Treatment Train Selection Process

The purpose of bar screening is to remove large particles from the water before the water is pumped to the beginning of the facility. This protects the pumps from damage. The different types of bar screens which were considered for the treatment trains were vertical bar screens and curved bar screens. Both of these treatment types do not create any negative evironmental impact outside of energy use. Additionally, these treatment types require the same energy usage. The vertical screen would have a larger cost than the curved screen. However, the vertical screen can typically handle fluctuations in flow and water quality parameters than the curved bar screen. Finally, the vertical screen would have a larger land use than the curved bar screen.

Alternative	Environmental impact (0.125)	Energy Efficiency (0.125)	Operational and Capital Cost (0.25)	Operational Flexibility (0.25)	Land Use (0.25)	Total Score
Manual Screen	3	3	2	1	1	1.75
Vertical Screen	2	2	2	3	2	2.25
Curved Screen	2	2	2	1	3	2

he water entering the 91st Avenue AWPF will have suspended solids in the water. Suspended solids are solid particles in the water which do not settle quickly enough to be removed by gravity. The purpose of coagulation and flocculation is to cause these particles to stick together (coagulation) then settle out of the water (flocculation). To complete this process, different types of coagulants and flocculants were compared. The first part of this process, which was considered, was coagulation. The different types of coagulants which were compared included Alum, Ferric Chloride, and Polydiallyldimethylammonium Chloride (PolyDADMAC).

Alum is aluminum sulfate; a compound frequently used in the water treatment process for coagulation. Alum was considered the most environmentally friendly of the different products because it is biodegradable and it is not corrosive. This compound can be consistently used with a large amount of water quality parameter fluctuations. Another coagulant considered was Ferric Chloride. This compound is also frequently used in water treatment as a coagulant. This chemical is corrosive and therefore has a more negative environmental impact than alum. However, this compound is much cheaper than alum.

The final coagulant considered for this process was Polydiallyldimethylammonium chloride (PolyDADMAC). PolyDADMAC is a cationic polyelectrode which is used for drinking water treatment [3]. This compound is not biodegradable and produces disinfection by products (DBPs). . The capital and operational cost of the use of this coagulant was not notable in comparison to ferric chloride and alum as coagulants. This compound has less operational flexibility than alum and ferric chloride because it is not able to work in a range of water quality parameters. Because of these reasons, PolyDADMAC was not chosen as a coagulant for any of the alternative treatment trains.

Coagulation						
Alternative	Environmental impact (0.125)	Energy Efficiency (0.125)	Operational and Capital Cost (0.25)	Operational Flexibility (0.25)	Land Use (0.25)	Total Score
Alum	3	2	2	3	2	2.375
Ferric Chloride	2	2	3	3	2	2.5
PolyDADMAC	1	2	2	2	2	1.875

Flocculation						
Alternative	Environmental impact (0.125)	Energy Efficiency (0.125)	Operational and Capital Cost (0.25)	Operational Flexibility (0.25)	Land Use (0.25)	Total Score
Cationic Polymers	2	2	2	2	2	2
Anionic Polymers	2	2	2	2	2	2
Nonionic Polymers	3	2	2	3	2	2.375

The first group of physical separation processes included slow sand filters, rapid media filters, and cartridge filters. This group of physical separation focuses on removing Total Suspended Solids (TSS) from the water. Slow sand filters were found to have a good environmental impact because these processes use natural biological treatment with no chemicals.

Contrarily, the rapid media filters were rated neutrally for the environmental impact because this process uses different chemicals for backwashing the filters. Finally, a cartridge filter was considered to have a bad environmental impact because it uses disposable filter media. Slow sand filters were considered to have good energy efficiency because they rarely require backwashing. Rapid media filters are considered neutral energy consumption because they require routine backwashing, and cartridge filters require the system to be under pressure to operate, resulting in bad energy consumption.

For cost, the rapid media filter and slow sand filters are considered to have neutral costs while the cartridge filter requires periodic media replacements which causes this to have the worst cost. When assessing these processes on operational flexibility, the rapid media filters and cartridge filters have the best operational flexibility because these processes can have their flow rates adjusted whereas the slow sand filter cannot be adjusted in this way. Finally, slow sand filters requirethe most land use, and cartridge filters require the least land use.

Physical Separation 1						
Alternative	Environmental impact (0.125)	Energy Efficiency (0.125)	Operational and Capital Cost (0.25)	Operational Flexibility (0.25)	Land Use (0.25)	Total Score
Slow Sand Filter	3	2	2	1	1	1.625
Rapid Media Filter	2	2	2	3	2	2.25
Cartridge filter	1	2	1	3	3	2.125

For the second physical separation process microfiltration (MF) and ultrafiltration (UF) are considered. MF removes larger total suspended solids (TSS) and some bacteria, while UF, with its smaller pore size, can remove smaller particles, including viruses and finer colloids. UF generally requires more energy and has higher costs due to increased fouling potential and more frequent cleaning or membrane replacement. However, it produces higher-quality effluence. MF is more cost-effective and less energy-intensive but provides a lower level of removal. Both systems are sensitive to influent water quality and can foul under high solids loading, requiring pretreatment. Land use for both systems is relatively compact and similar.

Physical Separation 2						
Alternative	Environmental impact (0.125)	Energy Efficiency (0.125)	Operational and Capital Cost (0.25)	Operational Flexibility (0.25)	Land Use (0.25)	Total Score
Microfiltration	3	1	2	1	3	2
Ultrafiltration	3	2	2	3	3	2.625
Adsorption (GAC/PAC)	3	1	2	3	2	2.25

For the final physical separation process, the different treatment processes have different results. Ion exchange is selected as the preferred method for dissolved ion (TDS) removal due to its balance of performance, cost, and efficiency. While reverse osmosis (RO) provides the highest level of removal—including monovalent ions, dissolved organics, and pathogens—it requires high operating pressures and produces a significant volume of brine waste, making it the most energy-intensive and expensive option. Nanofiltration (NF) operates at lower pressures and is more energy-efficient than RO but primarily removes divalent ions and larger organics, resulting in lower overall treatment performance for TDS removal.In contrast, ion exchange selectively removes targeted ions such as hardness and nitrates, making it a more efficient and cost-effective solution when full desalination is not required. Although ion exchange does require chemical regeneration and produces a brine waste stream, this waste is typically less than that produced by RO systems. In terms of reliability, RO systems provide the most consistent effluent quality, followed by NF. However, ion exchange can still achieve reliable performance when properly maintained, though its effectiveness depends on resin condition and influent water variability. Additionally, ion exchange systems have the smallest land use footprint compared to RO and NF, which both require moderate space. Overall, ion exchange offers a practical and efficient solution for targeted ion removal with lower energy and cost demands

Physical Separation 3						
Alternative	Environmental impact (0.125)	Energy Efficiency (0.125)	Operational and Capital Cost (0.25)	Operational Flexibility (0.25)	Land Use (0.25)	Total Score
Reverse Osmosis	1	1	1	3	2	1.75
Nanofiltration	3	3	2	1	2	2
Membrane Bioreactor	2	1	1	2	1	1.375
Ion Exchange	2	2	2	3	3	2.5

AOPs are processes which use highly oxidizing agents such as hydroxyl radicals (•OH) to degrade organic molecules and cause the creation of water and carbon dioxide [3]. The design of the 91st Avenue AWPF requires the use of one of these processes. For these treatment trains, two different AOPs were considered. These include the combination of chlorine, ozone, hydrogen peroxide, and UV. Neither UV or hydrogen peroxide are AOPs alone. None of these compounds or processes can create •OH on their own and therefore must be evaluated in combination with each other. For this stage, the following decision matrix was used.

AOP						
Alternative	Environmental impact (0.125)	Energy Efficiency (0.125)	Operational and Capital Cost (0.25)	Operational Flexibility (0.25)	Land Use (0.25)	Total Score
Ozone/UV	3	1	1	3	2	2
Chlorination/UV	2	3	2	3	3	2.625
H2O2/UV	3	3	2	3	3	2.75

Brine Management						
Alternative	Environmental impact (0.125)	Energy Efficiency (0.125)	Operational and Capital Cost (0.25)	Operational Flexibility (0.25)	Land Use (0.25)	Total Score
Concentration and crystallization	3	2	3	2	1	2.125
Membrane Distillation	1	2	1	2	2	1.625
High-Pressure Reverse Osmosis	3	2	1	1	1	1.375

The first brine management technique was brine concentration/crystallization. These techniques are frequently used in large scale processes such as data centers or nuclear energy facilities because of their efficiency. Because these processes are so efficient, they can be used in a process called zero liquid discharge. This is when the waste from the brine management does not contain water and is rather solid salts from the brine. However, this process has many drawbacks. The first drawback is the cost of these processes. These processes have a very high capital cost as well as a very high operation cost because this process requires extreme energy consumption. These processes are additionally prone to a variety of different issues such as scaling which reduce the operational flexibility of these processes. Brine production directly influences required influent pumping capacity and was therefore incorporated into lift station sizing to ensure reliable operation under peak flow conditions.

Once all the different treatment processes had been researched, these processes were organized into three different treatment trains to be analyzed and assessed. These different treatment trains were assessed based on five different criteria. These different criteria include environmental impact, energy efficiency, cost, operational flexibility, and land use. Evaluating the treatment of trains on environmental impact included assessing the trains for different environmental factors such as by-products produced. Energy efficiency evaluated the energy required to operate the different processes. The cost evaluation of the different treatment processes assessed both the operational and the capital cost for the different processes. Evaluating the operational flexibility of the treatment processes was a way of assessing how effectively the different treatment processes were able to treat the water through water quality parameter fluctuations. Finally, the different treatment processes were assessed for land use. This assessed how much land each process would require when the plant is being designed.

Overall Trains						
Alternative	Environmental impact (0.125)	Energy Efficiency (0.125)	Operational and Capital Cost (0.25)	Operational Flexibility (0.25)	Land Use (0.25)	Total Score
Treatment Train 1	22	18	17	21	16	18.5
Treatment Train 2	20	16	17	21	17	18.25
Treatment train 3	20	17	17	22	18	18.875

	Treatment train 1	**Treatment train 2**	**Treatment train 3**
Bar Screening	Vertical Screen	Vertical Screen	Vertical Screen
Coagulant	Alum	Ferric Chloride	Ferric Chloride
Flocculant	Nonionic Polymers	Nonionic Polymers	Nonionic Polymers
Physical Treatment 1	Rapid Media Filter	Rapid Media Filter	Rapid Media Filter
Physical Treatment 2	Carbon Adsorption	Ultrafiltration	Ultrafiltration
Physical Treatment 3	Nanofiltration	Ion Exchange	Ion Exchange
Advanced Oxidation Process	Hydrogen Peroxide	Ozone	Hydrogen Peroxide
Brine Management	Crystallization	Crystallization	Crystallization
UV			
Final Chlorination			