The City of Phoenix 91st Avenue Advanced Water Purification Facility Report

Clearwater Jacks Engineering

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CENE 486C

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Abbreviations

AAC- Arizona Administrative Code

ABET- Accreditation Board for Engineering and Technology Inc.

ADEQ- Arizona Department of Environmental Quality

AWPF- Advanced Water Purification Facility

AWP- Advanced Water Purification

AWWA- American Water Works Association

AZ Water- Arizona Water Association

BOD- Biochemical Oxygen Demand

CINT- Civil Engineering Intern

CJE- Clearwater Jacks Engineering

CWA- Clean Water Act

DENG- Design Engineer

EAS- Extended Aeration System

EINT- Environmental Engineering Intern

ENT- Engineering in Training

EOPC- Engineers Opinion of Probable Cost

EPA- Environmental Protection Agency

FPS- Feet Per Second

FRW- Tres Rios Flow Regulating Wetlands

GAC- Granulated Activated Carbon

HDPE- High-Density Polyethylene

HRT- Hydraulic Retention Time

MCESD- Maricopa County Environmental Services Department

MF- Microfiltration

MGD- Millon Gallons of Water per Day

NF- Nanofiltration

NPDWR- U.S. Environmental Protection Agency National Primary Drinking Water Regulations

NPSH- Net Positive Section Head

O&M- Operation and Maintenance Cost

OPCC- Opinion of Probable Construction Cost

PAC- Polyaluminum Chloride

PVC- Polyvinyl Chloride

PE- Professional Engineering License

PVNGS – Palo Verda Nuclear Generation Station

TDH- Total Dynamic Head

RO- Reverse Osmosis

SDC- Student Design Competition

SDWA- Safe Drinking Water Act

SENG- Senior Engineer

UF- Ultrafiltration

VIT- Vertical Industrial Turbine

WEF- Water Environment Federation

WTP- Water Treatment Plant

WWTP- Wastewater Treatment Plant

91st Ave WWTP- 91st Avenue Wastewater Treatment Plant

Abstract

The 91st Avenue Wastewater Treatment Plant (91st Ave WWTP) in Tolleson, Arizona plans to implement an Advanced Water Purification Facility (AWPF) capable of treating 30 million gallons of water per day (MGD). The plant requested up to three different alternative treatment trains, a pump station along with pump systems for an entirely new water facility. This complete design will feature a physical separation process, pump station design, chemical treatment process, advanced treatment process, disinfection process, and brine management process. These alternatives were chosen using a decision matrix for each individual process. From the decision matrices, three treatment train designs will be made and evaluated for the best alternative. Each treatment train design will feature ultraviolet disinfection (UV) and chorine disinfection to ensure that each treatment is up to code and regulation from the Environmental Protection Agency (EPA), the Arizona Department of Environmental Quality (ADEQ), and the Maricopa County Environmental Services Department (MCESD).

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1.0 Project Introduction

Clearwater Jacks Engineering (CJE) will use the following subsections to explain the design problem, project background, project constraints and limitations, unique deliverables, and main objectives.

1.1 Design Problem

CJE must design an Advanced Water Purification Facility (AWPF) for the 91st Avenue Wastewater Treatment Plant (91st Ave WWTP) for the Arizona Water Association (AZ Water) Student Design Competition (SDC) sponsored by the Water Environment Federation (WEF). The goal for this project is to design a complete AWPF capable of treating 30 million gallons of water per day (MGD) of secondary effluent released to the Tres Rios Flow Regulating Wetlands (FRW). This design must be up to standards from the Environment Protection Agency (EPA), Arizona Department of Environmental Quality (ADEQ), and Maricopa County Environmental Services Department (MCESD).

1.2 Project Background

The 91st Ave WWTP is in the metropolitan area of Phoenix, Arizona which is shown in Appendix *A*. The plant wants to address water scarcity with the development of an AWPF. This new facility sources water from the FRW outfall 005. The surrounding area with highways and main roads is shown in *Appendix B*. The 91st Ave WWTP, FRW, available parcels given by the city, and the Salt River are shown in Appendix *C*. The effluent from the FRW is treated effluent that is above average quality for secondary effluent, however, the water will need to be treated again to reduce levels of total dissolved solids (TDS) and remove pathogens for potable use. Figure 1-1 below shows the available parcel site map for the AWPF.

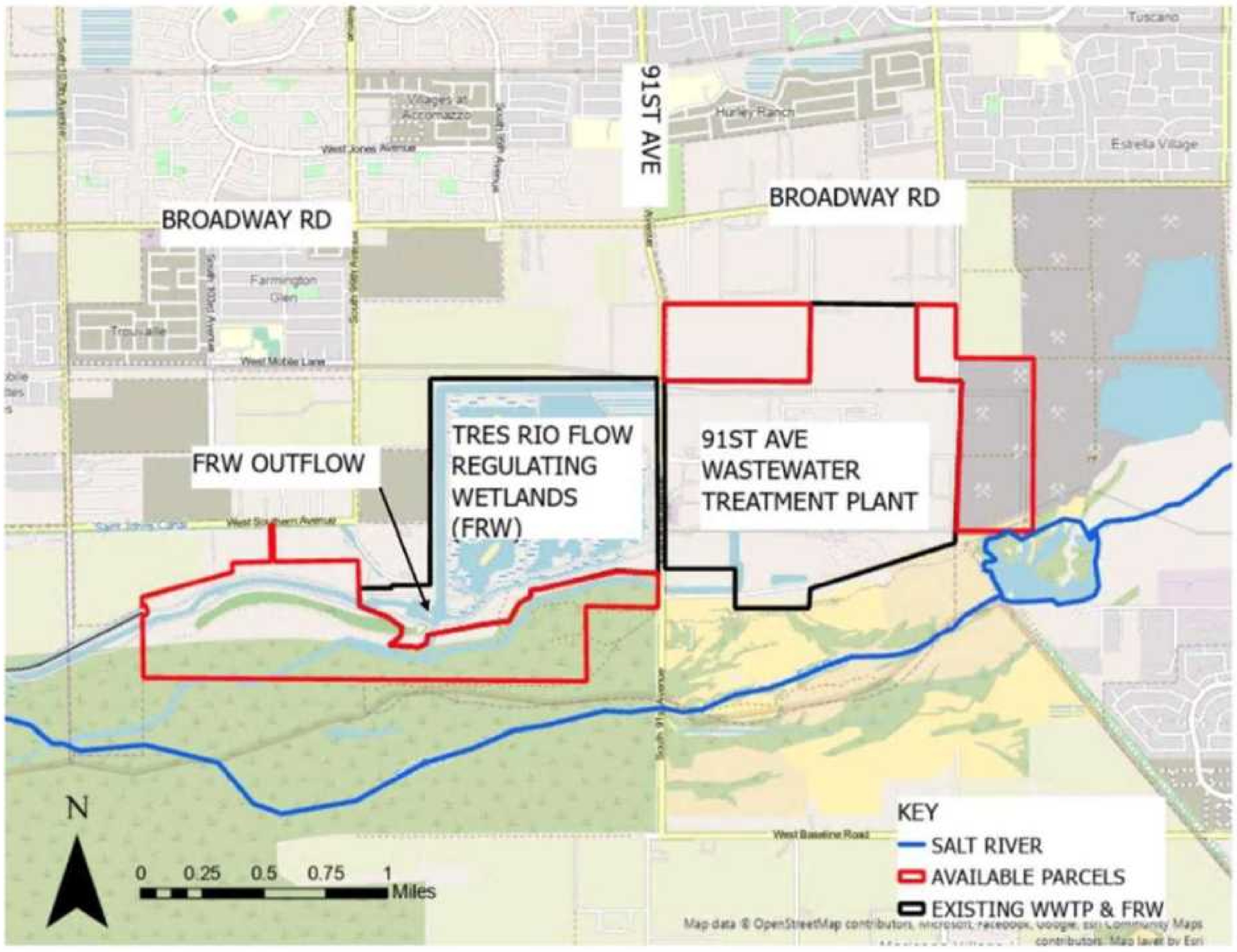

Figure 1-1: Available Parcels Site Map

1.3 Constraints/Limitations

When completing the design for the AWPF for the 91st Ave WWTP, CJE will experience some constraints and limitations. The project will need to be integrated into the existing hydraulic conditions. The design must also be in city-owned property and cannot be implemented in private land around the location. The plant must have a design flow capacity of 30 MGD.

The project requires the team to follow the regulations from the EPA, ADEQ, and MCESD. The design will have to abide by the National Primary Drinking Water Regulation (NPDWR), Safe Drinking Water Act (SDWA), and Arizona's Water Reuse Guideline or Regulation for Direct Potable Water Reuse, all under the guidance of the EPA. Under the jurisdiction of the ADEQ, the plant must abide by the Arizona Administrative Code Title 18. Furthermore, the standards of the MCESD will abide by the American Water Works Association (AWWA) C653-03 and the ADEQ bulletin number eight.

Pathogen removal and inactivation must use a minimum of three treatment barriers and a pathogen reduction using standard log removal requirements of 13-log virus and 10-log protozoa (Cryptosporidium and Giardia) per Arizona Administrative Code (AAC) R18-9E828. TDS reduction must achieve a salinity of less than 750 milligrams per liter. Per AAC R18-9-F832 the treatment train design must include three separate treatment processes including but not limited to physical separation, advanced oxidation process, and a UV process with a dose of at least 300 millijoule per centimeter squared.

1.4 Main Objectives and Unique Deliverables

The project's main objective is to select the best alternative from three treatment train options, and perform preliminary design of the selected option, as well as design a pump station that conveys 30 MGD.

The project must provide a narrative of how the source of water constituents are managed by the advanced water treatment train. Treatment processes do not need to be designed for constituents of concern, but the provided narrative must specify which treatment process will handle the constituents of concern. A flow diagram of the AWPF must be provided along with a pipe and pump station to convey the water from the TRW to the proposed AWPF. Decision matrices for all three treatment trains, a proposed hydraulic profile, and preliminary sizing of all major equipment and units to meet design goals must be included. An Operation and Maintenance (O&M) requirement and costs along with an Opinion of Probable Construction Costs (OPCC) is required. A construction sequencing plan and a plan to engage and educate the community on the topic of the AWPF are also required.

2.0 Alternative Design Evaluation

The following sections explain the alternatives used for each treatment process used to create an alternative treatment train. This section will review the alternatives and criteria for parcel decision, physical separation, physical treatment, chemical treatment, advanced treatment, disinfection treatment, brine management, and hydraulic design by using decision matrices.

Alternatives were judged using selected criteria to best fit the AWPF's goals and limitations. Percentage weights were assigned to each criteria showing which criteria were considered most important to least important according to CJE's standards. After weighting, alternatives were given a score from 1-3, 1 being the worst, 2 being moderate, and 3 being the best option for that criterion. After all rankings are done, scores are multiplied by the weighting and added to see which design best met the goals and was possible to construct for the AWPF.

2.1 Parcel Selection Evaluation

This section reviews alternatives for the parcel selection for the AWPF. This section also covers the criteria, weighting, scoring, and the decision matrix created. When determining eligible parcels for the location of the AWPF, several initial criteria were established to evaluate potential sites. Parcels were required to be owned by the State of Arizona, located on the same side of the Salt River and the FRW outflow, free from current land use, and outside of designated flood zones of the Salt River. Therefore, based on initial criteria, Parcel 101-33-003 and Parcel 101-33-007 (shown in *Figure 1-1*) were identified as suitable candidates. Parcels were judged using the criteria of accessibility, size, availability, and potential hazards. Evaluation criteria, rationale for weighting, scoring, and the detailed parcel selection decision matrix can be found in *Appendix D.* Table 2-1 shows a simplified decision matrix for the parcel based on the weighted criteria and the chosen alternative (indicated in bold), Parcel 101-33-003, located on north side of the 91st Ave WWTP (shown in Figure 1-1). This parcel choice gives the 91st Ave WWTP opportunities to expand in future years and is also relatively available to start construction.

Table 2-1: Parcel Selection Simplified Decision Matrix

Parcel	Accessibility (30%)	Size (30%)	Availability (20%)	Potential Hazards (20%)	Total Score
101-33-003	**3**	**2**	**3**	**3**	**2.4**
101-33-007	1	3	2	3	1.9

2.2 Physical Separation Selection Evaluation

Physical separation selection evaluation presents alternatives and criteria used to assess the physical separation processes, including physical and fine screening. The process is essential as it removes large debris from the influent water such as garbage, branches, and other material that can harm equipment in the AWPF.

2.2.1 Physical Screening Alternatives & Criteria

Physical screening options considered were bar screens and trash racks selected based on their reliability and their widespread use in the industry. The FlexRake FPFS Thru-Bar Cleaning Fine Screen was evaluated as the bar screen alternative (see *Appendix E* for data sheet) and the Duperon Self-Cleaning Trashrack was evaluated for the trash rack alternative (see *Appendix F* for data sheet). Evaluation criteria, rationale for weighting, scoring, and the detailed physical screening decision matrix can be found in *Appendix G*. Table 2-2 shows a simplified decision matrix for the physical screening process based on the weighted and the chosen alternative (indicated in bold and highlighted), bar screens (FlexRake FPFS Thru-Bar Cleaning Fine Screen). The bar screen was used as the physical screening alternative for all three treatment train alternatives.

Table 2-2: Physical Screening Simplified Decision Matrix

Physical Screening	Cost (15%)	Effectiveness (25%)	Durability (20%)	Maintenance (15%)	Material (10%)	Footprint (15%)	Total Score
FlexRake FPFS Thru-Bar Cleaning Fine Screen	**2**	**1**	**2**	**2**	**2**	**2**	**1.75**
Duperon Self-Cleaning Trashrack	1	2	1	1	1	1	1.25

2.2.2 Fine Screening Alternatives & Criteria

Fine screening alternatives considered were step screens and wedge wire screens. HUBER Fine Screen STEP SCREEN SSV was evaluated as the step screen alternative (see *Appendix H* for data sheet). The Johnson Vee-Wire Flat Panel Wedge Wire Screen was evaluated as the wedge wire screen alternative (see *Appendix I* for data sheet). Table 2-3 shows a simplified decision matrix for fine screening based on the weighted criteria and the chosen alternatives (indicated in bold and highlighted). Through the alternative selection process, the step screens (HUBER Fine Screen STEP SCREEN SSV) and wedge wire screens (Johnson Vee-Wire Flat Panel Wedge Wire Screen) were used as fine screening technology for alternative treatment trains. The detailed scoring and decision matrix can be found in *Appendix J*.

Table 2-3: Fine Screening Simplified Decision Matrix

Fine Screening	Cost (15%)	Effectiveness (25%)	Durability (20%)	Maintenance (15%)	Material (10%)	Footprint (15%)	Total Score
HUBER Fine Screen STEP SCREEN SSV	**2**	**2**	**3**	**2**	**1**	**1**	**1.95**
Johnson Vee-Wire Flat Panel Wedge Wire Screen	**1**	**3**	**3**	**3**	**3**	**3**	**2.7**

2.3 Chemical Treatment Selection Evaluation

This section evaluates different chemical compounds used for coagulation and flocculation processes. This process reduces hardness and creates flocs that are a conglomeration of fine pollutants, to reduce TSS by sedimentation. Coagulant and flocculant chemicals considered alternatives were aluminum sulfate, polyaluminum chloride (PAC), and aluminum chloride. Criteria that coagulation and flocculation were evaluated with cost, effectiveness, sludge production, dose range, and toxicity. Evaluation criteria, rationale for weighting, scoring, and the detailed coagulation/flocculation decision matrix can be found in *Appendix K*. Table 2-4 shows a simplified decision matrix for coagulation/flocculation based on the weighted criteria and chosen alternatives (indicated in bold and highlighted). Through this alternative selection process, the following chemicals were used for coagulation/flocculation in alternative treatment trains: aluminum sulfate and polyaluminum chloride (PAC).

Table 2-4: Coagulation & Flocculation Simplified Decision Matrix

Coagulant & Flocculant	Cost (20%)	Effectiveness (30%)	Sludge Production (15%)	Dose Range (15%)	Toxicity (20%)	Total Score
Aluminum Sulfate	**2**	**2**	**1**	**2**	**3**	**2.25**
Polyaluminum Chloride	**2**	**3**	**3**	**3**	**3**	**2.8**
Aluminum Chloride	1	1	2	1	2	1.5

2.4 Physical Treatment Selection Evaluation

Physical treatment selection evaluation presents alternatives and criteria used to assess physical treatment processes, including sedimentation and filtration. This process is essential as it removes suspended solids, flocs created in the coagulation/flocculation process, and finer pollutants from the water.

2.4.1 Sedimentation Alternatives & Criteria

Criteria for the sedimentation process were cost, effectiveness, durability, maintenance, size, and versatility of shape. The criteria' weights and scoring for sedimentation can be found in *Appendix L-1*. The evaluation criteria, the rationale for weighting, scoring, and the detailed sedimentation decision matrix can be found in *Appendix L-2*. Alternatives considered were conventional settling tanks, tube settlers, and plate settlers. Conventional settling tanks that were evaluated were the Ares Tech Clarifier Tank (data sheet can be found in *Appendix M*). Tube settlers that were evaluated during the alternatives were Brentwood Tube Settler Systems (data sheet can be found in *Appendix N)*. Lastly, Jim Myer & Sons, INC. Mega-Settler Plate Settler Systems were used for plate settler evaluations (data sheet can be found in *Appendix O*). Table 2-5 shows a simplified decision matrix for sedimentation based on the weighted criteria and chosen alternatives (indicated in bold and highlighted). Through this alternative selection process, conventional settling tanks (Ares Tech Clarifier Tank) and plate settlers (Jim Myer & Sons, INC. Plate Settler System) were considered as sedimentation technologies in alternative treatment trains.

Table 2-5: Sedimentation Simplified Decision Matrix

Sedimentation	Cost (15%)	Effectiveness (25%)	Durability (20%)	Maintenance (15%)	Size (10%)	Versatility Shape (15%)	Total Score
Ares Tech Clarifier Tank	**3**	**1**	**3**	**3**	**1**	**2**	**1.88**
Brentwood Tube Settler System	2	2	1	1	2	3	1.81
Jim Myer & Sons, INC. Plate Settler System	**1**	**3**	**2**	**2**	**3**	**3**	**2.22**

2.4.2 Filtration Alternatives & Criteria

Criteria for the filtration process were cost, effectiveness, durability, maintenance, size, and footprint. The criteria weights, scoring, and detailed decision matrix for filtration can be found in *Appendix P*. Filtration technology alternatives considered were rapid sand filtration, microfiltration (MF), and slow sand filtration. For rapid sand filtration, Filters ITM Sand Filters were used (data sheet can be found in *Appendix Q*). GORE MF Media was used for the MF alternative (data sheet can be found in *Appendix R*). Then, for slow sand filtration, the Nalco UltraSand Plus High Efficient Filter was used (the data sheet can be found in *Appendix S*). Table 2-6 shown below is the simplified decision matrix for filtration based on the weighted criteria and chosen alternatives (indicated in bold and highlighted). Through this alternative selection process, rapid sand filtration (Filters ITM Sand Filter) and microfiltration (GORE Microfiltration Media) were considered as filtration technologies in alternative treatment trains.

Table 2-6: Filtration Simplified Decision Matrix

Filtration	Cost (20%)	Effectiveness (25%)	Durability (15%)	Maintenance (15%)	Size (15%)	Footprint (10%)	Total Score
Filters ITM Sand Filters	**2**	**1**	**2**	**2**	**2**	**2**	**1.83**
GORE Microfiltration Media	**1**	**3**	**1**	**1**	**3**	**1**	**1.67**
Nalco UltraSand High Efficient Filter	2	2	2	1	1	1	1.50

2.5 Advanced Treatment Selection Evaluation

Advanced treatment selection evaluation presents alternatives and criteria. This treatment process removes TDS, ions, pathogens, and other pollutants. CJE determined that granular activated carbon (GAC) was a non-negotiable treatment for the quality of water to protect the advanced treatment membranes and polish water from odors and color. Criteria for advanced treatment alternatives were cost, effectiveness, durability, maintenance, and footprint. Criteria weights, scoring, and detailed decision matrix for advanced treatment can be found in *Appendix T*. Advanced treatment alternatives considered were reverse osmosis (RO), ultrafiltration (UF), and nanofiltration (NF). The FilmTec BW30 PRO-400/34 Element was evaluated as the RO alternative (see data sheet in *Appendix U*). The DuPont Ultrafiltration Capabilities was used as the alternative for UF (see data sheet in *Appendix V*). Lastly, the NF-400 Industrial Nanofiltration Systems was the alternative for NF (data sheet in *Appendix W)*. Table 2-7 shown below is the simplified decision matrix for advanced treatment based on the weighted criteria and chosen alternatives (indicated in bold and highlighted). Through this alternative selection process, ultrafiltration (DuPont Ultrafiltration Capabilities), nanofiltration (NF-400 Industrial Nanofiltration System) and, reverse osmosis (FilmTech BW30 PRO-400/34 Element) were all considered as advanced treatment technologies in alternative treatment trains.

Table 2-7: Advanced Treatment Simplified Decision Matrix

Advanced Treatment	Cost (20%)	Effectiveness (25%)	Durability (20%)	Maintenance (15%)	Footprint (20%)	Total Score
FilmTec BW30 PRO-400/34 Element	**1**	**3**	**2**	**1**	**1**	**1.7**
DuPont Ultrafiltration Capabilities	**3**	**1**	**3**	**2**	**3**	**2.35**
NF-400 Industrial Nanofiltration Systems	**2**	**2**	**3**	**2**	**2**	**2.2**

2.6 Disinfection Treatment Selection Evaluation

Disinfection treatment selection focuses on selection of an alternative for an advanced oxidation process (AOP). This is a critical barrier as it forms a hydroxyl radical that can eliminate organic compounds, pathogens and bacteria in the water. In addition, CJE will include a UV disinfection process and a chlorine residual provided through chlorine gas due to competition requirements along with requirements from the Arizona Administration

Code R18-4501 to R18-4-540. Criteria for advanced oxidation process (AOP) technologies were cost, effectiveness, dosage, maintenance, and footprint. Criteria weights, scoring, and detailed decision matrix for AOP can be found in *Appendix X*. The alternatives considered were ozone and UV, ozone and hydrogen peroxide, and hydrogen peroxide and UV. The MiPRO AOP was used for the ozone and UV alternative (see data sheet in *Appendix Y*). The Capital Controls Ozone Generation System was used for the ozone and hydrogen peroxide AOP alternative (see data sheet in *Appendix Z*). Finally, the ADVANOX AOP was for the alternative using hydrogen peroxide and UV (see data sheet in *Appendix AA)*. Table 2-8 shown below is the simplified decision matrix for AOP based on the weighted criteria and chosen alternatives (indicated in bold and highlighted). Through this alternative selection process, UV/hydrogen peroxide (Capital Controls Ozone Generation System) and ozone/UV (MiPRO AOP) were all considered as AOP technologies in alternative treatment trains.

Table 2-8: AOP Simplified Decision Matrix

AOP	Cost (20%)	Effectiveness (25%)	Dose (20%)	Maintenance (15%)	Footprint (20%)	Total Score
Ozone/UV (MiPRO AOP)	**2**	**3**	**2**	**3**	**1**	**2.2**
Ozone/Hydrogen Peroxide (Capital Controls Ozone Generation System)	**1**	**2**	**3**	**3**	**3**	**2.35**
Hydrogen Peroxide/UV (ADVANOX AOP)	3	1	1	3	2	1.90

2.7 Brine Management Selection Evaluation

Brine management evaluation focuses on selection of an alternative for handling reject water from the advanced treatment process. This process is critical to the treatment train as it provides an effective strategy to manage brine, ensuring discharge from the advanced treatment process aligns with environmental protection goals. Brine management criteria were cost, effectiveness, durability, maintenance, and size. Criteria weighted reasonings, scoring, and detailed decision matrix for brine management are shown in *Appendix AB*. Alternatives considered were brine storage tanks, evaporation ponds, and membrane distillation. For brine storage tanks, CST Aquastore 2.5 MG Tanks were considered (data sheet can be found in *Appendix AC*). The evaporation ponds would be supplied by LennTech Water Treatment Solutions (details can be found in *Appendix AD*). The Memsys Membrane Distillation System (MDS) would be used as the technology for membrane distillation (data sheet can be found in *Appendix AE*). Table 2-9 below shows the simplified brine management decision matrix and chosen alternatives (indicated in bold and highlighted). Through this alternative selection process, brine storage tanks (CST Aquastore Tanks), evaporation ponds (Lenntech Water Treatment Solutions) and, membrane distillation (Memsys Membrane Distillation System (MDS)) were all considered as brine management technologies in alternative treatment trains.

Table 2-9: Brine Management Simplified Decision Matrix

Brine Management	Cost (20%)	Effectiveness (25%)	Durability (20%)	Maintenance (15%)	Size (20%)	Total Score
CST Aquastore Tanks	**2**	**3**	**2**	**3**	**3**	**2.25**
Lenntech Water Treatment Solutions Evaporation Ponds	**3**	**2**	**2**	**1**	**1**	**1.85**
Memsys Membrane Distillation System	**1**	**3**	**1**	**1**	**2**	**1.70**

2.8 Treatment Trains Selection Evaluation

This section describes three treatment train alternatives, discusses the criteria, and the decisions that were involved in selecting a final treatment train for the AWPF.

2.8.1 Treatment Train Selection Process & Criteria

When creating the three alternative treatment trains, decision matrices mentioned in Section 2.1 through 2.7 were used to form the trains based on each process and the ranked technologies. Treatment trains were created based on pairings CJE selected to create efficient, suitable, and practical treatment trains.

Each treatment train alternative was scored using weighted criteria of cost, operational flexibility, footprint, and additional CJE criteria which included construction time, environmental impact, and treatment performance. The cost criteria consider total cost of each treatment train to ensure an economically feasible treatment design. Operational flexibly judges the flexibility of the treatment train to perform daily operations and if the train can withstand unexpected increase or decrease of flow rates along with possible expansions. Since the facility has a limited amount of space, the footprint criteria identify the spatial demand for each treatment train. The construction time criteria judges how long each treatment train will take to construct considering the technology used. Environmental impact criteria identifies if the treatment train has a large energy usage or can produce harmful environmental by-products. Lastly, the most important criteria is treatment to ensure that the treatment train can release effluent water that meets codes and regulations from the EPA, AEDQ, and MCESD for direct potable drinking water. These criteria weight reasonings, scoring, and detailed decision matrix for the treatment trains are found in *Appendix AF.*

2.8.2 Treatment Train #1 Alternative

Figure 2-1 is a visualized treatment train with the treatment processes selected for Treatment Train #1. The train shows the water process throughout its entirety along with chemical additions and brine management in green. Treatment Train #1 was designed with the intention to remove liquid discharge by enabling water recovery and reuse while converting residual brine into solid salts for safe disposal.

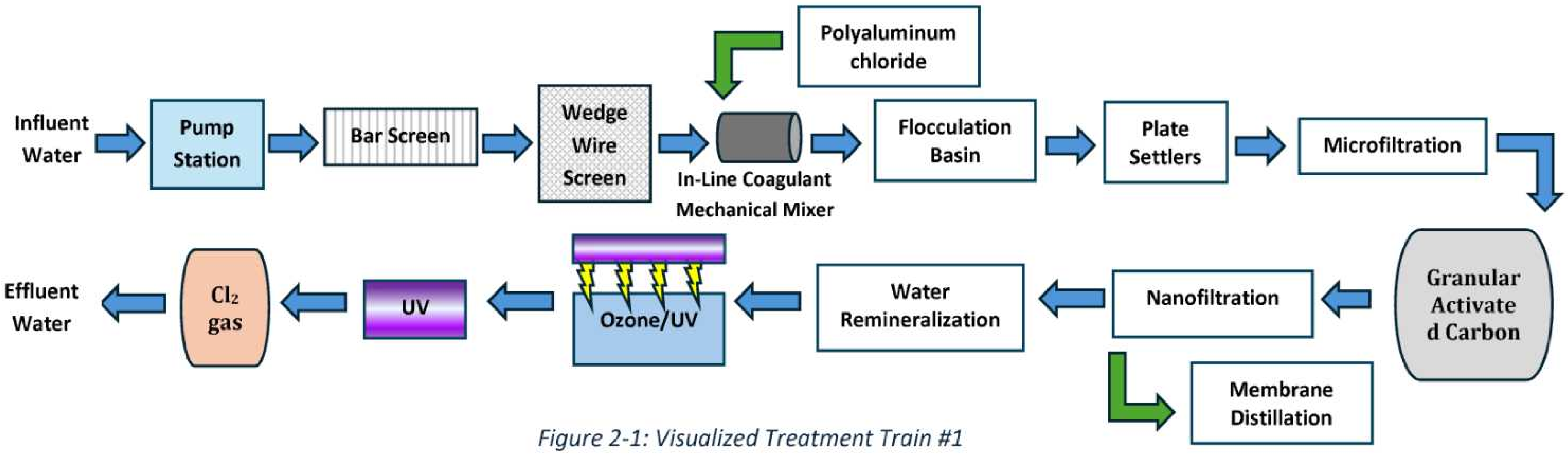

Figure 2-1: Visualized Treatment Train #1

2.8.3 Treatment Train #2 Alternative

Figure 2-2 is a visualized treatment train with the treatment processes selected to form Treatment Train #2. The train shows the water process throughout its entirety along with chemical additions and brine management in green arrows. Treatment Train #2 was designed using treatment alternatives that were most cost effective.

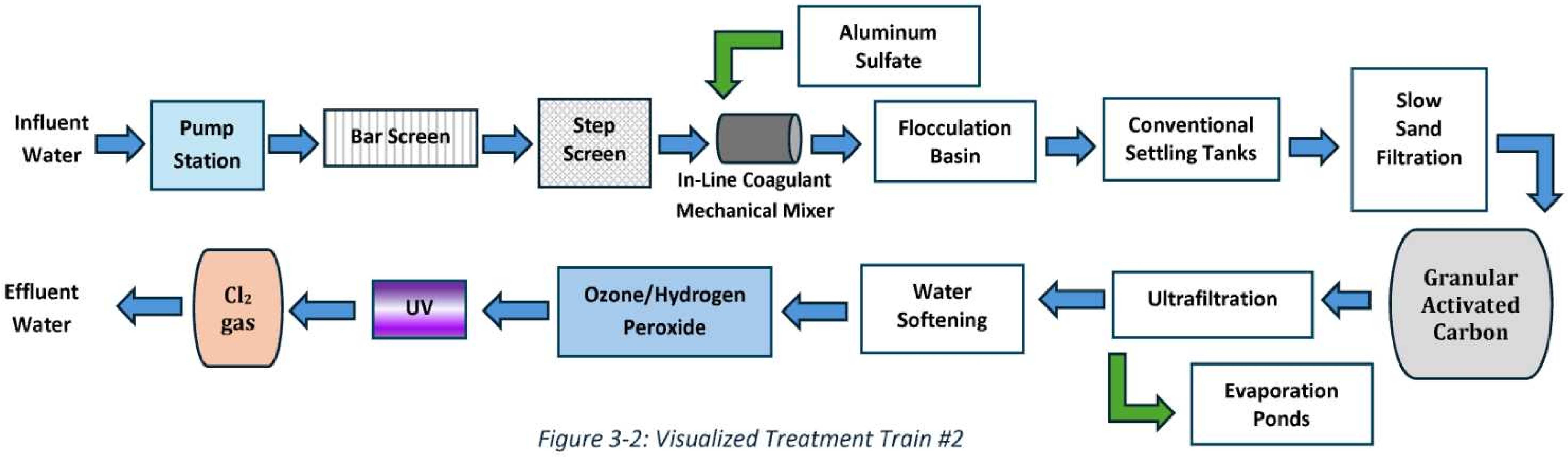

Figure 3-2: Visualized Treatment Train #2

2.8.4 Treatment Train #3 Alternative

Figure 2-3 is a visualized treatment train with the treatment processes selected to form Treatment Train #3. The train shows the water process throughout its entirety along with chemical additions and brine management in green arrows. Treatment Train #3 was designed using treatment alternatives that had the best treatment performance, resulting in the best quality of drinking water.

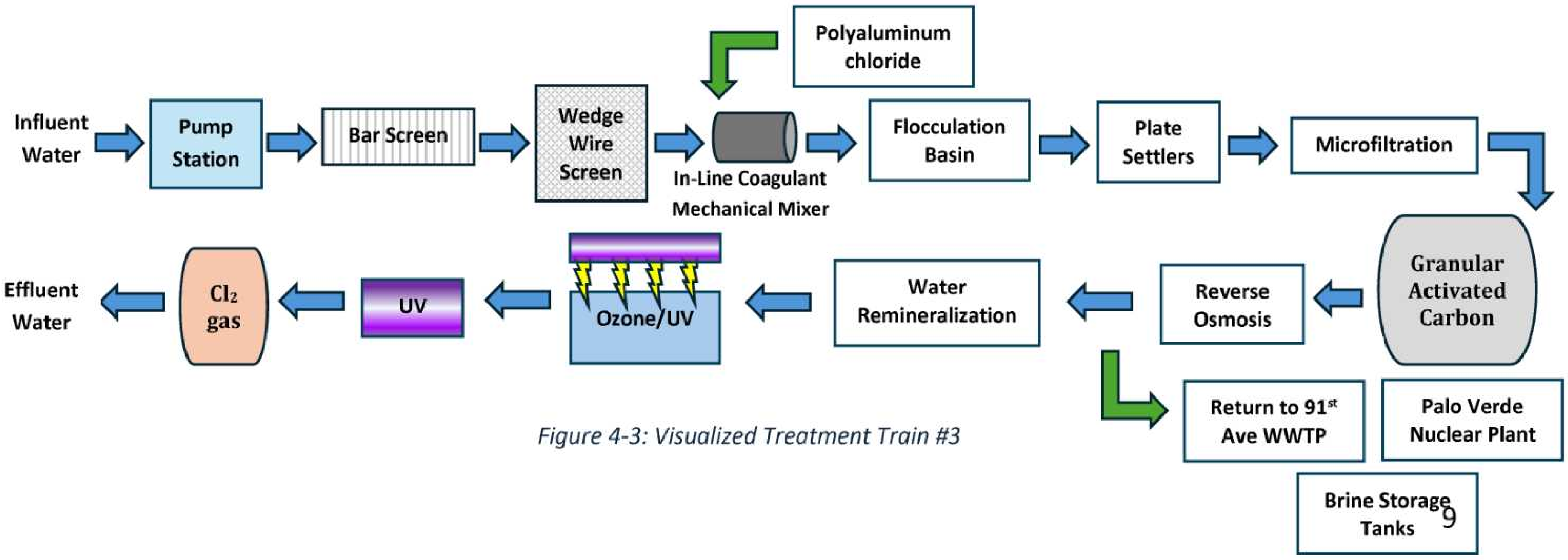

Figure 4-3: Visualized Treatment Train #3

2.8.5 Final Treatment Train Selection

When selecting the optimal treatment train, many factors were considered. Treatment Train #3 exceled at having operational flexibility, short construction time, low footprint, and peak treatment performance but had a high cost and a large environmental impact. Treatment Train #2 had low cost, low environmental impact, and a short construction time. However, this treatment train did not have operational flexibility, required high footprint, and low treatment performance. Treatment Train #1 had a small footprint and had the required treatment performance; however, it was considered high cost, low operational flexibility, had a large environmental impact, and a long construction time. After weighing these criteria, the treatment train alternative with the best weighted score from the decision matrix was Treatment Train #3. These criteria, weight reasonings, and the detailed decision matrix for the treatment train selection can all be found in *Appendix AF*. Table 2-10 is a simplified decision matrix with the weighted criteria and the selected treatment train.

Table 2-10: Treatment Train Simplified Decision Matrix

Treatment Train	Cost (20%)	Operational Flexibility (25%)	Footprint (20%)	Construction Time (5%)	Environmental Impact (15%)	Treatment Performance (15%)	Total Score
Treatment Train #1	2	2	2	2	2	2	2
Treatment Train #2	3	1	3	1	1	1	1.67
Treatment Train #3	**1**	**3**	**1**	**2**	**2**	**3**	**2.17**

2.9 Hydraulic Component Evaluations

The selection of the conveyance system and pumping infrastructure was decided by weighted decision matrices using critical criteria tailored to the effluent from the FRW to find the reliably long-term and efficient options. The decision matrices in the following sub-sections will analyze the pump types, pipe materials, and pipe diameter.

2.9.1 Pump Selection

Selecting a pump type capable of pushing high volume, has a compact structural footprint, and is easily accessible for maintenance are the criteria of the matrix. The Vertical Turbine is the optimal choice because the motor is vertically mounted, and the motor is easy to access unlike the submersible which requires equipment to lift or dry pits requiring more footprint to access. The detailed decision matrix for pump type can be seen in *Appendix AG*.

Table 2-11: Pump Simplified Decision Matrix

Pump Selection	Maintenance Accessibility (60%)	Structural Footprint (40%)	Total Score
Vertical Turbine	**3**	**3**	**3.00**
Dry Pit Centrifugal	2	1	1.60
Submersible Pump	1	3	1.80

2.9.2 Pipe Material Selection

The pipe material evaluated includes Ductile Iron (Lined), AWWA C905 polyvinyl chloride (PVC), and High-Density Polyethylene (HDPE). Criteria focused on lifespan/durability, lifecycle cost, and the hydraulic efficiency the pipe material provides. Since the water quality has high levels of hardness and can lead to scaling problems, each material will render it negligible due to their smoothness. The selected material is the C905 PVC because the Ductile Iron is expensive to install and needs to be replaced more often. HDPE production is cheaper than Ductile Iron Pipes, but the installation is more expensive. The detailed decision matrix for pipe material can be found in *Appendix AG*.

Table 2-12: Pipe Material Simplified Decision Matrix

Pipe Material	C Factor (20%)	Life Cycle Cost (40%)	Durability (40%)	Total Score
C905 PVC	**3**	**3**	**2**	**2.60**
Ductile Iron	2	2	2	2.00
HPDE	3	2	2	2.00

2.9.3 Pipe Diameter Selection

Velocity, total dynamic head in feet, lifecycle cost, and future growth/surge capacity were the criteria to select the most reliable and efficient pipe diameter for the force main. Pipe costs can vary as they get larger and become more difficult to install. The velocity is also important, to achieve scouring, the velocity must be greater than two feet per second (FPS). Velocity and total dynamic head were analyzed by developing a system curve for various pipe diameters using Hazen-Williams Equation for head loss due to friction (calculations can be found in *Appendix AH*). The 42" diameter was selected because it is capable of future and surge capacities, not overly expensive, produces the second least head loss due to friction, and the velocity is 5.98 FPS. The decision matrix is shown in *Appendix AI*.

Table 2-13: Pipe Diameter Simplified Decision Matrix

Pipe Diameter	Velocity (40%)	Energy Efficiency (30%)	Lifecycle Cost (10%)	Future Capacity (20%)	Total Score
Diameter 36”	2	2	3	1	1.90
Diameter 42”	**3**	**3**	**2**	**2**	**2.70**
Diameter 48”	1	3	1	3	2.40

3.0 Final Design Recommendation

This section summarizes the final design recommendations for the treatment trains and hydraulic design.

3.1 Location of AWPF

As discussed in *Section 2.1*, Parcel 101-33-003 on the north side of the existing 91st Ave WWTP was selected for the AWPF. Figure 3-1 shows the proposed location for AWPF and the location of the hydraulic station.

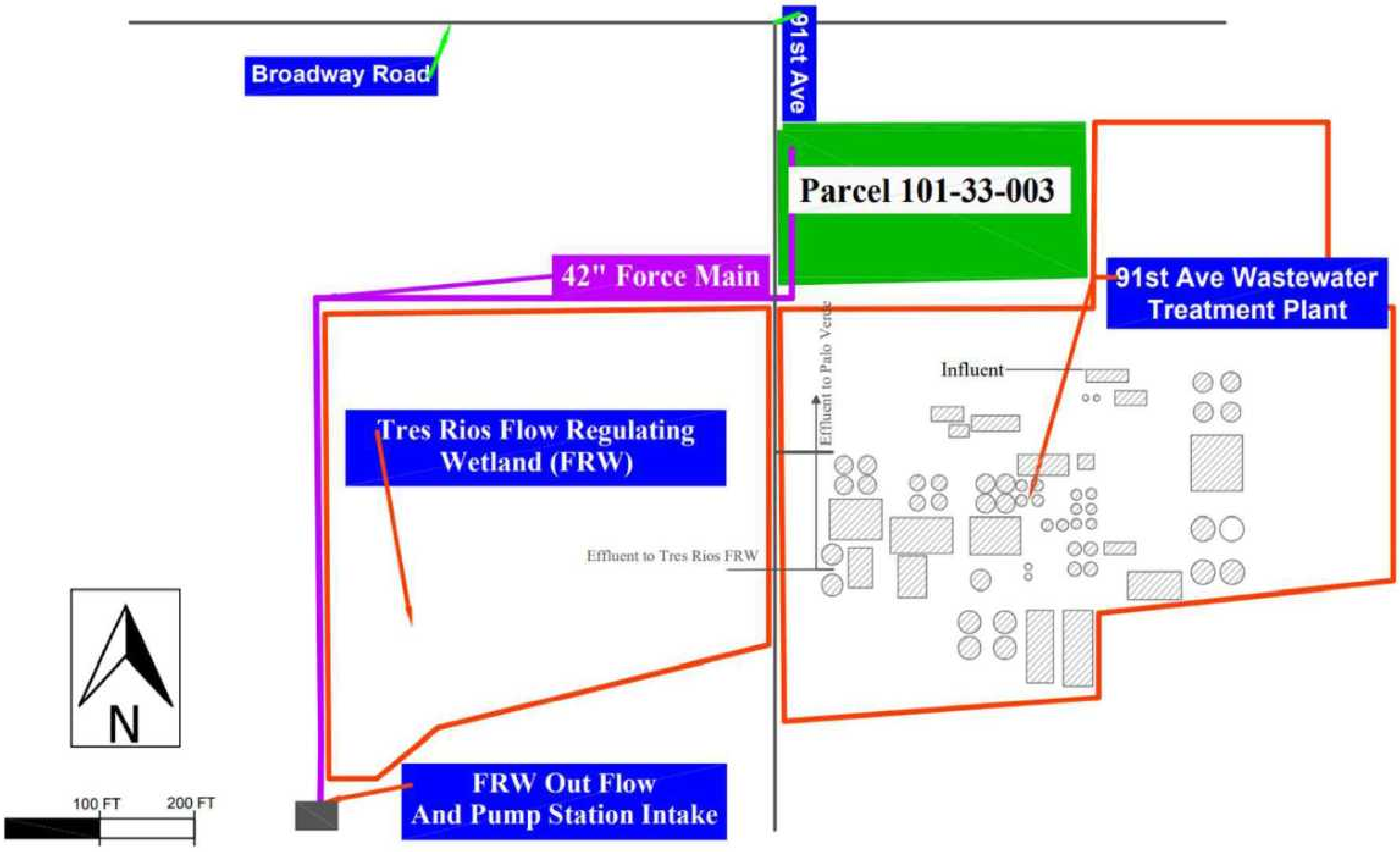

Figure 3-1: Proposed AWPF Location Map

3.2 Treatment Train Final Design

As mentioned above, the final treatment train selected was Treatment Train #3 based on the decision matrix. The reasoning was explained in further detail in *Section 2.8.5* and *Appendix AF*.

3.2.1 Existing and Proposed AWPF Site Layout

The proposed AWPF is located on an 88-acre parcel east of 91st Avenue. To optimize the hydraulic grade line and protect downstream equipment, the raw water intake, bar screens, and pump station are located at the edge of the Tres Rios Flow Regulating Wetland. This configuration mitigates debris intake prior to conveying influent through the force main. At the AWPF site, the treatment processes are arranged sequentially to streamline hydraulic routing and provide constructability and maintenance clearances. Open-air pretreatment structures, including flocculation basins and plate settlers, are positioned near the MF and RO buildings. The RO effluent is bifurcated. Permeate is routed through remineralization, an AOP, and chlorine gas disinfection to meet potable distribution standards. The RO concentrate is diverted to a 1.03-acre brine transfer pad. This footprint facilitates the transfer of 10 MGD of rejected water. The brine is distributed equally to the Palo Verde Nuclear Generating Station (PVNGS) and the 91st Avenue WWTP. This layout maximizes operational efficiency within the 88-acre footprint while managing municipal brine production. The existing layout can be viewed in *Appendix AJ.* The proposed layout can be viewed in *Appendix AK.*

3.2.2 Existing and Proposed Process Flow Diagram

The 91st Ave WWTP's existing process flow is shown in Figure 3-2 below, 91st Ave WWTP's existing process flow consists of the WWTP's effluent being sent to the PVNGS, FRW, Salt River, and Hayfield Wetlands.

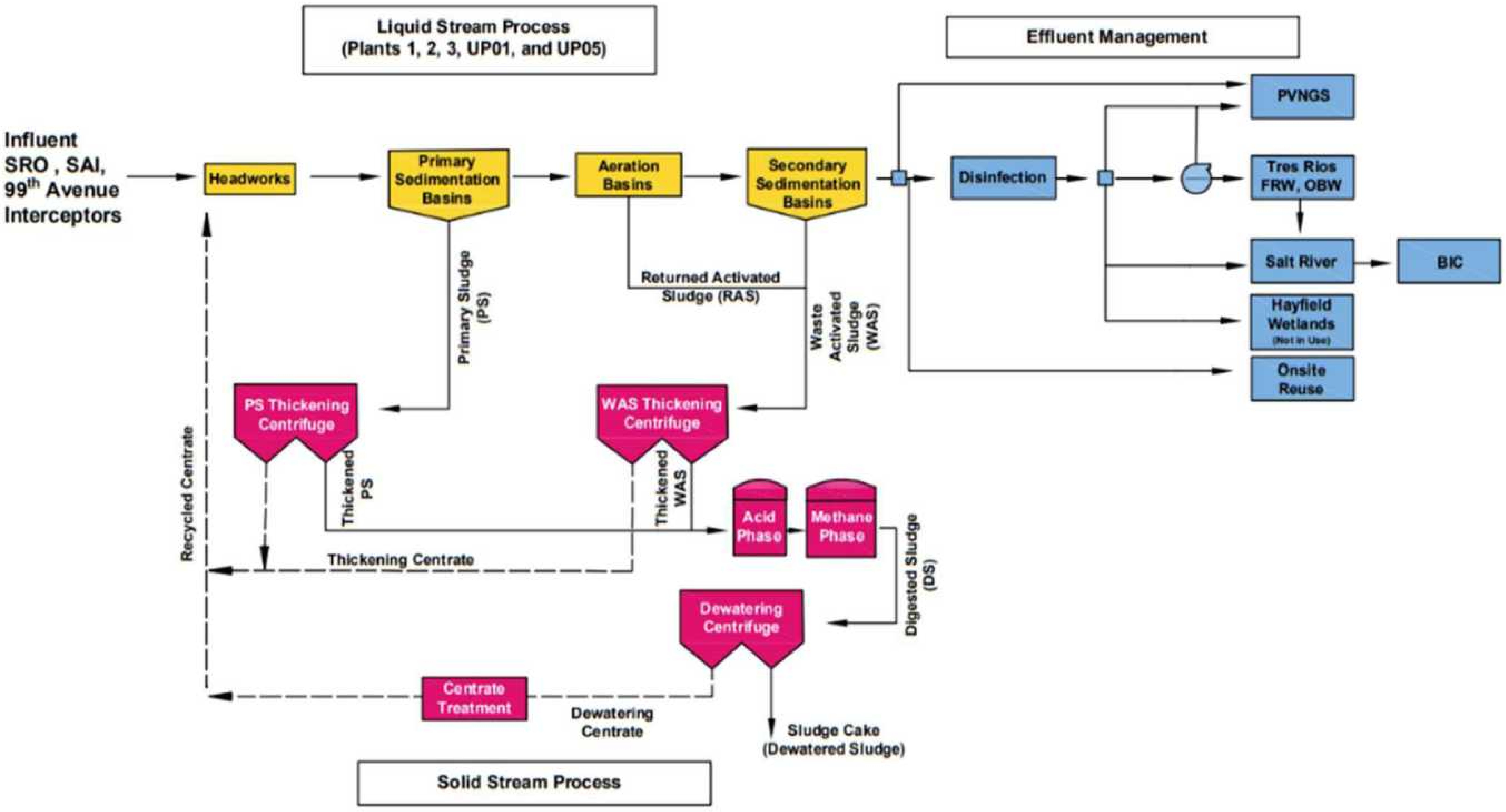

Figure 3-2: 91st Ave WWTP Existing Process Flow Diagram

CJE proposes that 40 MGD of effluent will also be delivered to the AWPF along with PVNGS, FRW, Salt River, and Hayfields Wetlands. In the proposed flow diagram that is depicted in Figure 3-3 below, shows the proposed flow going through the AWPF.

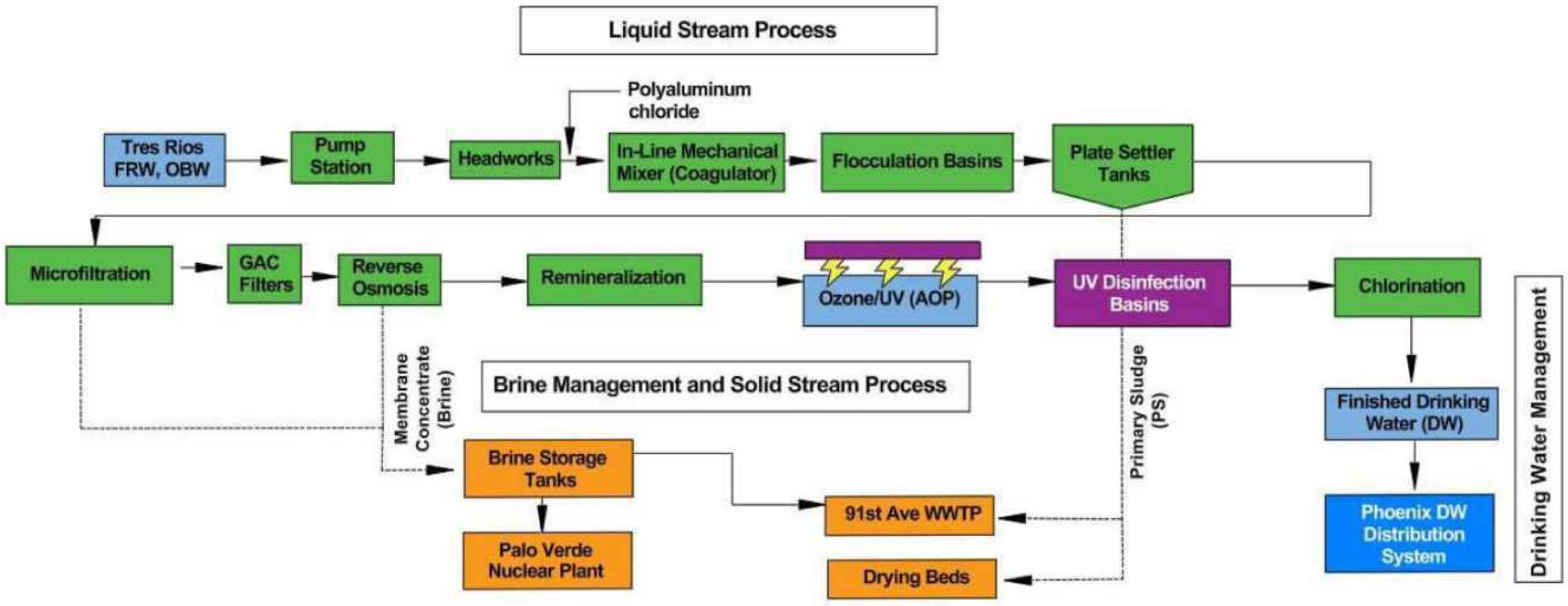

Figure 3-3: CJE Proposed Process Flow Diagram for AWPF

3.2.3 Treatment Train Design

The final design consists of a preliminary screening using six FlexRake Duperon Tear Drop Shaped bar screens to remove large pollutants such as garbage, branches and other large particles that can negatively impact the treatment train process. The calculations for removal efficiency, number of screens, head loss, and area of the bar screens can be found in *Appendix AL*. The bar screens are then followed by Vee-Wire Flat Panel Wedge Wire Screens manufactured by Johnson's Screening with ten units being implemented into the design which support the removal of smaller particles such as slurries, debris, suspended solids, and impurities from the influent. Calculations can be found in *Appendix AM.*

For the coagulation design, a General Duty LS Series In-Line Mixer was used to inject the polyaluminum chloride (PAC) into the 42-inch diameter pipe where the coagulant is rapidly mixed for 0.5 seconds for a length of four feet. The coagulation process helps the water form flocs made up from smaller particles to reduce the TSS levels and improve turbidity. The volume, power, head loss, and velocity gradient calculations can be found in *Appendix AN*. The flocculation design consists of four JMS Inc. MegaFloc Horizontal Paddle Wheel Flocculator Systems, serving the same purpose as coagulation and preparing the influent for sedimentation. The flocculation basin dimension calculations, land usage, head loss, quantity of flocculation basins, and hydraulic detention time can be found in *Appendix AN*.

For the sedimentation process, six JMS Inc. Mega Plate Settlers System will be used. Sedimentation tanks will be designed to settle the flocs and other suspended solids, so the overall water quality can be low in TSS to reach drinking water standards. The calculations for the sedimentation basin dimensions, head loss, quantity of sedimentation basins, and land usage can all be found in *Appendix AO*. The membranes chosen for MF are designed by GORE, with the model being one micrometer, hydrophilic (ePTFE) MF membrane. A total of 22 units with 100 membranes in each unit will be used for filtration to help with bacteria, viruses, and pathogens. Calculations for backwash, land usage, head loss, and treatment efficiency can be found in *Appendix AP.*

For the GAC process, the MPW Flex Media Filtration was used with a total of seven filters with one offline. GAC filters remove organic compound to polish the water before advancing to the RO treatment to protect the membranes. The calculations for the GAC filters include area per filter, volume, hydraulic loading rate and land usage which can be found in *Appendix AQ*. RO process will use DuPont BW30 Pro-400/34 Element Membranes which will remove TDS such as salts, ions, pathogens, PFAS, and pharmaceuticals. A total of 45 units holding 20 membranes will be sufficient to treat 40 MGD and additional membranes on standby. After RO, remineralization of the water will be done with six MECO Softening and Ion Exchange Unit. Calculations for the land usage, head loss, and treatment efficiency process of RO can be found in *Appendix AR,* along with the water balancing and remineralization processes.

For the advanced oxidation process (AOP), two basins using Wedeco MiPRO AOP were designed. AOP using ozone and UV breaks down organic and inorganic contaminants in water to purify drinking water and eliminate pollutants that conventional methods cannot remove. The volume of the basins, contact time, and area were calculated and can be found in *Appendix AS*. Disinfection will consist of chlorine and UV radiation. Chlorine will be converted from liquid to gas, so gas can be pumped into the water, creating a chlorine residual to comply with EPA, MCESD, and ADEQ standards. For UV, the Ultraqua UV Disinfection Systems will be used to inactivate and kill bacteria, viruses, and microorganisms that could be present within the water. The calculations done for UV are land usage, basin dimensions, and UV characteristics which can be found in Appendix AT.

Brine will be stored in three CST-Aquastore GFS Tanks that have a volume of 2.5MGD and hold brine for twelve hours. The brine stored will be dispersed equally between the PVNGS for cooling and electricity and the WWTP plant for retreatment. Calculations for the tank design and retention time process can be found in *Appendix AU.*

Table 3-1: Sizing for AWPF Treatment Processes

Treatment Stage	Process Equipment	Physical Sizing	Key Design Parameters & Function
Intake (Tres Rios)	Coarse Static Bar Screens	6 Units (Total Area: 126 ft^2)	Protects the primary pump station.
Headworks	Mechanical Bar & Wedge-Wire Screens	10 Units (Total Area: 320 ft^2)	Provides fine screening and additional coarse screening.
Coagulation	In-Line Mechanical Mixer	Length: 16.1 ft, Radius: 1.75 ft	Detention Time = 2 seconds.
Flocculation	Flocculation Basins	4 Basins (809 ft L x 42 ft W x 3.5 ft D)	Hydraulic Retention Time (HRT) = 25 minutes.
Sedimentation	Plate Settler Tanks	6 Tanks (130 ft L x 14 ft W)	Settles flocs from the coagulation & flocculation process
Filtration	Microfiltration Filters	Total Land Acreage: 0.5 acres	Pressurized via intermediate pumps; removes fine particulates and dissolved organics.
GAC Tank	GAC Systems	7 Filters, Dimensions per filter (81 ft L x 20 ft W, 15 ft D)	Poshes the influent before entering the RO systems
Advanced Filtration	RO System	Total Land Acreage: 0.5 acres	Produces two streams: treated water and reject brine.
Brine Management	Vertical Storage Tanks	3 x 9 ft Diameter	Provides surge buffering prior to off-site pumping.
Remineralization	In-Line Static Mixer	Length: 16.1 ft, Radius: 1.75 ft	Restores minerals to the treated RO water.
AOP	Ozone Contact & Medium Pressure UV	Total Area: 159 ft^2	Ozone Contact Time = 3.33 minutes. UV Velocity = 0.5 fps; UV Contact Time = 10 seconds.
Final Disinfection	UV & Chlorine Gas	Total Area: 159 ft^2	Provides additional disinfection to meet potable distribution standards.
Total Land Area		**4.5 acres**	

3.2.4 Treatment Train Water Quality Comparison

Table 3-1 is a water quality table that shows the initial water quality in the influent and the final water quality in the effluent after the water has passed through the AWPF treatment process. The prompt provided the parameters shown below, and the effluent water quality meets all the drinking water codes and regulations for water quality according to EPA, MCESD, and ADEQ. The entire water quality table with each process and finished water quality can be found in *Appendix AV*.

Table 3-2: Water Quality Table Results After AWPF

Parameters	Units	Influent	Effluent
Alkalinity	mg/L as $CaCO^3$	181.0	60.0
Calcium	mg/L as $CaCO^3$	194.6	70.0
Chloride	mg/L	367.0	0.4
Magnesium	mg/L as $CaCO^3$	131.6	30.0
pH	Unitless	7.4	7.4
Orthophosphate	mg/L as P	3.2	0.0
Potassium	mg/L	23.0	0.2
Silica$_2$	mg/L as SiO^2	16.0	0.2
Sodium	mg/L	256.0	2.7
Sulfate	mg/L	181.0	1.9
TDS	mg/L	1142.0	0.2
Temperature	C	25.0	25.0
TKN	mg/L as N	3.3	0.0
TSS	mg/L	8.6	0.0

3.3 Hydraulic Design

The hydraulic design for the AWPF entails the infrastructure that will convey 40 MGD of effluent from the FRW to the intake of the AWPF. This section details the design of the pump station, selected pump, pipe design, and the design of the hydraulic profile.

3.3.1 Pump Station Design

The pump station serves as a critical conveyance component from the FRW to the AWPF, designed to deliver 40 MGD. This flow rate accounts for an additional 25% of reject water volume from the RO systems, ensuring the facility meets its production goal of 30 MGD of potable water (Orange County Water District, 2010).

The intake structure sump will house five total pumps, configured with four operating duty pumps and one standby pump. Sump dimensions (detailed in Appendix AW) follow the Hydraulic Institute's American National Standard for Rotodynamic Pump for Pump Intake Design, Section 9.8. To protect equipment and aquatic life, the intake is sized with a 92.80-square-foot effective area to maintain an inlet velocity of 0.5 FPS, complying with Clean Water Act (CWA) Section 316(b) regulations to prevent entrapment (Environmental Protection Agency, 2014, August 15). Additionally, strainer screens are attached directly to the pump intakes to protect equipment from further downstream.

The pump station is designed for a Total Dynamic Head (TDH) of 86.18 feet at the design flow rate. This total head primarily consists of 58 feet of static head, calculated from the sump's low water level (15 feet below grade) to the headworks of the AWPF (40 feet above grade). Elevating the headworks provides sufficient hydraulic head for gravity conveyance throughout the pretreatment train; additionally intermediate pumps are later utilized to achieve necessary pressures for the MF and RO processes. The remainder of the TDH accounts for 23.18 feet of friction loss through 9,900 linear feet of 42-inch diameter force main, alongside 5 feet of minor losses from bends and valves. A detailed plan and profile drawing of the pump station is provided in *Appendix AX*.

Based on the pump decision matrix, the station will utilize five 27ML-BRZ Pentair Fairbanks NIJHUIS Vertical Turbine Pumps operating in parallel. As noted, the proposed configuration relies on four pumps operating continuously to meet capacity while the fifth remains on standby to rotate into activity, allowing scheduled maintenance without disrupting flow. Each unit is powered by a 250 HP motor and features a 20-inch discharge nozzle. The pump assembly includes a 22.50-inch suction bell, a 27-inch nominal bowl diameter, and 15.14-inch mixed-flow impellers. Constructed of 316 stainless steel with a ceramic epoxy coating, the pumps are highly resistant to scaling caused by water hardness. The mixed-flow impellers allow the passage of solids up to 2.75-inches in diameter without clogging, ensuring reliable operation. Based on the performance curves found in Appendix *AG*, these pumps will operate at approximately 80% efficiency.

3.3.2 Pipe Design

The piping system is designed to convey the pressurized effluent from the intake of the pump station to the AWPF headworks inlet over an estimated distance of 9900 feet. Based on the hydraulic analysis of pump system curves, the selected diameter and material are 42-inch and AWWA C905 PVC respectively. For the design flow of 40 MGD, the velocity of effluent in the pipe will be 5.98 FPS. This velocity sits in the optimal range of a sufficient speed to prevent any settling and scouring and any organic matter but also low enough to minimize head loss due to friction. To address the water quality challenges of hardness, the PVC pipe was selected due to its cheap lifespan and smooth surface in *Appendix AX*.

3.3.3 Hydraulic Profile Design

The hydraulic profile for the AWPF displays the potential energy of the influent as it progresses through the treatment train. To start the hydraulic profile, the influent goes through the bar screen and arrives at the intake of the pump station. Inside the pump station the minimum allowable water level is 945.00 ft and discharges from the sump at 965.00 ft into the 42” force main which it leads to the headworks of the AWPF at an elevation of 1,011.10 ft. As the treated water flows past plate settlers it enters intermediate pumps to pressurize the flow through the sequence of microfiltration, GAC, and RO as they require more energy to push through the friction loss of membranes and filters. After the RO treatment, the flow separates into brine which will temporarily be stored in vertical tanks that diverges the brine equally to two destinations: the PVNGS and the 91st Ave WWTP. While the treated water flows from RO, water will be remineralized in an in-line static mixer with minimal head loss. The hydraulic profile can be found in *Appendix AY.* Calculations for the hydraulic profile can be found in *Appendix: AZ.*

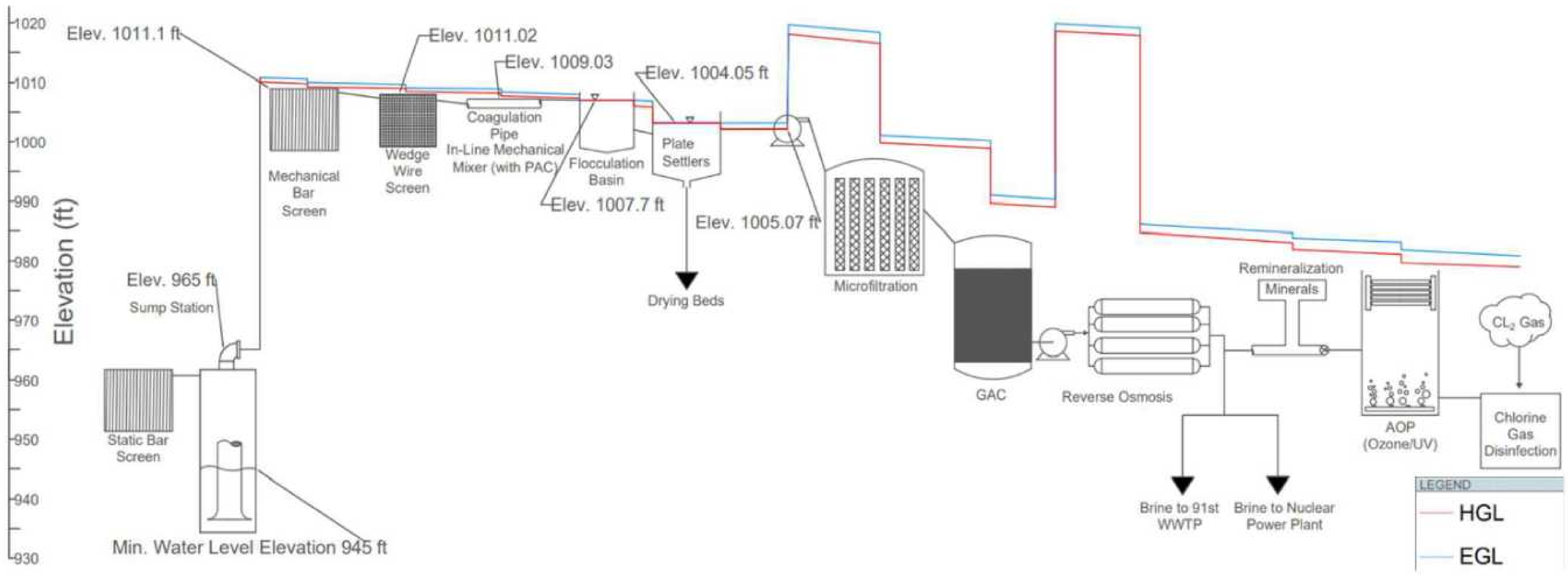

Figure 3- 4: Hydraulic Profile of AWPF

4.0 Cost Analysis

In the following sections, CJE will provide the Engineer's Opinion of Probable Cost (EOPC), the annual Operation and Maintenance (O&M) cost, and the construction cost for the AWPF.

4.1 Engineer's Opinion of Probable Cost

CJE's simplified EOPC for the pump station & hydraulic design are shown in Table 4-1 below. The multiplier represents the scaling factor to make the cost accurately show the estimated cost for units at larger sizes than available in the RS Means free trial U.S. 2018 Price Index database. The detailed EOPC for the pump station and hydraulic design are shown in *Appendix BA*. The pump station and hydraulic design are projected to be around $3,400,000.

Table 4-1: Simplified EOPC for Pump Station & Hydraulic Design

Capital Expenditures				
Qty	**Description**	**Unit**	**Multiplier**	**Extended Total O&P**
69	Sheet piling, steel, 38 psf, 25' excavation	Ton	1.00	$93,743
400	Wellpoints, each additional month, includes operation, equipment rental, and fuel	LF Hdr	1.00	$143,428
200	Wellpoints, complete installation, includes one month operation, equipment rental, fuel and removal of system	LF Hdr	1.00	$110,542
1,005	Excavating, bulk bank measure, hydraulic, crawler mounted	B.C.Y.	1.00	$1,698
20,514	Excavating, trench or continuous footing, common earth	B.C.Y.	1.00	$69,132
50	Structural concrete, cast in place	C.Y.	1.00	$14,11
158	Structural concrete, cast in place	C.Y.	1.00	$63,903
9,920	Water supply distribution piping, piping polyvinyl chloride, 42" diameter, AWWA C905	L.F.	1.00	$1,706,537
5	Water utility distribution valve, gate valves, 36" diameter, includes valve box and mechanical joint	Ea.	1.25	$438,911
5	Water utility distribution valve, butterfly valves with boxes, 24" diameter, includes valve box and mechanical joints	Ea.	1.75	$106,341
5	Motor control center, starters, incl starters & structures	Ea.	1.00	$88,162
5	Motor control center, structures	Ea.	1.00	$13,518
5	Pumps	Ea.	1.42	$295,901
5	Variable frequency drives, custom-engineered, 460 V, 200 HP motor size	Ea.	1.25	$209,030
Total			1.00	**$3,354,964**

Table 4-2 shows CJE's EOPC for the treatment train. CJE predicts the treatment train's material will cost around $372,000,000 for all treatment process. A detailed cost table is available in *Appendix BB*.

Table 4-2: Simplified EOPC for Treatment Train

Treatment Train Capital Cost	
Bar Screen	$550,000
Fine Screening Facility	$750,000
Coagulation & Flocculation	$250,000
Sedimentation	$930,000
GAC	$4,360,000
Microfiltration	$151,100,000
Reverse Osmosis	$201,800,000
Remineralization	$360,000
AOP	$4,300,000
UV & Chlorine	$3,600,000
Brine Management	$4,500,000
Labor	$680,323,848
Grand Total	**$1,052,823,848**

4.2 Annual Operation & Maintenance

O&M cost per year for the treatment train is predicted to be around $60,000,000 per year. Table 4-3 shows the simplified O&M costs accounting for energy, chemicals, systems, maintenance/replacements, and labor needed for both hydraulic and treatment train design; *Appendix BC* shows the detailed table.

Table 4-3: Simplified O&M for Treatment Train

Category	Cost
Energy	$16,734,556
Chemicals	$30,980,475
Systems	$4,375,930
Maintenance	$2,250,835
Labor	$2,046,500
Total Cost	**$59,951,720**

5.0 Public Outreach Plan

CJE proposes a series of public engagement and educational meetings throughout the greater Metro Pheonix area. These informational sessions will be held in schools, at local city events and other public community spaces. The purpose of these meetings will be to educate residents about advanced water treatment processes and build public trust. CJE also proposes the construction of a dedicated educational center as a long-term outreach initiative. This center will be located between the 91st WWTP and FRW and will be near the AWPF site. Figure 5-1 below shows the proposed site for the 91st Ave AWPF and FRW Educational Center.

Figure 5-1: Proposed Educational Center Location

Engineers and plant operators will host tours and field trips at the educational center, providing visitors with direct insight into facility operations. These educational tours will offer a rich cultural, educational, and community value by demonstrating the environmental buffer, advanced treatment processes used at the AWPF and the broader benefits of advanced water purification. To build public trust, several strategies will be implemented, including the establishment of independent oversight panels composed of community representatives and scientific experts, the development of open-access data dashboards, and third-party validation through partnerships with academic institutions. In addition, a long-term pilot program will be conducted to demonstrate the facility's performance and allow the public to review operational water quality data. The facility will prioritize transparency in its operations to foster a strong, trust-based relationship with the community. By clearly communicating the need for the AWPF, the project will help residents better understand regional water challenges and evaluate associated tradeoffs. Ultimately, the success of the facility depends on both educating the public and building lasting trust in its operations and benefits.

6.0 Construction Sequencing

The first phase for the construction sequence, month one, will be the site preparation on Parcel 101-33-003 for the AWPF, which will include clearing, grading, excavation, and establishing temporary utilities which will take three to four months to complete.

During month one, the construction of two temporary side canals will occur to allow FRW discharge to the Salt River while the AWPF pump station is constructed. Figure 6-1 shows the design for the canals. These canals will be constructed using a compacted native soil such as clay, with gravel being implemented for erosion control. Native grasses, reeds, and shrubs will also be planted for the canal, with rock weirs being constructed for flow control. This canal will be around six and a half feet deep, with roughly three and a half feet of freeboard. The entire outfall will be closed off during construction to prevent any leakage onto the construction site for the outfall. The dimensions of the canals were designed with the purpose of conveying the flow from Outfall 005.

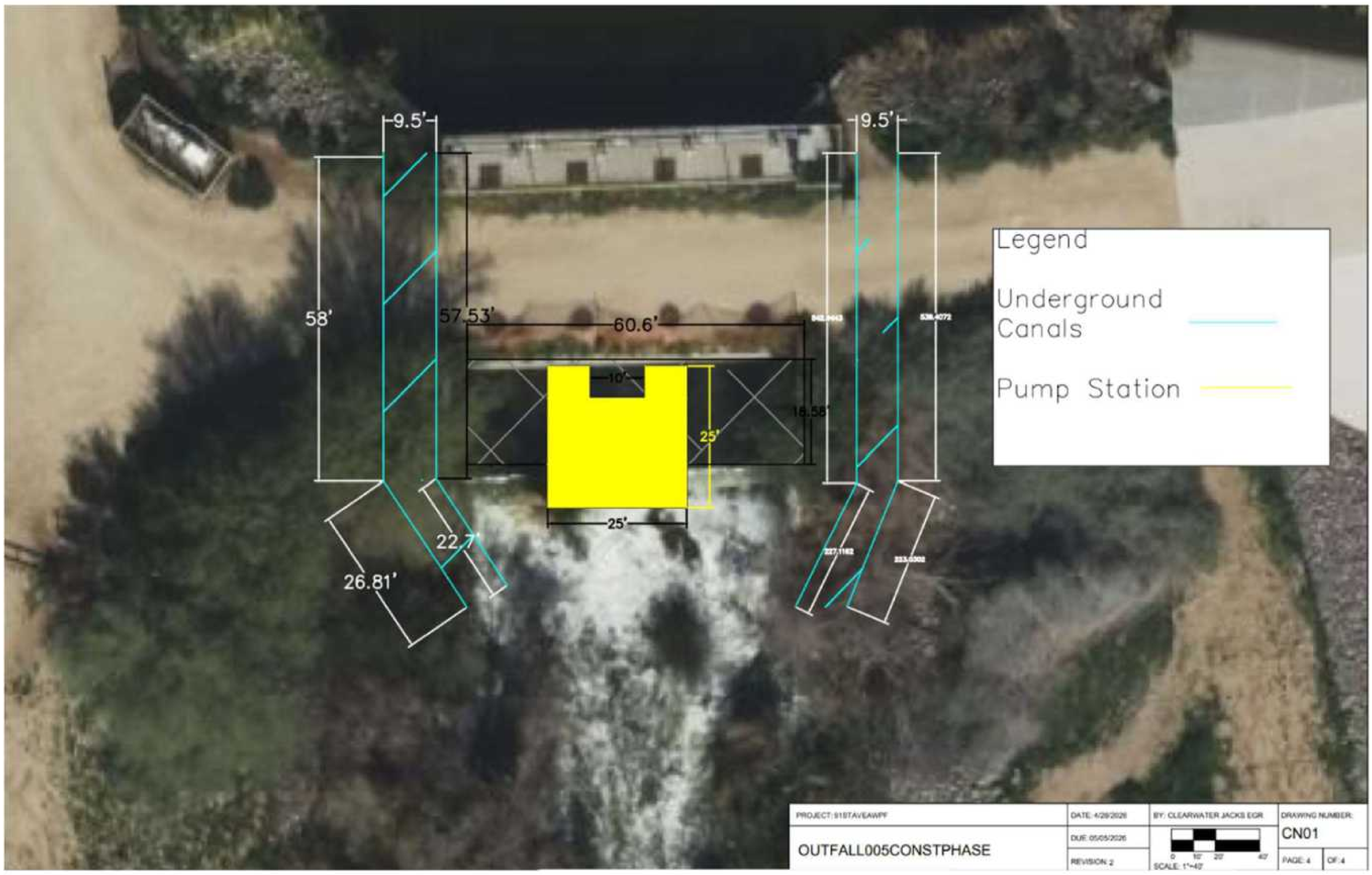

Figure 6-1: Design for Canal at Outfall 005

After the site is prepared, the construction of the sump will consist of deep excavation, foundation and reinforced structure, along with installation of screens and instrumentation, which will take around four-six months and will occur on month three. Structural build begins after partial completion of the pumps, during month five, followed by the pump installation which will occur around month eight, and electrical/control systems.

During month six, the construction of the treatment train begins, with the large basins being constructed first, then followed by the membrane facilities, which will take the longest time, around six months for the civil structures and another eight for the internal structure and equipment.

During month ten, the pipe network construction will begin, which will overlap with treatment construction. Construction of the pipes will take around 12 months and will be completed during month 22.

In month 16, the mechanical and electrical construction will occur, with RO, MF, UV, AOP, and instrumentation will be implemented into the site, which will take around ten months to complete.

The next phase will be the construction of the education center which will occur during month 12 and will take around 12 months to complete.

The final phase of the project will begin during month 26, and will be dry testing, wet testing, full operation, and the gradual start-up of the treatment train, and will take six months to complete, totaling 32 months of construction time. The table of the construction sequence phasing plan can be found in *Appendix BC.*

7.0 Project Impacts

The AWPF will benefit the environment by increasing water supply resilience, because it will create a local, drought-resilient source of drinking water by turning the reclaimed wastewater into a potable water source, which will help reduce the reliance on stressed surface water sources, and will positively affect the water supply of other sources with less extraction. This will also help protect ecosystems and aquatic habitats. The site will also affect the environment negatively using energy and increasing emission rates due to operations. Construction may cause harm to the environment as well. The positive and negative impacts will also be implemented globally, as an increased carbon footprint/energy demand is going to impact the planet, contributing to global emissions, and the localization of the water source helps the planet as well. The site will also negatively impact the riparian habitat developed in the Salt River from current effluent discharge.

The facility will help communities with public health protection, as it will produce purified water that meets health standards, and produce reliable drinking water for users. The facility will also support Phoenix’s growing population and economic development by ensuring a stable water supply. The site will also offer an education center for the public, which will contribute to their understanding of potable reuse, building trust long-term. The City of Phoenix will also have an improved water quality consistency benefiting the health of the community. The public may react to the facility negatively initially, due to the “toilet-to-tap" stigma around potable reuse, and construction may disrupt nearby neighborhoods, affect traffic and negatively affect quality of life. Public health risks may also include emerging contaminants of concern such as PFAS, pharmaceuticals, micro- and nano- plastics that are not currently regulated.

Arizona has a “closed-loop water cycle” mindset, which will be reinforced further with the facility. Water will be seen as reusable opposed to being disposable, which will support long-term desert living identity. Some challenges that may occur for the cultural impacts will be indigenous views on water reuse, as it may conflict with the mindset of water being a sacred resource. There will need to be a community outreach plan for community involvement, and may need to involve an equity solution, as minority communities of Phoenix may feel disproportionately hosting infrastructure. This can occur with poor governance of the city and unevenly distributing to higher-income communities.

Worker safety and health impacts include strong regulatory safety requirements, as water facilities must comply with strict operational monitoring and chemical handling rules. This will reduce the risk of worker harm, as well as promote a safe, organized environment. Some negative impacts for worker safety include exposure to chemicals such as ozone, chlorine, and cleaning agents for membranes, confined space that may lead to life safety hazards, and biological exposure.

The facility will benefit the economy with long-term costs and savings. It will diversify a water supply, reduce vulnerability to water shortages, and stabilize water rates over time. It will generate federal and local investment which demonstrates economic commitment. Jobs will be created during design, construction, and plant operations, benefiting the local economy. The site will have a high capital and operating cost, which will negatively impact the economy. A possible long payback period may cause economic fall, meaning that if the payback sum is large, it may cause poor cash flow, meaning loss of jobs and may increase debt.

8.0 Summary of Engineering Work

This section summarizes how the project was accomplished and any changes in the scope and schedule. These changes will be described along with how they affected the overall project.

Using Microsoft Project, a proposed Gantt chart can be found in *Appendix BD*, which was compared to a revised chart, found in *Appendix BE*. There was a major change to the proposed schedule due to delays in the scheduled site visit causing a minor delay in the 30% deliverable. Task 2.0: Site Investigation minimally impacted the project's schedule as the design was not focused on the 91st WWTP, but more so impacted the alternative parcel selection decision. The matrix was completed as soon as the site visit was completed, which kept CJE on track for the 60% deliverable.

Additional adjustments were made to the proposed schedule, including the removal of Task 5.3: Life Cycle Cost since it wasn't a requirement for the project submittal. Furthermore, Task 4.1: Treatment Processes Design was extended through spring break due to the volume and complexity of calculations required to develop a complete treatment train. Lastly, Task 4.3.4: Hydraulic Profile Design experienced repeated delays due to ongoing modifications to the final treatment train, as the team evaluated and refined options between Treatment Train #1 and Treatment Train #3.

CJE deliberately followed the proposed schedule and met weekly to delegate design work for each treatment train process and hydraulic design. This strategy allowed minimal setbacks and allowed CJE to follow the proposed schedule.

9.0 Summary of Engineering Costs

In the following sections will explain the total staffing hours and engineering costs for the project.

9.1 Staffing Hours

Engineering work was completed with a senior engineer (SENG), design engineer (DENG), civil engineering intern (CINT), and environmental engineering intern (EINT). The predicted hours for the project were projected to be 673 hours. The bulk of the hours were to be completed by the DENG with the most time-consuming task being *Task 4.0: Final Design*. In Table 8-1, below shows the detailed proposed summary of work in *Appendix BF* shows the detailed proposed summary of work hours.

Table 9-1: Proposed Summary of Work

Task	SENG (hrs)	DENG (hrs)	CINT (hrs)	EINT (hrs)	Totals
Task 1.0: Research and Preparation	2	5	16	16	39
Task 2.0: Site Investigation	8	8	22	22	60
Task 3.0: Treatment Selection	14	29	51	52	146
Task 4.0: Final Design	11	121	35	34	201
Task 5.0: Cost Analysis	3	10	13	15	41
Task 6.0: Project Impacts	2	4	7	8	21
Task 7.0: Project Deliverables	5	15	28	28	77
Task 8.0: Project Management	13	45	15	15	88
Summary	**59**	**237**	**187**	**190**	**673**

The actual work hours that were completed were 844 hours. Most of the work hours came from the DENG, EINT, and CINT. The most time-consuming tasks were Task 7.0: Project Deliverables, Task 4.0: Final Design, and Task 3.0: Treatment Selection. Table 8-2 shows the actual work hours total for all team members. A detailed summary of actual hours can be found in *Appendix BG*.

Table 9-2: Actual Summary of Work

Task:	SENG (hrs)	DENG (hrs)	CINT (hrs)	EINT (hrs)	Totals
Task 1.0: Research and Preparation	3	6	9	34	52
Task 2.0: Site Investigation	10	2	0	3	15
Task 3.0: Treatment Selection	2	47	15	38	102
Task 4.0: Final Design	27	130	88	18	263
Task 5.0: Cost Analysis	3	30	12	9	54
Task 6.0: Project Impacts	1	9	2	9	21
Task 7.0: Project Deliverable	31	126	36	77	270
Task 8.0: Project Management	19	13	8	27	67
Summary	**96**	**363**	**170**	**215**	**844**

The difference between the proposed and actual hours was 171 hours. This increase of hours was due to Task 4.0: Final Design and Task 7.0: Project Deliverable being underestimated during the proposal processes. Time needed to complete Task 4.0: Final Design of both the treatment train and hydraulic design took about 50 more hours than predicted. Time needed to complete Task 7.0: Project Deliverables increased by almost 200 hours due to the deliverables being estimated at only 77 hours for all needed project deliverables. However, for Task 2.0: Site Investigation did show a significant decline in hours from proposed to actual. This decline for hours in Task 2.0: Site Investigation was due to the project's objective being a brand-new facility and not focusing on improvements for the 91st Ave WWTP.

9.2 Cost of Engineering Services

Cost of Engineering Services was broken down into three different categories of personnel, supplies, and travel. For the proposed cost of engineering services, the proposed total cost was $89,718. In Table 8-3 below, shows the broken-down costs of engineering services.

Table 9-3: Proposed Cost of Engineering Services

Category	Sub-Category	Classification	Quantity	Unit	Rate	Unit	Cost ($)
1.0 Personnel		SENG	59	hours	315	$/hr	$18,585
		DENG	237	hours	225	$/hr	$53,325
		CINT	187	hours	40	$/hr	$7,480
		EINT	190	hours	40	$/hr	$7,600
						Subtotal:	**$86,990**
2.0 Supplies		WEF Membership	4	membership	21	$/membership	$84
		Computer Lab Rental	15	days	100	$/day	$1,500
						Subtotal:	**$1,584**
3.0 Travel	**3.1 Site Visit**	Mileage	302	miles	0.28	$/mile	$85
		Car Rental	1	day	50.75	$/day	$51
	3.2 Comp.	Mileage	284	miles	0.28	$/mile	$80
		Car	2	days	50.75	$/day	$102
		Hotel (one night)	3	night-room	142	$/night-room	$426
		Per Diem (2 days)	10	Day-person	40	$/day-person	$400
						Subtotal:	**$1,144**
Total Cost of Engineering Services							**$89,718**

The actual cost of engineering services increased due to the increase in engineering hours. The cost for supplies and travel remained the same as the proposal. The actual cost of engineering services came out to $130,043, below in Table 8-4 for broken down cost.

Table 9-4: Actual Cost of Engineering Services

Category	Sub-Category	Classification	Quantity	Unit	Rate	Unit	Cost ($)
1.0 Personnel		SENG	96	hours	315	$/hr	$30,240
		DENG	363	hours	225	$/hr	$81,675
		CINT	170	hours	40	$/hr	$6,800
		EINT	215	hours	40	$/hr	$8,600
						Subtotal:	**$127,315**
2.0 Supplies		WEF Membership	4	membership	21	$/membership	$84
		Computer Lab Rental	15	days	100	$/day	$1,500
						Subtotal:	**$1,584**
3.0 Travel	**3.1 Site Visit**	Mileage	302	miles	0.28	$/mile	$85
		Car Rental	1	day	50.75	$/day	$51
	3.2 Comp.	Mileage	284	miles	0.28	$/mile	$80
		Car	2	days	50.75	$/day	$102
		Hotel (one night)	3	night-room	142	$/night-room	$426
		Per Diem (2 days)	10	Day-person	40	$/day-person	$400
						Subtotal:	**$1,144**
						Total Cost of Engineering Services	**$130,043**

The cost of engineering services was underestimated by $40,325 due to the increase in personnel hours.

10.0 Conclusion

The report presented the design and evaluation of the AWPF for the City of Phoenix 91st Ave WWTP, with the objective of treating secondary effluent to provide 30 MGD of water meeting potable, drinking water standards. Through a systematic evaluation of alternatives using weighted decision matrices, the project identified and developed an optimal treatment train, hydraulic system, and facility layout that satisfies regulatory requirements established by the EPA, ADEQ, and MCESD.

The analyses demonstrated that a multi-barrier treatment approach by incorporating physical screening, coagulation and flocculation, sedimentation, filtration, advanced membrane treatment, and advanced oxidation provide effective removal of TDS, pathogens, and contaminants of concern. Selected processes such as wedge wire screening, polyaluminum chloride coagulation, plate settling, and advanced membrane filtration were determined to offer the best balance of effectiveness, durability, and operational feasibility based on scoring criteria and design constraints. Additionally, the hydraulic design, including pump station and pipeline systems, is shown to reliably convey the design flow of 30 MGD while maintaining system efficiency and integration with existing infrastructure.

The primary network is designed to deliver the 40 MGD design flow safely and reliably. The pump station overcomes the 86.18 feet of TDH utilizing the 250 HP Pentair Fairbanks vertical turbine pumps operating at 80% efficiency pushing 6945 GPM per pump. The station feeds into the 9,920 feet of 42-inch PVC force main to the headworks of the AWPF. By setting up the headworks at an elevation of 1,011.1 feet, the entire pretreatment train functions on gravity flow. Through calculations using Hazen-Williams confirmed the flow moves efficiently through the yard piping, reaching the MF feed sump. The MF uses intermediate pumps to transition the water into highly pressurized MF and RO membrane stages. The conveyance and treatment systems are fully equipped to manage the necessary reject brine distribution while consistently delivering the target 30 MGD of purified, potable water to the distribution grid.

Table 10-1 shows the summary of the construction timeline for the AWPF. This project will be constructed in eight phases over the span of 32 months. These phases are described in more detail in Section 6.0: Construction Sequencing.

Table 10-1: Construction Phasing Timeline

Phase	Process	Time
1	Site Preparation	Month 1-4
2	Excavation	Month 3-9
3	Structural Building	Month 5-10
4	Treatment Train Construction	Month 6-20
5	Pipe Construction	Month 10-22
6	Education Center	Month 12-24
7	Mechanical/Electrical Construction	Month 16-26
8	Testing and Full Operation	Month 26-32

Table 10-2 shows the summary of the overall construction cost for the AWPF which includes the treatment train and the hydraulic design. The cost analysis is addressed in further detail in Section 4.0: Cost Analysis.

Table 10-2: AWPF Construction Cost Summary Table

AWPF Cost Analysis			
Capital Cost	Hydraulic Station	$3,059,062	$1,061,447,010
	Treatment Train	$1,058,387,948	
Total Capital Cost			**$1,061,447,010**
O&M	Hydraulic Station	$609,017	$60,560,737
	Treatment Train	$59,951,720	
Total O&M Cost Per Year			**$60,560,737**

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