Final Design of the 91st Avenue Regional Advanced Water Purification Facility

COPPERHEAD
ENGINEERS

CENE 486C PROJECT TEAM:

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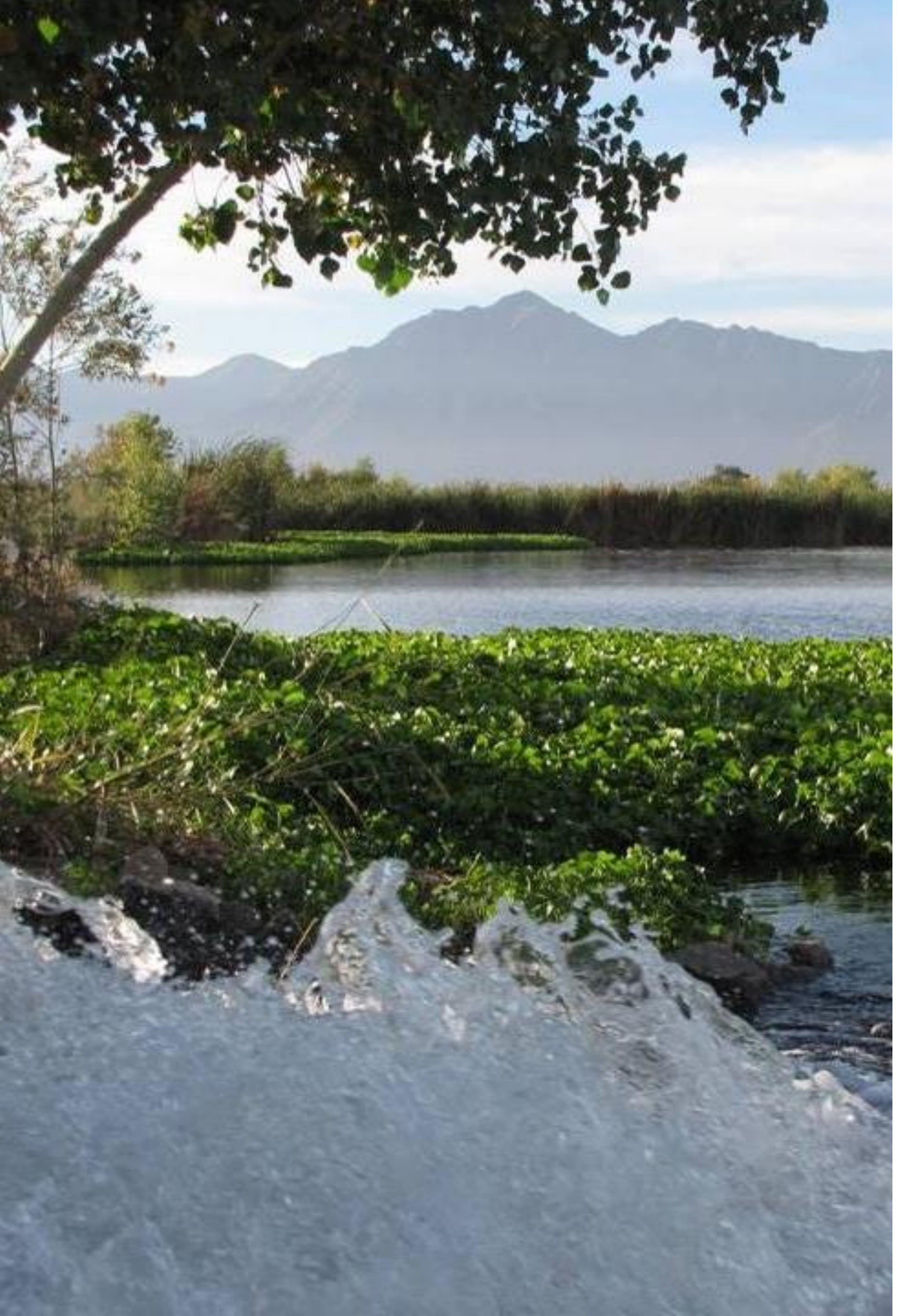


Design Problem

Water scarcity is increasing in Arizona as demand outpaces natural supply. To address this, the state is turning to Advanced Water Purification(AWP) as a new water source.

This project aims to design an Advanced Water Purification Facility (AWPF), using effluent from the 91st Avenue Wastewater Treatment Plant. And produce potable water back into the Arizona Drinking System. The facility will protect against pathogens, viruses, and organics by using treatment barriers.

Project Location

- Located in Tolleson Arizona , a suburb in SW Phoenix

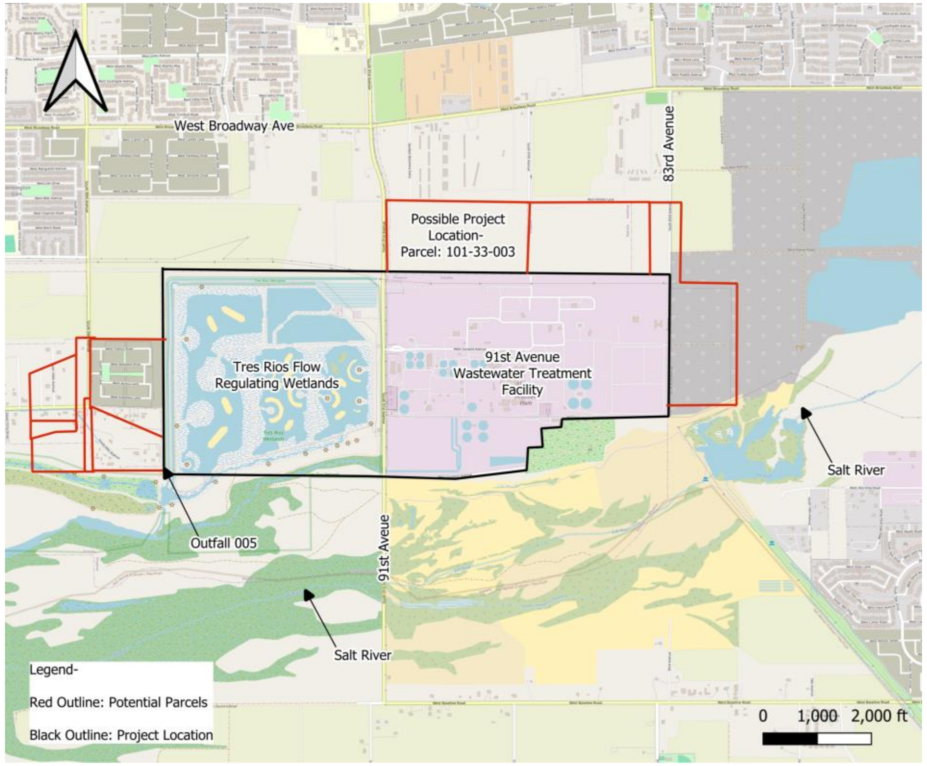


Figure 1: Site Map

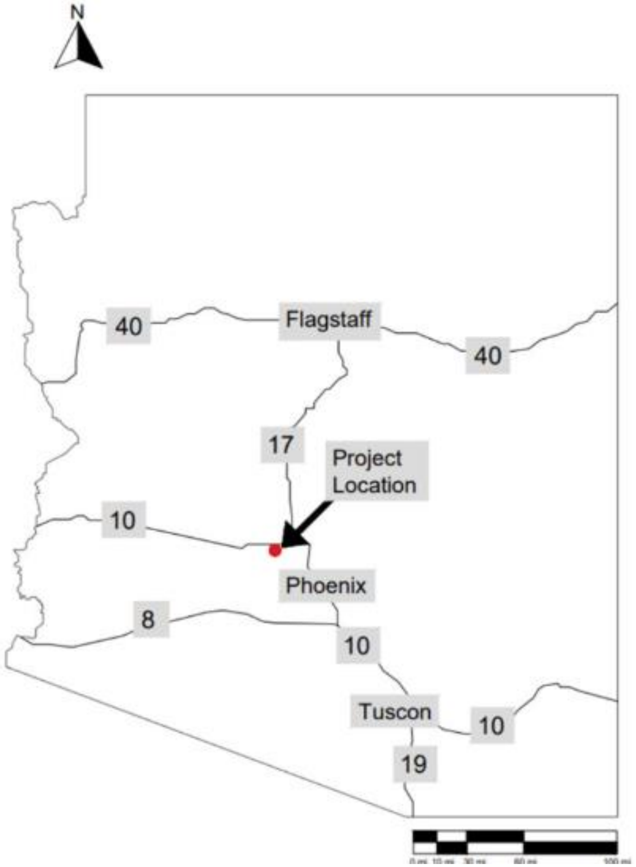


Figure 2: Location Map

Treatment Selection Process

Decision Matrices

5 different categories:

- Environmental Impact - 12.5%
- Energy Efficiency - 12.5%
- Operational and Capital Cost - 25%
- Operational Flexibility - 25%
- Land Use - 25%

Each Category rated 1-3, 1 being bad and 3 being the best

Bar Screening

- **Selected Bar Screen: Vertical**

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

Table 1: Bar Screen Decision Matrix

Coagulation and Flocculation

- **Selected Coagulants: Alum & Ferric Chloride**

- **Selected Flocculant: Nonionic Polymers**

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

Table 2: Coagulation & Flocculation Decision Matrix

Physical Separation 1

- **Selected PS1: Rapid Media Filter**

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

Table 3: Physical Separation 1 Decision Matrix

Physical Separation 2

- **Selected PS2's : Ultrafiltration & GAC**

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

Table 4: Physical Separation 2 Decision Matrix

Physical Separation 3

- **Selected PS3's : Nanofiltration & Ion Exchange**

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

Table 5: Physical Separation 3 Decision Matrix

Advanced Oxidation Process and UV

- **Selected AOP's : Ozone/UV & H2O2/UV**

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

Table 6: AOP Decision Matrix

Brine Management

- **Selected Brine Management : Concentration and Crystallization Basins**

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

Table 7: Brine Management Decision Matrix

Treatment Train Alternatives

Treatment Alternative 1:
- Vertical Bar Screen
- Alum & Nonionic Polymers
- Rapid Media Filter
- GAC
- Nanofiltration
- H202
- Crystallization Basins

Treatment Alternative 2:
- Vertical Bar Screen
- Ferric & Nonionic Polymers
- Rapid Media Filter
- Ultrafiltration
- Ion Exchange
- Ozone
- Crystallization Basins

Treatment Alternative 3:
- Vertical Bar Screen
- Ferric & Nonionic Polymers
- Rapid Media Filter
- Ultrafiltration
- Ion Exchange
- H202
- Crystallization Basins

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

Table 8: Treatment Train Alternative Decision Matrix

Wet Pit Selection Process

Decision Matrices

4-5 different categories:

- Performance
- Strength
- Operational and Capital Cost
- Operational Flexibility
- Constructability

Each Category rated 1-5, 1 being bad and 5 being the best

Pipe Material

- **Selected Pipe Material: Ductile Iron Pipe**

Criteria	Hydraulic Preformance (0.20)	Structural Strength (0.15)	Constructability (0.30)	Sustaibaility (0.20)	Corrosion Resistance (0.15)	Total Score
PCCP	4	5	3	4	3	3.85
DIP	4	4	5	4	4	4.25
Steel	4	4	4	3	3	3.65
HDPE	3	2	3	3	5	3

Table 9: Pipe Material Decision Matrix

Wet Well Diameter

- **Selected Diameter of Wet Well: 35 feet**

Criteria	Footprint (0.20)	Efective Volume Control(0.30)	onstructability/Excavation (0.2	Safety/Stability (0.25)	Total Score
25'	5	2	3	3	3.1
30'	4	4	4	4	4
35'	3	5	5	5	4.5
40'	2	5	3	4	3.6

Table 10: Diameter Decision Matrix

Final Treatment Train Design

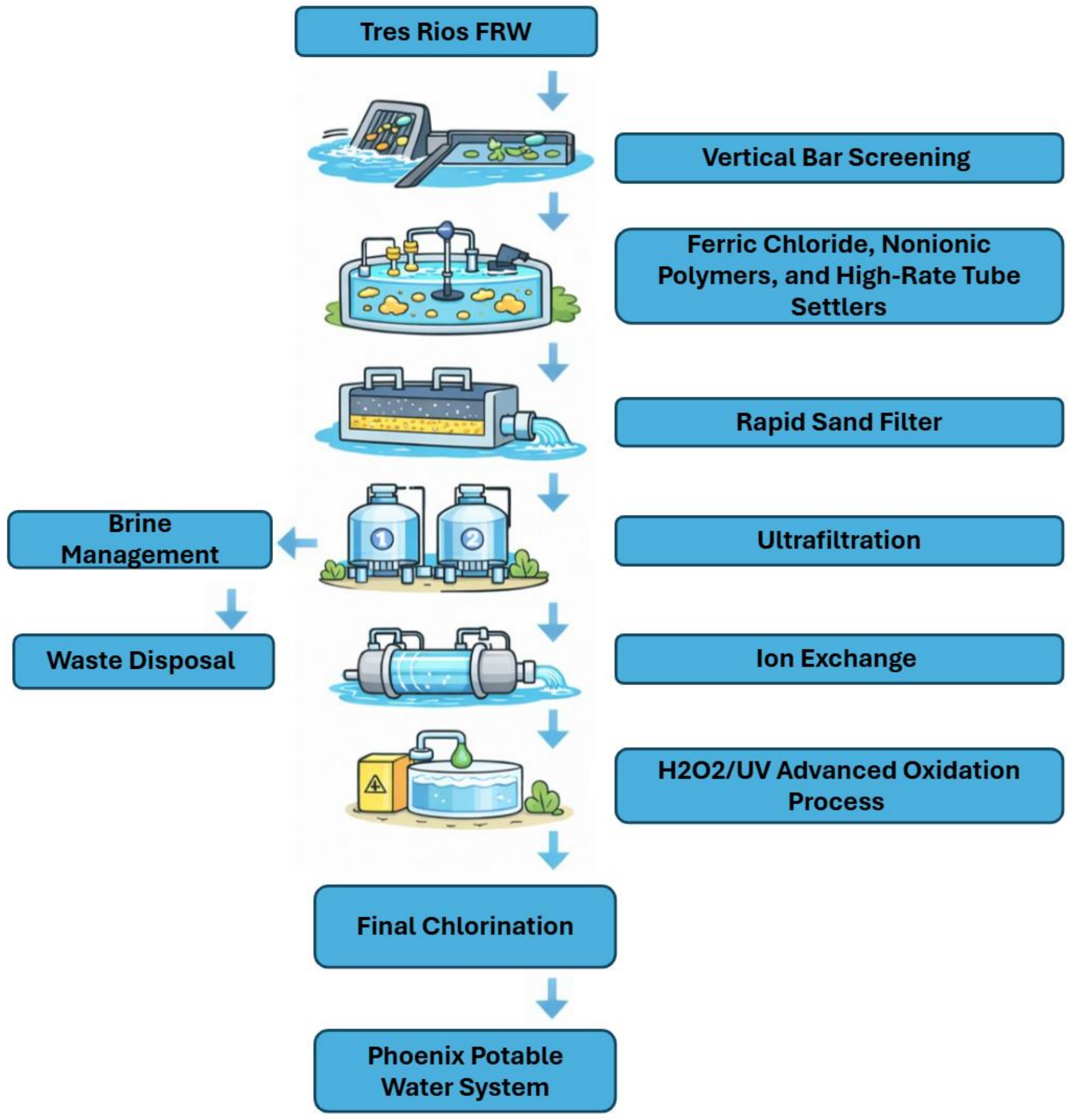


Figure 3: Treatment Train Flow Diagram

Figure 4: Vertical Bar Screens

Bar Screening

Remove large solids

- 5 multi-rake bar screening systems from Smith and Loveless

Coagulation and Flocculation

Removes Total Suspended Solids from the system by aggregating particles into large flocs

- Coagulation
    - Dose range: 2-100 mg/L
    - Estimated dose: 15 mg/L
    - Daily mass: 667.63-33,381.6 lbs/day
    - Estimated daily mass: 5007.25 lbs/day
- Flocculation
    - Dose range: 0.05-0.5 g/m^3
    - Estimated dose: 0.1 g/ m^3
    - Daily mass: 16.7-167 lbs/day
    - Estimated Daily Mass: 33.4 lbs/day

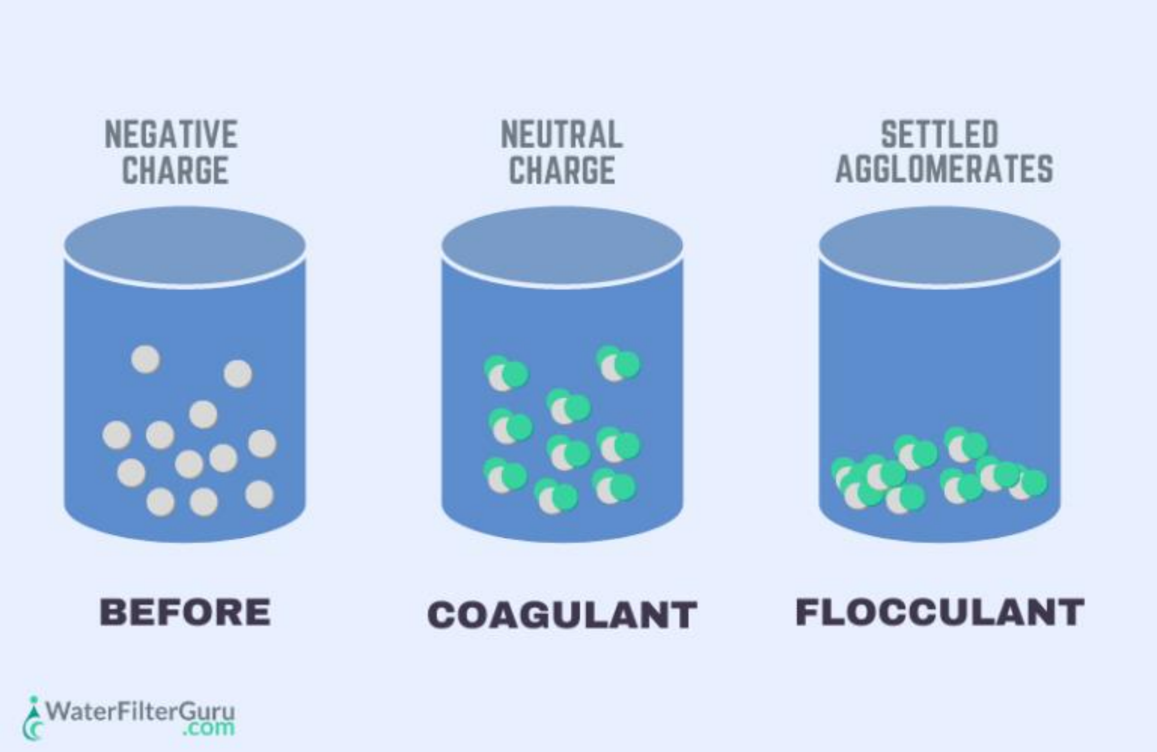


Figure 5: Coagulation/Flocculation Process

High-Rate Tube - Settler

Sedimentation basin

- # of tanks = 4
- Basin Length 1: 77.89 m
- Tube Length 2: 58.42 m
- Tube Width 3: 4.8 m
- Depth of Basin 4: 4 m

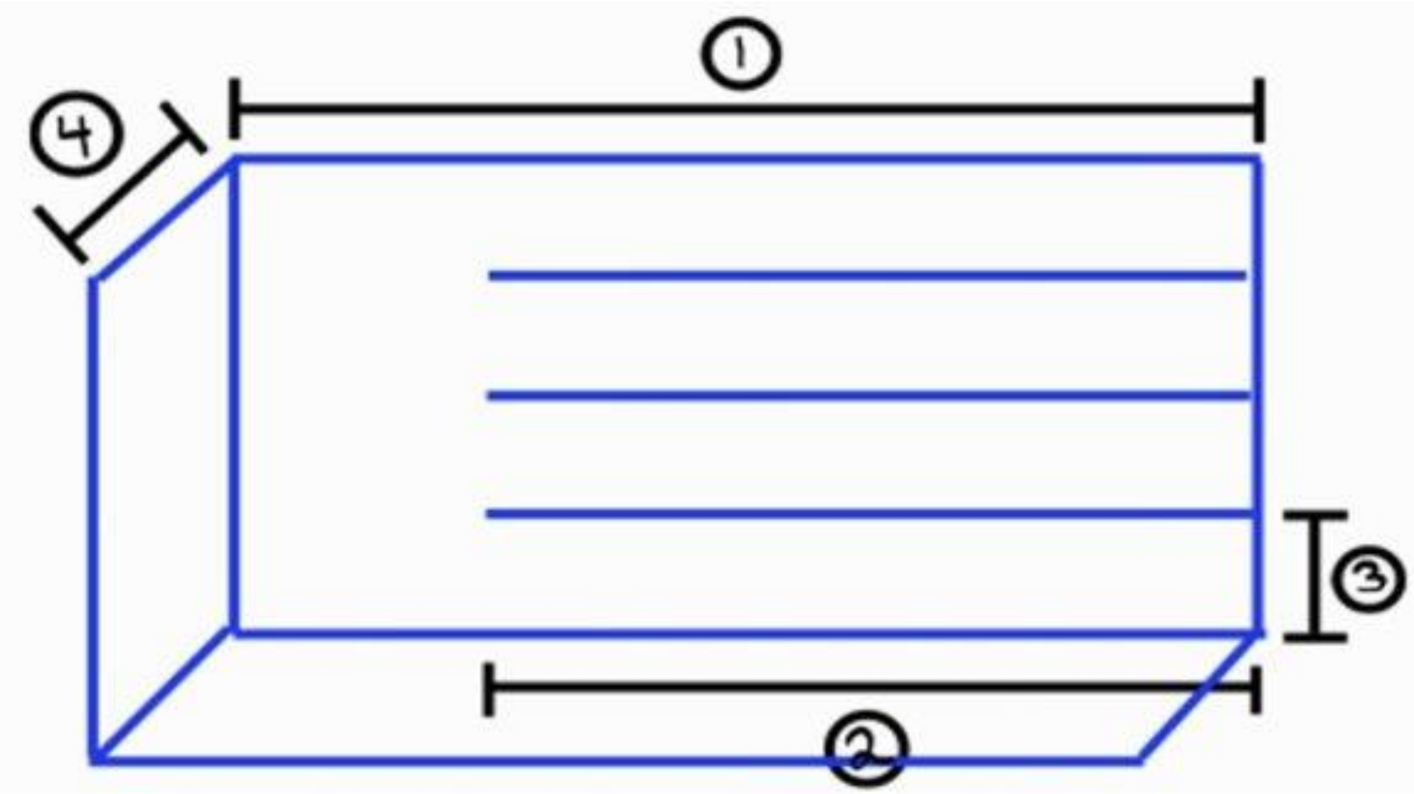


Figure 6: Tube Settler Diagram

Physical Separation 1

Removes remaining solids

- Media: Sand and Granular Activated Carbon (GAC)
- Rapid media filter
    - Tank surface area: 650 m^2
    - 9 beds
    - Flow rate: 40 MGD
    - Filtration rate: 293 m/d

Figure 7: Rapid Sand Filter Example [a]

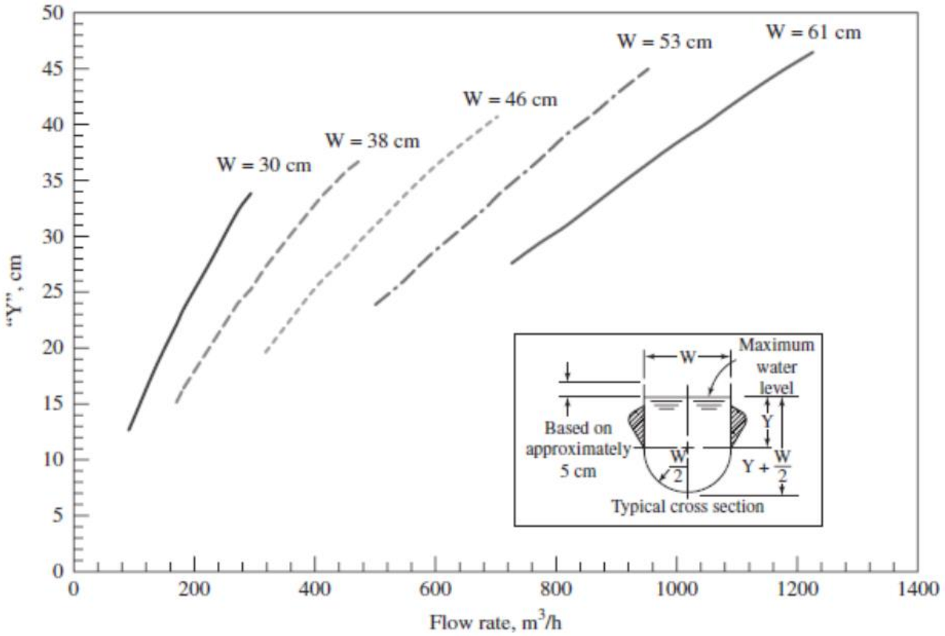


Figure 8: Rapid Sand Filter Design Resource [b]

Physical Separation 2

Ultrafiltration

- Pore size: 0.001-0.1 microns
- Model: UF-0880-LP UF Membrane Model
- 50 units
    - Flow per Unit: 704.5 gpm
- Facility flow rate: 27777.7 gpm

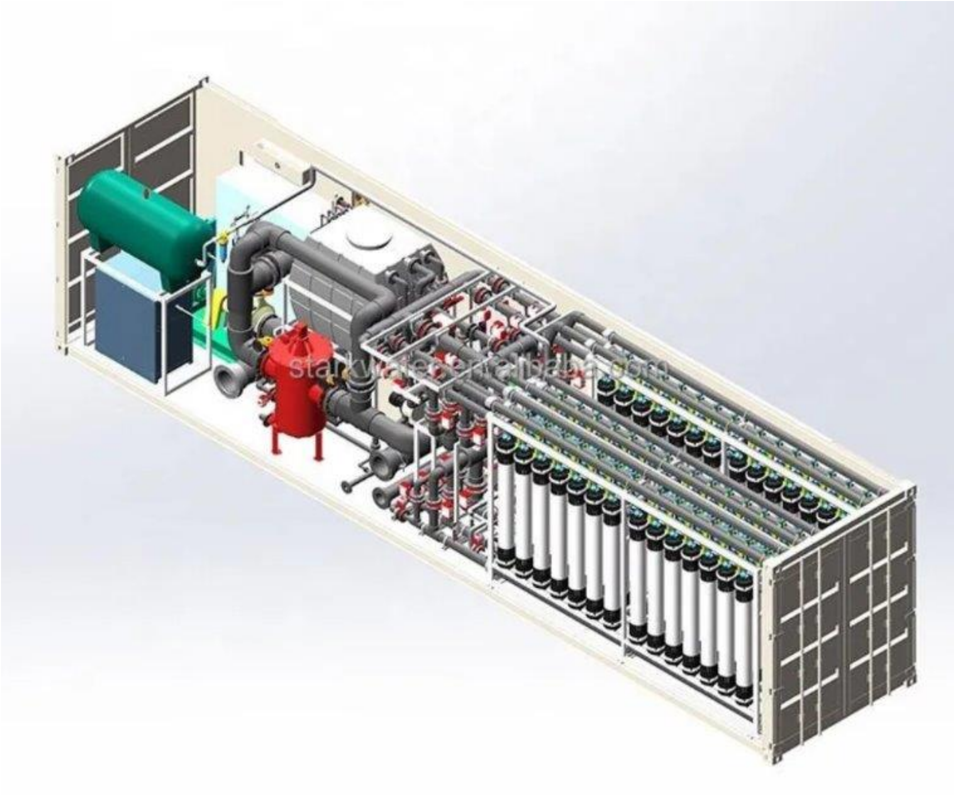


Figure 9: STARK Hollow Fiber UF Water Purifier

Physical Separation 3

Figure 10: Industrial Mixed-Bed Deionizer from Industrial Water System

- Ion Exchange
  - Flow rate per vessel: 1,000 gpm
  - 30 vessels total, 2 for redundancy
  - Approximate retention time: 8hours
    - What does this mean

Advanced Oxidation Process and UV

Hydrogen Peroxide and UV

- 300 mJ/ cm^2 intensity required for UV
- Will use the TrojanUVFlexAOP
- Combines hydrogen peroxide injection and UV
    - Total of 13 units

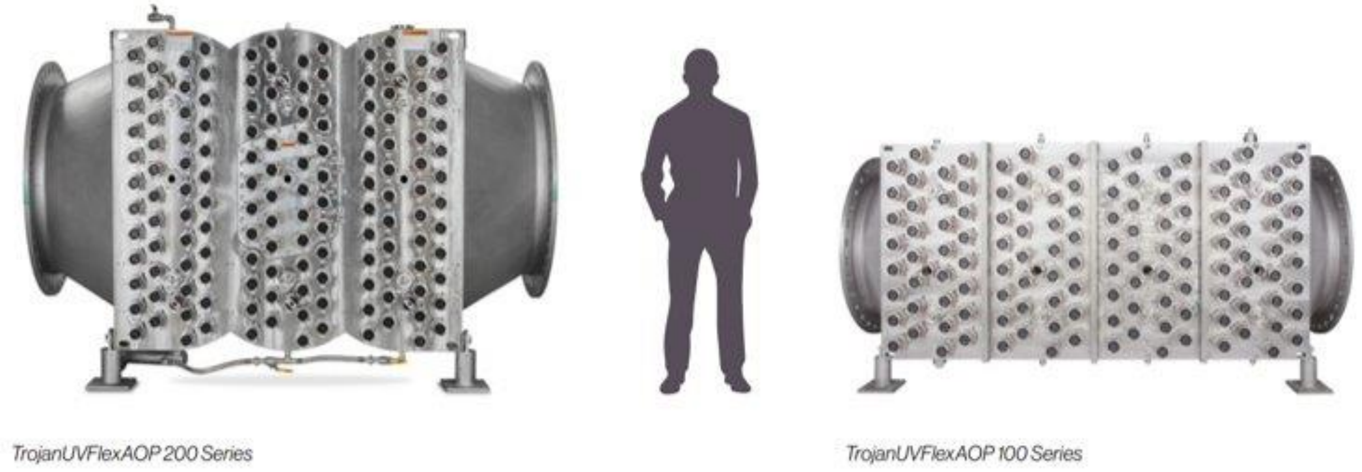


Figure 11: TrojanUVFlexAOP System

Final Chlorination

Maintain a chlorine residual of 0.2 mg/L for four hours after entering potable water system

- ADEQ Surface Water Treatment Rule
- Recommended dose: 0.8 mg/L
- Dose range: 0.21 – 1.27 mg/L

$$C = C_0 e^{-k_d t}$$

Equation 1: First Order Decay

Condition	kd (1/d)
Distribution system pipe	0.71 - 11.09
Distribution system storage tank	0.36 - 1

Table 11: Chlorine Decay Rates

Figure 12: Standard Crystallization Basin

Brine Management

- Concentration and crystallization
  - 6 basins
  - Flow per unit: 1500 gpm
  - Facility brine flow: 6944.4 gpm

Estimated LRVs

Coag and Flocc	UF	UV/AOP	Chlorine	Total
0	2	6	5	13
2	1	6	1	10
1	1	6	3	11

Required LRVs:

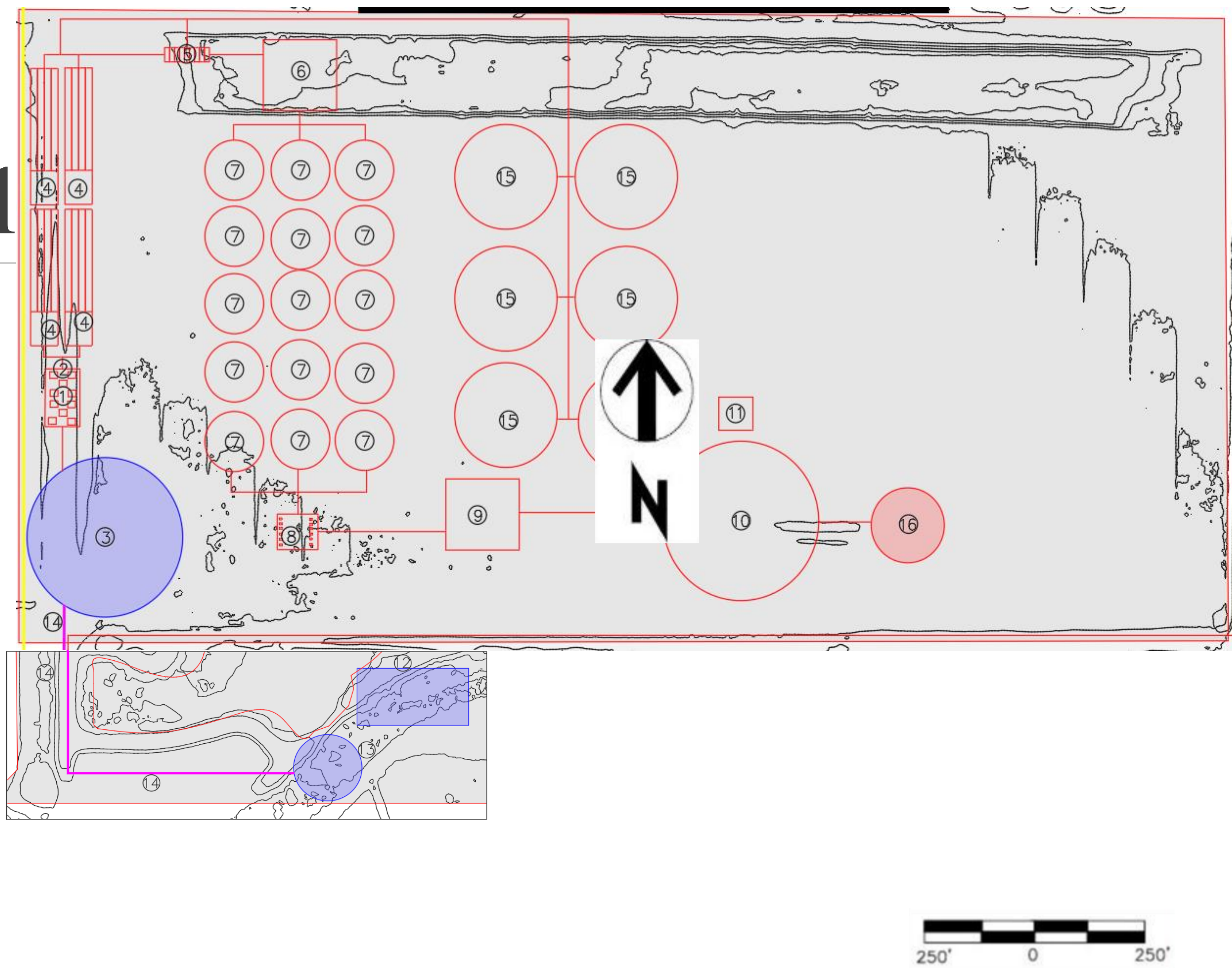
- Virus – 13
- Giardia - 10
- Crypto - 10

Proposed Layouts

etail

Legend

1. Curved Screen
2. Headworks
3. Equalization Storage Tank
4. High Rate Sedimentation Basin
5. Rapid Sand Filter w/GAG
6. Microfiltration
7. Ion Exchange
8. Advanced Oxidation/ UV+h202
9. Final Chlorination
10. Final Storage Tank/Distribution
11. Electrical & Control Building
12. Outfall 005
13. Wet Pit
14. Proposed Conveyance Pipeline
15. Crystallization Basin
16. Final Distribution Pump



Overall Layout

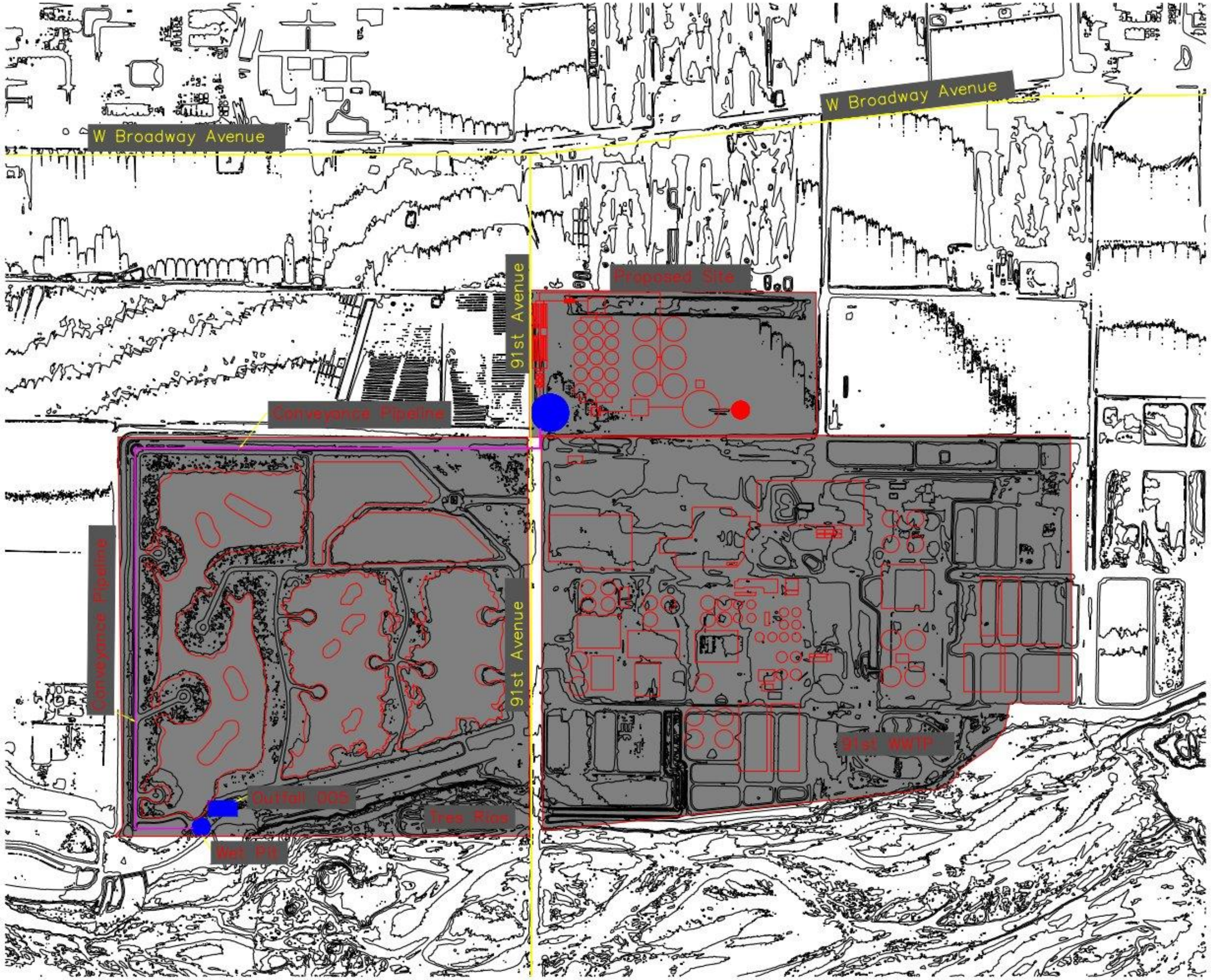
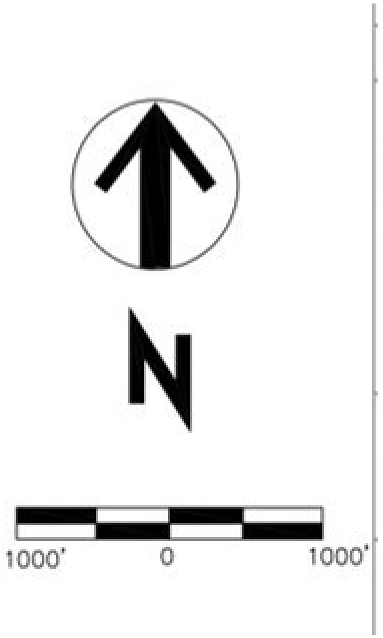


Figure 14: Overall Site layout



Final Wet Pit Design

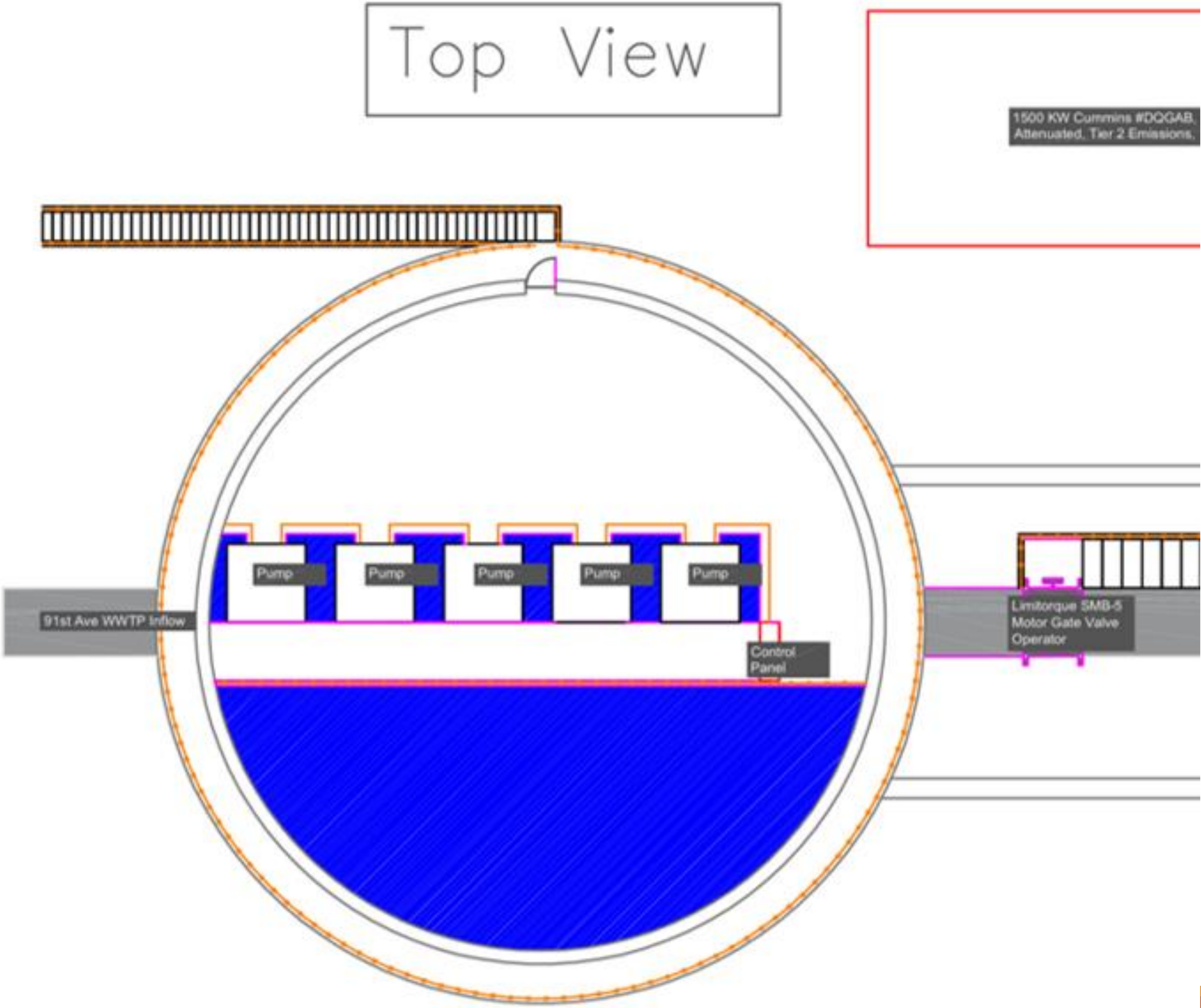


Figure 15: Top View of Wet Pit

Daily Demand Calculations

Gallons per person per Day (gpcd):	100
Flow Demand(MGD):	30
Population Served:	300,000
PFhour:	2
PF Day:	48
gal/day	30000000

Table 12: Flow Conversions

- **Selected Pump:** Goulds VIT Vertical Industrial Turbine Pump (Model VIC/VIT),Size 20GHO, 1-Stage,1180 RPM, Open Sump (Wet Pit) Configuration
- **Design Flow:** 40 MGD (27,778 gpm)
- **Required Demand Distribution:** 30 MGD (20,833 gpm)

Daily demand @ 40 MGD						
GPM	**MGD**	**Daily Volume (gal/day)**	**Per-Capita (population)**	**GPCD (gpcd)**	**Losses (MGD)**	**Minutes of Flow**
25000	36	36000000	300000	120	6	8.64
20833	30	30000000	300000	100	0	10.36
27778	40	40000000	300000	133	10	7.77

Table 13:Daily Demand Calculations

Pipe Calculations

- **Pipe Material:** DIP (Ductile Iron Pipe)
- **Pipe Length:** 10,826.8 ft
- **Pipe Size:** 42 in
- **TDH:** 62.1 ft
- **Static Head**: 24.61 ft
- **Design Flow:** 6945 gpm (per pump)

Pipe Calcs (42")										
Q (gpm per pump)	**Q (cfs)**	**A (ft2)**	**V (ft/s)**	**Rh**	**S**	**hL (ft)**	**hminor (ft)**	**TDH (ft)**	**Hstatic (ft)**	**hmajor (ft)**
0	0	9.62	0	0.88	0	0	0.00	24.61	24.61	0
2,500	22.28	9.62	2.32	0.88	0.0004	4.38	0.50	29.49	24.61	4.38
6,250	55.7	9.62	5.79	0.88	0.0026	23.9	3.12	51.63	24.61	23.9
6,945	***61.89***	***9.62***	***6.43***	***0.88***	***0.0031***	***33.64***	***3.86***	***62.11***	***24.61***	***33.64***
10,000	89.13	9.62	9.26	0.88	0.0053	57.07	7.99	89.67	24.61	57.07
10,417	***92.84***	***9.62***	***9.65***	***0.88***	***0.0057***	***61.55***	***8.68***	***94.84***	***24.61***	***61.55***
12,000	***106.95***	***9.62***	***11.12***	***0.88***	***0.0086***	***92.68***	***11.52***	***128.80***	***24.61***	***92.68***
14,000	***124.78***	***9.62***	***12.97***	***0.88***	***0.0114***	***123.21***	***15.67***	***163.49***	***24.61***	***123.21***
16,000	***142.60***	***9.62***	***14.82***	***0.88***	***0.0146***	***157.85***	***20.47***	***202.93***	***24.61***	***157.85***

Table 14: Pipe Calculations

Pipe Raw Dims. (DIP)									
Dia (in)	**Dia (ft)**	**Out Dia (in)**	**Out Dia (mm)**	**Class**	**Thick (in)**	**Weight (lbs)**	**Weight (lbs)**	**H-W: C**	**n**
42	3.5	44.5	1130.3	53	0.65	285.2	920.1	120	0.013

Table 15: Pipe Dimension Calculations

Pump Calculations

- **Pump ID:** Goulds VIT, size20GHO
- **Speed:** 1180 RPM
- **Required Power:**124.9 hp
- **NPSHr:** 21.8 ft
- **TDH:** 62.1 ft
- **Efficiency:** 87.3%
- **Design Flow:** 6945 gpm
- **Static head:** 24.61 ft

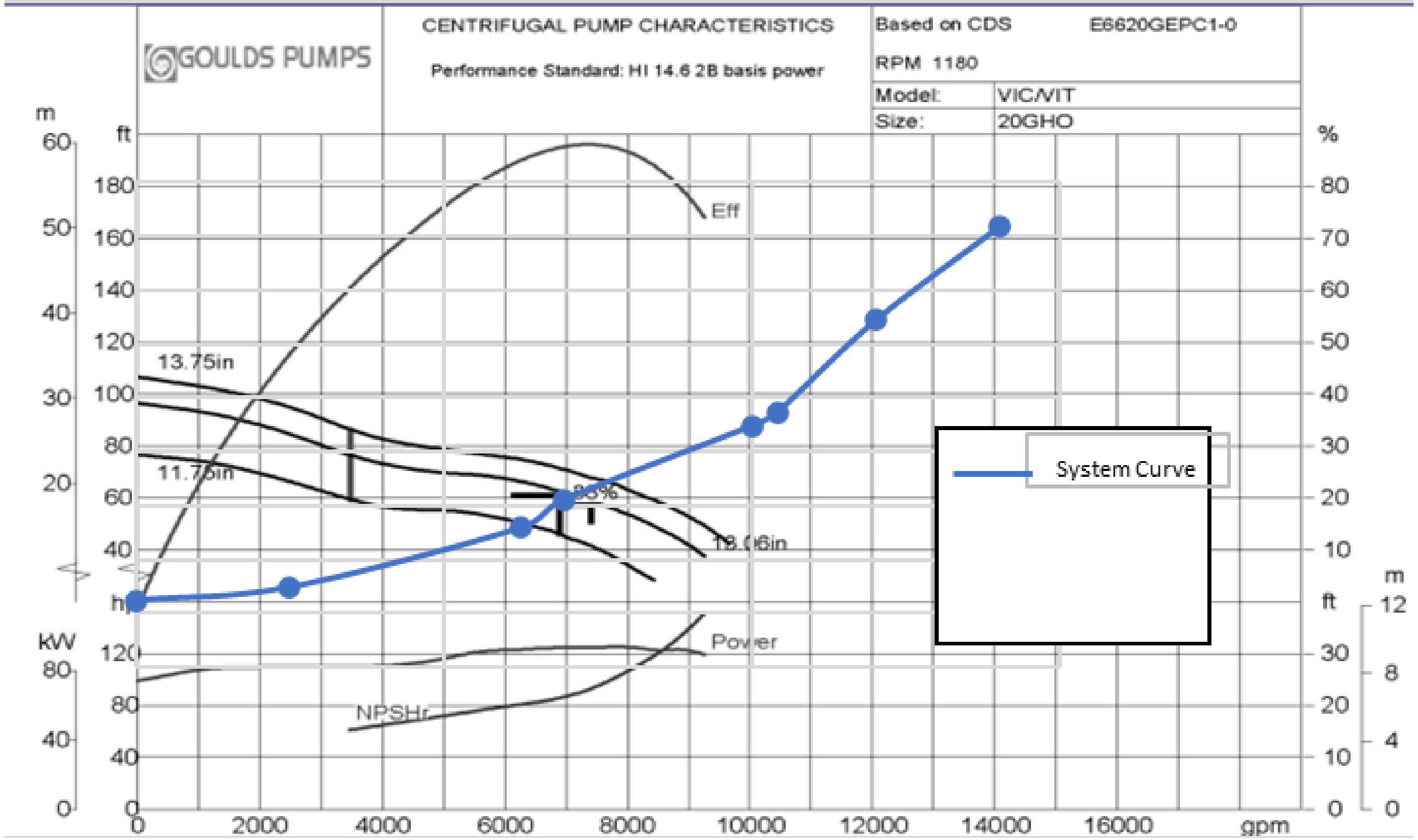


Figure 16: Goulds Pumps System Curve

Wet Well Calculations

- **Required Design Distribution:** 30 MGD
- **Design Flow:** 40 MGD
- **Wet Well Design Diameter:** 35 ft
- **Wet Well Design Depth:** 26 ft
- **Wet Well Cross-Sectional Area:** 962 ft²

Equalization Tank Calcs		MGD	MG/hr
	Diurnal Flow	70	
	ΔQ	34	1.4167
	4 hr peak	6.2	

Table 16: Equalization Calculations

	Wet Well Calcs. 35'								
	Q (gpm)	A (ft)	Vwat per 1' (gal)	Δh (level swing, in ft)	Vbuffer (3min buffer)	Veq (Million gal)	Veq (gal)	Geometric Volume (gal)	Wet Well depth (ft)
30 MGD	20833	962	7197	8.68	62500	5.67	5670000	187122	26
36 MGD	25000	962	7197	10.42	75000	5.67	5670000	187122	26
40 MGD	***31249***	***962***	***7197***	***13.03***	***93747***	***5.67***	***5670000***	***187122***	***26***
70 MGD	48611	962	7197	20.26	145833	5.67	5670000	187122	26

Table 17: Wet Well Calculations

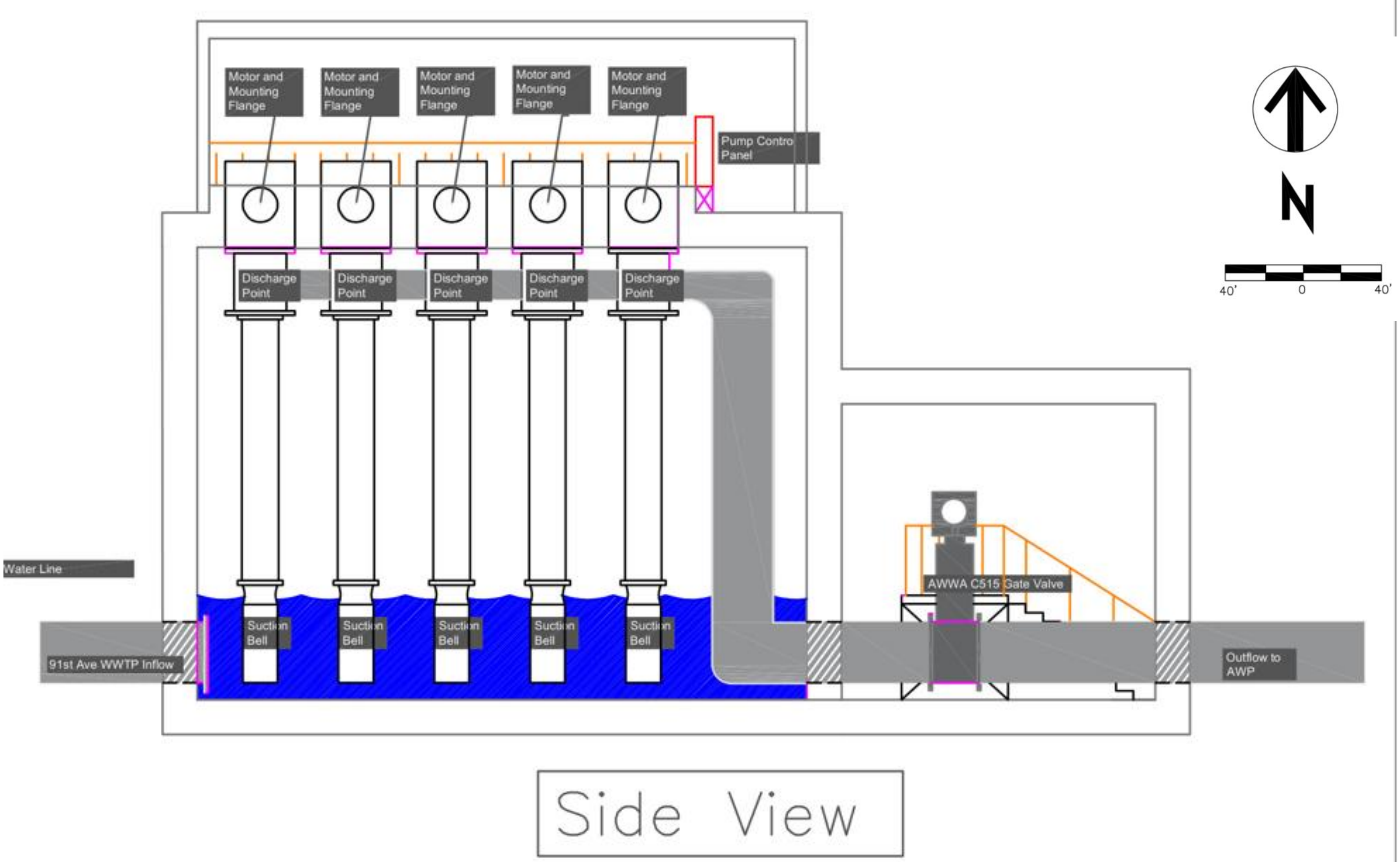


Figure 17: Side View of Wet Pit

Hydraulic Profile

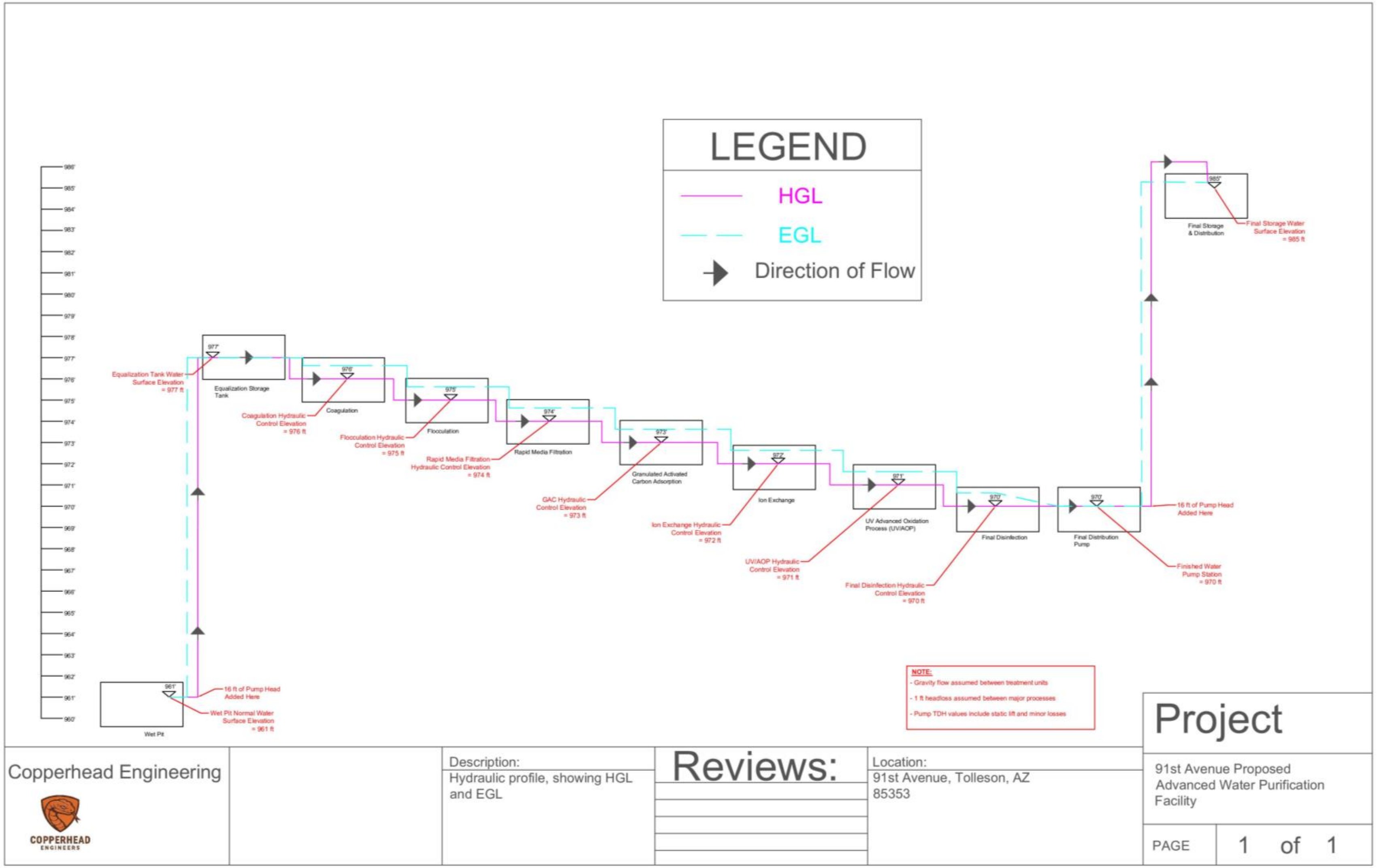


Figure 18: Hydraulic Profile

Simplified Hydraulic Profile

Location	Elevation (ft)	HGL (ft)	EGL (ft)	Description
Wet Pit (Start)	961	961.00	961.64	System starting point
Pump Discharge (to EQ Tank)	977	977.00	977.64	Initial pump lift (~16 ft added head)
End of Treatment Train	970	970.00	970.64	Gravity-driven flow with 1 ft of head-loss per process
Final Storage & Distribution	985	985.00	985.00	Final pump lift to storage

Table 18: Hydraulic Profile Details

Public Outreach

Public Outreach

Public Engagement
Provide opportunities for community members to participate in meetings, town halls, and public forums to build familiarity and confidence in the project.

School and University Partnerships
Engage students through educational programs and partnerships to promote early awareness and support for water reuse initiatives.

Demonstration Events
Host events that showcase the treatment process and offer the community a chance to experience the final purified water firsthand.

Information Sessions
To explain the project, address concerns, and answer questions from the public.

Figure 19: Tres Rios Flow Regulating Wetlands

Final Outcomes

Project Outcomes

Once the design process was completed the engineers created a list to ensure that all requirements were met. They are given below:

Outflow: 30 MGD

Salinity : 740 mg/L

3 Treatment Barriers:

- Ultrafiltration
- Hydrogen Peroxide and UV
- Final Chlorination

AOP & UV

Brine Management

References

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REFENCE: Flocculation Calcs

Flocculation

Nonionic Polymer Range: $0.05 - 0.5\ g/m^3$

Low Dose

$0.05\ g/m^3\ (m^3/264.17\ gal)$
$= 0.0001893\ g/gal$

$0.0001893\ g/gal\ (40\ MGD)$
$= 7572\ g/day$

$7572\ g/day\ (lb/453.59\ g)$
$= 16.69\ lbs/day$

High Dose

$0.5\ g/m^3\ (m^3/264.17\ gal)$
$= 0.001893\ g/gal$

$0.001893\ g/gal\ (40\ MGD)$
$= 75{,}720\ g/day$

$75\,720\ g/day\ (lbs/453.59\ g)$
$= 166.9\ lbs/day$

Estimated Dose

$0.1\ g/m^3\ (m^3/264.17\ gal)$
$= 0.0003785\ g/gal$

$0.0003785\ g/gal\ (40\ MGD)$
$= 15{,}140\ g/day$

$15{,}140\ g/day\ (lbs/453.59\ g)$
$= 33.38\ lbs/day$

REFENCE: High-Rate Sedimentation Calcs

High Rate sedimentation Basin - sizing

40 MGD = 181,843.6 $\frac{m^3}{d}$

Tank Surface Area, As = 181,843.6 $\frac{m^3}{d}$ / 180 m^3/d - m^2

↳ assumed overflow Rate

As = 1010.24 m^2

3 tanks = 336.75 m^2 each

Selected width = 4.8 m

↳ Settler length = $\frac{336.75\ m^2}{4.8\ m}$ = 70.16 m

↳ tank length = $\frac{70.16}{0.75}$ = 93.54 m

(0.75 — efficency)

SWD = 4m Depth of sludge = 2m

Approach velocity = $\frac{60{,}614.5 \frac{m^3}{d} / 1400 * 60}{4.8m * 3.6}$ = 0.041 m/s > 0.01 m/s

Tube velocity = $\frac{0.584 \frac{m}{s}}{4.8m(\sin(1.05))}$ = 0.0024 m/s < 0.0025 m/s

↳ a little slow but OK

REFENCE: Rapid Sand Filter Calcs

$\# \text{ of Beds} = 0.0195 * \left(151416.5 \frac{m^3}{d}\right)^{0.5} = 7.6 = 8 \text{ beds}$

$\text{Area of Bed} = \frac{151416.5 \frac{m^3}{d}}{8 * 293 \frac{m^3}{d\text{-}m^2}} = 64.6\ m^2$

(293: assumed filtration rate)

Assumed Cell width = 3.5 m

$\text{Bed length} = \frac{64.6\ m^2}{2*3.5\ m} = 9.23\ m$

$L/W = \frac{9.23\ m}{3.5\ m} = 2.64$

Gullet width = 0.6 m

$\# \text{ of launders} = \frac{9.23\ m}{2\ m} = 4.62 = 5$

$\text{Spacing of troughs} = \frac{9.23\ m}{5} = 1.85\ m$

$\text{Max Particle Travel Distance} = \frac{9.23\ m}{2*5} = 0.92\ m$

$\text{Max Backwash Trough Flow} = 40 \frac{m}{hr} * 0.92\ m * 2 * 3.5\ m = 258.4\ m^3/hr$

Through a figure in refrenced textbook:

$W = 0.53\ m \quad Y = 0.375\ m$

Trough Freeboard = 0.05 m   Trough Depth: 0.64

Margin of Safety = 0.15 m

$\text{Trough Elevation} = 0.69\ m\left(\frac{1+30}{100}\right) - 0.69\ m + 0.64\ m + 0.15\ m = 1\ m$

$\text{Backwash Tank Volume} = 40\ m/hr * 9.23\ m * 0.25 * 3.5\ m * 4 = 1292\ m^3$

REFENCE: Ion Exchange Calcs

Ion Exchange

Facility flow rate = 27 777.78 gpm

Flow Rate / Ion Exchange = 1000 gpm

$$\# \text{ of Units} = \frac{27\,777.78 \text{ gpm}}{1000 \text{ gpm}} = 27.78 \text{ Units} \rightarrow 28 \text{ units}$$

REFENCE: Advanced Oxidation Calcs

AOP

Facility flow rate = 20 833.33 gpm

Flow Rate per AOP unit = 1750 gpm

$$\# \text{ of Units} = \frac{20\,833.33 \text{ gpm}}{1750 \text{ gpm}} = 11.90 \text{ units} \rightarrow 12 \text{ units}$$

REFENCE: UV Dose Calcs

$D = I(t)$

Where:

D = UV Dose, mJ/cm^2

I = UV Intensity, mW/cm^2

t = Exposure time, s

$$I = 1000\ W\ (1000\ mW/W) / 46698.16\ cm^2$$
$$= 21.41\ mW/cm^2$$

↳ Where cross sectional area ($46698.16\ cm^2$) and power ($1000\ W$) given by manufacturer website

$$D = I(t)$$

$$t = \frac{D}{I} = \frac{300\ mJ/cm^2}{21.41\ mW/cm^2} = \boxed{14.01\ s}$$

REFENCE: Final Chlorination Calcs

$C = 0.2\ mg/L$ $\quad t = 4\ hrs = 0.167d$

low $k_d = 0.36d^{-1}$ $\quad$ high $k_d = 11.09d^{-1}$

$$C = C_0 e^{-k_d t} \longrightarrow C_0 = Ce^{k_d t}$$

$$\text{low } C_0 = (0.2\ mg/L)\, e^{(0.36d^{-1})(0.167d)} = 0.212\ mg/L$$

$$\text{high } C_0 = (0.2\ mg/L)\, e^{(11.09d^{-1})(0.167d)} = 1.270\ mg/L$$

REFENCE: Brine Management Calcs

Crystalizers

Brine flow rate = 6944.44 gpm

Flow rate per crystalizer = 1500 gpm

$$\# \text{ of Units} = \frac{6944.44 \text{ gpm}}{1500 \text{ gpm}} = 4.63 \text{ units} \rightarrow 5 \text{ units}$$