)				
Minimum UVT	%	85	85	85
UV Dose	mJ/m^2	40	40	40
Duty Reactors		2	2	2
Standby Reactors		1	1	1
Chlorine Disinfection				
Chlorine Type		Sodium Hypochlorite	Sodium Hypochlorite	Sodium Hypochlorite
Chlorine Concentration	%	12	12	12
Chlorine Dose	mg/L	1.5	1.5	1.5
Contact Time Required	mg/L per minute	8	8	8
Contact Volume Required for 0.9 Baffle Factor	m^3	103	132	154
Residuals				
Backwash Rate	m/hour	70	70	70
Backwash Duration	minutes	20	20	20
Filter-to-waste Rate	m/hour	12	12	12
Filter-to-waste Duration	Minutes	10	10	10

5.3 Treatment Plant Location

For the purpose of developing high level cost estimates it was assumed that the surface water treatment option would also be sited at the reservoir 340 location (Figure 8). Additional sites were being considered in parallel at the time of writing and will be published in a separate report. The reservoir 340 site was selected because the Town already has development rights for the land and it is hydraulically favourable for connection to the distribution system.

5.4 Raw Water Conveyance

5.4.1 Proposed Intake

In order to service the Town's domestic water demand, Self and Larratt (2020) recommended the future intake in the North Basin of Osoyoos Lake to extend to 30 m depth with a 3 m clearance above the sediment for optimal drinking water quality (Figure 11). The new intake location is proposed to be adjacent to the existing Station No. 8 Intake. The major components and sizing characteristics of the proposed intake are summarized in Table 16.

Figure 11 Osoyoos Lake Proposed Intake Location

Table 16 Proposed Osoyoos Lake Intake Concept

Parameter	Intake
Location	Adjacent to the existing Station No.8
Size	750 mm
Material	HDPE
Length	240 m
Installed Depth	30 m
Screening	Stainless steel fish screen
Mussel Control	Provision of chlorine dosing line at the intake screen

Self and Larratt (2020) recommended intake installation depth of 30m increases the complexity of the pipe installation, since the target depth is at the limit of advanced open water diving, and increases the pipe pressure rating, which reduces the pipe selection availability. Therefore, it is recommended that should the surface water treatment option proceed to subsequent design stages, the target depth for the intake be further evaluated to determine if a shallower installation at 20 m is feasible to reduce construction costs and risks during installation. Moreover, based on the Osoyoos Lake surface water quality listed on Table 4, and the proposed surface water treatment (further discussed in Section 5.3 through Section 5.6), it is expected that the proposed water treatment process will be fully capable of treating water quality at shallower depths.

5.4.2 Proposed Intake Pump Station

The existing Station No. 8 facility was built in the 1960s and is nearing its end of service life. Therefore, it is recommended that a new Intake Pump Station be built to replace the existing and to meet current and future domestic water demands.

The new Intake Pump Station location is proposed to be adjacent to the existing Station No. 8 and will be initially furnished with 4 vertical turbine pumps able to operate in a duty/standby configuration with a firm capacity of 304 L/s (26.3 MLD). Later expansions will be accomplished by adding additional pumps drawing from the same wetwell. The vertical turbine pumps would pump raw water to the proposed surface water treatment plant location, near the existing domestic 340 Reservoirs, via a 600 mm ductile iron class 250 watermain (Figure 12). The vertical turbine pumps and watermain proposed concept is summarized in Table 17.

Table 17 Proposed Intake Vertical Turbine Pump and Watermain Concept

Parameter	Vertical Turbine Pumps
Discharge Location	Proposed WTP near existing 340 Domestic Reservoirs
Pump Type	Vertical Turbine Pump
Number of Pumps	4 (Duty/Standby Configuration)
Watermain Diameter	600 mm
Watermain Pipe Type	Ductile Iron
Pressure Rating	250 psi
Watermain Length	4.0 km
Static Head	82.5 m
Dynamic Head	86.5 m
Fluid Velocity	0.8 m/s
Horsepower Requirement	500 HP
Starter Type	VFD

Notes:
km - kilometers; L/s - liters per second; psi - pounds per square inch, VFD - variable frequency drive.

Figure 12 Plan and Profile of Proposed Raw Water Pipeline Connecting Osoyoos Lake Intake to Treatment Plant at the Reservoir Site

green = 4 kilometers of 600 mm diameter piping

SECTION 6 FINANCIAL ANALYSIS

This section presents the probable construction costs for the groundwater and surface water treatment options presented above. Additional details are provided in Appendix D.

6.1 Opinion of Probable Cost

The cost estimate prepared is a Class 4 estimate with an expected accuracy of +50 percent to -30 percent, based on the Association for the Advancement of Cost Engineering (AACE) International cost estimate classification system (American Society for Testing and Materials [ASTM] E 2516-11). This estimate is preliminary in nature given the limited site information and is expected to fall with a range. At the high end of the range, a contingency of 50 percent is applied. The cost could also be lower by 30 percent. The estimate is indicative of the approximate magnitude of cost of the alternatives and is to be used for comparison purposes only. Where possible, quantity takeoffs were completed for all elements shown in sufficient detail in the concept drawings provided in this memorandum. Where possible, vendor estimates were obtained for elements. For all items known to exist but not defined in the project drawings, allowance was applied using experience and values from past projects. A 10 percent general contractor overhead and profit and 15 percent engineering services allowances are applied on the estimated capital costs. The following assumptions were made for the Class 4 cost estimate:

- No allowance has been made for land purchase to build the proposed lake intake and pump station, watermain, or treatment plant.
- Geotechnical conditions on the site are suitable to build the proposed lake intake and pump station, watermain, or treatment plant.
- Excavation for the proposed water treatment plants, assume a relatively flat construction area, where 20 percent of the required excavation is granular material and the remaining 80 percent requires rock blasting.
- Estimated cost is based on the treatment systems as described for the groundwater and surface water options in Section 4 and Section 5.
- The groundwater option includes approximately 6.0 km of 200 to 600 mm diameter piping to supply the treatment system.
- The surface water option includes approximately 4.0 km of 600 mm diameter piping to pump domestic MDD from the proposed intake pump station to the water treatment plant.
- The surface water option assumes the required raw water pump station is sited at the IR 8 Pump Station and a new intake pipe sized to 750 mm diameter to supply Stage 3 flowrates.
- Both options assume the water treatment plant will be an on-grade facility to minimize rock blasting and excavation requirements.
- The surface water option includes development of an Environmental Impact Assessment Study, permitting and environmental monitoring during construction to facilitate the construction of a shoreline intake pump station adjacent to the existing IR 8 facility.

- The surface water option includes sheet piling to build new intake pump station, and jack and boring for the new 750 mm intake pipe.
- Standby power generation costs $1000/kW, with the groundwater pump system 20 percent more expensive because of the need more generator units due to the multiple well locations compared to the surface water option.
- Generator sized for pumping the maximum daily demand condition.
- Overall electrical and instrumentation costs are approximately 20 percent of the total capital costs (see Appendix C for more details).
- Goods and services tax (GST) in the amount of 5 percent is not included.
- Canadian Provincial Sales Tax is applied to equipment quotations and accounted for in the direct costs.
- Financing and legal fees are not included.

Tables 18 and 19 provide a discipline breakdown of the Class 4 cost estimate for the initial development of each option and expansions to 32 and 37.5 MLD finished water flowrates.

Table 18 Groundwater Treatment Estimate of Capital Cost

Item No.	Discipline	25 MLD (Base)	32 MLD (Stage 2)	37.5 MLD (Stage 3)	TOTAL
01	General Requirements	$1,260,000	$550,000	$480,000	$2,290,000
02	Civil and Environmental	$9,937,000	$3,989,000	$4,495,000	$18,421,000
03	Structural	$2,164,000	$1,274,000	$150,000	$3,588,000
04	Architectural	$1,268,000	$907,000	$0	$2,175,000
05	Process Mechanical	$12,887,000	$3,312,000	$3,312,000	$19,511,000
06	Building Mechanical	$1,806,000	$1,140,000	$0	$2,946,000
07	Electrical and Instrumentation	$9,586,000	$4,055,000	$3,221,600	$16,862,600
	Sub-Total	**$38,908,000**	**$15,227,000**	**$11,658,600**	**$65,793,600**
	Contractor OH&P (10%)	$3,891,000	$1,523,000	$1,166,000	$6,579,000
	Sub-Total	**$42,799,000**	**$16,750,000**	**$12,824,600**	**$72,372,600**
	Engineering (15%)	$6,420,000	$2,513,000	$1,924,000	$10,856,000
	Contingency (30%)	$12,840,000	$5,025,000	$3,847,000	$21,712,000
	Total Estimated Construction Cost	**$62,059,000**	**$24,288,000**	**$18,595,600**	**$104,940,600**

Table 19 Surface Water Treatment Estimate of Capital Cost

Item No.	Discipline	25 MLD (Base)	32 MLD (Stage 2)	37.5 MLD (Stage 3)	TOTAL
01	General Requirements	$1,280,000	$225,000	$225,000	$1,730,000
02	Civil and Environmental	$8,138,000	$250,000	$250,000	$8,638,000
03	Structural	$4,541,000	$794,000	$794,000	$6,129,000
04	Architectural	$1,515,000	$313,500	$313,500	$2,142,000
05	Process Mechanical	$15,100,000	$2,606,000	$2,606,000	$20,312,000
06	Building Mechanical	$1,935,000	$432,000	$432,000	$2,799,000

Item No.	Discipline	25 MLD (Base)	32 MLD (Stage 2)	37.5 MLD (Stage 3)	TOTAL
07	Electrical and Instrumentation	$7,523,000	$694,000	$694,000	$8,911,000
	Sub-Total	**$40,032,000**	**$5,314,500**	**$5,314,500**	**$50,661,000**
	Contractor OH&P (10%)	$4,003,000	$531,000	$531,000	$5,066,000
	Sub-Total	**$44,035,000**	**$5,845,500**	**$5,845,500**	**$55,727,000**
	Engineering (15%)	$6,605,000	$877,000	$877,000	$8,359,000
	Contingency (30%)	$13,211,000	$1,754,000	$1,754,000	$16,718,000
	Total Estimated Construction Cost	**$63,851,000**	**$8,476,500**	**$8,476,500**	**$80,804,000**

The cost estimate herein is based on our assessment of current conditions at the project location. This estimate reflects our professional opinion of accurate costs at this time and is subject to change as the project design matures. Carollo Engineers has no control over variances in the cost of labour, materials, equipment, services provided by others, contractor's methods of determining prices, competitive bidding or market conditions, practices, or bidding strategies. Carollo Engineers cannot and does not warrant or guarantee that proposals, bids, or actual construction costs will not vary from the costs presented herein.

6.2 Life Cycle Cost Comparison

Life cycle costs were developed for both groundwater and surface water treatment plants. The cost estimate prepared is a Class 4 estimate with an expected accuracy of +50 percent to -30 percent, based on the AACE International cost estimate classification system (ASTM E 2516-11). Operating costs were based on consumables such as chemical dosing, power consumption and operator full-time equivalent requirements. The following assumptions were made to estimate life cycle costs:

- Flow projections based on 2023 maximum daily flow of 19.7 MLD with a 2.55 peak factor between maximum and average daily flows.
- 10 percent water conservation applied to the current average daily water usage and 2 percent growth rate assumed for all consumables, paralleling population growth assumptions.
- Design horizons for staged upgrades are based on the following:
    - Initial build serves 25 years through 2050, providing 25 MLD.
    - Stage 2 build adds one additional treatment train, increasing flowrate to 32 MLD, with the upgrade expected in 2064.
    - Stage 3 build adds an additional treatment train, increasing flowrate to 37.5 MLD, with the upgrade expected in 2071.
- A 3 percent discount rate applied to account for time value of money.
- Building heating and cooling costs based on 0.5 kilowatts per square meter and lighting energy usage estimated based on 0.08 watts per square meter.
- Electricity costs based on $0.08355 per kilowatt-hour (2023 billing rate).
- Full burden labour cost for 1 full-time equivalent of $350,000.
- Chemical costs:
    - 12 percent bulk sodium hypochlorite $0.77 per litre (L).
    - PaCl Coagulant $1.05/L.

   - Coagulant aid polymer $5.1 per kilogram (kg).
   - Flocculant aid polymer $8.15/kg.
- Equipment replacement cost allocated at 2 percent per annum of the process mechanical, building mechanical, electrical and instrumentation direct costs.

Tables 20 and 21 provides a breakdown of the net present value estimate. Detailed breakdowns of the life cycle cost allocations for each alternative are located in Appendix D.

Table 20 Groundwater Estimate of Net Present Value Costs

Item No.	Parameter	25 MLD (Base)	32 MLD (Stage 2)	37.5 MLD (Stage 3)
01	Initial Capital	$62,059,000	$62,059,000	$62,059,000
02	Operations and Maintenance	$22,584,000	$32,570,000	$37,074,000
03	Future Expansions	$0	$7,446,000	$11,946,000
	Total Life Cycle	$84,643,000	$102,075,000	$111,079,000

Table 21 Surface Water Estimate of Net Present Value Costs

Item No.	Parameter	25 MLD (Base)	32 MLD (Stage 2)	37.5 MLD (Stage 3)
01	Initial Capital	$63,853,000	$63,853,000	$63,853,000
02	Operations and Maintenance	$25,093,000	$36,188,000	$41,193,000
03	Future Expansions	$0	$2,599,000	$4,712,000
	Total Life Cycle	$88,946,000	$102,640,000	$109,758,000

SECTION 7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

A summary of the key findings from the treatment feasibility assessment for the groundwater and surface water sources are presented below. The conclusions have been organized by Category, as developed in the previous sections of the report.

7.1.1 Source Water Availability

- **Groundwater:** The groundwater aquifers in the region have served the Town well for over 50 years. The development of new groundwater wells will be required to meet demands from population growth. Additionally, several of the existing wells will require refurbishment to continue to reliably produce water at the target yields. Siting and development of these future wells have not been considered in detail and will require further hydrogeological investigations to confirm locations and capacities. Construction of new wells will be further limited by availability of land to purchase for this purpose. Based on the aquifer studies completed to-date, the groundwater source availability is expected to meet the future needs to 2050.
- **Surface Water:** While the town has historically relied on surface water for irrigation purposes, a new surface water supply intake and pump station would be required to support the domestic water

demands. Availability of the surface water is not expected to present any issues to meet the future needs to 2050. A key advantage of developing the surface water source for domestic needs, is the ability to retain the highest quality wells as back-up or supplemental water sources. Additionally, the existing groundwater wells could be connected to the irrigation supply network and used to offset irrigation demands without the need for further treatment.

- **Summary:** For source water availability, the surface water source offers a more robust and resilient long term water supply solution.

7.1.2 Raw Water Conveyance Infrastructure

- **Groundwater:** A common groundwater transmission main is needed to connect the groundwater supplies and convey the raw water to a centralized water treatment plant. This presents a relatively complex pumping system operation and may effect to total installed pumping capacity. Further analysis of the combined pump performance would need to be completed to confirm whether this would be an issue. Additionally, as noted in the source water availability, several of the existing wells will require refurbishment to continue to reliably produce water at the target yields. Review of the pump operating conditions could be considered as each of these wells is refurbished.
- **Surface Water:** The surface water solution will require the construction of a new raw water pump station adjacent to the Osoyoos Lake foreshore and extending an intake pipe approximately 240 m into the lake. With a single access point on the lake, expansion of the raw water supply can be easily accommodated to meet water demands from local or regional growth. Working adjacent to the lake will require provincial and federal permitting requirements that will need to be managed to facilitate construction. Installation of a submerge intake will also involve specialty contractors. Finally, a new 4 kilometre transmission main is need to connect the raw water pump station to the centralized water treatment plant.
- **Summary:** Both systems will require significant investment in the raw water extraction and conveyance infrastructure to meet the 2050 water demands. With the construction of an entirely new facility adjacent to the foreshore, the surface water option introduces higher project risk and is considered to be less favourable for this category.

7.1.3 Treatability

- **Groundwater:** With the groundwater wells located in an unconfined, highly vulnerable aquifer, the minimum treatment requirements would include two stages of disinfection (UV and chlorination) to satisfy provincial health guidelines for microbial contaminants. In addition, the groundwater source exhibits elevated levels of organics, nutrients (ammonia), manganese, iron, and PFAS. Results of the pilot testing indicate possible limitations in the biological treatment for manganese removal due to the interference by the elevated ammonia. The proposed treatment train offers limited organics removal, meaning the disinfection byproduct formation would remain a challenge unless additional treatment (e.g. GAC contactors) is provided. Finally, additional treatment may need to be added in the future to reduce the organics and PFAS levels.
- **Surface Water:** Osoyoos Lake water quality is typical of the lower elevation lakes within the Okanagan Valley system and is characterized as a high-quality source with low turbidity, low to moderate organics, and seasonal algae events. Based on the water quality characteristics, a conventional surface water treatment approach focusing on multi-barrier treatment for removal of

microbial pathogens is considered suitable. Given the elevated organics and potential for algae events, DAF is considered a suitable technology for clarification with several installations in the region. The key challenge with the surface water treatment relates to algae toxins (e.g. microcystin) and the associated taste and odour compounds (Geosmin and MIB), both of which may need to be managed using PAC during water quality events.

- **Summary:** From a treatability perspective the surface water option offers access to the highest quality water source for the Town. The interaction between ammonia and metals present in the groundwater increases the complexity of the groundwater treatment solution while maintaining effectively untreated organics. The surface water treatment plant requires less stages of treatment, effectively reduces the organics and involves less complex processes to meet the provincial and drinking water quality.

7.1.4 Operations and Maintenance

- **Groundwater**: The number of raw water quality parameters requiring treatment introduces a higher level of operational complexity of the groundwater system. From a mechanical perspective, the pressure filter vessels are relatively simple to operate and can be highly automated. The key operational challenges for the groundwater system will be maintaining the health of the biological filter through the seasonal water demands, managing the decentralized well network, and managing the disinfection process to limit the production of disinfection byproducts.
- **Surface Water**: The surface water treatment solution provides a robust approach capable of managing a wide range in future water quality conditions. Operation of a chemically assisted clarification/filtration processes requires skilled operators to effectively manage the coagulation chemistry to maintain proper treatment performance. This typically involves a steeper learning curve initially, however, once the seasonal chemistry fluctuations are understood the can process performance can be effectively managed. Similar processes (DAF and filtration) are installed in Peachland, Penticton, West Kelowna, and Vernon. Another operational challenge presented by the surface water relates to managing the algae toxins and the associated taste and odour events. While only required intermittently, the use of PAC can be messy and has specific health and safety requirements.
- **Summary**: Both the surface water and groundwater systems will require experienced water treatment staff to ensure reliable treatment performance. The groundwater system would be more automated and is expected to be slightly less complex to operate.

7.1.5 Financial

- **Groundwater:** The proposed groundwater treatment plant has a lower footprint than the surface water option, but the large number of pressure vessels required and the need for constructing new production wells results in capital costs similar to the surface water option. There is also higher uncertainty for the groundwater equipment costs because pressure filtration at this scale is not typical in the region – note that the estimate is still considered Class 4. Lifecycle costs for the groundwater option are highly dependent on plant expansion, which will require the addition of new treatment units and new wells. The initial build has favourable lifecycle costs but the value of this option decreases as the system is expanded.

- **Surface Water:** The proposed surface water treatment plant has slightly higher expected capital costs primarily but the upfront investment is more valuable because future expansion does not require modifying the intake or raw water main. Operational costs are higher for the surface water system because of higher chemical use and higher labour requirements, but overall lifecycle costs are lower when considering capacity expansion because expansion capital costs are low compared to the groundwater option.
- **Summary:** Both the surface water and groundwater systems will be a substantial capital investment for the Town and will require increases to the current operating budgets. However, these costs are expected based on similar treatment plants in the region.

7.2 Recommendation

The proposed surface water treatment solution provides the greatest flexibility for source water availability and accesses the highest available water quality without significant additional costs. This option will allow the Town to meet current and future drinking water demands. Based on the preceding feasibility analysis, the surface water treatment option is recommended as the preferred approach to provide a reliable supply of drinking water that meets the provincial and federal drinking water quality guidelines.

SECTION 8 REFERENCES

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APPENDIX A

TM 1 - TOWN OF OSOYOOS PRELIMINARY GARP SCREENING

TECHNICAL MEMORANDUM

TO:	Martin Earle, Ph. D., E.I.T. (Carollo Engineers)	**DATE:**	December 11, 2024
FR:	Ryan Rhodes, P.Geo. (WWAL)	**REFERENCE:**	24-136-01VR

RE: **PRELIMINARY GROUNDWATER AT RISK OF PATHOGENS (GARP) SCREENING FOR THE TOWN OF OSOYOOS SUPPLY WELLS**

BACKGROUND & OBJECTIVE

The Town of Osoyoos currently meets their water demands through a combination of surface and groundwater sources that are distributed through two separate water systems: Irrigation Systems 8 & 9 and the Municipal System. Irrigation Systems 8 & 9 predominately service agricultural customers outside of the Town core and source water from two intakes into Osoyoos Lake. The Municipal System supplies the majority of residential, commercial, and industrial customers and sources water exclusively through the Town's six operating groundwater production wells. The Town also recently installed two test supply wells on Maple Drive in 2023 (as reported in WWAL, 2023), with consideration to installing larger diameter production wells at the same location in the future.

It is our understanding the Town is currently evaluating their long-term source options for the municipal system. The two source options being considered are continued reliance on groundwater or transition to surface water from Osoyoos Lake. To inform this process, Carollo Engineers requested WWAL provide an opinion on the likely Groundwater At Risk of containing Pathogens (GARP) status for the Town's six production wells and two test wells on Maple Street (assuming similar production wells would be completed in the future). The potential for a supply well to be considered GARP was assessed using the criteria outlined in the Version 3 – Guidance Document for Determining Ground Water at Risk of Containing Pathogens (Ministry of Health, 2017). This technical memorandum is not intended to provide a definitive determination of the GARP status of the wells. It is intended for planning purposes and is subject to change if and when further and more detailed assessment is carried out.

HYDROGEOLOGICAL SETTING & WELL CONSTRUCTION DETAILS

As shown on attached Figure 1, there are two principal aquifers mapped in the Osoyoos area: the West Osoyoos Aquifer (No. 193 IIA) and the East Osoyoos Aquifer (No. 194 IIA). Aquifer 193 extends across the lower elevation areas on the western side of Osoyoos Lake, from the northern end of the lake to the US border. This unconfined, water bearing unit is composed of sand and gravel and is classified as having high productivity, high demand, and high vulnerability to surface contamination. Aquifer 194 is mapped along the eastern shore of Osoyoos Lake and extends to the base of the mountain slopes on the eastern wall of the valley. This partially confined unit is also composed of sand and gravel, and is classified as having moderate productivity, moderate demand, and high vulnerability to surface contamination. A confining layer of semi-permeable sediments is often encountered near the lake but is not consistently present at higher elevations. A third, relatively small, confined aquifer (Aquifer 195 IIIB) is located along the eastern shore of Osoyoos Lake, south of Highway 3 and parallel to Lakeshore Drive.

As displayed on attached Figure 1, the Town's supply and test wells were all installed within 200 m of Osoyoos Lake. Five are located within 100 m of the lake and three are located within 15 m. Wells 1, 6, and 8 are located on the west side of the lake (Aquifer 193), while Wells 3, 4, 5, 8, Test Well 1, and Test Well 2 were installed on the east side of the lake (Aquifer 194). The Town also has Well 7, which is located in close proximity to Well 6 on the west side of the lake. However, the Interior Health Authority (IHA) denied the Town's application for new source approval at this location due to proximity to a sanitary line, and the well has never been put into service. Table 1 below provides select construction details for the Town's supply and test wells. All of the Town's wells are considered shallow (the deepest extends to a depth of 30.1 m) and quite productive.

Table 1 – Town of Osoyoos Groundwater Well Construction Details

Town of Osoyoos Well ID	Diameter (mm/in)	Top of Screen Depth (m/ft)	Finished Well Depth (m/ft)	Depth to Water (m/ft)	Well Yield (L/s / US gpm)	Aquifer ID
1	300 / 12	6.8 /22.3	9.2 / 30.2	1.4 / 4.5	18.6 / 295	193
3	300 / 12	9.8 / 32.0	16.2 / 53.1	2.4 / 7.9	39.1 / 620	194
4	200 / 8	16.0 / 52.5	30.1 / 98.7	2.5 / 8.3	45.1 / 715	194
5	400 / 16	18.9 / 62.0	26.5 / 86.9	3.1 / 10.0	75.7 / 1200	194
6	250 / 10	10.3 / 33.7	14.3 / 46.9	5.7 / 18.8	41.0 / 650	193
7 (Inactive)	250 / 10	12.0 / 39.4	19.5 / 64.0	7.9 / 25.9	25.2 / 400	193
8	300 / 12	8.8 / 28.7	13.3 / 43.6	2.1 / 6.9	41.0 / 650	193
Test Well 1	200 / 8	19.4 / 63.5	24.1 / 79.0	2.1 / 7	15.1 / 240	194
Test Well 2	200 / 8	23.2 / 76.0	23.2 / 86.5	3.7 / 12	10.1 / 160	194

PREVIOUS GARP RELATED INVESTIGATIONS

In 2011/2012, WWAL conducted a Groundwater Under the Direct Influence of surface water (GUDI) study for the Town's six active supply wells (i.e., Wells 1, 3, 4, 5, 6 & 8). This study was based on guidance documents and standards of the day, all of which have since been updated.

For the initial phase of the study, water quality data was reviewed, and each supply well was screened using criteria outlined in the GUDI guidance documents. The preliminary screening indicated that all wells except Well 3 were potentially GUDI. This conclusion was reached based on several factors including the wells being within 100 m of Lake Osoyoos, accessing water from an unconfined aquifer, and having preliminary 60-day capture zones that intercepted the lake. Since Well 3 was located approximately 185 m from the lake, this location was deemed to be not a GUDI risk.

The second phase of the study focused solely on Wells 5, 6, and 8, which were deemed to have the most potential to be considered GUDI. Water quality samples and field parameters of untreated groundwater from the three wells and surface water were collected on multiple occasions throughout the study period from late 2010 through summer 2011. The study included collection of eight Microparticulate Analysis (MPA) samples from the wells, all of which returned low risk results. Based on the data collected, WWAL concluded that Wells 1 and 3 were not considered GUDI, while Wells 4, 5, 6 and 8 were at low risk of being considered GUDI.

It is important to note the following:

- The study focused on the GUDI status of the wells, rather than the more comprehensive GARP definition currently used.

- There were issues with the sampling program that resulted in all of the intended samples not being collected. Consequently the report was only issued in draft form and never finalized.

ASSESSMENT OF LIKELY GARP STATUS

Table 2 below provides a summary of our GARP screening for the Town of Osoyoos groundwater wells, with green indicating likely low risk and orange as potential risk. As mentioned, this preliminary screening is based on the most recent GARP guidance document criteria.

Our preliminary screening returned the following findings:

- The prevalence of microbiological parameters in raw water was not assessed in detail for this high-level assessment. Historical raw water sampling has indicated that total coliform bacteria and *E.Coli* are not frequently detected in raw water. The Town of Osoyoos 2023 Annual Water System Report indicates that more than 350 negative bacteriological tests for *E. coli* and total coliforms were collected from the groundwater distribution system throughout that year but this is not necessarily indicative of raw groundwater quality. For the Maple Street test wells, an untreated groundwater sample was collected from each during well testing in 2023 and samples were negative for *E. coli* and total coliforms. We did not flag presence of recurring bacteria as a risk factor.
- The Annual Water System Report also indicates that daily spot tests of the distribution system are conducted for turbidity, with no issues noted in the report. For the test wells, turbidity was measured throughout testing, with the results all measuring below 1 NTU. It is likely that all the wells produce water with turbidity consistently below 1 NTU.
- Section 8 of the Heath Hazard Regulation (HHR) indicates a well must be located at least 30 m from a "probable source of contamination", and in our experience, IHA considers both gravity and pressure sewer lines as probable sources. Since the Town's supply wells are located in close proximity to roads where sewer infrastructure is likely buried, we suspect that the current supply wells do not meet this requirement. However, the test wells were purposely located more than 30 m from any road, and we therefore assume they meet the HHR requirement.
- Although several supply wells have a top of well screen depth that is less than 15 m below ground, none of the wells are located within the natural boundary of Osoyoos Lake or a flood prone area. The test wells both have well screen depths that exceed 15 m and are outside of any flood prone areas.
- All wells, except for Well 3, are located within 150 m of Osoyoos Lake. Bathymetry mapping indicates the bottom of the lake is upwards of 40 m deep in areas close to the wells; therefore, all wells have intake depths between the high-water mark and the bottom depth of the lake.
- As mentioned, sewer lines are typically considered by IHA as a probable source of enteric virus. All supply and test wells are located with 300 m of sewer lines and are installed in unconfined/partially confined aquifers (i.e., a consistent barrier to viral transport is not present).
- All supply wells were installed prior to 2005 and, therefore, are unlikely to have a proper surface seal. However, all supply wells except Well 8 are located in pump control buildings with concrete floors and are at low risk for contaminate entry at the wellhead. The two test wells both have proper surface seals installed.
- All wells have proper well caps, are properly flood proofed, and meet wellhead protection requirements.
- The supply and test wells are installed in either Aquifer 193 or 194, both of which are considered highly vulnerable to surface contamination.

Table 2 – Town of Osoyoos Groundwater Well Preliminary GARP Screening

Stage 1 GARP Screening Criteria	Well #1	Well #3	Well #4	Well #5	Well #6	Well #8	Test Well #1	Test Well #2
Recurring total coliform bacteria, fecal coliform bacteria, or Escherichia coli (E. coli).								
Intermittent/Consistent Turbidity > 1 NTU?								
Well Located within HHR Setback?								
Has intake < 15m below ground & located within flood-prone area?								
Has intake between high water mark and surface water bottom (or <15 m below normal water level) and within 150 m of natural boundary of Surface Water?								
Located within 300 m of probable source of enteric viruses without a barrier to viral transport.?								
Surface Seal								
Well Cap								
Flood Proofing								
Wellhead Protection								
Highly Vulnerable Aquifer								
Karst Bedrock								
GARP Screening Result	**Potentially GARP**	**Potentially GARP**	**Potentially GARP**	**Potentially GARP**	**Potentially GARP**	**Potentially GARP**	**Potentially GARP**	**Potentially GARP**

Notes: Green = low risk; Orange = potential risk

CONCLUSIONS

Based on our preliminary GARP screening, all of the wells are flagged as potentially GARP.

Under the current GARP guidance document, there are three possible outcomes for a formal GARP determination:

1) **GARP.** Viruses, bacteria, and large diameter pathogens such as *giardia* and *cryptosporidium* all potentially present.
2) **GARP-virus only.** Viruses (and likely bacteria) potentially present, but larger diameter pathogens not a risk.
3) **Low GARP risk.** Secure groundwater sources with low pathogen risk.

Based on the shallow nature of the wells in unconfined aquifers and with nearby sanitary lines, it would be difficult or impossible to definitively prove that viruses would never be present. <u>It is our opinion all of the wells should be considered GARP virus-only sources at a minimum</u>. Considering the previous investigations completed, which included MPA sampling of the wells deemed the highest GUDI risk all returning low risk results, it is less certain whether larger diameter pathogens and surface water influence are true risk factors or whether aquifer filtration prevents that risk. An updated and more detailed Level 3 GARP assessment in the context of the current assessment framework would be required to confirm a GARP-virus only determination is adequate. In the absence of such a study, IHA typically falls back on the GARP screening, which in this case flags all of the wells as potentially GARP.

We trust that the professional opinions and advice presented in this document are sufficient for your current requirements. Should you have any questions, or if we can be of further assistance in this matter, please contact the undersigned.

WESTERN WATER ASSOCIATES LTD.

Paul Williamson, M.Sc., P.Geo.
Hydrogeologist

PROFESSIONAL GEOSCIENTIST — PROVINCE OF BRITISH COLUMBIA — R. M. RHODES #32839 — 27-Jun-2025

Ryan Rhodes, P.Geo.
Principal Hydrogeologist

Attachments: Figure 1

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Ministry of Health (MoH). 2017. Guidance Document for Determining Groundwater at Risk of Containing Pathogens (GARP). Version 3. September 2017.

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Western Water Associates Ltd (WWAL). 2023. Town of Osoyoos Groundwater Exploration Program: WPID 28644 & WPID 28646.

Figure 1 - Aquifers & Osoyoos Municipal Supply/Test Well Locations				western water ASSOCIATES LTD Consultants in Hydrogeology and Water Resources Management
Date: December 2024	Image Source: Google Earth Pro (2023)		WWAL Project: 24-136-01VR	
Drawn by: PW	Checked by: RR	Client: Carollo Engineers	Project: Town of Osoyoos Preliminary GARP Screening	

APPENDIX B

TM 2 - REVIEW OF BIOFILTRATION DESIGN CRITERIA FOR MANGANESE REMOVAL

VALUE PLANNING - TECHNICAL MEMORANDUM 2

TOWN OF OSOYOOS

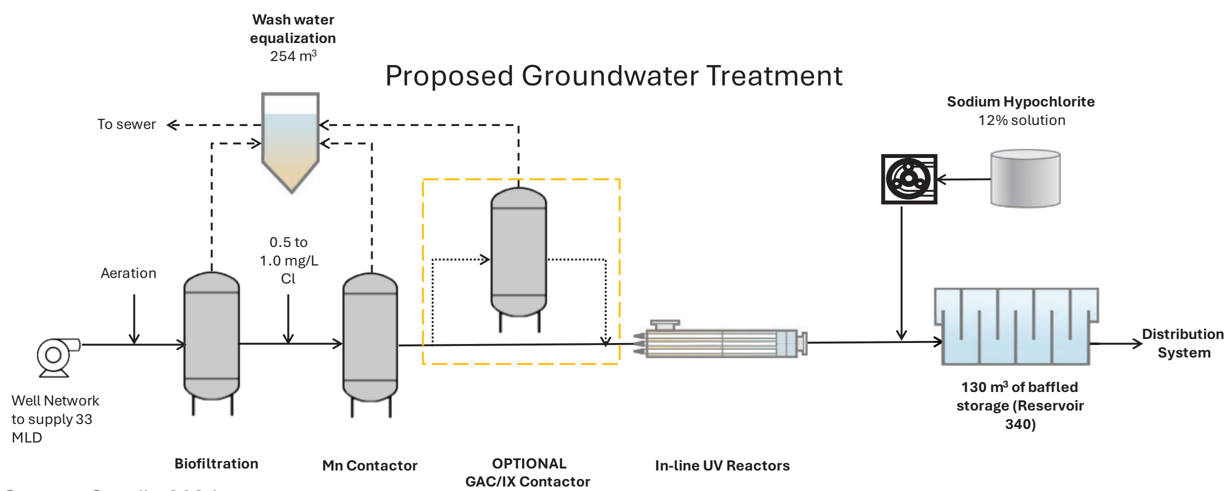
Pilot Study for Surface WTP

Permit to Practice 1004446
PROFESSIONAL
PROVINCE OF
S. C. H. HORSMAN
36256
BRITISH COLUMBIA
ENGINEER
2025-01-28

Project No.:	203185-00
Date:	January 28, 2025
Prepared By:	Martin Earle, PhD, EIT
Reviewed By:	Stephen Horsman, P.Eng., PE, PMP
Subject:	Review of Biofiltration Design Criteria for Manganese Removal

1.0 BACKGROUND

The Town of Osoyoos (Town) is planning construction of a water treatment plant (WTP) to meet the Provincial drinking water quality guidelines. Carollo Engineers Canada Ltd. (Carollo) previously analyzed the existing data on the two available water sources (existing groundwater network and Osoyoos Lake) and provided recommendations in the Source Water and Treatment Feasibility Study (Carollo 2024). In support of value planning analysis for the project, the Town has requested that the design criteria for the proposed groundwater treatment approach be further developed to help validate the Town's decision to select the preferred long-term solution for the communities drinking water supply. The initial concept design consisted of two stage filtration with biofiltration for ammonia reduction followed by manganese removal using a manganese contactor (Figure 1). This memorandum conducts a more detailed evaluation of the unit process selection and associated design criteria (e.g. loading rates, unit redundancy, etc.) for reduction of manganese present in the Osoyoos groundwater using a treatment centralized facility.



Source: Carollo 2024

Figure 1 Proposed Groundwater Process Flow Diagram

1.1 Blended Groundwater Water Quality

The raw water quality for the Town's groundwater supply varies based on the location and age of the groundwater wells. An estimate of the blended water quality from the combined operating wells and the parameter ranges from individual wells is presented in Table 1.

Table 1 Town of Osoyoos Groundwater Quality Ranges and Estimated Blended Characterization in 2023 (Carollo 2024, Table 3)

Parameter	MAC (AO)(4)	Blended Value(1)(2)	Sample Ranges (Individual Wells)(3)
Alkalinity (mg/L as $CaCO_3$)	-	187 (162 – 206)	174 – 252
Hardness (mg/L as $CaCO_3$)	(80-100)	**240** (230 – 253)	172 – **309**
Ammonia (mg/L as N)	0.1*	**0.35** (0.31 – 0.40)	0.03 – **0.66**
Chloride (mg/L)	(250)	17.3 (14.2 – 23.1)	6.3 – 50.9
Iron (mg/L)	(0.3)	0.08 (0.08 – 0.09)	< 0.01 – **0.30**
Manganese (mg/L)	0.12 (0.02)	**0.096** (0.086 – 0.109)	0.002 – **0.140**
Nitrate (mg/L as N)	10	1.19 (0.94 – 1.56)	< 0.01 – 5.45
Nitrite (mg/L as N)	1.0	0.01 (0.01 – 0.02)	< 0.01 – 0.03
Turbidity (NTU)	1.0	0.39 (0.28 – 0.55)	< 0.1 – 0.84
TDS (mg/L)	(500)*	323 (311 – 343)	241 – 433
TOC (mg/L)	4.0	3.87 (3.39 – 4.33)	2.53 – **4.52**
pH (mg/L)	(7.0-10.5)*	8.1 (7.8 – 8.2)	7.7 – 8.1

Notes:
(1) Minimum, mean, and maximum for blended values, weighted by supply flowrate.
(2) Blended value includes test wells 8 and 9, which only have one observation.
(3) 2023 water quality data collected for production wells Well 1, Well 3, Well 4, Well 5, Well 6, and Well 8 and test wells Well 9 and Well 10.
(4) Values with asterisk from Canadian Drinking Water Quality Guidelines (Health Canada 2022), otherwise values from the B.C. Drinking Water Officers' Guide (Ministry of Health 2023). Values above the guideline value are bold.
$CaCO_3$ - calcium carbonate; DOC - dissolved organic carbon; MAC - maximum acceptable concentration; mg/L - milligrams per liter ; N - nitrogen; NTU - nephelometric turbidity unit; TDS - total dissolved solids; TOC - total organic carbon.

2.0 INDUSTRY LITERATURE REVIEW

Data on non-proprietary manganese removing biofilters was collected from published literature, Carollo designs and Mangazur® (proprietary process piloted for Osoyoos) installations and pilots.

2.1 Loading Rates from Literature

Most biofiltration systems are simple processes constructed without proprietary equipment. In some cases these systems are seeded with media from existing facilities, which jumpstarts the biological activity for the manganese removal process, but often they rely on existing microorganisms in the water source colonizing the media. Accordingly, there is variation across reported data in biofilter performance. Additionally, biofilters are not often designed to maximize the loading rate due to non-financial considerations such as maintaining public health protection through biological filter stability, ease of operations, and resiliency to treat variable water quality conditions.

Bruins et al. (2014) conducted an extensive study of over 100 biofilters in the Netherlands, Belgium, Germany, Jordan and Serbia. The large sample size of this study allows broad conclusions to be made about what is typical for these systems. They found that effective manganese removal occurred when filter loading rate[1] was below 10.5 metres per hour (m/hour) and the empty bed contract time (EBCT)[2] was above 11.5 minutes. The data demonstrates that only filters with loading rates below 10.5 m/hour achieved complete manganese removal, but also that some filters with lower loading rates were still unable to achieve complete manganese removal due to the impact of other water quality parameters. The authors suggest that the impact of loading rate may be conflated with the impact of longer EBCTs. Therefore, these results suggest that a higher loading rate may achieve complete manganese removal provided the filter is deep enough to provide sufficient contact time, and that other relevant parameters effecting manganese removal are satisfied (i.e., pH, dissolved oxygen, iron loading, and ammonia removal). The study concludes that optimum manganese removal can be achieved when the following conditions are met:

Filter Design Criteria

- ✓ Filter Loading Rate < 10.5 m/hour
- ✓ EBCT > 11.5 minutes

Influent Water Quality

- ✓ Iron Loading < 2.7 kg/m^2

Filtered Water Conditions

- ✓ Ammonia Removal > 85%
- ✓ pH > 7.1
- ✓ Oxygen concentration > 1 mg O_2/L

Few studies have experimented with varying loading rates, but Evans et al. (2020) observed reduced manganese removal across surface water biofilters when loading rates were increased from 9.5 to 14.7 m/hour. Biofilters reported in literature are often operated at loading rates below 10.5 m/hour. Breda et al. (2019) reported on 10 biofilters in Denmark with loading rates below 5 m/hour. The biofilter studied by Ramsay et al. (2018), also located in Denmark, was operated at 5 m/hour. Haukelidsaeter et al. (2023) reported on a biofiltration plant in the Netherlands operated at a maximum of just 2.6 m/hour. Sorlini et al. (2015) discussed biofilters in Italy operating at 10 m/hour and Brandhuber et al. (2013) briefly described a biofiltration plant in Arizona designed for a loading rate of 9 m/hour.

One study demonstrated that manganese removal is still possible at loading rates as high as 24 m/hour, but this performance was not demonstrated at full-scale (Štembal et al. 2005). Mouchet (1992) mentioned three treatment plants with two stage filtration, first for iron then for manganese, where the manganese biofilters had loading rates between 10 and 24 m/hour. Keithly et al. (2023) described biofilters across the US operated at loading rates from 2.4 to 14.8 m/hour. Complete manganese removal was achieved by a full-scale filter and a pilot-scale filter operating at 11.7 and 14.8 m/hour, respectively. Brandhuber et al. (2013) noted a proprietary biofiltration system in Japan (CHEMILES, NAGAOKA Corporation) which had design loading rates between 5 and 16.7 m/hour.

Taken together, data from published studies suggest that the typical filter loading rates for manganese removing biofilters to be below 10.5 m/hour. Excellent manganese removal is possible at higher loading rates, however the manganese removal performance is dependent upon other factors such as ammonia concentrations, influent water quality, EBCT, filtrate pH and oxygen concentrations.

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[1] Filter Loading Rate (m/hour) is the vertical flow velocity across the filter media calculated as the flow rate per filter (m^3/hour) divided by the filter surface area (m^2)

[2] Empty bed contact time (minutes) is the total duration that the treated water is in contact with the filter media, calculated as the bed volume (m^3) divided by the flowrate (m^3/minute).

2.2 Carollo Reference Design

Carollo has designed and piloted biofilters which target manganese removal. One example is a biofilter system currently under construction in Minnesota. Water is sourced from a variety of wells which contain significant concentrations of iron (>0.7 mg/L), organic carbon (>3 mg/L), and ammonia (>3 mg/L), and moderate concentrations of manganese (>0.05 mg/L), making it a good candidate for biofiltration. Carollo conducted a 9-month pilot study to test biofiltration with GAC media. Testing included modifying loading rates. During the initial acclimation period, the loading rate had to be reduced from 9.8 m/hour to 3.8 m/hour before ammonia-oxidizing bioactivity was observed. After acclimation, loading rates were increased first to 13.1 m/hour but had to be reduced to 9.3 m/hour before effluent manganese concentrations approached the aesthetic objective (Figure 2). The loading rate of the pilot had to be further reduced to 4.6 m/hour before effluent manganese concentrations were reliably below the objective value. Based on this data, the full-scale facility was designed for a loading rate of 8.1 m/hour.

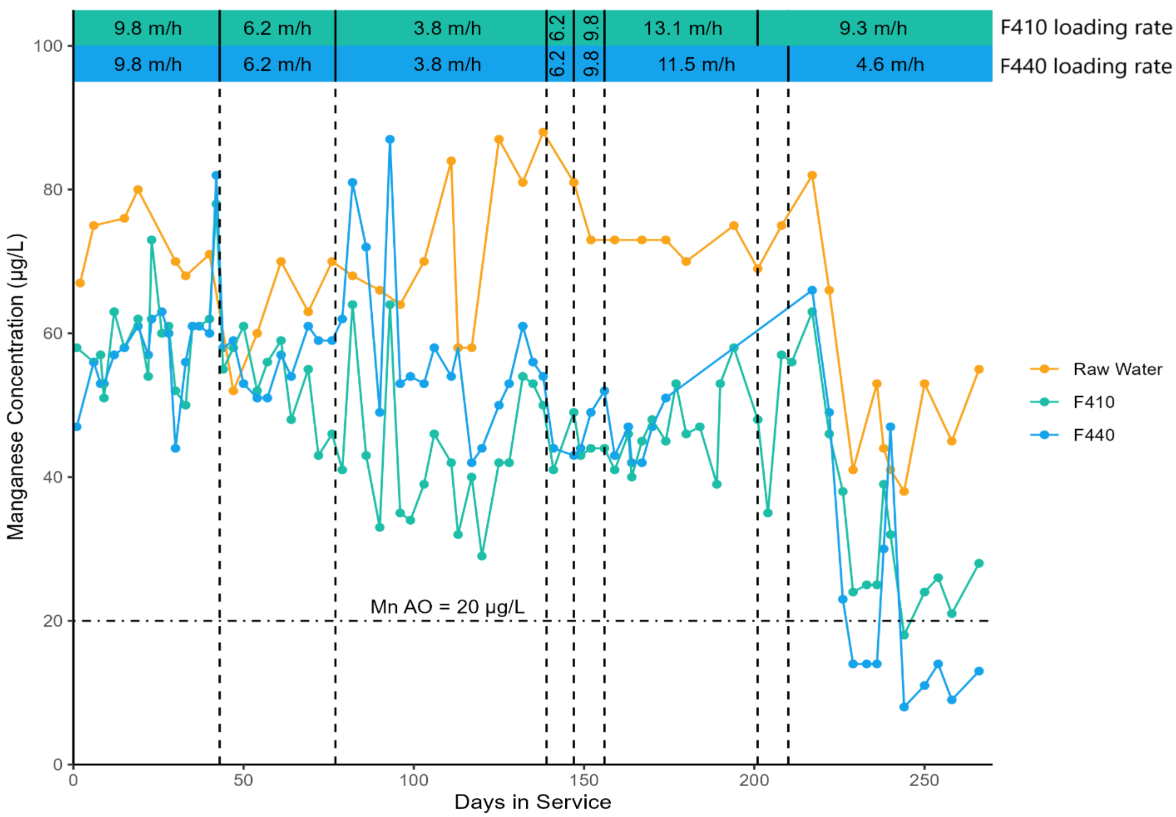

Figure 2 Manganese Treatment Results from Extended Biofiltration Piloting in Minnesota

2.3 Loading Rates from Mangazur® Systems

Mangazur® biofilters are package systems manufactured by SUEZ (now Veolia). These systems typically use proprietary filter media called BIOLITE™, which does not come pre-coated with manganese, in a pressure filter configuration. The only pre-treatment typically provided for these systems is aeration, which is normally done using process air (i.e., not pure oxygen). The manganese removal process for these systems is often jump-started by inoculating the filter with an established manganese removing microbial community.

There are limited publications on Mangazur® systems. Belanger (2022) reported on three systems located across New England which operated at loading rates ranging from 9.8 m/hour to 19.6 m/hour. One of the three plants described was designed to operate a manganese filter at a loading rate of 29.8 m/hour, however actual operation was below this value. Effluent manganese concentrations and EBCTs were not described in this study, therefore, it cannot be determined if these systems met the Health Canada manganese aesthetic objective of 20 micrograms per liter (µg/L). Ammonia concentrations were also not described for these systems.

McCormick et al. (2022) studied three biofilters in New Brunswick, which operated at loading rates of 7.2, 12.0, and 22.9 m/hour, corresponding to EBCTs of 12, 8 and 4 minutes, respectively. All three systems see almost complete manganese removal, with raw water manganese concentrations ranging from 0.37 to 0.95 mg/L. These systems had very low concentrations of ammonia (< 0.05 milligrams of nitrogen per liter [mg N/L]).

Mouchet (1992) described the use of Mangazur® biofilters in France, but only when there were low concentrations of iron and ammonia, reporting that typical filtration rates ranged from 10 to 40 m/hour when groundwater contained only manganese. Specifically, they highlighted a large plant in Sorgues which reduced manganese concentrations from 1.0 mg/L to below the aesthetic objective while operating at a filtration rate of 31 m/hour.

TRUE Consulting provided a short memo which described two Mangazur® biofiltration systems in BC, located in the District of 100 Mile House and the Caribou Regional District (TRUE 2024). These systems both have filter loading rates of 18 m/hour. No EBCT was provided for these systems, but annual reports from the two districts describe manganese removal to below the aesthetic objective from initial concentrations of approximately 0.30 and 0.45 mg/L, respectively (District of 100 Mile House 2023; Caribou Regional District 2023). No ammonia concentrations were reported for these systems.

Finally, a Mangazur® system was piloted in Osoyoos in 2012 (SUEZ 2013). The system was seeded with media from an installation in Maniwaki and it treated water from Well 8, which had manganese concentrations ranging from 90 to 200 µg/L. Ammonia concentrations in Well 8 were not reported during the study period, however sampling from Well 8 indicates a historical ammonia value of 0.18 mg/L as N. The pilot system was operated at a maximum filter loading rate of 30 m/hour and was able to achieve effluent manganese concentrations near but not consistently below the aesthetic objective.

2.4 Iron and Ammonia Impact Manganese Removal

Filter loading rate and EBCT vary significantly for manganese removing biofilters. There are multiple reasons for this, including different levels of risk tolerance, but one important factor is the co-occurrence of iron, ammonia, and manganese. These three contaminants are often present in groundwater because reducing conditions (low dissolved oxygen and low pH) cause iron and manganese to dissolve from the sediment or rock which is bearing the water and the reduction of nitrates to ammonia, which are often present because of agriculture.

Elevated concentrations of dissolved iron and ammonia have been demonstrated to delay the removal of dissolved manganese in biofilters. Specifically, manganese will be removed in a deeper portion of the filter, after the iron and ammonia have been fully removed (Ramsay et al. 2018). Accordingly, additional contact time (i.e., EBCT) is required to achieve biological manganese removal when iron and ammonia are also present. This can be accomplished by either increasing the filter bed depth or by reducing the filter loading rate. Some treatment plants provide separate biofilters for the removal of iron and manganese, with ammonia removal usually occurring within the iron biofilter (Breda et al. 2019; Mouchet 1992). The blended groundwater based on the existing well network is expected to have an average ammonia concentration of 0.35 mg N/L (Table 1), with levels expected to fluctuate between 0.31 and 0.40 mg/L.

2.5 Summary of Industry Data

Non-proprietary biofilters described in literature typically had loading rates below 10.5 m/hour, above which reduced manganese removal performance has been observed (Bruins et al. 2014). This is in agreement with a recent Carollo biofiltration design in Minnesota which validated a loading rate of 8.1 m/hour. However, data on Mangazur® biofilters specifically demonstrate excellent manganese removal to below the aesthetic objective at loading rates as high as 31 m/hour. It is critical to note that these high loading rates were achieved in groundwater with low concentrations of ammonia. Nonetheless, it is clear that biofilters can achieve manganese removal goals at loading rates exceeding 10.5 m/hour, but higher loading rates should be substantially demonstrated through pilot testing before proceeding with design.

Table 2 Manganese removing biofilter loading rates

Location	Source Water Type	Scale	Loading Rate (m/hour)	Reference
Netherlands (>100 facilities)	Ground	Full-scale	<10.5(1)	Bruins et al. 2014
California	Surface	Pilot-scale	9.5	Evans et al. 2018
Denmark (10 facilities)	Ground	Full-scale	<5	Breda et al. 2019
Denmark	Ground	Full-scale	5	Ramsay et al. 2018
Netherlands	Ground	Full-scale	2.6	Haukelidsaeter et al. 2023
Italy	Ground	Full-scale	10	Sorlini et al. 2015
Arizona	Ground	Full-scale	9	Brandhuber et al. 2013
Japan	Ground	Full-scale	<16.7	Brandhuber et al. 2013
Croatia	Ground	Pilot-scale	24	Štembal et al. 2005
France	Ground	Full-scale	<24	Mouchet 1992
United States	Ground	Full-scale	<11.7	Keithly et al. 2023
United States	Ground	Pilot-scale	14.8	Keithly et al. 2023
Minnesota	Ground	Pilot-scale	4.6	Carollo unpublished study
Minnesota	Ground	Full-scale	8.1	Carollo unpublished study
United States	Ground	Full-scale	<19.6(2)	Belanger 2022
New Brunswick	Ground	Full-scale	<22.9(2)	McCormick et al. 2022
France	Ground	Full-scale	31(2)	Mouchet 1992
British Columbia	Ground	Full-scale	18(2)	TRUE 2024
Osoyoos	Ground	Pilot-scale	30(2)(3)	SUEZ 2013

Notes:
(1) Only biofilters achieving Health Canada aesthetic objective included.
(2) Mangazur® biofilter.
(3) Manganese concentrations below current aesthetic objective were not achieved during this study.

3.0 TREATMENT PROCESS DESIGN CRITERIA EVALUATION

3.1 Redundancy Considerations

Redundancy is required for water treatment process equipment to allow for continual service through routine maintenance events and unplanned shutdowns. The Drinking Water Officers' Guide (DWOG) provides guidance for the redundancy of water treatment equipment (Ministry of Health 2023). For granular media filters, it is recommended that the facility be capable of meeting design flowrates with the largest filter out of service (i.e., N+1 redundancy) and that the filtration rate stay the same or not increase substantially during backwashing. Specifically, the guide recommends an increase of less than 10 percent in hydraulic loading rate to prevent the possibility of particulate breakthrough. Selection of an appropriate level of redundancy varies depending on the function provided by the equipment, the ease of replacement or repair, and overall system redundancy.

Where a treatment process is designed to achieve health-based objectives, as opposed to aesthetic objectives, the designer may elect to provide a higher level of redundancy within the respective unit processes. For example, chlorine disinfection systems often serve as the last line of defense providing both primary and secondary disinfection. Given the importance of effective chlorination to public health protection, these systems often include multiple layers of redundancy from dosing pumps and piping, carrier of flush water piping, injection quills, etc. For the proposed biological filters, the treatment performance targets both health and aesthetic based objectives, therefore warranting consideration to a higher level of redundancy.

Functionally, an aerobic biofilter has five types of components, the aeration system, piping, valves, instrumentation, and the filter vessel itself. Failure rates for aeration systems and filter vessels are not necessarily high, but they require frequent maintenance and their function can only be provided by additional equivalent equipment. The filter vessels themselves would be considered to have a long lead time and not readily replaceable. The connected piping and components are all relatively common parts and likely to be available in stock from local suppliers. For a biofilter, both the required duty vessels plus a standby filter vessel would typically be in-service, providing "online" redundancy. This ensures the standby filter remains biologically acclimated. When taking a filter vessel or connected pipe system out of service, the flowrate through the remaining online vessels would necessarily increase based on the proportion of online filters and the influent flowrate.

Finally, the overall system redundancy should be factored into the selection of the appropriate level of component or unit process redundancy. This includes consideration of factors such as: location of the water treatment facilities in relation to the configuration and orientation of the distribution network, number and location of groundwater supply wells, vulnerability of the water sources, and availability of secondary or backup water supply sources. The Town's groundwater supply network includes a total of six production wells and two test wells ready for development. All eight wells are located within a highly vulnerable aquifer with relatively shallow screen depths in relation to Osoyoos Lake levels and close proximity to the 1:200 year flood elevation. The Town's groundwater supply is the only source of potable water for the community.

For water systems that rely on a single centralized treatment facility, it is common to layout the facility using a multi-train configuration. This increases the redundancy within the piping and ancillary systems by reducing or eliminating singles points of failure. For the Town's, consideration of a two-train facility would provide a reasonable balance between system redundancy, operational complexity and turn-down ability.

3.2 Treatment Configuration and Loading Rate Scenarios

Based on the data presented, Carollo developed three design scenarios for the Town's consideration.

1. **Conservative Scenario**: Use a two-stage treatment approach, each with a loading rate of 14.8 m/hour, allowing ammonia and manganese to be removed in separate stages. This approach would provide the Town with the greatest operational flexibility because it is expected to allow the WTP to treat the Town's wells with poor water quality without needing to blend the water with higher quality wells. Using separate vessels for manganese and ammonia removal increases the capital and operational costs, however, it offers the greatest flexibility for groundwater well selection and highest reliability for removal of manganese in the finished water.
2. **Moderate Scenario**: This approach balances costs with performance by targeting manganese and ammonia removal in a single treatment stage operated at a 10 m/hour loading rate. The lower loading rate provides additional contact time to allow removal of both ammonia and manganese from the water. The ability to remove manganese and ammonia across the same biofilter is well supported by literature but this assumption carries some performance risk compared to the conservative two-stage biofiltration scenario. This approach will be less resilient to poor raw water quality than the conservative scenario and will benefit from blending water sources to achieve higher quality raw water. It is expected that this approach will reduce capital and operational costs compared to the two-stage filtration approach, despite the larger vessel size.
3. **Aggressive Scenario**: The third scenario considers a single stage filtration approach operated at a loading rate of 14.8 m/hour. This option has the highest risk of not achieving the manganese removal objectives due to the shorter contact time within the biofilters for both ammonia and manganese removal. This scenario would have the lowest initial capital cost, while also being the most vulnerable to changes in raw water quality. This approach would likely not be capable of treating the Town's most contaminated wells without blending with higher quality wells. This option has the highest potential for manganese release in the system and provides the least operational flexibility for the Town when selecting groundwater wells to meet water demands.

The conservative, moderate, and aggressive loading rates were applied to a theoretical maximum daily demand (MDD) of 25 million litres per day (MLD) to allow for comparison between design approaches. All options use the same size pressure filter, which was assumed to be 3.0 metre (m) diameter with a bed depth of 2.4 m. The treatment process assumed a two train configuration, with each train having an additional filter to satisfy redundancy requirements.

Table 3 Comparison of Design Criteria for the Scenarios

Parameter	Conservative	Moderate	Aggressive
Loading Rate (m/hour)	14.8	10.0	14.8
EBCT (minutes)	9(2)	14	9
Number of Vessels(1)	24	16	12
Level of Redundancy(1)	17%	12.5%	17%
Estimated Building Footprint (m^2)	1,400	1,000	900

Notes:
(1) Assumed that all systems have 2 treatment trains with 1 redundant unit process per train.
(2) Contact time based on each stage of treatment. The combined contact time for the filtered water is 18 minutes.
(3) Pilot testing would be recommended for all scenarios to confirm ammonia and manganese removal assumptions.

4.0 CONCLUSIONS

- Loading rates for manganese removing biofilters vary across the industry, from as low as 2.6 to as high as 31 m/hour.
- Installations with Mangazur® biofilters often operate at high loading rates compared to facilities with non-proprietary equipment.
- The high loading rates observed for the reference Mangazur® biofilters may be possible where there is limited competition from iron and ammonia.
- Biofilter manganese removal limits are affected by the filter loading rate, EBCT, concentration of ammonia, iron loading, dissolved oxygen and pH. The dissolved oxygen, iron loading, and pH are expected to remain within the recommended limits for optimum manganese removal.
- The blended Town of Osoyoos groundwater is expected to have an average ammonia concentration of 0.35 mg N/L, which may interfere with biological manganese removal unless additional contact time is provided.
- Single stage treatment with biofilter has been demonstrated to effectively remove both ammonia and manganese at the levels observed in the Town’s groundwater supply (e.g., Bruins et al. 2014).
- Redundancy requirements vary for water treatment equipment based on their function, likelihood of failure, and the ability to maintain reliable service with alternative measures. N+1 redundancy is the minimum required per the DWOG for the granular media filters operating to achieve health based objectives.

5.0 RECOMMENDATIONS

- Three design scenarios were presented for planning consideration. Each scenario offers a balance of cost, treatment performance, and reliability to achieve the quality water objectives for the Town of Osoyoos. The risk of reduced treated water quality and the potential need for additional costs increases from the conservative to the aggressive scenario. Accordingly, in the absence of pilot testing results demonstrating the ability to achieve the higher loading rates, Carollo recommends adopting the moderate design scenario, with a filter loading rate of 10 m/hour, to advance through the value planning exercise. This is expected to balance the observed reduction in manganese removal efficiency caused by the presence of ammonia in the source water.
- The filter design loading rate of 10 m/hour should be confirmed through pilot study which demonstrates effective removal of ammonia and manganese for a period of 6-8 months. To accurately assess removal performance this study should treat water representative of the expected blended water quality from the Town's existing and future groundwater well network.
- Configuration of a two-train facility with unit process system redundancy of N+1 for each train is recommended based on the unit process selection and the fact that the facility will serve as the sole source of drinking water for the Town.

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APPENDIX C

TM 3 - E&IC COST BENCHMARKING

VALUE PLANNING TECHNICAL MEMORANDUM 3

TOWN OF OSOYOOS

Pilot Study for Surface WTP

Permit to Practice 1004446
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2025-01-28

Project No.:	203185-00
Date:	January 28, 2025
Prepared By:	Sherif Freiga, P.Eng.
Reviewed By:	Stephen Horsman, P.Eng., PE, PMP
Subject:	E&IC Cost Benchmarking

1.0 BACKGROUND

The Town of Osoyoos (Town) is considering changing the source of their water supply from their existing groundwater supply to a new surface water supply, drawing from Osoyoos Lake. Preliminary cost estimation was completed by Carollo Engineers Canada Ltd. (Carollo) as part of the Source Water Feasibility Study (Carollo 2024).

The Source Water Treatment Feasibility Study included an electrical, instrumentation, and controls (EIC) cost component to address the electrical systems, instrumentation, and automation requirements for the water treatment plant. The EIC scope encompasses:

- Electrical Systems include power distribution, transformers, motor control centers (MCC), switchgears, and emergency power.
- Instrumentation includes flow meters, pressure transmitters, water quality sensors, and analyzers with chemical dosing.
- The Control System consists of supervisory control and data acquisition (SCADA) systems, programmable logic controllers (PLC), variable frequency drives (VFD), communication cabling and associated communication infrastructure.

For the proposed water supply and treatment facilities, the study assumed EIC costs would account for 20 percent of the total capital expenditure (CAPEX). This memorandum documents the basis for the EIC costs previously presented in the Source Water Assessment Feasibility Study (Carollo 2024). The initial EIC cost estimate was prepared based on experience with similar projects and industry benchmark data.

This document is designed to:

- Outline the core assumptions used in the estimate for the Town's project.
- Provide detailed benchmarking data from other projects and industry guidelines to support the EIC cost estimate.
- Inform and guide future cost estimation processes.

2.0 ASSUMPTIONS AND CORE CONSIDERATIONS

2.1 Project-Specific Assumptions

- The proposed treatment plant has a capacity of approximately 25 million liters per day (MLD).
- The design includes modern process monitoring and automation for efficiency and reliability.
- EIC costs include systems for intake pumping and treatment processes.
- Scoping definitions:
  - Electrical Power: Covers power distribution equipment such as transformers, MCCs, switchgear, cabling, and emergency power systems.
  - Instrumentation: Includes monitoring equipment like flow, pressure, and quality sensors as well as process analyzers.
  - Control Systems: Comprises SCADA systems, PLCs, and associated communication networks that permit a centralized and remote operation.

3.0 ASSUMPTIONS AND CORE CONSIDERATIONS

The following data validates the assumption of 20 percent EIC costs for the proposed water supply and water treatment infrastructure.

3.1 Industry Reports and Guidelines

3.1.1 American Water Works Association and Water Environment Federation

According to American Water Works Association’s Water Treatment Plant Design and Water Environment Federation's Design of Municipal Wastewater Treatment Plants, the typical EIC costs for water treatment facilities range between 15 percent and 25 percent of CAPEX. Facilities with basic automation, such as conventional filtration systems, generally fall within the lower range (15 - 18 percent), while those incorporating advanced treatment processes, such as membrane filtration, ultraviolet (UV) disinfection, or chemical treatment with extensive monitoring, align with the higher range of 20 - 25 percent.

3.1.2 RSMeans Cost Data

According to the RSMeans cost data, EIC cost estimates for advanced water treatment facilities-managed by membrane-based or highly automated plants-fall within a CAPEX range of 20 - 30 percent. Projects involving robust SCADA integration, VFDs, and complex instrumentation systems feature on the higher end of this scale due to facility complexity and automation requirements.

3.2 EIC Cost Benchmarking

Table 1 presents the recent comparable projects to inform the validation of EIC cost assumptions.

Table 1 EIC Costs for recent Carollo Projects

Location	Bid Year	Scope	Flowrate (MLD)	Total Construction Cost(1)	EIC Cost(1)	% EIC
Willmar, MN	2024	Groundwater treatment including aeration, biofiltration, chemical dosing, EIC.	8.0	$17,248,000	$3,700,000	21.5%
Kansas City, MO	2022	Electrical and lime slaker rehab for combined groundwater and surface system.	910	$13,081,000	$4,786,000	36.6%
Edmond, OK	2022	Reservoir intake replacement for surface water system.	115	$66,425,000	$11,496,000	17.3%
Edmond, OK	2020	Solids removal and handling for surface water system.	115	$38,175,000	$7,402,000	19.4%
Edmond, OK	2022	Main processes including electrical service, GAC, high lift pump station, recycled water pump station for surface water system.	115	$191,899,000	$43,613,000	22.7%
Centennial, CO	2022	Solids removal and handling for combined groundwater and surface system.	150	$17,321,000	$3,926,000	22.7%
Centennial, CO	2024	Chemical dosing, yard piping, EIC for combined groundwater and surface system.	150	$53,668,000	$8,305,000	15.5%
Brighton, CO	2024	Pellet softening, greensand, GAC for groundwater system.	75	$167,269,000	$44,873,000	26.8%

Notes:
(1) Costs in US dollars.
GAC - granular activated carbon.

3.2.1 Key Observations from Benchmarking

EIC costs for groundwater treatment plants generally vary between 22 percent and 27 percent. Advanced technologies driving these costs include biofiltration, GAC adsorption, and UV disinfection. The Brighton, CO project had an EIC cost of 26.8 percent because the plant included pellet softening and GAC systems, which is indicative of higher complexity and automation for such treatment processes.

EIC costs for surface water treatment plants generally vary between 15.5 percent and 22.7 percent, reflecting the relatively less complicated pre-treatment system but more complex filtration and disinfection processes. In fact, the Edmond 01B project showed an EIC cost of 22.7 percent due to advanced treatment processes, which proved the impact of higher automation and control system integration in surface water facilities.

3.2.2 Groundwater vs. Surface Water Treatment Systems

In general, EIC costs for ground water treatment systems, using biofiltration, catalytic manganese removal, GAC adsorption, UV disinfection, and residuals handling, range from approximately 22 percent to 27 percent of total CAPEX. EIC costs for surface water treatment systems using dissolved air flotation clarification, granular media filtration, powdered activated carbon/GAC, and residuals handling range from approximately 15 percent to 22 percent of total CAPEX.

3.2.3 Key Drivers of EIC Costs

The major drivers of EIC cost in water treatment projects are the level of automation, instrumentation requirements, energy optimization, and process complexity.

The level of automation is a key driver, whereby the integration of SCADA systems and remote operation capabilities significantly increases the cost of EIC. SCADA systems provide centralized monitoring, control, and data analysis, enabling real-time decision-making and operational efficiency that is so crucial in modern treatment facilities.

Also, instrumentation requirements, especially for plants where almost constant monitoring of parameters like turbidity, pH, chemical dosage, and flow rates are critical for maintaining process reliability for the conformation of water quality standards, can be a significant cost enhancer.

Standby power and energy optimization also influences the EIC costs. Standby power can comprise as much as 25 percent of the total Electrical costs for a new facility. Use of VFDs make the operation of plants more energy-efficient by automatically adjusting the speed of motors according to demand, reducing energy consumption and operational costs throughout a plant's lifetime, but at the cost of increased EIC capital costs.

The final factor that influences EIC system sophistication is treatment process complexity. Complex processes, such as membrane filtration and advanced oxidation, require much more sophisticated electrical and control systems than traditional treatments. These increase the initial investment and maintenance costs of the treatment plant. Together, these factors underscore the importance of a tailored approach to EIC system design and cost estimation. The proposed technologies for both groundwater and surface water would be considered low-to-moderate complexity, affirming the selection of the midpoint 20 percent basis for EIC cost estimation.

4.0 CONCLUSION AND RECOMMENDATIONS

From the benchmarking data and the specific requirements of the proposed 32 MLD water treatment plant, an assumption of 20 percent EIC costs is reasonable and reflects industry norms for similar projects of this scale and complexity. This is a mid-range value that balances the anticipated levels of automation and capacity of the plant, allowing sufficient instrumentation and control systems without overestimating costs.

As details of the design are advanced, it is recommended that the specific EIC cost allocation be refined based on validating the initial assumptions, updating benchmarks based on market conditions and project-specific data, and adjusting contingencies as to account for the cost of materials and labor for electrical and control systems.

APPENDIX D

TM 4 - UPDATED CAPITAL AND OPERATION COSTS FOR THE GROUNDWATER AND SURFACE WATER TREATMENT ALTERNATIVES

VALUE PLANNING TECHNICAL MEMORANDUM 4

TOWN OF OSOYOOS

Pilot Study for Surface WTP

Project No.:	203185-00
Date:	February 5, 2025
Prepared By:	Sherif Freiga, P.Eng., Martin Earle, PhD, EIT
Reviewed By:	Stephen Horsman, P.Eng., PE, PMP
Subject:	Updated Capital and Operational Costs for the Groundwater and Surface Water Treatment Alternatives

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PERMIT TO PRACTICE
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1.0 BACKGROUND

The Town of Osoyoos (Town) is considering changing the source of their water supply from their existing groundwater supply to a new surface water supply, drawing from Osoyoos Lake. Preliminary budgeting was completed by Carollo Engineers Canada Ltd. (Carollo) as part of the Source Water Feasibility Study (Carollo 2024).

The Source Water Treatment Feasibility Study included a cost component to compare the capital and operational costs of the water supply and treatment infrastructure for the existing groundwater system with a new surface water system. Through a Value Planning process, the general design criteria and the specific parameters for each of the groundwater and surface water systems have progressed beyond the Feasibility Study assumptions. This memorandum documents the results of these changes on the capital and operational costs for each of the evaluated water supply and treatment alternatives.

This document is designed to:

- Document the basis of cost for each of the water supply and treatment alternatives.
- Present the updated capital and operational costs for the surface water and groundwater alternatives.
- Support value-based decision making for the preferred water supply and treatment alternative.

2.0 BASIS OF COST ASSUMPTIONS AND CORE CONSIDERATIONS

2.1 General Assumptions

- The proposed treatment plant has a capacity of approximately 25 million litres per day (MLD) under the initial build scenario, with provision for stage 2 expansion to 32 MLD (2064) and stage 3 expansion to 37.5 MLD (2071) by expanding the water treatment plant (WTP) by 1 and 2 trains, respectively.
- A common location was selected at the 340 metres (m) Reservoir site for siting of a centralized treatment for both the groundwater and surface water treatment alternatives.
- Standby power required for raw water supply and treatment operation for the initial build.

- All process areas to be enclosed in temperature protected or climate controlled spaces to prevent freezing.
- Materials of construction assumed to include:
  - Cast-in-place slab on grade concrete main floor for filter process area and ancillary process areas.
  - Superstructure to include pre-cast, insulated concrete wall panels 4.5 m high for process areas and 3.5 m high for administrative areas.
  - Buried and submerged walls constructed of cast-in-place concrete.
  - Chemical containment areas lined with high-density polyethylene.
  - Roof constructed of open web steel joists with q-decking, R-40 roofing insulation and thermoplastic polyolefin roofing membrane.
  - Interior walls constructed of masonry block.
- Major electrical and process mechanical systems to have N+1 redundancy.
- Contractor overhead and profit of 10 percent applied to all direct costs.
- Insurance and bonding are estimated at 2 percent of direct costs.
- Contingency of 30 percent applied to the direct cost plus overhead.
- Engineering services of 15 percent applied to the direct costs plus overhead.
- Per- and polyfluoroalkyl substances treatment is excluded.
- Land purchase costs are excluded.
- Specialty field investigations (geotechnical, environmental, archaeological, etc.) are excluded.

2.2 Groundwater Treatment

- Raw water supply assumptions include:
  - Dedicated raw water transmission main provided to connect existing Well 1, Well 3, Well 4, Well 5, Well 6, and Well 8.
  - A total of two existing wells require rehabilitation within the initial build scenario and 2 existing wells rehabilitated at each of the Stage 2 and ultimate build scenarios.
  - Four new production wells required at initial build, which are planned to be sited at Well 7, Test Well 9 and Test Well 10 locations and connected to the raw water transmission main.
  - Four new production wells are required for each of the Stage 2 and Ultimate build scenarios.
- Civil, structural, and architectural quantities were scaled from Feasibility Report assumptions to determine process area footprints from the 25 MLD, 32 MLD and 37.5 MLD treatment scenarios.
- Filter process area of 560 square metres (m^2)provided that consists of 2-trains of 8 biological filtration pressure vessels designed to operate at 10 metres per hour (m/hr) with one vessel out of service for each train.
- Stage 2 expansion includes construction of an additional 960 m^2 filter process area capable of housing sufficient filtration capacity for the Stage 2 and ultimate design flows.
- Ancillary process areas of 400 m^2 provided to house inlet piping manifold, blower equipment, chlorine storage and dosing, maintenance shop and UV disinfection.
- Administration area of 400 m^2 provided on mezzanine level for office area for operations staff, control room, laboratory, electrical room and mechanical room.

2.3 Surface Water Treatment

- Raw water supply assumptions include:
  - Raw water pump station to be constructed adjacent to the foreshore at Intake Pump Station 8 consisting of cast-in-place wetwell complete with:
    - New 750 millimetres (mm) pipe intake pipe installed 240 m from shore to a depth of 30 m below the normal water level in Osoyoos Lake.
    - Four vertical turbine raw water supply pumps operating on variable frequency drives required to convey flows for the initial build scenario. Stage 2 and ultimate build scenarios to include replacement of the existing pumps with proportionally larger units.
  - Dedicated 600 mm raw water transmission main provided from Intake Pump Station 8 to the centralized water treatment plant. Raw water transmission main is sized for the initial build at 1.1 metres per second (m/s) maximum velocity and could accommodate stage 3 expansion to 37.5 MLD at increased flow velocities up to 1.6 m/s.
- Civil, structural, and architectural quantities were scaled from Feasibility Report assumptions to determine process area footprints from the 25 MLD, 32 MLD and 37.5 MLD treatment scenarios.
- Filter process area of 600 m^2 provided that consists of 4-trains of 2-stage flocculation, dissolved air flotation and deep bed granular media filtration and pipe gallery. DAF and filtration unit processes sized based on process loading rate of 10 m/hr, until demonstrated otherwise through pilot testing.
- Ancillary process areas of 600 m^2 provided to consist of side stream rapid mixing, chemical storage and dosing area (coagulant, coagulant aid, flocculant aid, and sodium hypochlorite), high-rate residuals treatment, backwash supply, UV disinfection and maintenance shop.
- Process tankage includes a 103 cubic metres (m^3) baffled CT tank, 1,500 m^3 wastewater holding, 1,500 m^3 backwash supply water tank.
- Administration area of 600 m^2 provided on the operating deck level for office area for operations staff, control room, laboratory, electrical room and mechanical room.

2.4 Comparison of Capital Cost

Table 1 and Table 2 present the estimated capital cost for each of the groundwater and surface water treatment alternatives. Detailed breakdowns of the capital costs estimates are provided in Attachment A.

Table 1 Groundwater Treatment Estimate of Capital Cost

Item No.	Discipline	25 MLD (Base)	32 MLD (Stage 2)	37.5 MLD (Stage 3)	TOTAL
01	General Requirements	$1,260,000	$550,000	$480,000	$2,290,000
02	Civil and Environmental	$9,937,000	$3,989,000	$4,495,000	$18,421,000
03	Structural	$2,164,000	$1,274,000	$150,000	$3,588,000
04	Architectural	$1,268,000	$907,000	$0	$2,175,000
05	Process Mechanical	$12,887,000	$3,312,000	$3,312,000	$19,511,000
06	Building Mechanical	$1,806,000	$1,140,000	$0	$2,946,000
07	Electrical and Instrumentation	$9,586,000	$4,055,000	$3,221,600	$16,862,600

Item No.	Discipline	25 MLD (Base)	32 MLD (Stage 2)	37.5 MLD (Stage 3)	TOTAL
	Sub-Total	**$38,908,000**	**$15,227,000**	**$11,658,600**	**$65,793,600**
	Contractor OH&P (10%)	$3,891,000	$1,523,000	$1,166,000	$6,579,000
	Sub-Total	**$42,799,000**	**$16,750,000**	**$12,824,600**	**$72,372,600**
	Engineering (15%)	$6,420,000	$2,513,000	$1,924,000	$10,856,000
	Contingency (30%)	$12,840,000	$5,025,000	$3,847,000	$21,712,000
	Total Estimated Construction Cost	**$62,059,000**	**$24,288,000**	**$18,595,600**	**$104,940,600**

Table 2 Surface Water Treatment Estimate of Capital Cost

Item No.	Discipline	25 MLD (Base)	32 MLD (Stage 2)	37.5 MLD (Stage 3)	TOTAL
01	General Requirements	$1,280,000	$225,000	$225,000	$1,730,000
02	Civil and Environmental	$8,138,000	$250,000	$250,000	$8,638,000
03	Structural	$4,541,000	$794,000	$794,000	$6,129,000
04	Architectural	$1,515,000	$313,500	$313,500	$2,142,000
05	Process Mechanical	$15,100,000	$2,606,000	$2,606,000	$20,312,000
06	Building Mechanical	$1,935,000	$432,000	$432,000	$2,799,000
07	Electrical and Instrumentation	$7,523,000	$694,000	$694,000	$8,911,000
	Sub-Total	**$40,032,000**	**$5,314,500**	**$5,314,500**	**$50,661,000**
	Contractor OH&P (10%)	$4,003,000	$531,000	$531,000	$5,066,000
	Sub-Total	**$44,035,000**	**$5,845,500**	**$5,845,500**	**$55,727,000**
	Engineering (15%)	$6,605,000	$877,000	$877,000	$8,359,000
	Contingency (30%)	$13,211,000	$1,754,000	$1,754,000	$16,718,000
	Total Estimated Construction Cost	**$63,851,000**	**$8,476,500**	**$8,476,500**	**$80,804,000**

3.0 LIFE CYCLE COST COMPARISON

3.1 General Assumptions

- Flow projections based on 2023 maximum daily flow of 19.7 MLD with a 2.55 peak factor between maximum and average daily flows.
- 10 percent water conservation applied to the current average daily water usage and 2 percent growth rate assumed for all consumables, paralleling population growth assumptions.
- Design horizons for staged upgrades are based on the following:
  - » Initial build serves 25 years through 2050, providing 25 MLD.
  - » Stage 2 build adds one additional treatment train, increasing flowrate to 32 MLD, with the upgrade expected in 2064.
  - » Stage 3 build adds an additional treatment train, increasing flowrate to 37.5 MLD, with the upgrade expected in 2071.

- A 3 percent discount rate applied to account for time value of money.
- Building heating and cooling costs based on 0.5 kilowatts per square meter and lighting energy usage estimated based on 0.08 watts per square meter.
- Electricity costs based on $0.08355 per kilowatt-hour (2023 billing rate).
- Full burden labour cost for 1 full-time equivalent of $350,000.
- Chemical costs:
  - 12 percent bulk sodium hypochlorite $0.77 per litre (L).
  - PaCl Coagulant $1.05/L
  - Coagulant aid polymer $5.1 per kilogram (kg)
  - Flocculant aid polymer $8.15/kg
- Equipment replacement cost allocated at 2 percent per annum of the process mechanical, building mechanical, electrical and instrumentation direct costs.

3.2 Comparison of Net Present Values

Table 3 and Table 4 present the estimated net present value for each of the groundwater and surface water treatment alternatives for the 25 MLD base (2025-2050), 32 MLD stage 2 (2025-2064), and 37.5 stage 3 (2025-2071) periods. Detailed breakdowns of the life cycle cost allocations for each alternative are included in Attachment B.

Table 3 Groundwater Estimate of Net Present Value Costs

Item No.	Parameter	25 MLD (Base)	32 MLD (Stage 2)	37.5 MLD (Stage 3)
01	Initial Capital	$62,059,000	$62,059,000	$62,059,000
02	Operations and Maintenance	$22,584,000	$32,570,000	$37,074,000
03	Future Expansions	$0	$7,446,000	$11,946,000
	Total Life Cycle	$84,643,000	$102,075,000	$111,079,000

Table 4 Surface Estimate of Net Present Value Costs

Item No.	Parameter	25 MLD (Base)	32 MLD (Stage 2)	37.5 MLD (Stage 3)
01	Initial Capital	$63,853,000	$63,853,000	$63,853,000
02	Operations and Maintenance	$25,093,000	$36,188,000	$41,193,000
03	Future Expansions	$0	$2,599,000	$4,712,000
	Total Life Cycle	$88,946,000	$102,640,000	$109,758,000

ATTACHMENT A CAPITAL COST ESTIMATES

COST ESTIMATE SUMMARY

ESTIMATE CLASS : 4

PROJECT : Osoyoos Source Water and Treatment Feasibility Study

JOB # : 203185

DATE : 01/24/2025

LOCATION : Town of Osoyoos

BY : ME

ELEMENT : Groundwater Treatment

REVIEWED: SH

Division	Discipline	32 MLD 2024 Feasibility	25 MLD	32 MLD	37.5 MLD
01	General Requirements	$1,510,000	$1,260,000	$550,000	$480,000
02	Civil & Site Work	$5,579,000	$5,537,000	$2,389,000	$2,195,000
03	Concrete	$1,895,000	$1,832,000	$1,124,000	$0
04	Masonry	$101,000	$95,000	$0	$0
05	Metals	$250,000	$237,000	$150,000	$150,000
06	Wood, Plastics and Composites	$200,000	$190,000	$120,000	$0
07	Thermal and Moisture Protection	$1,097,000	$818,000	$652,000	$0
08	Doors and Windows	$150,000	$150,000	$90,000	$0
09	Finishes	$75,000	$75,000	$45,000	$0
11	Process Mechanical Equipment	$22,996,000	$12,887,000	$3,312,000	$3,312,000
12	Furnishings	$35,000	$35,000	$0	$0
13	Special Construction	$5,900,000	$4,400,000	$1,600,000	$2,300,000
15	Building Mechanical & Plumbing	$1,900,000	$1,806,000	$1,140,000	$0
16	Electrical	$6,375,000	$6,275,000	$1,955,000	$1,235,000
17	Instrumentation	$3,500,000	$3,311,000	$2,100,000	$1,986,600
	Total Direct Costs	$51,563,000	$38,908,000	$15,227,000	$11,658,600
	General Contract Overhad and Profit 10%	$5,157,000	$3,891,000	$1,523,000	$1,166,000
	Subtotal	$56,720,000	$42,799,000	$16,750,000	$12,824,600
	Engineering Costs 15%	$8,508,000	$6,420,000	$2,513,000	$1,924,000
	Contingency 30%	$17,016,000	$12,840,000	$5,025,000	$3,848,000
TAL ESTIMATED CONSTRUCTION COST (EXCL. GST)		$82,244,000	$62,059,000	$24,288,000	$18,596,600

The cost estimate herein is based on our assessment of current market conditions at the project location. This estimate reflects our professional opinion of accurate costs at this time and is subject to change as the project design matures. Carollo Engineers has no control over variances in the cost of labor, materials, equipment, services provided by others, contractor's methods of determining prices, competitive bidding or market conditions, practices or bidding strategies. Carollo Engineers cannot and does not warrant or guarantee that proposals, bids or actual construction costs will not vary from the costs presented herein.

COST ESTIMATE DETAILED BREAKDOWN

PROJECT : Osoyoos Source Water and Treatment Feasibility Study
JOB # : 203185
LOCATION : Town of Osoyoos
ELEMENT : Groundwater Treatment

DATE : 01/24/2025
BY : ME
REVIEWED SH

				32 MLD (2024 Feasibility Study)			25 MLD (Base)			32 MLD (Stage 2)			37.5 MLD (Stage 3)		
SPEC. NO.	DESCRIPTION	UNIT	UNIT COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST
01000	**GENERAL REQUIREMENTS**														
	Bonding & Insurance	LS	2% of Direct Cost	1	$1,010,000		1	$760,000		1	$300,000		1	$230,000	
	Survey Layout and Project Record Documents	LS	$50,000	1	$50,000		1	$50,000		1	$25,000		1	$25,000	
	Temporary Utilities, Lighting, Structures, Facilitites	LS	$50,000	1	$50,000		1	$50,000		1	$25,000		1	$25,000	
	Traffic Control	LS	$150,000	1	$150,000		1	$150,000		1	$75,000		1	$75,000	
	Mob/De-mob	LS	$250,000	1	$250,000		1	$250,000		1	$125,000		1	$125,000	
	Total General Requirements					**$1,510,000**			**$1,260,000**			**$550,000**			**$480,000**
02000	**SITEWORK**														
	Earthwork														
	WTP Common Excavation & Backfill, Dispose Unsuitable, Import Suitable	cu.m	$60	1,200	$72,000		1,090	$66,000		690	$42,000		0	$0	
	WTP Common Excavation, Dispose Unsuitable, Import Suitable	cu.m	$55	4,800	$264,000		4,350	$240,000		2,760	$152,000		0	$0	
	Clearing, Grubbing, Shrub Removal,	LS	$150,000	1	$150,000		1	$142,000		1	$150,000		1	$150,000	
	Top soil Stripping, Dispose Off-site (approx. 200mm Depth)	cu.m	$50	600	$30,000		567	$29,000		360	$18,000		360	$18,000	
	Subgrade Preparation	sq.m.	$2.0	2,600	$5,200		2,459	$5,000		1,560	$4,000		1,560	$4,000	
	Subbase, approx. 250mm Depth	sq.m.	$20	2,600	$52,000		2,459	$50,000		1,560	$32,000		1,560	$32,000	
	Base, approx. 75mm Depth	sq.m.	$8.0	2,600	$20,800		2,459	$20,000		1,560	$13,000		1,560	$13,000	
	Utilities														
	200mm PVC DR 18 Watermain	l.m	$300	2,100	$630,000		2,100	$630,000		700	$210,000		700	$210,000	
	300mm PVC DR 18 Watermain	l.m	$500	300	$150,000		300	$150,000		100	$50,000		100	$50,000	
	450mm PVC DR 18 Watermain	l.m	$650	1,300	$845,000		1,300	$845,000		430	$280,000		430	$280,000	
	500mm PVC DR 18 Watermain	l.m	$800	400	$320,000		400	$320,000		130	$104,000		130	$104,000	
	600mm PVC DR 18 Watermain	l.m	$1,200	1,700	$2,040,000		1,700	$2,040,000		570	$684,000		570	$684,000	

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COST ESTIMATE DETAILED BREAKDOWN

PROJECT : Osoyoos Source Water and Treatment Feasibility Study
JOB # : 203185
LOCATION : Town of Osoyoos
ELEMENT : Groundwater Treatment

DATE : 01/24/2025
BY : ME
REVIEWED SH

				32 MLD (2024 Feasibility Study)			25 MLD (Base)			32 MLD (Stage 2)			37.5 MLD (Stage 3)		
SPEC. NO.	DESCRIPTION	UNIT	UNIT COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST
	Watermain Tie-ins & Thrust Blocks Allowance	LS	$1,000,000	1	$1,000,000		1	$1,000,000		1	$650,000		1	$650,000	
	Total Sitework					$5,579,000			$5,537,000			$2,389,000			$2,195,000
03000	**CONCRETE**														
	Cast-in Place Concrete Wall	cu.m	$2,400		$0			$0			$0			$0	
	Suspended Cast-in-Place Floor	cu.m	$2,800		$0		80	$224,000			$0			$0	
	Concrete Slab on Grade Floor (Edge Thickened)	cu.m	$1,800	780	$1,404,467		612	$1,102,000		432	$778,000		0	$0	
	Pre-cast Tilt-up Concrete Walls, 3.5 m H (incl. Insulation & Installation)	l.m	$1,600	0	$0		100	$160,000		0	$0		0	$0	
	Pre-cast Tilt-up Concrete Walls, 4.5 m H (incl. Insulation & Installation)	l.m	$2,000	200	$400,200		128	$256,000		128	$256,000		0	$0	
	Equipment Pad	ea.	$1,500	10	$15,000		10	$15,000		10	$15,000		0	$0	
	Misc. Concrete Allowance (Containment, Landings, etc)	ea.	$75,000	1	$75,000		1	$75,000		1	$75,000		0	$0	
	Total Concrete					$1,895,000			$1,832,000			$1,124,000			$0
04000	**MASONRY**														
	Concrete block (Non-structural)	sq.m	$500	200	$100,050		189	$95,000		0	$0		0	$0	
	Total Masonry					$101,000			$95,000			$0			$0
05000	**METALS**														
	Miscellaneous Metals	LS	$250,000	1	$250,000		1	$237,000		1	$150,000		1	$150,000	
	Total Metals					$250,000			$237,000			$150,000			$150,000
06000	**WOOD, PLASTICS and COMPOSITES**														
	Miscellaneous Wood, Plastics and Composites	LS	$200,000	1	$200,000		1	$190,000		1	$120,000		0	$0	
	Total Wood, Plastics & Composites					$200,000			$190,000			$120,000			$0

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COST ESTIMATE DETAILED BREAKDOWN

PROJECT : Osoyoos Source Water and Treatment Feasibility Study
JOB # : 203185
LOCATION : Town of Osoyoos
ELEMENT : Groundwater Treatment

DATE : 01/24/2025
BY : ME
REVIEWED SH

				32 MLD (2024 Feasibility Study)			25 MLD (Base)			32 MLD (Stage 2)			37.5 MLD (Stage 3)		
SPEC. NO.	DESCRIPTION	UNIT	UNIT COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST
07000	**THERMAL AND MOISTURE PROTECTION**														
	Roofing	sq.m	$575	1,734	$996,998		1,248	$718,000		960	$552,000		0	$0	
	Gutter and drains	LS	$75,000	1	$75,000		1	$75,000		1	$75,000		0	$0	
	Sealants	LS	$25,000	1	$25,000		1	$25,000		1	$25,000		0	$0	
	Total Thermal And Moisture Protection					**$1,097,000**			**$818,000**			**$652,000**			**$0**
08000	**DOORS & WINDOWS**														
	Doors & Windows Allowance	LS	$150,000	1	$150,000		1	$150,000		1	$90,000		0	$0	
	Total Doors & Windows					**$150,000**			**$150,000**			**$90,000**			**$0**
09000	**FINISHES**														
	Interior Painting and Trims	LS	$75,000	1	$75,000		1	$75,000		1	$45,000		0	$0	
	Total Finishes					**$75,000**			**$75,000**			**$45,000**			**$0**
11000	**PROCESS MECHANICAL EQUIPMENT**														
	Treatment Process														
	Pressure biofilter	LS	$11,220,000	1	$11,220,000		78%	$8,766,000		20%	$2,192,000		20%	$2,192,000	
	Pressure Mn dioxide contactor	LS	$5,610,000	1	$5,610,000		0	$0			$0			$0	
	UV reactors	LS	$489,000	1	$489,000		1	$489,000		50%	$245,000		50%	$245,000	
	Sodium hypochlorite storage	LS	$10,000	1	$10,000		1	$10,000			$0			$0	
	Chemical metering pumps	LS	$31,000	1	$31,000		1	$31,000			$0			$0	
	Backwash Pumps	LS	$153,000	1	$153,000		1	$153,000			$0			$0	
	Treatment Residuals														
	Wash water storage	LS	$450,000	1	$450,000		1	$352,000		20%	$88,000		20%	$88,000	
	Wash water equalization	LS	$450,000	1	$450,000		1	$352,000		20%	$88,000		20%	$88,000	
	Process Piping, Valves, Flow Meter, and Appurtenances Allowance	LS	$750,000	1	$750,000		1	$586,000		20%	$147,000		20%	$147,000	
	Equipment Installation & Commissioning	LS	0% of Equipme	1	$3,833,000		1	$2,148,000		1	$552,000		1	$552,000	
	Total Process Equipment					**$22,996,000**			**$12,887,000**			**$3,312,000**			**$3,312,000**

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COST ESTIMATE DETAILED BREAKDOWN

PROJECT : Osoyoos Source Water and Treatment Feasibility Study
JOB # : 203185
LOCATION : Town of Osoyoos
ELEMENT : Groundwater Treatment

DATE : 01/24/2025
BY : ME
REVIEWED SH

				32 MLD (2024 Feasibility Study)			25 MLD (Base)			32 MLD (Stage 2)			37.5 MLD (Stage 3)		
SPEC. NO.	DESCRIPTION	UNIT	UNIT COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST
12000	**FURNISHINGS**														
	Furnishings Allowance	LS	$35,000	1	$35,000		1	$35,000			$0			$0	
	Total Furnishings					**$35,000**			**$35,000**			**$0**			**$0**
13000	**SPECIAL CONSTRUCTION**														
	New Groundwater Wells	LS	$800,000	5	$4,000,000		4	$3,200,000		2	$1,600,000		2	$1,600,000	
	Replace Existing End-of-Life Wells	LS	$350,000	4	$1,400,000		2	$700,000		0	$0		2	$700,000	
	Convert Reservoir to Baffled Storage	LS	$500,000	1	$500,000		1	$500,000			$0			$0	
	Total Special Construction					**$5,900,000**			**$4,400,000**			**$1,600,000**			**$2,300,000**
15000	**MECHANICAL**														
	Building Plumbing	LS	$150,000	1	$150,000		1	$150,000		60%	$90,000		0%	$0	
	Building Heating, Ventilation, A/C	LS	$1,750,000	1	$1,750,000		95%	$1,656,000		60%	$1,050,000		0%	$0	
	Total Mechanical					**$1,900,000**			**$1,806,000**			**$1,140,000**			**$0**
16000	**ELECTRICAL**														
	Groundwater Wells														
	Groundwater Wells New Power Pole Service and Transformer	ea.	$100,000	5	$500,000		4	$400,000		2	$200,000		2	$200,000	
	Electrical	LS	$1,500,000	1	$1,500,000		1	$1,500,000		50%	$750,000		50%	$750,000	
	Well Pump and Electrical Upgrades	LS	$1,750,000	1	$1,750,000		1	$1,750,000			$0			$0	
	Treatment Process														
	WTP New Power Pole Service and Transformer	LS	$200,000	1	$200,000		1	$200,000			$0			$0	
	Electrical	LS	$2,000,000	1	$2,000,000		1	$2,000,000		48%	$960,000		12%	$240,000	
	Standby Power Generation	LS	$350,000	1	$350,000		1	$350,000			$0			$0	
	Electrical Permitting, Testing, Commissioning, O&M Manuals	LS	$75,000	1	$75,000		1	$75,000		1	$45,000		1	$45,000	
	Total Electrical					**$6,375,000**			**$6,275,000**			**$1,955,000**			**$1,235,000**

COST ESTIMATE DETAILED BREAKDOWN

PROJECT : Osoyoos Source Water and Treatment Feasibility Study
JOB # : 203185
LOCATION : Town of Osoyoos
ELEMENT : Groundwater Treatment

DATE : 01/24/2025
BY : ME
REVIEWED SH

				32 MLD (2024 Feasibility Study)			25 MLD (Base)			32 MLD (Stage 2)			37.5 MLD (Stage 3)		
SPEC. NO.	DESCRIPTION	UNIT	UNIT COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST
16000	**INSTRUMENTATION**														
	Instrumentation and Integration	LS	$3,500,000	1	$3,500,000		1	$3,311,000		48%	$1,680,000		12%	$420,000	
	Total Instrumentation					**$3,500,000**			**$3,311,000**			**$2,100,000**			**$1,986,600**
Sub-Total Estimate (Excl. GST, Engineering & Contingency)						**$51,563,000**			**$38,908,000**			**$15,227,000**			**$11,659,000**

COST ESTIMATE SUMMARY

PROJECT : **Osoyoos Source Water and Treatment Feasibility Study**

ESTIMATE CLASS : 4

JOB # : **203185**

DATE : 01/24/2025

LOCATION : **Town of Osoyoos**

BY : ME

ELEMENT : **Surface Water Treatment**

REVIEWED: SH

Division	Discipline	32 MLD 2024 Feasibility	25 MLD	32 MLD	37.5 MLD
01	General Requirements	$1,370,000	$1,280,000	$225,000	$225,000
02	Civil & Site Work	$7,040,000	$6,088,000	$250,000	$250,000
03	Concrete	$4,365,000	$4,188,000	$725,000	$725,000
04	Masonry	$176,000	$140,000	$40,000	$40,000
05	Metals	$250,000	$213,000	$29,000	$29,000
06	Wood, Plastics and Composites	$150,000	$150,000	$37,500	$37,500
07	Thermal and Moisture Protection	$1,301,000	$1,022,000	$238,000	$238,000
08	Doors and Windows	$150,000	$150,000	$21,000	$21,000
09	Finishes	$125,000	$118,000	$17,000	$17,000
11	Process Mechanical Equipment	$17,242,400	$15,100,000	$2,606,000	$2,606,000
12	Furnishings	$75,000	$75,000	$0	$0
13	Special Construction	$2,050,000	$2,050,000	$0	$0
15	Building Mechanical & Plumbing	$2,325,000	$1,935,000	$432,000	$432,000
16	Electrical	$5,425,000	$4,974,000	$394,000	$394,000
17	Instrumentation	$3,000,000	$2,549,000	$300,000	$300,000
	Total Direct Costs	$45,044,400	$40,032,000	$5,314,500	$5,314,500
	General Contract Overhad and Profit 10%	$4,505,000	$4,004,000	$532,000	$532,000
	Subtotal	$49,549,400	$44,036,000	$5,846,500	$5,846,500
	Engineering Costs 15%	$7,433,000	$6,606,000	$877,000	$877,000
	Contingency 30%	$14,865,000	$13,211,000	$1,754,000	$1,754,000
TAL ESTIMATED CONSTRUCTION COST (EXCL. GST)		$71,847,400	$63,853,000	$8,477,500	$8,477,500

The cost estimate herein is based on our assessment of current market conditions at the project location. This estimate reflects our professional opinion of accurate costs at this time and is subject to change as the project design matures. Carollo Engineers has no control over variances in the cost of labor, materials, equipment, services provided by others, contractor's methods of determining prices, competitive bidding or market conditions, practices or bidding strategies. Carollo Engineers cannot and does not warrant or guarantee that proposals, bids or actual construction costs will not vary from the costs presented herein.

COST ESTIMATE DETAILED BREAKDOWN

PROJECT : Osoyoos Source Water and Treatment Feasibility Study
JOB # : 203185
LOCATION : Town of Osoyoos
ELEMENT : Surface Water Treatment

DATE : 01/24/2025
BY : ME
REVIEWED: SH

				32 MLD (2024 Feasibility Study)			25 MLD (Base)			32 MLD (Stage 2)			37.5 MLD (Stage 3)		
SPEC. NO.	DESCRIPTION	UNIT	UNIT COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST
01000	**GENERAL REQUIREMENTS**														
	Bonding & Insurance	LS	2% of Direct Cost	1	$870,000		1	$780,000		1	$100,000		1	$100,000	
	Survey Layout and Project Record Documents	LS	$50,000	1	$50,000		1	$50,000		0	$12,500		0	$12,500	
	Temporary Utilities, Lighting, Structures, Facilitites	LS	$50,000	1	$50,000		1	$50,000		0	$12,500		0	$12,500	
	Traffic Control	LS	$150,000	1	$150,000		1	$150,000		0	$37,500		0	$37,500	
	Mob/De-mob	LS	$250,000	1	$250,000		1	$250,000		0	$62,500		0	$62,500	
	Total General Requirements					**$1,370,000**			**$1,280,000**			**$225,000**			**$225,000**
02000	**SITEWORK**														
	Earthwork														
	Pump Station Common Excavation & Backfill, Dispose Unsuitable, Import Suitable	cu.m	$60	3,200	$192,000		3,200	$192,000			$0			$0	
	WTP Common Excavation, Dispose Unsuitable, Import Suitable	cu.m	$55	2,360	$129,800		2,360	$130,000		590	$33,000		590	$33,000	
	WTP Rock Blasting, Dispose	cu.m	$110	9,440	$1,038,400		5,900	$649,000		1,475	$163,000		1,475	$163,000	
	Clearing, Grubbing, Shrub Removal	LS	$175,000	1	$175,000		63%	$150,000		16%	$28,000		16%	$28,000	
	Top soil Stripping, Dispose Off-site (approx. 200mm Depth)	cu.m	$50	800	$40,000		500	$25,000		125	$7,000		125	$7,000	
	Subgrade Preparation	sq.m.	$2.0	3,800	$7,600		2,375	$5,000		594	$2,000		594	$2,000	
	Subbase, approx. 250mm Depth	sq.m.	$20	3,800	$76,000		2,375	$48,000		594	$12,000		594	$12,000	
	Base, approx. 75mm Depth	sq.m.	$8.0	3,800	$30,400		2,375	$19,000		594	$5,000		594	$5,000	
	Utilities														
	600mm DI Class 250 Watermain Open Excavation Installation & Surface Restoration	l.m	$1,200	4,000	$4,800,000		3,600	$4,320,000		0	$0		0	$0	
	600mm DI Class 250 Watermain Tie-ins & Thrust Blocks Allowance	LS	$550,000	1	$550,000		1	$550,000		0	$0		0	$0	
	Total Sitework					**$7,040,000**			**$6,088,000**			**$250,000**			**$250,000**
						.			.			.			.
03000	**CONCRETE**														
	Pump Station Cast-in Place Concrete Wall	cu.m	$2,500	300	$750,000		300	$750,000			$0			$0	

COST ESTIMATE DETAILED BREAKDOWN

PROJECT : Osoyoos Source Water and Treatment Feasibility Study
JOB # : 203185
LOCATION : Town of Osoyoos
ELEMENT : Surface Water Treatment

DATE : 01/24/2025
BY : ME
REVIEWED: SH

				32 MLD (2024 Feasibility Study)			25 MLD (Base)			32 MLD (Stage 2)			37.5 MLD (Stage 3)		
SPEC. NO.	DESCRIPTION	UNIT	UNIT COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST
	Pump Station Suspended Cast-in-Place Floor	cu.m	$2,800	60	$167,000		60	$168,000			$0			$0	
	Pump Station Concrete Slab on Grade Floor (Edge Thickened)	cu.m	$1,500	60	$90,000		60	$90,000			$0			$0	
	WTP Concrete Raft Slab (Edge Thickened)	cu.m	$1,800	800	$1,440,000		800	$1,440,000		107	$194,000		107	$194,000	
	Cast-in Place Concrete Wall	cu.m	$2,500	474	$1,184,000		431	$1,077,000		64	$159,000		64	$159,000	
	Pre-cast Tilt-up Concrete Walls, 3.5 m H (incl. Insulation & Installation)	l.m	$1,600	100	$160,000		100	$160,000		0	$0		0	$0	
	Pre-cast Tilt-up Concrete Walls, 4.5 m H (incl. Insulation & Installation)	l.m	$2,000	176	$351,000		140	$280,000		80	$160,000		80	$160,000	
	Equipment Pad	ea.	$1,500	15	$23,000		15	$23,000		8	$12,000		8	$12,000	
	Misc. Concrete Allowance (Containment, Landings, etc)	ea.	$200,000	1	$200,000		1	$200,000		1	$200,000		1	$200,000	
	Total Concrete					**$4,365,000**			**$4,188,000**			**$725,000**			**$725,000**
04000	**MASONRY**														
	Concrete block (Non-structural)	sq.m	$500	351	$175,600		280	$140,000		80	$40,000		80	$40,000	
	Total Masonry					**$176,000**			**$140,000**			**$40,000**			**$40,000**
05000	**METALS**														
	Miscellaneous Metals	LS	$250,000	1	$250,000		85%	$213,000		11%	$29,000		11%	$29,000	
	Total Metals					**$250,000**			**$213,000**			**$29,000**			**$29,000**
06000	**WOOD, PLASTICS and COMPOSITES**														
	Miscellaneous Wood, Plastics and Composites	LS	$150,000	1	$150,000		1	$150,000		1	$37,500		1	$37,500	
	Total Wood, Plastics & Composites					**$150,000**			**$150,000**			**$37,500**			**$37,500**
07000	**THERMAL AND MOISTURE PROTECTION**														
	Roofing	sq.m	$575	2,044	$1,175,139		1,560	$897,000		195	$113,000		195	$113,000	
	Gutter and drains	LS	$75,000	1	$75,000		1	$75,000		1	$75,000		1	$75,000	
	Sealants	LS	$50,000	1	$50,000		1	$50,000		1	$50,000		1	$50,000	
	Total Thermal And Moisture Protection					**$1,301,000**			**$1,022,000**			**$238,000**			**$238,000**

COST ESTIMATE DETAILED BREAKDOWN

PROJECT : Osoyoos Source Water and Treatment Feasibility Study
JOB # : 203185
LOCATION : Town of Osoyoos
ELEMENT : Surface Water Treatment

DATE : 01/24/2025
BY : ME
REVIEWED: SH

				32 MLD (2024 Feasibility Study)			25 MLD (Base)			32 MLD (Stage 2)			37.5 MLD (Stage 3)		
SPEC. NO.	DESCRIPTION	UNIT	UNIT COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST
08000	**DOORS & WINDOWS**														
	Doors & Windows Allowance	LS	$150,000	1	$150,000		1	$150,000		13%	$21,000		13%	$21,000	
	Total Doors & Windows					**$150,000**			**$150,000**			**$21,000**			**$21,000**
09000	**FINISHES**														
	Interior Painting and Trims	LS	$125,000	1	$125,000		94%	$118,000		13%	$17,000		13%	$17,000	
	Total Finishes					**$125,000**			**$118,000**			**$17,000**			**$17,000**
11000	**PROCESS MECHANICAL EQUIPMENT**														
	Lake Intake Pumpstation														
	Raw Water Pumps	ea.	$120,000	4	$480,000		4	$480,000		1	$120,000		1	$120,000	
	Process Piping and Valves	LS	$150,000	1	$150,000		1	$150,000		25%	$38,000		25%	$38,000	
	Treatment Process														
	DAF clarifier and filter equipment	LS	$8,996,400	1	$8,996,400		85%	$7,644,000		21%	$1,911,000		21%	$1,911,000	
	UV reactors	LS	$489,000	1	$489,000		85%	$416,000			$0			$0	
	Chemical Storage	LS	$50,000	1	$50,000		1	$50,000		1	$25,000		1	$25,000	
	Backwash Pumps	LS	$153,000	1	$153,000		1	$153,000		1	$77,000		1	$77,000	
	Treatment Residuals														
	Wash water storage	LS	$1,200,000	1	$1,200,000		85%	$1,020,000			$0			$0	
	Wash water equalization	LS	$1,200,000	1	$1,200,000		85%	$1,020,000			$0			$0	
	Wash water Package DAF Thickener	LS	$750,000	1	$750,000		1	$750,000			$0			$0	
	Skid-mounted centrifuge (c/w feed pump, liquid polymer makeup)	LS	$400,000	1	$400,000		1	$400,000			$0			$0	
	Process Piping, Valves, Flow Meter, and Appurtenances Allowance	LS	$500,000	1	$500,000		1	$500,000			$0			$0	
	Equipment Installation & Commissioning	LS	0% of Equipme	1	$2,874,000		1	$2,517,000		1	$435,000		1	$435,000	
	Total Process Equipment					**$17,242,400**			**$15,100,000**			**$2,606,000**			**$2,606,000**
12000	**FURNISHINGS**														
	Furnishings Allowance	LS	$75,000	1	$75,000		1	$75,000		0	$0		0	$0	
	Total Furnishings					**$75,000**			**$75,000**			**$0**			**$0**
13000	**SPECIAL CONSTRUCTION**														
	Sheet Piling, Dewatering and Tremiplug for Pump Station Wetwell	LS	$1,250,000	1	$1,250,000		1	$1,250,000			$0			$0	

COST ESTIMATE DETAILED BREAKDOWN

PROJECT : Osoyoos Source Water and Treatment Feasibility Study
JOB # : 203185
LOCATION : Town of Osoyoos
ELEMENT : Surface Water Treatment

DATE : 01/24/2025
BY : ME
REVIEWED: SH

				32 MLD (2024 Feasibility Study)			25 MLD (Base)			32 MLD (Stage 2)			37.5 MLD (Stage 3)		
SPEC. NO.	DESCRIPTION	UNIT	UNIT COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST	QTY	SUBTOTAL	TOTAL COST
	Horizontal Directional Drilling 750 mm pipe 240m Extension to 30m Depth	LS	$450,000	1	$450,000		1	$450,000			$0			$0	
	Convert Reservoir to Baffled Storage	LS	$350,000	1	$350,000		1	$350,000			$0			$0	
	Total Special Construction					**$2,050,000**			**$2,050,000**			**$0**			**$0**
15000	**MECHANICAL**														
	Lake Intake Pumpstation														
	Building Plumbing	LS	$25,000	1	$25,000		1	$0		1	$0		1	$0	
	Building Heating, Ventilation, A/C	LS	$50,000	1	$50,000		1	$0		1	$0		1	$0	
	Treatment Process														
	Building Plumbing	LS	$150,000	1	$150,000		1	$150,000		1	$150,000		1	$150,000	
	Building Heating, Ventilation, A/C	LS	$2,100,000	1	$2,100,000		85%	$1,785,000		13%	$282,000		13%	$282,000	
	Total Mechanical					**$2,325,000**			**$1,935,000**			**$432,000**			**$432,000**
16000	**ELECTRICAL**														
	Lake Intake Pumpstation														
	WTP New Power Pole Service and Transformer	LS	$100,000	1	$100,000		1	$100,000			$0			$0	
	Electrical	LS	$750,000	1	$750,000		1	$750,000		10%	$75,000		10%	$75,000	
	Standby Power Generation	LS	$550,000	1	$550,000		1	$550,000			$0			$0	
	Treatment Process														
	WTP New Power Pole Service and Transformer	LS	$200,000	1	$200,000		1	$200,000			$0			$0	
	Electrical	LS	$3,000,000	1	$3,000,000		85%	$2,549,000		10%	$300,000		10%	$300,000	
	Standby Power Generation	LS	$750,000	1	$750,000		1	$750,000			$0			$0	
	Electrical Permitting, Testing, Commissioning, O&M Manuals	LS	$75,000	1	$75,000		1	$75,000		0	$19,000		0	$19,000	
	Total Electrical					**$5,425,000**			**$4,974,000**			**$394,000**			**$394,000**
16000	**INSTRUMENTATION**														
	Instrumentation and Integration	LS	$3,000,000	1	$3,000,000		1	$2,549,000		10%	$300,000		10%	$300,000	
	Total Instrumentation					**$3,000,000**			**$2,549,000**			**$300,000**			**$300,000**
Sub-Total Estimate (Excl. GST, Engineering & Contingency)						**$45,044,000**			**$40,032,000**			**$5,315,000**			**$5,315,000**

ATTACHMENT B LIFE CYCLE COST ESTIMATES

LIFE CYCLE COST ESTIMATE

ESTIMATE CLASS : 4

PROJECT : **Osoyoos Source Water and Treatment Feasibility Study**

JOB # : **203185**

DATE : 01/24/2025

LOCATION : **Town of Osoyoos**

BY : ME

ELEMENT : **Groundwater Treatment**

REVIEWED: SH

Water Consumption / Usage				
	2023		2050	
MDD, MLD	19.7		25	
				2.55 multiplier with 10%
ADD, MLD	6.95		11.87	reduction for conservation
Summer ADD, MLD	11.9		20.3	
Annual Consumption, m3	2430397		4331777	

Chemical Usage	2023			
SHS	unit cost		0.77	$/L
	delivery volume		12000	L
	delivery cost		598	$/delivery
	daily consumption		145	L/day
	number of deliveries		4	
	yearly cost	$	40,711	
	delivery costs	$	2,990	
Total chemical		**$**	**44,000**	**$/year**
Electrical Power				
Rate	2023		0.08355	$/kwh
Raw water pumping	Annual Consumption		2,430,397	m3
	Annualized Average		6,659	m3/d
	Annualized Average		0.077	m3/s
	Static Head		78	m
	Dynamic Head		30	m
	TDH		108	m
	Annual Avg Pumping		117	kW
	Avg Annual Operatir		24.00	h
	kWh per day		2,799	kWh
	Electrical cost per da		234	$/d
		$	85,372	$/year
Lighting and HVAC	HVAC		0.05	kw/m2
	area		960	m2
	HVAC runtime		12	hour/day
	HVAC power		576	kwh/day
	Lighting power		0.08	W/m2
			0.88	kwh/day

LIFE CYCLE COST ESTIMATE

ESTIMATE CLASS : 4

PROJECT : Osoyoos Source Water and Treatment Feasibility Study

JOB # : 203185

DATE : 01/24/2025

LOCATION : Town of Osoyoos

BY : ME

ELEMENT : Groundwater Treatment

REVIEWED: SH

	Cost 2023		17592.31505	$/year
UV Disinfection	power		105.0617224	kwh/day
	cost		3203.936019	$/year
Process Loads	power		50	kwh/day
	cost	$	1,525	
Total power	**2023**	**$**	**108,000**	**$/year**
Labour				
Operations	FTE			
	rate			
	cost	**$**	**350,000**	**$**
Mech, EIC Equipment Replacement				
Equipment replacement	**cost**	**$**	**486,000**	**$**
Subtotal		$	988,000	per year
Miscellaneous		$	20,000	2% of annual costs
Total		$	1,008,000	per year

Net Present Value

Growth	2%			
Discount Rate	3%			
	Initial Capital	**O&M Costs**	**Upgrades**	**Total**
25 MLD (2050)	$62,059,000	$ 22,583,720		$84,642,720
32 MLD (2064)	$62,059,000	$ 32,569,522	$7,445,653	$102,074,174
37.5 MLD (2071)	$62,059,000	$ 37,073,650	$4,500,355	$103,633,005

LIFE CYCLE COST ESTIMATE

PROJECT :	**Osoyoos Source Water and Treatment Feasibility Study**	**ESTIMATE CLASS :**	4
JOB # :	**203185**	**DATE :**	01/24/2025
LOCATION :	**Town of Osoyoos**	**BY :**	ME
ELEMENT :	**Surface Water Treatment**	**REVIEWED:**	SH

Water Consumption / Usage

	2023	2050	Average
MDD, MLD	19.7	25	
ADD, MLD	6.95	11.87	2.55 multiplier with 10% reductior
Summer ADD, MLD	11.9	20.3	
Annual Consumption, m3	2430397	4331777	

Chemical Usage 2023

12% Sodium Hypochlorite	unit cost		0.77	$/L
	delivery volume		12000	L
	delivery cost		598	$/delivery
	daily consumption		145	L/day
	number of deliveries		4.4	
	yearly cost 2023	$	40,711	
	delivery costs 2023	$	2,990	
Coagulant	unit cost		1.05	$/kg
	delivery volume		28000	kg
	delivery cost	-		$/delivery
	daily consumption		102	L/day
			139	kg/day
	yearly consumption		50838	kg
	number of deliveries		1.8	
	yearly cost 2023	$	53,380	$
	delivery costs 2023	-		$
Coagulant aid	unit cost		5.1	$/kg
	delivery volume		1100	kg
	delivery cost	-		$/delivery
	daily consumption		6.09	L/day
			6.95	kg/day
	yearly consumption		2535	kg
	number of deliveries		2.30	
	yearly cost 2023	$	12,930	$
	delivery costs 2023	-		$
Floc aid	unit cost		8.15	$/kg
	delivery volume		1040	kg
	delivery cost	-		$/delivery
	daily consumption		1.40	L/day

LIFE CYCLE COST ESTIMATE

PROJECT :	**Osoyoos Source Water and Treatment Feasibility Study**
JOB # :	**203185**
LOCATION :	**Town of Osoyoos**
ELEMENT :	**Surface Water Treatment**
ESTIMATE CLASS :	4
DATE :	01/24/2025
BY :	ME
REVIEWED:	SH

				1.40	kg/day
		yearly consumption		512	kg
		number of deliveries		0.49	
		yearly cost 2023	$	4,175	$
		delivery costs 2023 -			$
Total chemical		**2023**	**$**	**114,000**	**$/year**
Electrical Power					
Rate		2023		0.08355	$/kwh
Raw water pumping		Annual Consumptioı		2,430,397	m3
		Annualized Average		6,659	m3/d
		Annualized Average		0.077	m3/s
		Static Head		73	m
		Dynamic Head		20	m
		Total Dynamic Heac		93	m
		Annual Avg Pumpin		100.4441226	kW
		Avg Annual Operatiı		24	h
		kWh per day		2,411	kWh
		Electrical cost 2023		201	$/d
			$	73,515	$/year
Lighting and HVAC	HVAC	0.05 kw/m2			
	area	1200 m2			
	HVAC runtime	12 hour/day			
		HVAC power		720	kwh/day
		Lighting power		0.08	W/m2
				1.10	kwh/day
		Cost 2023	$	21,990	$/year
DAF				539	kwh/day
			$	16,426	$/year
Backwash pumps		Flowrate		0.77	m3/sec
		TDH		15	m

LIFE CYCLE COST ESTIMATE

ESTIMATE CLASS : 4

PROJECT : Osoyoos Source Water and Treatment Feasibility Study

JOB # : 203185

DATE : 01/24/2025

LOCATION : Town of Osoyoos

BY : ME

ELEMENT : Surface Water Treatment

REVIEWED: SH

	Power required			161.865	kW
	Daily power consum			26.9775	kWh/day
	Cost 2023			822.70	$/year
Centrifuge				105	kwh/day
	cost 2023			27300	$/year
UV Disinfection	power			105.0617224	kwh/day
	cost 2023			3203.936019	$/year
Total Electrical Power		**2023**	**$**	**143,000**	**$/year**
Labour					
Operations	FTE				
	rate				
Labour Total	**cost**		**$**	**350,000**	**$/year**
Mech, EIC Equipment Replacement					
Equipment replacement	**cost**		**$**	**491,000**	**$**
Subtotal			$	1,098,000	per year
Miscellaneous			$	22,000.00	2% of annual costs
Total			$	1,120,000.00	per year

Net Present Value

Growth	2%			
Discount Rate	3%			
	Initial Capital	**Surface Water**	**Upgrades**	**Total**
25 MLD (2050)	$63,853,000	$ 25,093,022		$88,946,022
32 MLD (2064)	$63,853,000	$ 36,188,358	$2,598,836	$102,640,193
37.5 MLD (2071)	$63,853,000	$ 41,192,945	$2,113,091	$107,159,036