Figure 1: WEF Logo [1]

Northern Waters Cave Creek Water Reclamation Plant Upgrade

Danielle Havermann, Mallory Rakowski, Janneza Miranda, Xiaoxi Zhong, and Ye Tian

CENE 486

4/22/22

Site Location

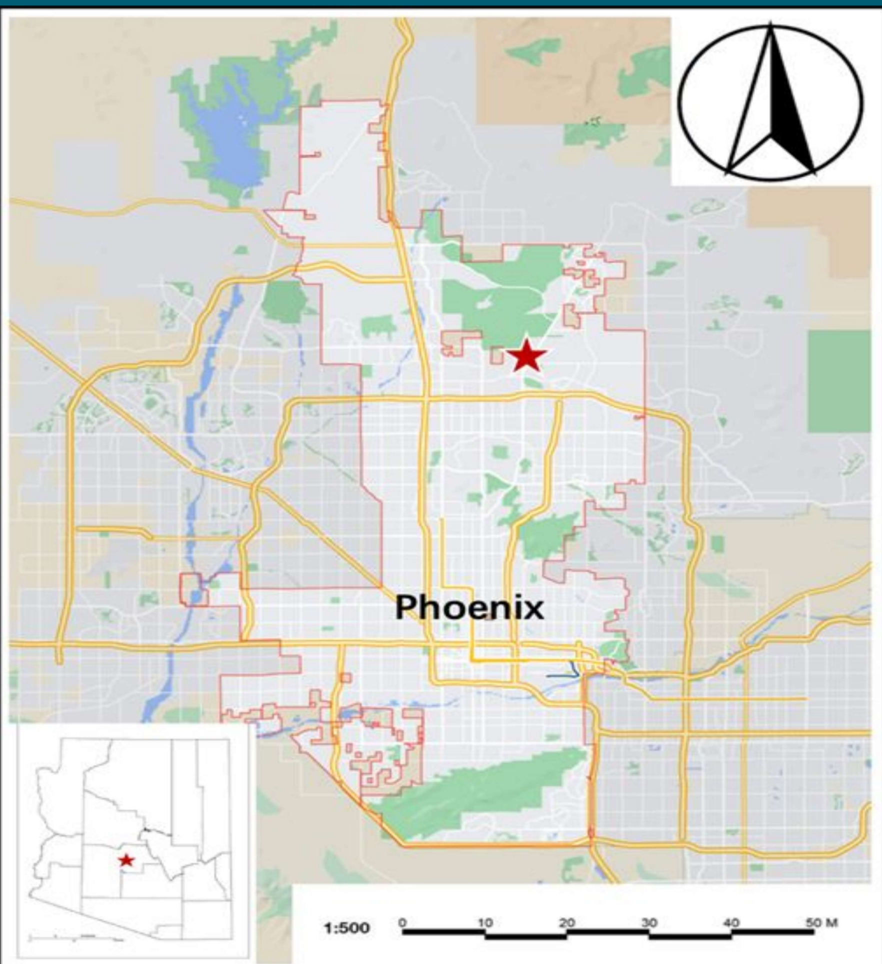


Figure 2: City Location in Relation to Phoenix [2]

Figure 3: Location in Relation to Nearby Roads [2]

Project Introduction

Background

- Opened 2002 and closed in 2009
- 8 million gallons per day (MGD)
- Produced A+ reclaimed effluent

Figure 4: Welcome to Cave Creek [3]

Purpose

- Reduce the impact of growth-related flows on the old existing infrastructure to meet treatment needs from now through 2070
- Provide proposed upgrades
- Recommended uses for the reclaimed effluent

Existing Conditions

- Large amounts of grit in the system
- Lack of grit removal system
- Will not meet future population needs without upgrades
- Operation & Maintenance (O&M) issues with the Ultraviolet (UV) disinfection system
- Lack of redundancy

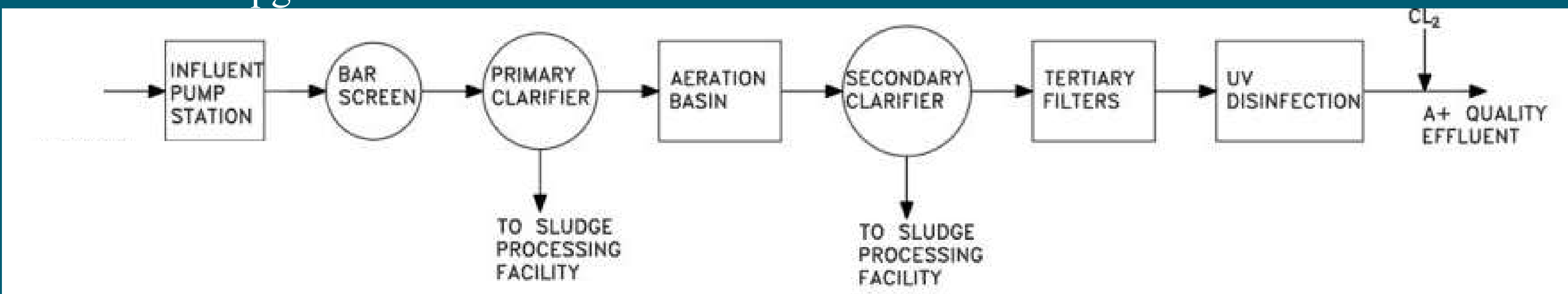


Figure 5: Existing Technology at the Site [4]

Future Population Projections

Equation 1: Population Projection [5]

$$P = P_0 e^{rt}$$

With the variables defined as:

P= Number of People at a Future Date
P_0= Present Population of People
r= Rate of Increase as a Decimal
t= Time Period (yr)

Equation 2: Growth Rate [5]

$$r = \left(\frac{(P_2 - P_1)}{P_1}\right) \times 100\%$$

With the variables defined as:

r – Growth Rate
P_2 – Current Population
P_1 – Initial Population

Table 1: Projected Population

Year	Projected Population
2030	45,000
2040	50,000
2050	56,000
2060	62,000
2070	70,000

Design Flow and Influent Loading Data per Phase

Table 2: Design Flow and Loading Data for Each Phase

Phase	Year	Population	Design Flow	Chemical Oxygen Demand (COD)	Biological Oxygen Demand (BOD)	Total Suspended Solids (TSS)
Number	Range	Range	MGD	mg/L	mg/L	mg/L
1	2021-2036	40,000-47,396	10	474.97	287.73	264.10
2	2037-2053	47,939-57,426	12	474.97	287.73	264.10
3	2054-2070	58,073-69,377	14	474.97	287.73	264.10

Decision Criteria and Options

Table 3: Decision Matrix for Effluent Use

Parameter	Weight (%)	Indirect Potable Reuse- Surface Water Blending	Direct Potable Reuse	Indirect Potable Reuse - Streambed Recharge	Indirect Potable Reuse - Well Injection (Aquifer Recharge)	Reclaimed Delivery
Environmental Impact	40	3	4	3	3	4
Social Impact	35	4	4	4	4	4
Life Cycle Cost	25	3	3	5	3	3
Total	100	3.35	3.75	3.85	3.35	3.75

Final Effluent Use Decision

- Aquifer recharge
- Promotes stable flows
- Riparian habitats
- Supply reclaimed water to current reclaimed users

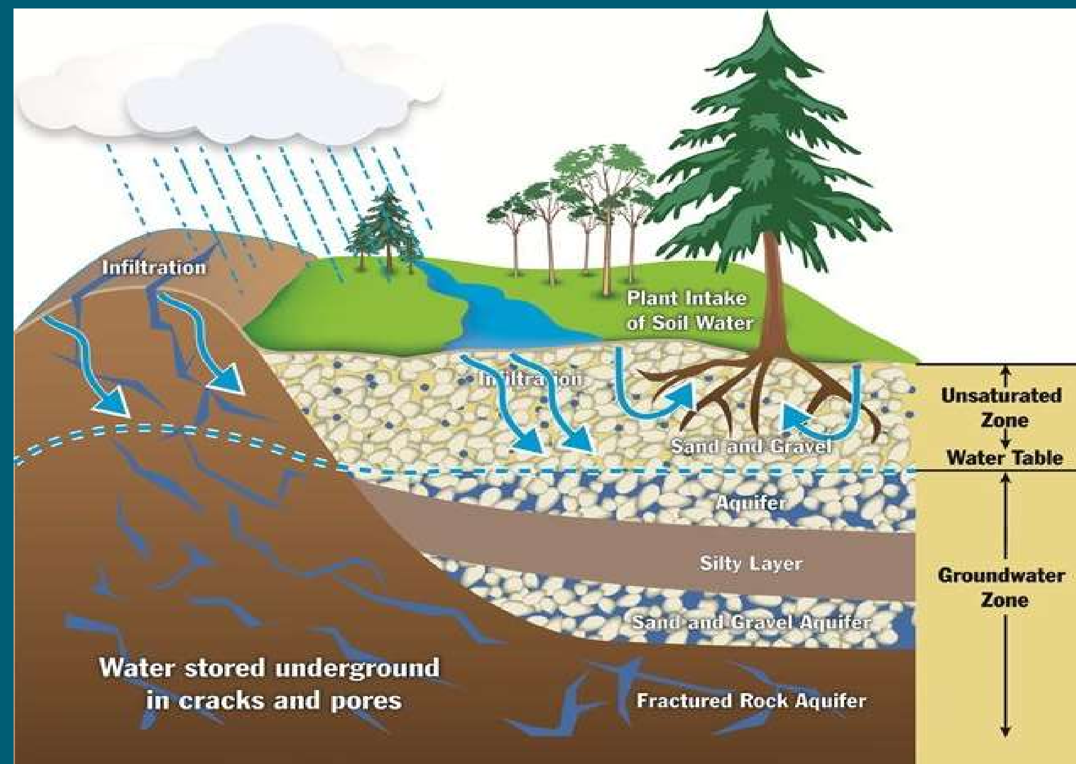


Figure 6: Diagram of Aquifer Infiltration [6]

Decision Criteria

Table 4: Technology Decision Criteria

Parameter	Weight (%)
Efficiency (Process Improvements)	25
Sustainability	15
Feasibility/Constructability	15
Process Life Cycle Costs	15
Maintenance and Operation	10
Staffing	10
Social and Environmental Impacts	10

Bar Screen Decision Matrix and Technology

Table 5: Screening Decision Matrix

Parameter	Weight (%)	Hand Cleaned Coarse Bar Screen	Continuous Belt Bar Screen	Fine Bar Screens
Efficiency (Process Improvements)	25	3	3	4
Sustainability	15	1	4	1
Maintenance and Operation	10	1	4	1
Staffing	10	4	2	4
Feasibility/ Constructability	15	4	2	1
Process Life Cycle Costs	15	4	2	4
Social and Environmental	10	2	4	4
Total	100	2.8	2.95	2.8

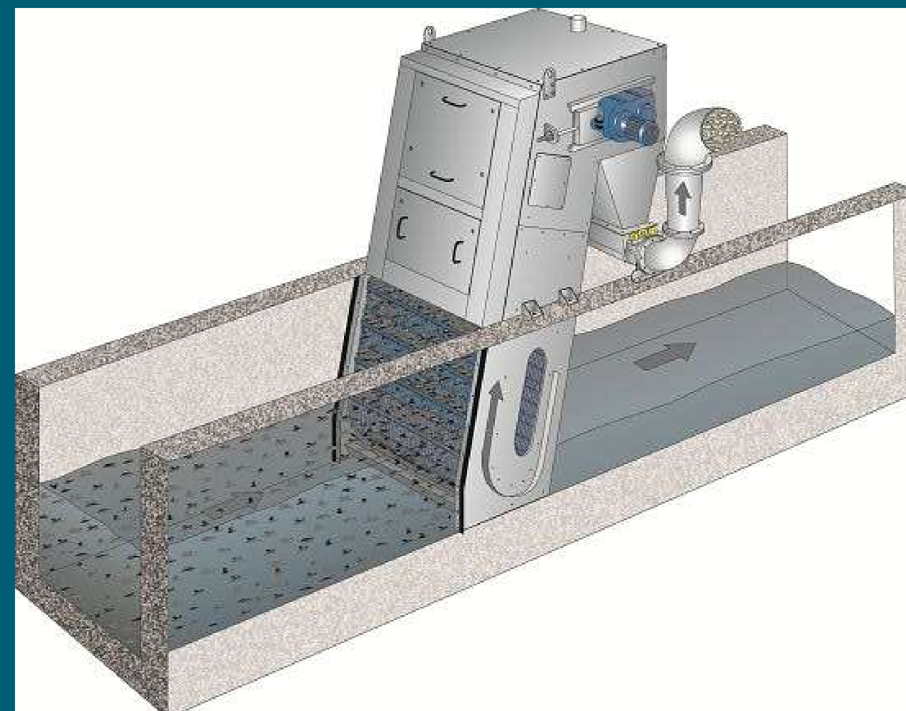


Figure 7: Noggerath Continuous Belt Bar Screen [7]

Disinfection Decision Matrix and Technology

Table 6: Disinfection Decision Matrix

Criteria	Weight (%)	UV Disinfection	Chlorine Disinfection	Peracetic Acid Disinfection	Microalgae
Efficiency (Process Improvements)	25	5	3	4	3
Sustainability	15	4	3	3	4
Maintenance and Operation	10	2	3	4	3
Staffing	10	4	4	3	5
Feasibility/ Constructability	15	5	5	3	2
Process Life Cycle Costs	15	5	5	3	4
Social and Environmental Impacts	10	4	3	4	5
Total	100	4.35	3.7	3.45	3.55

Figure 8: Trojan UV Signa Lamp Cleaning [8]

Design Technology

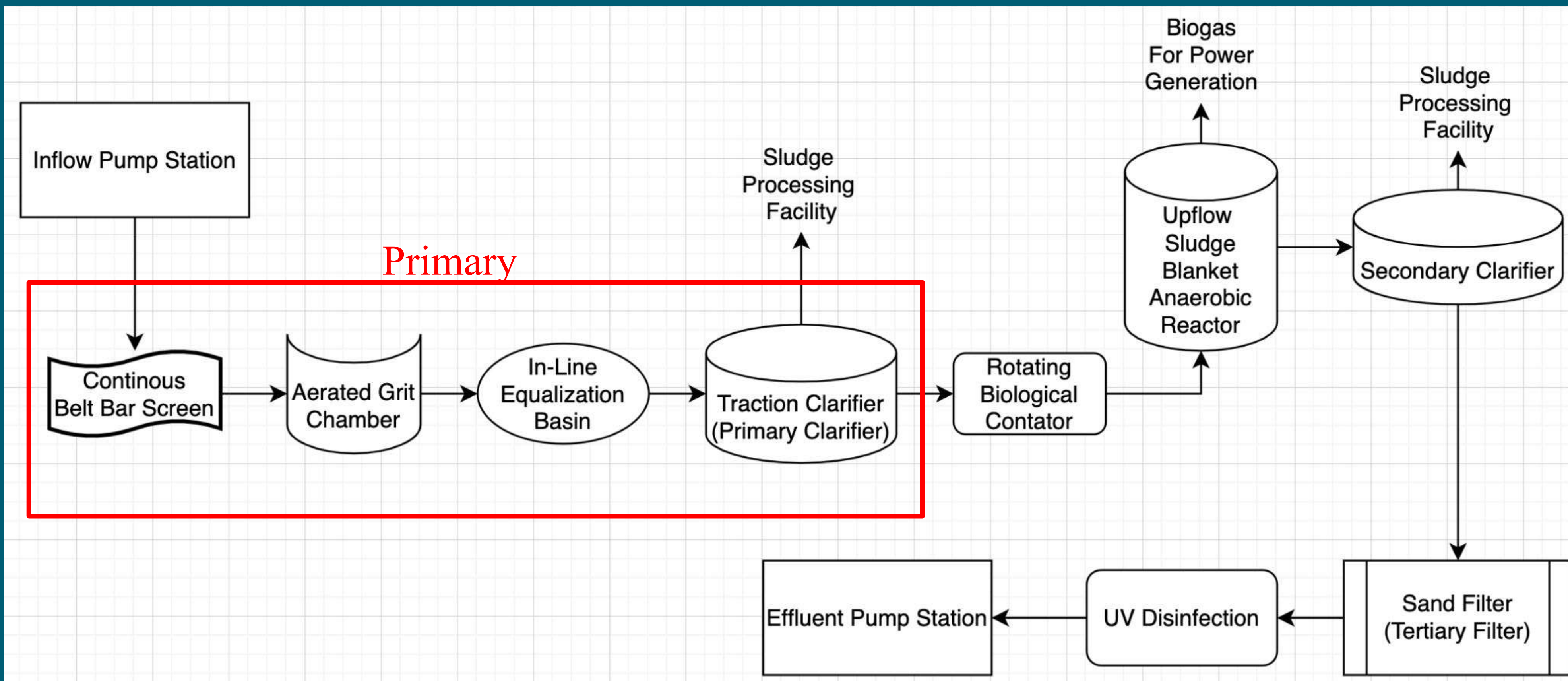


Figure 9: Final Flow Diagram

Design Technology

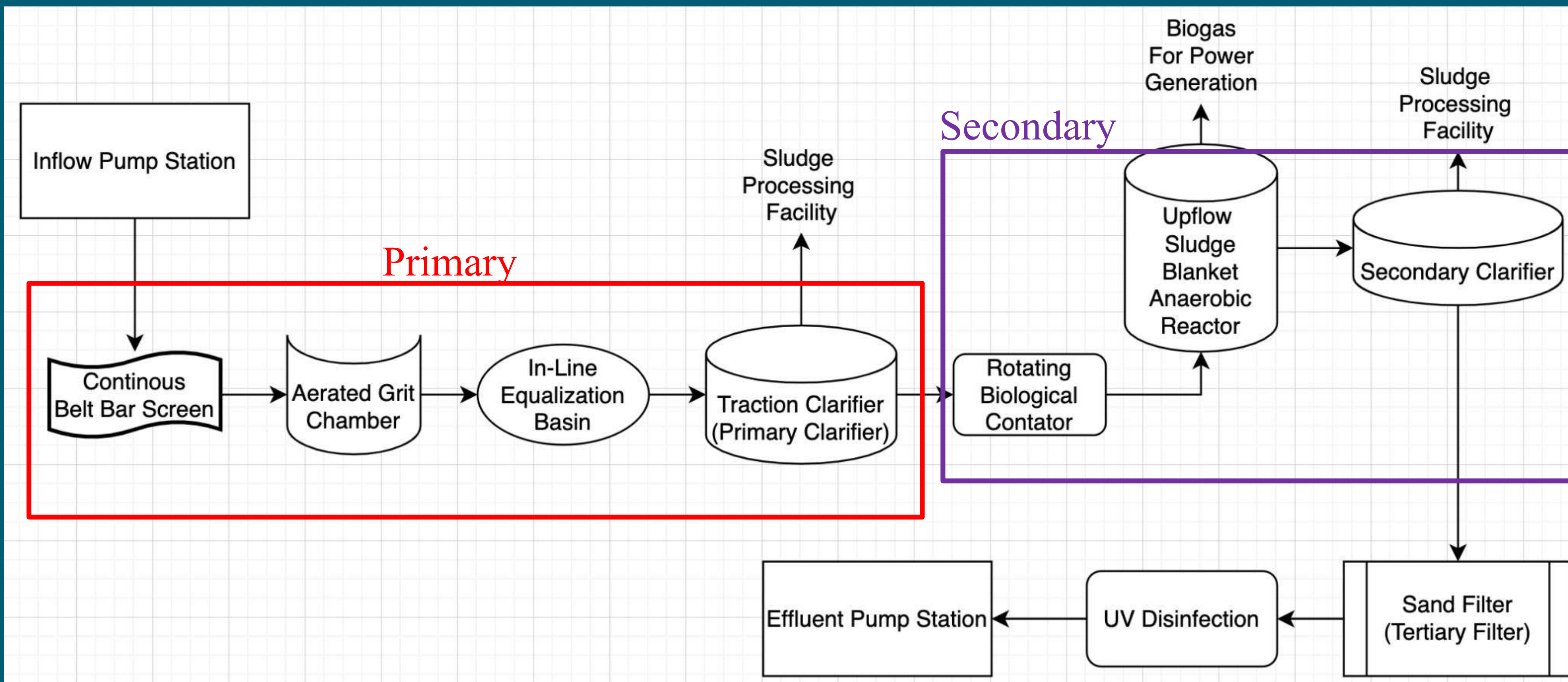


Figure 9: Final Flow Diagram

Design Technology

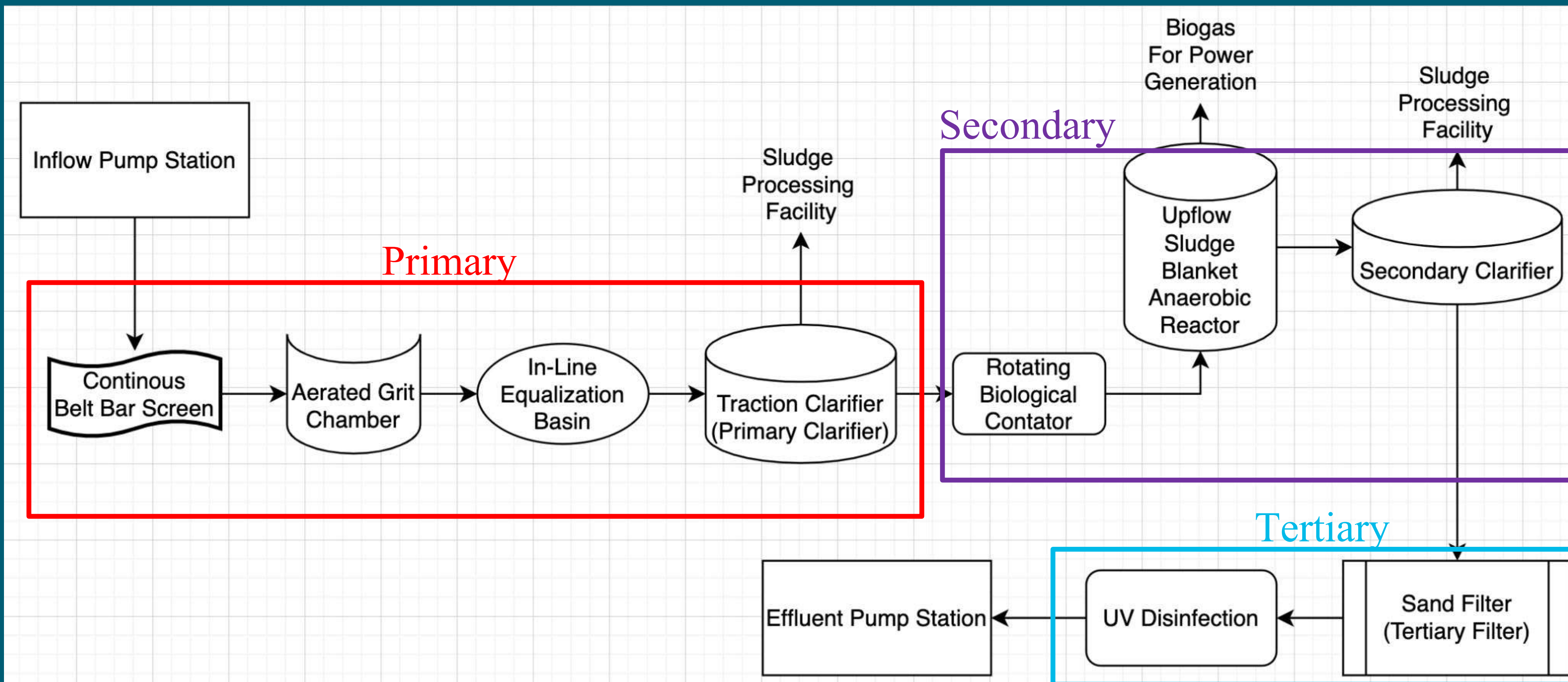


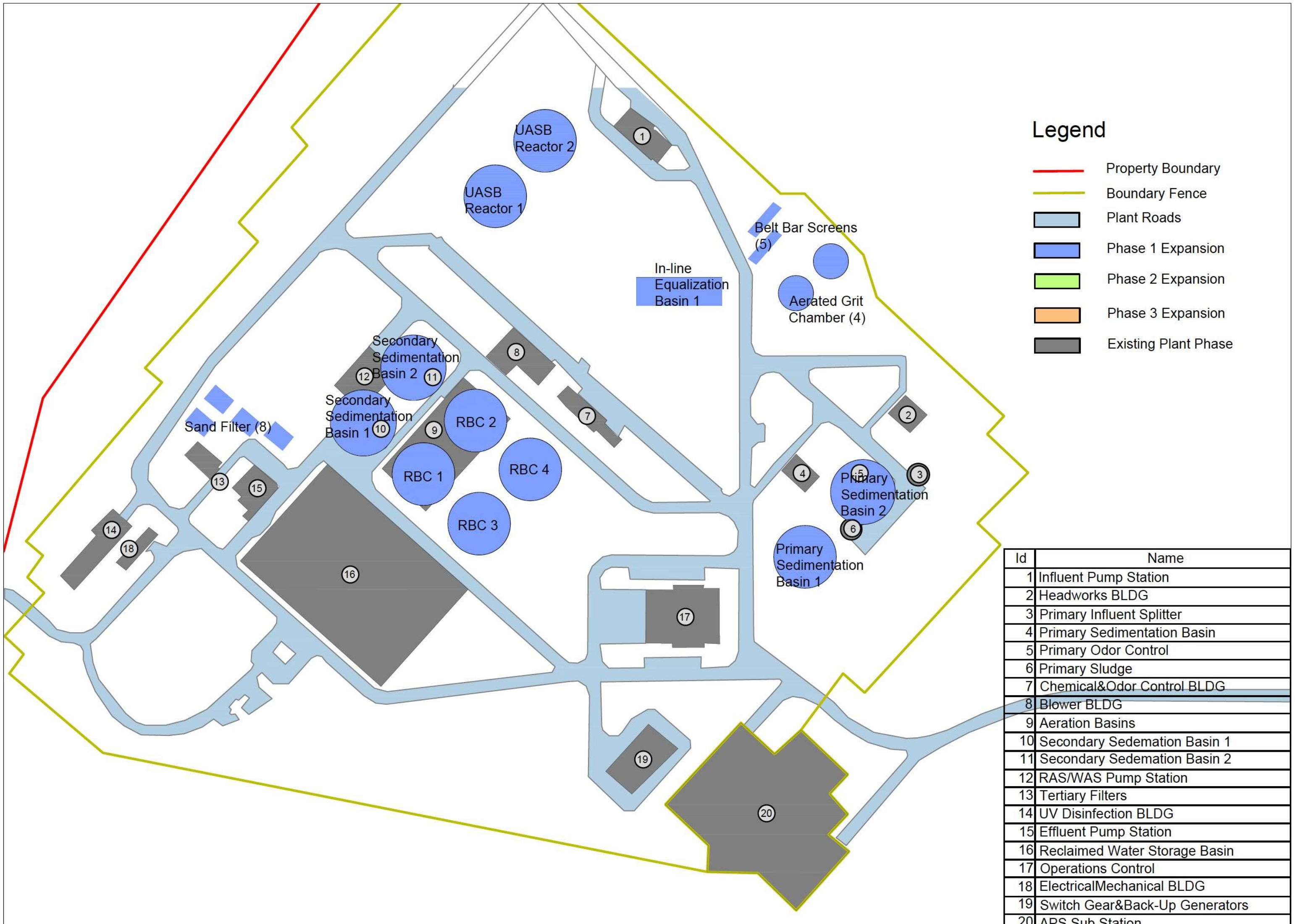
Figure 9: Final Flow Diagram

Calculations

- Based on influent loading information and flow rate
- Manufacturer information
- Research of new technologies
- Accounting for redundancy and future upgrades
- Phased design for increasing flow conditions

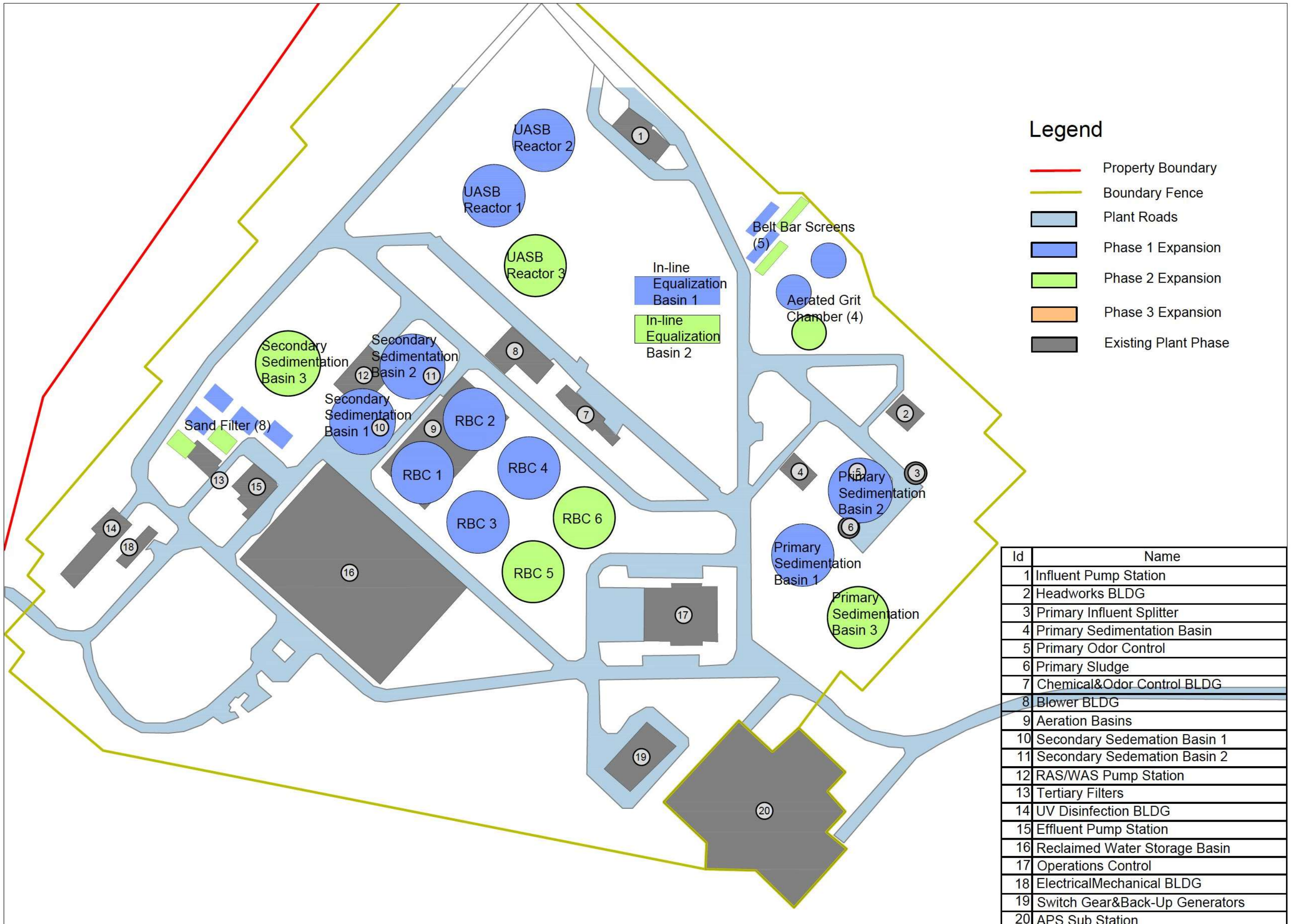
Table 7: In-Line Equalization Basin Calculations

In-Line Equalization Basin		
Parameter	**Units**	**Value**
Number of Basins	(-)	2.00
Storage Volume	(m^3)	2513.27
Height	(m)	8.00
Radius	(m)	10.00



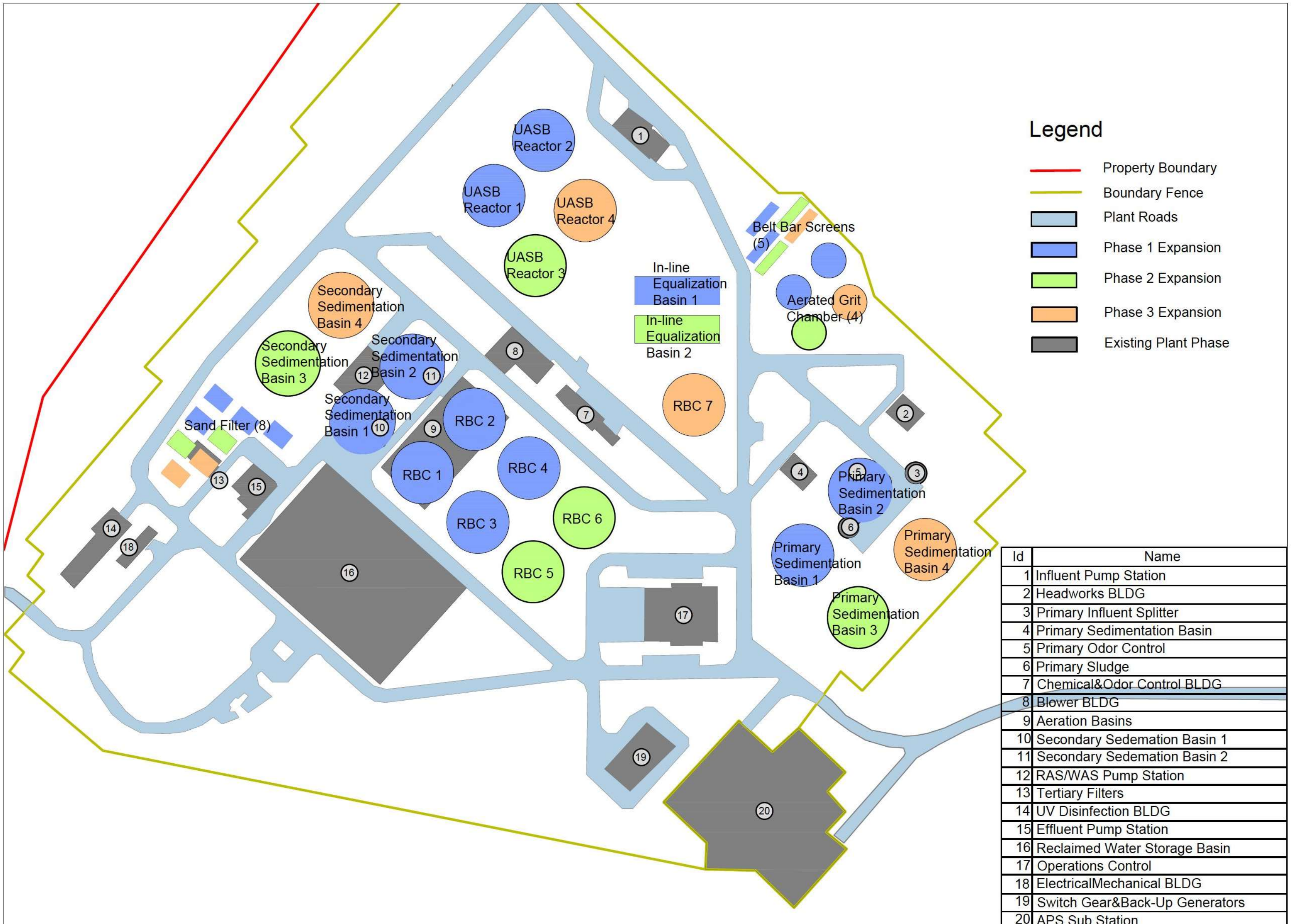
Id	Name
1	Influent Pump Station
2	Headworks BLDG
3	Primary Influent Splitter
4	Primary Sedimentation Basin
5	Primary Odor Control
6	Primary Sludge
7	Chemical&Odor Control BLDG
8	Blower BLDG
9	Aeration Basins
10	Secondary Sedemation Basin 1
11	Secondary Sedemation Basin 2
12	RAS/WAS Pump Station
13	Tertiary Filters
14	UV Disinfection BLDG
15	Effluent Pump Station
16	Reclaimed Water Storage Basin
17	Operations Control
18	ElectricalMechanical BLDG
19	Switch Gear&Back-Up Generators
20	APS Sub Station

Figure 10: Phase 1 Expansion



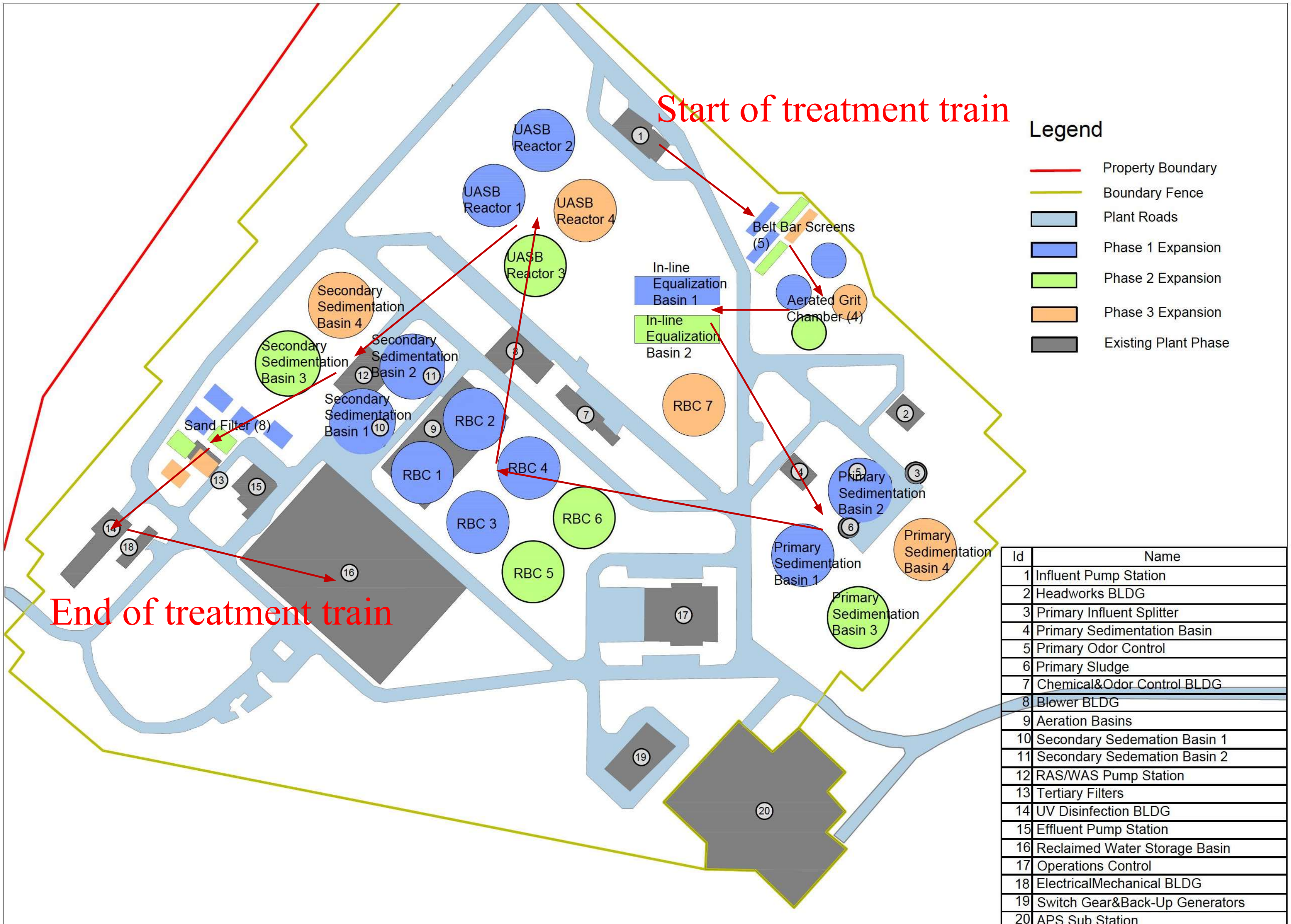
Id	Name
1	Influent Pump Station
2	Headworks BLDG
3	Primary Influent Splitter
4	Primary Sedimentation Basin
5	Primary Odor Control
6	Primary Sludge
7	Chemical&Odor Control BLDG
8	Blower BLDG
9	Aeration Basins
10	Secondary Sedemation Basin 1
11	Secondary Sedemation Basin 2
12	RAS/WAS Pump Station
13	Tertiary Filters
14	UV Disinfection BLDG
15	Effluent Pump Station
16	Reclaimed Water Storage Basin
17	Operations Control
18	ElectricalMechanical BLDG
19	Switch Gear&Back-Up Generators
20	APS Sub Station

Figure 11: Phase 2 Expansion



Id	Name
1	Influent Pump Station
2	Headworks BLDG
3	Primary Influent Splitter
4	Primary Sedimentation Basin
5	Primary Odor Control
6	Primary Sludge
7	Chemical&Odor Control BLDG
8	Blower BLDG
9	Aeration Basins
10	Secondary Sedemation Basin 1
11	Secondary Sedemation Basin 2
12	RAS/WAS Pump Station
13	Tertiary Filters
14	UV Disinfection BLDG
15	Effluent Pump Station
16	Reclaimed Water Storage Basin
17	Operations Control
18	ElectricalMechanical BLDG
19	Switch Gear&Back-Up Generators
20	APS Sub Station

Figure 12: Final Design with Phases



Id	Name
1	Influent Pump Station
2	Headworks BLDG
3	Primary Influent Splitter
4	Primary Sedimentation Basin
5	Primary Odor Control
6	Primary Sludge
7	Chemical&Odor Control BLDG
8	Blower BLDG
9	Aeration Basins
10	Secondary Sedemation Basin 1
11	Secondary Sedemation Basin 2
12	RAS/WAS Pump Station
13	Tertiary Filters
14	UV Disinfection BLDG
15	Effluent Pump Station
16	Reclaimed Water Storage Basin
17	Operations Control
18	ElectricalMechanical BLDG
19	Switch Gear&Back-Up Generators
20	APS Sub Station

Figure 13: Water Flow Route

Pump Design and Selection

- Slurry pump SRL-CML model is a submersible pump
- Three pumps in parallel with fourth pump for redundancy

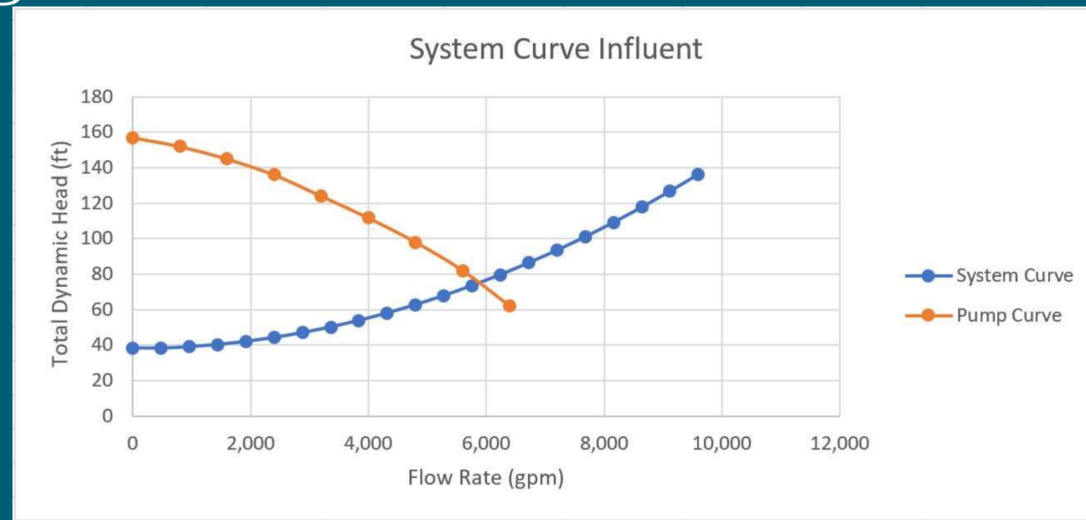


Figure 14: System Curve Influent

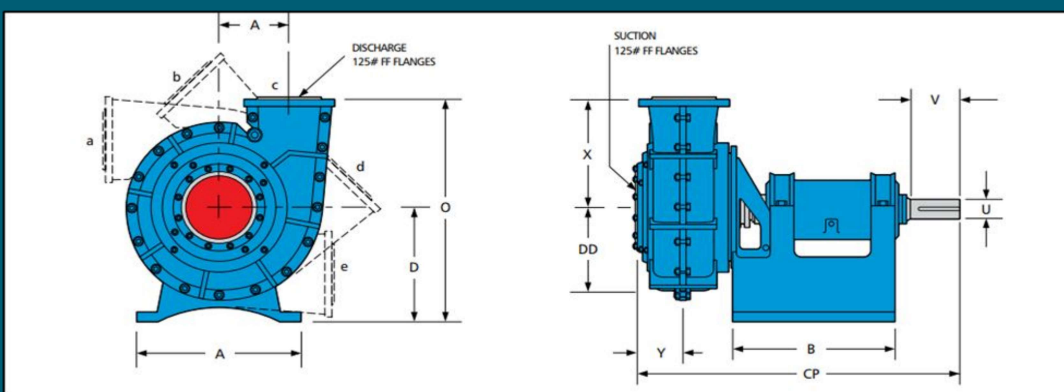


Figure 15: SRL-CML Pump Diagram [9]

Benefits:

- Occupies less space
- Low noise level
- Easily cooled
- Flexible installation

Hydraulic Grade Line

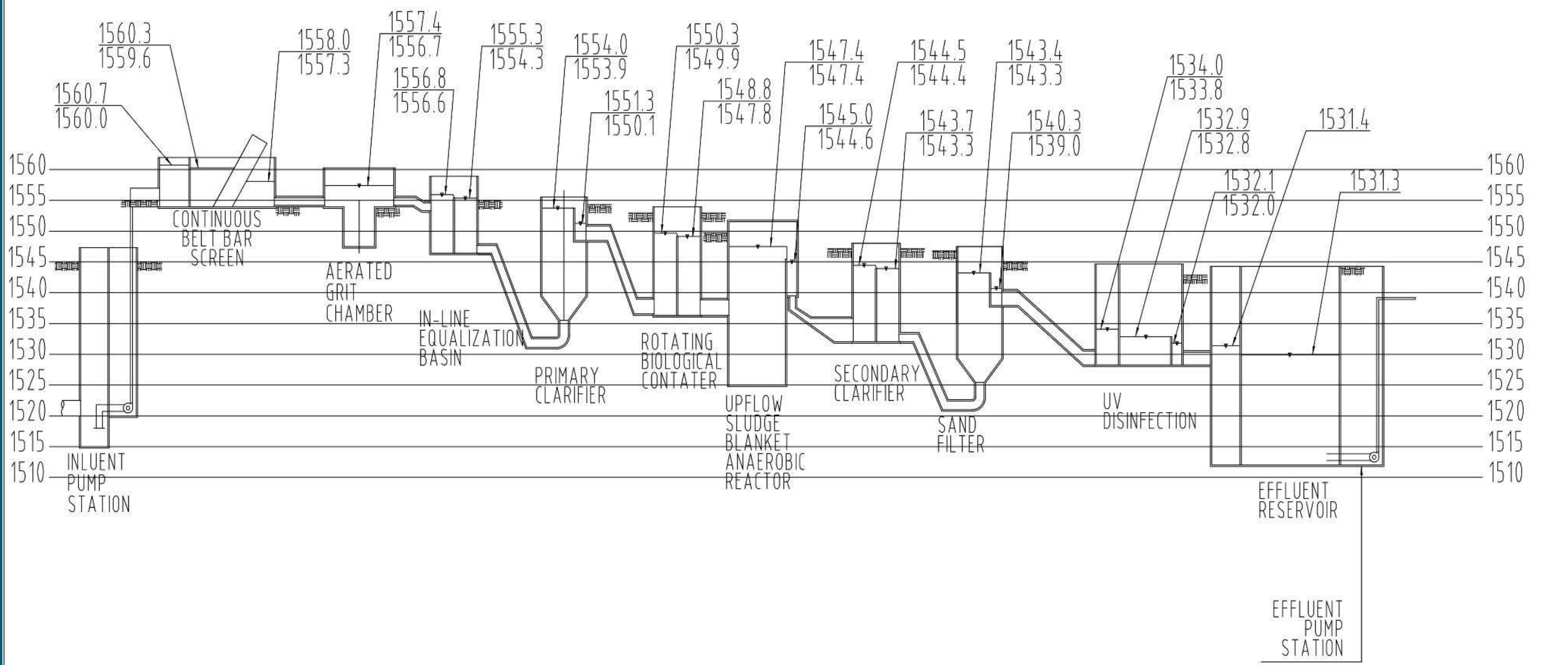


Figure 16: Design Hydraulic Grade Line

Use of Biogas

- Mix of gases including methane and carbon dioxide
- Created from the up flow anaerobic sludge blanket reactor
- Generates electricity to power the plant
- Cost savings estimated to be $44M over the plant lifetime

Figure 17: UASB Reactor [10]

Cost Savings

Table 8: Biogas Producton Savings

Criteria	Phase 2	Phase 3
Number of Cogeneration Engine	2	4
Efficiency	39.40%	39.40%
Electrical Output/Engine, kW	1067	1067
Hours of Operation, hr/day	12	12
kWh/day	25608	51216
kWh/yr	9346920	18693840
$/yr	$ 934,692	$ 1,869,384

- High electrical and thermal efficiency for maximum return on investment
- Robust, flexible design with high reliability on difficult gases
- Available as containerized ‘plug and play’ units for quick installation

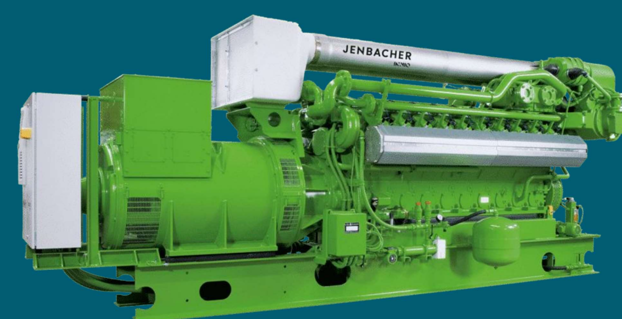


Figure 18: INNIO Jenbacher J320 [11]

Technical Specifications

J320 GS

Electrical Output

1067 kWe

No. of Cylinders /arrangement:
20 / V 70°

Combustion:
Lean burn principle

Bore:
135mm (5.31 inch)

Stroke:
170mm (6.69 inch)

Speed:
1,500 rpm (50Hz)
1,200/1,800 (60Hz)

Dimensions:
5,700mm (length) x 1,800mm (width) x 2,300mm (height)

Gen-set Weight:
10,500 kg

Cost of Construction

- Remove existing units
- Price for each unit
- Excavation and reinforce concret
- Pipes (30%)
- Electrical connections (35%)

Table 9: Capital Cost Summary

Unit	2021 Capital Cost	2037 Capital Cost	2054 Capital Cost
Influent Pump Station	$ 1,010,000	$ -	$ -
Screen System	$ 891,891	$ 975,981	$ 525,729
Grit Removal	$ 470,993	$ 255,059	$ 282,929
Equalization Basin	$ 309,375	$ 268,060	$ -
Primary Clarifiers	$ 1,244,100	$ 625,474	$ 680,820
Aeration Basins	$ 188,100,000	$ 98,288,707	$ 68,081,956
Secondary Clarifiers	$ 1,402,500	$ 536,120	$ 583,560
Sand Filter	$ 13,406,250	$ 7,186,245	$ 7,822,130
UV Disinfection	$ 2,003,100	$ 16,500	$ 369,600
Biogas	$ 10,125	$ 56,585	$ 61,592

Table 10: Construction Cost Summary

Summary of CCWRP Estimated Construction Cost	
Capital Cost	$ 395,465,381
Permitting	$ 143,000
Contingency	$ 11,863,961
Total	$ 407,472,342

Life Cycle Cost

Interest Rates

- Phase 1: 8%
- Phase 2: 8.5%
- Phase 3: 9%

Equation 3: Life Cycle Cost [12]

$$\text{Life Cycle Cost} = \text{Initial Cost} + \text{O\&M } (A/G, 8\%, 50) - \text{Residual Value } (P/A, 8\%, 50) - \text{Saving Cost}$$

Table 11: Yearly Operation and Maintenance Cost

CCWRP Yearly Operation & Maintenance Cost						
Unit	Yearly Initial Maintenance (2021-2036)		Yearly Phase2 Maintenance (2037-2053)		Yearly Phase3 Maintenance (2054-2070)	
Influent Pump Station	$	35,640	$	38,669	$	42,150
Screen System	$	85,810	$	93,103	$	101,483
Grit Removal	$	36,323	$	39,411	$	42,958
Equalization Basin	$	20,788	$	22,555	$	24,585
Primary Clarifiers	$	91,814	$	99,618	$	108,584
Aeration Basins	$	12,760,944	$	13,845,624	$	15,091,730
Secondary Clarifiers	$	90,798	$	98,516	$	107,383
Sand Filter	$	1,015,502	$	1,101,819	$	1,200,983
UV Disinfection	$	86,011	$	93,322	$	101,721
Biogas	$	5,645	$	6,125	$	6,676
Total $/yr	$	14,229,275	$	15,438,764	$	16,828,252

Table 12: Life-Cycle Cost Summary

Life-Cycle Cost		
Particulars	Cost	
Construction Cost	$	407,472,342
O&M Cost	$	729,711,379
Sampling&Laboratory	$	11,303,289
No. of Years		50
Interest Rate		8%
Residual Value	$	101,868,086
Life-Cycle Cost	$	9,425,626,729

Economic Impacts

(-) Increased water rates

(+) Locally sourced materials

(+) Biosolids sold to farmers for revenue

(+) Biogas savings

Social Impacts

(-) Plant expansion into surrounding community

(+) Increases water security

(+) Increased trust in upgraded infrastructure

(+) Jobs for the surrounding community

Environmental Impacts

(-) Odors and emissions from the plant

(-) Unregulated contaminants polluting aquifer

(+) Reduces demand for surface and groundwater sources

(+) Aquifer recharge and aiding riparian habitats

Final Recommendations

- Phased design for flows ranging from 10 to 14 MGD
- Implementation of Belt Bar Screen and Aerated Grit Chamber to increase grit removal and decrease wear on the system
- Upgraded UV System to aid in O&M and redundancy
- Streambed recharge and supplying current reclaimed water users

Figure 19: CCWRP Sign [4]

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Thank you!

Any questions?

Capital Cost Estimation

Item #	Item	Size/Description	unit	2021 Quantity	2021 cost/unit	2037 Quantity	2037 cost/unit	2054 Quantity	2054 cost/unit	2021 Capital Cost	2037 Capital Cost	2054 Capital Cost
Influent Pump Station										$ 1,010,000.00	$ -	$ -
1	Pump	Slurry Abrasive pump, Model 10x8-21	EA	4	$ 150,000.00	0	$ 162,460.67	0	$ 176,836.25	$ 600,000.00	$ -	$ -
2	Pipe, Valves &Fittings	Estimation of pipes, valves and fittings (30% of unit cost)								$ 180,000.00	$ -	$ -
3	Electrical	Estimation of electrical connections and instrumentation (35% of unit cost)								$ 210,000.00	$ -	$ -
4	Removal Existing	Remove existing pumps	EA	4	$ 5,000.00		$ -		$ -	$ 20,000.00	$ -	$ -
Screen System										$ 891,891.00	$ 975,981.41	$ 525,728.87
1	Continuous Belt Bar Screen	Noggerath® Continuous Belt Screen, Model BS-XL	EA	2	$ 267,000.00	2	$ 289,180.00	1	$ 314,768.53	$ 534,000.00	$ 578,359.99	$ 314,768.53
2	Concrete	Normal weight reinforced concrete	CY	12	$ 545.00	12	$ 590.27	6	$ 642.51	$ 6,540.00	$ 7,083.29	$ 3,855.03
3	Pipe, Valves &Fittings	Estimation of pipes, valves and fittings (30% of unit cost)								$ 162,162.00	$ 175,632.98	$ 95,587.07
4	Electrical	Estimation of electrical connections and instrumentation (35% of unit cost)								$ 189,189.00	$ 204,905.15	$ 111,518.24
5	Removal Existing	Remove existing bar screens	EA	0	$ -	2	$ 5,000.00	0	$ -	$ -	$ 10,000.00	$ -
Grit Removal										$ 470,992.50	$ 255,059.19	$ 282,929.16
1	Aerated Grit Chamber	SPIRAC® Technology Grit Chamber	EA	2	$ 140,000.00	1	$ 151,629.96	1	$ 165,047.17	$ 280,000.00	$ 151,629.96	$ 165,047.17
2	Concrete	Normal weight reinforced concrete	CY	10	$ 545.00	5	$ 590.27	10	$ 642.51	$ 5,450.00	$ 2,951.37	$ 6,425.05
3	Pipe, Valves &Fittings	Estimation of pipes, valves and fittings (30% of unit cost)								$ 85,635.00	$ 46,374.40	$ 51,441.67
4	Electrical	Estimation of electrical connections and instrumentation (35% of unit cost)								$ 99,907.50	$ 54,103.47	$ 60,015.28
Equalization Basin										$ 309,375.00	$ 268,060.11	$ -
1	In Line Equalization Basin	AIRE-O2 TRITON ®, Model TR Series 2.0	EA	1	$ 150,000.00	1	$ 162,460.67	0	$ 176,836.25	$ 150,000.00	$ 162,460.67	$ -
2	Excavation	Excavation and earthwork for installation of equalization basin	CY	750	$ 50.00	0	$ 54.15	0	$ 58.95	$ 37,500.00	$ -	$ -
3	Pipe, Valves &Fittings	Estimation of pipes, valves and fittings (30% of unit cost)								$ 56,250.00	$ 48,738.20	$ -
4	Electrical	Estimation of electrical connections and instrumentation (35% of unit cost)								$ 65,625.00	$ 56,861.24	$ -
Primary Clarifiers										$ 1,244,100.00	$ 625,473.59	$ 680,819.56
1	Traction Clarifier	Peripheral Traction Clarifier W/ weirs, baffles, and mechanical mechanisms, Model PTP12	EA	2	$ 350,000.00	1	$ 379,074.90	1	$ 412,617.92	$ 700,000.00	$ 379,074.90	$ 412,617.92
2	Excavation	Excavation and earthwork for installation of primary clarifier basin	CY	900	$ 60.00	0	$ 64.98	0	$ 70.73	$ 54,000.00	$ -	$ -
3	Pipe, Valves &Fittings	Estimation of pipes, valves and fittings (30% of unit cost)								$ 226,200.00	$ 113,722.47	$ 123,785.38
4	Electrical	Estimation of electrical connections and instrumentation (35% of unit cost)								$ 263,900.00	$ 132,676.22	$ 144,416.27
Aeration Basins										$ 188,100,000.00	$ 98,288,706.98	$ 68,081,956.31
1	Rotating Biological Reactor	Napier-Reid's RBC with Bio-Rotor™ Technology	EA	4	$ 20,000,000.00	2	$ 21,661,423.03	1	$ 23,578,166.69	$ 80,000,000.00	$ 43,322,846.05	$ 23,578,166.69
2	Upflow Anaerobic Sludge Blanket	ANUBIX™ – B reactor	EA	2	$ 15,000,000.00	1	$ 16,246,067.27	1	$ 17,683,625.01	$ 30,000,000.00	$ 16,246,067.27	$ 17,683,625.01
3	Excavation	Excavation and earthwork for installation of aeration basin	CY	80,000	$ 50.00	0	$ 54.15	0	$ 58.95	$ 4,000,000.00	$ -	$ -
4	Pipe, Valves &Fittings	Estimation of pipes, valves and fittings (30% of unit cost)								$ 34,200,000.00	$ 17,870,674.00	$ 12,378,537.51
5	Electrical	Estimation of electrical connections and instrumentation (35% of unit cost)								$ 39,900,000.00	$ 20,849,119.66	$ 14,441,627.10
5	Removal Existing	Remove existing aeration basin	EA	1	$ 5,000.00	0	$ 5,415.36	0	$ 5,894.54	$ 5,000.00	$ -	$ -
Secondary Clarifiers										$ 1,402,500.00	$ 536,120.22	$ 583,559.63
1	Spiral Scraper Clarifier	110' COP™ Spiral Blade Clarifier	EA	2	$ 300,000.00	1	$ 324,921.35	1	$ 353,672.50	$ 600,000.00	$ 324,921.35	$ 353,672.50
2	Excavation	Excavation and earthwork for installation of secondary clarifier basin	CY	5000	$ 50.00	0	$ 54.15	0	$ 58.95	$ 250,000.00	$ -	$ -
3	Pipe, Valves &Fittings	Estimation of pipes, valves and fittings (30% of unit cost)								$ 255,000.00	$ 97,476.40	$ 106,101.75
4	Electrical	Estimation of electrical connections and instrumentation (35% of unit cost)								$ 297,500.00	$ 113,722.47	$ 123,785.38
Sand Filter										$ 13,406,250.00	$ 7,186,244.78	$ 7,822,130.48
1	Sand Filter	Super sand tertiary system W/ 8 basins & 4 filters per basin	EA	4	$ 2,000,000.00	2	$ 2,166,142.30	2	$ 2,357,816.67	$ 8,000,000.00	$ 4,332,284.61	$ 4,715,633.34
2	Concrete Wall	Concrete Masonry Unit wall around the top of filter basin	SF	0	$ 25.00	850	$ 27.08	850	$ 29.47	$ -	$ 23,015.26	$ 25,051.80
3	Excavation	Excavation and earthwork for installation of sand filter	CY	2500	$ 50.00	0	$ 54.15	0	$ 58.95	$ 125,000.00	$ -	$ -
4	Pipe, Valves &Fittings	Estimation of pipes, valves and fittings (30% of unit cost)								$ 2,437,500.00	$ 1,306,589.96	$ 1,422,205.54
5	Electrical	Estimation of electrical connections and instrumentation (35% of unit cost)								$ 2,843,750.00	$ 1,524,354.95	$ 1,659,239.80
UV Disinfection										$ 2,003,100.00	$ 16,500.00	$ 369,600.00
1	Trojan UV Signa Bank	Trojan UV Signa bank with 161,000W bulbs per bank W/ controls, sluice gate, and connection	EA	14	$ 86,000.00	2	$ 5,000.00	4	$ 56,000.00	$ 1,204,000.00	$ 10,000.00	$ 224,000.00
2	Removal Existing	Remove existing UV system and controls	EA	2	$ 5,000.00	0	$ 5,415.36	0	$ 5,894.54	$ 10,000.00	$ -	$ -
3	Pipe, Valves &Fittings	Estimation of pipes, valves and fittings (30% of unit cost)								$ 364,200.00	$ 3,000.00	$ 67,200.00
4	Electrical	Estimation of electrical connections and instrumentation (35% of unit cost)								$ 424,900.00	$ 3,500.00	$ 78,400.00
Biogas										$ 10,125.00	$ 56,585.05	$ 61,592.07
1	Collection Hood	Hanon Gas Collection Hood, Model WD03	EA	5	$ 1,500.00	5	$ 1,624.61	5	$ 1,768.36	$ 7,500.00	$ 8,123.03	$ 8,841.81
2	Cogeneration Engine	Jenbacher Type 3 cogeneration engine	EA	0	$ 15,600.00	2	$ 16,895.91	2	$ 18,390.97	$ -	$ 33,791.82	$ 36,781.94
3	Electrical	Estimation of electrical connections and instrumentation (35% of unit cost)								$ 2,625.00	$ 14,670.20	$ 15,968.31

Number of Units

Treatment Type	Phase	Number of Units	Phase	Number of Units Added	Number of Units Total	Phase	Number of Units Added	Number of Units Total
Belt Bar Screen	1	2	2	2	4	3	1	5
Aerated Grit Chamber		2		1	3		1	4
In-Line Equalization Basin		1		1	2		0	2
Traction Primary Clarifier		2		1	3		1	4
RBC		4		2	6		1	7
UASB Reactor		2		1	3		1	4
Spiral Scraper Secondary Clarifier		2		1	3		1	4
Sand Filter		4		2	6		2	8
UV		36 Banks		8	44 Banks		6	50 Banks

RBC Decision Matrix

Parameter	Weight (%)	Membrane Bioreactors	Trickling Filters	Rotating Biological Contactors	Moving Bed Biofilm Reactors
Efficiency (Process Improvements)	25	4	2	3	3
Sustainability	15	3	3	3	4
Maintenance and Operation	10	2	4	4	3
Staffing	10	4	5	4	2
Feasibility/ Constructability	15	3	4	4	3
Process Life Cycle Costs	15	3	5	4	3
Social and Environmental Impacts	10	3	2	3	2
Total	100	3.25	3.4	3.5	2.95

UASB Calculations

Upflow Anaerobic Sludge Blanket Reactor		
Parameter	**Units**	**Value**
Number of Reactors	(-)	2.00
Reactor Volume (V)	(m3)	7097.65
Height (H)	(m)	10.80
Diameter (D)	(m)	28.93
Sludge Bed Height	(m)	2.00
Sludge Bed Volume	(m3)	2839.06
TSS Removal	(%)	75.00
COD Removal	(%)	80.00
BOD Removal	(%)	67.00
Gas Liquid Separator (GLS)		
GLS Volume	(m^3)	1774.41
GLS Upflow Velocity	(m/hr)	2.00
GLS Height	(m)	2.70
Diameter of Separator	(m)	18.29

Sand Filter Calculations

Sand Filter		
Parameter	**Units**	**Value**
Number of Beds	(-)	4.00
Area of Bed (A)	(m^2/filter bed)	19.72
Width of one cell (W)	(m)	3.00
Length (L)	(m)	3.29
Gullet Width	(m)	0.60
Number of Troughs (N)	(-)	3.00
Trough Spacing	(m)	1.10
Depth of Trough (D_T)	(m)	0.54
Depth of Expanded Bed (D_e)	(m)	0.70
Depth of Unexpanded Bed (D)	(m)	0.50
Filter Backwash Volume (V)	(m^3)	182.37
Backwash Tank Volume	(m^2)	364.74
TSS Removal	(%)	86.00
COD Removal	(%)	86.00
BOD Removal	(%)	68.00

Effluent BOD, COD, and TSS

Influent TSS	Effluent TSS	Influent COD	Effluent COD	Influent BOD	Effluent BOD
mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
264.10	1.83	474.97	0.30	287.73	0.16

Figure 1. 17: Swamme Jain Friction Factor

$$f = \frac{0.25}{\left(\left(\log\left(\frac{K_s}{3.7D} + \frac{5.74}{R_e^{0.9}}\right)\right)^2\right)}$$

Where:
f = Darcy Weisbach Friction Factor
D = Diameter (ft)
K_s = Pipe roughness
R_e = Reynold's Number

Figure 1. 18: Major Head Loss

$$h_{L_f} = f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)$$

Where:
h_{Lf} = Friction Loss (ft)
V = Velocity (ft/s)
g = Gravitational Constant (ft/s^2)

Figure 1. 19: Minor Head Loss

$$h_{L_m} = K\left(\frac{V^2}{2g}\right)$$

Where:
h_{Lm} = Minor Headloss (ft)
K = Minor Loss Coefficient

Figure 1. 20: Total Dynamic Headloss

$$TCH = h_{L_f} + \sum h_{L_m} + \Delta Elev.$$

Where:
TDH = Total Dynamic Head (ft)
$\Delta Elev$ = Change in elevation (ft)

Headworks

The existing channels leading to the bar screens has a maximum depth and width of 7 feet and 2 feet. The channel allows for 2 feet of freeboard, providing a maximum flow depth of 5 feet. However, to support a functioning HGL, the channel elevation was raised by 2 feet, increasing the maximum depth to 9 feet. This design accounts for 2 feet of freeboard, which provides a maximum depth of flow at 7 feet.

The cross-sectional flow area of the channel was measured by multiplying the maximum flow depth by the channel width. The maximum allowable velocity in the channel for Phase 2 and Phase 3 was computed by using Manning's Equation (**Error! Reference source not found.**). However, the slope and channel roughness were assumed to be 0.0007 and 0.012, respectively.

Equation 7: Manning's Equation [29]

$$Q = VA = \left(\frac{C}{n}\right) AR^{\frac{2}{3}}\sqrt{S}$$

Where:

V = Velocity (ft/s)

C = 1.49 $ft^{1/3}/s$

n = Mannings Roughness Coefficient

R = Hydraulic Radius (ft)

S = Slope

The channel reconstruction was determined by computing the headloss through the existing headworks channel (Equation 8), proposed bar screens, grit chamber, and the primary splitter box. The headloss was summed and then subtracted by the existing bar screen headloss of 1.2 feet, respectively. The HGL profile elevations were adjusted for the improved preliminary units. The headworks channel elevations are required to be raised by at least 1.5 feet to ensure constant flow. However, for the expansion of the plant, the channel operating floor will be raised to 2 feet. Table 31 displays the headloss computations that were utilized for the HGL adjustment and channel reconstruction.

Equation 8: Headloss in Channel [29]

$$h_L = L \times S$$

Where:

h_L = Headloss (ft)

L = Channel Length (ft)

S = Slope (ft/ft)

Table 31: Computed Headloss for HGL Profile Adjustments and Channel Reconstruction

HGL Adjustments and Channel Reconstruction	
Headloss through Existing Bar Screens (ft)	1.2
Headloss through Headworks Channel (ft)	0.06
Headloss through Grit Chamber (ft)	0.20
Headloss through Proposed Bar Screens (ft)	2.25
Headloss from Primary Splitter Box to Headworks (ft)	0.80
Total Headloss Before Adjustment (ft)	2.1
Total Adjusted Headloss (ft)	1.5

The required bar screen expansion was determined by calculating approach velocities for both phases. The approach velocity was determined by dividing the peak flow rate by the cross-sectional area of the channel (Equation 9). The velocity through the bar screens and headloss was computed from Equation 10 and 11.

Equation 9: Continuity Equation [29]

$$Q = VA$$

Where:

Q = Design Flow Rate (cfs)

A = Cross-Sectional Area of Channel (ft^2)

Equation 10: Continuity Equation for Velocity Through Bar Screens [30]

$$V_b = \frac{V_a \times A_a}{A_{net}}$$

Where:

V_b = Velocity Through Bar Screen (ft/s)

V_a = Maximum Velocity in Channel (ft/s)

A_a = Flow Aera of Channel (ft_2)

A_{net} = Net Area of Bar Screen (ft^2)

Equation 11: Headloss through Bar Screens [29]

$$h_L = \frac{\left(0.7\left(V_{thru}^2 - V_{approach}^2\right)\right)}{2g}$$

Where:

V_{thru} = Velocity through Bar Screens (ft/s)

$V_{approach}$ = Approach Velocity (ft/s)

The final design for Phase 2 will require two bar screens to support the varied flows and predicted peak flow of 20 MGD, as one will be used for redundancy. Phase 3 will require constructing one additional channel with a width and maximum channel depth of 2 feet and 9 feet. Phase 3 will utilize both bar screens that were implemented in Phase 2. To allow for redundancy, one additional bar screen will be added to the constructed channel. Table 32 and Table 33 display the measurements for required expansion.

Table 32: Phase 2 – Headworks Expansion Computations

Phase 2: Bar Screen Influent Parameters for 2025-2037	
Peak Flow (MGD)	20
Flow (cfs)	30.9
Channel Dimensions	
Channel Width (ft)	2
Freeboard (ft)	2
Channel Depth (ft)	9
Maximum Channel Water Depth (ft)	7
Cross-Sectional Channel Flow Area (ft^2)	14
Headloss in Channel (in)	0.70
Phase 2: Bar Screen Expansion for 2025-2037	
Maximum Design Velocity for One Channel (ft/s)	2.21
Maximum Design Velocity for Two Channels (ft/s)	1.11
Velocity Through Bars for One Channels, One Screen (ft/s)	2.23
Redundancy: Velocity Through Bars for Two Channels, Two Screens (ft/s)	1.12
Headloss Through Bar Screen (in)	0.89

Table 33: Phase 3 – Headworks Expansion Computations

Phase 3: Bar Screen Influent Parameters for 2037-2050	
Peak Flow (MGD)	33
Flow (cfs)	51.1
Channel Dimensions	
Channel Width (ft)	2
Freeboard (ft)	2
Channel Depth (ft)	9
Maximum Channel Water Depth (ft)	7
Cross-Sectional Channel Flow Area (ft^2)	14
Headloss in Channel (in)	0.70
Phase 3: Bar Screen Expansion for 2037-2050	
Maximum Design Velocity for One Channel (ft/s)	3.65
Maximum Design Velocity for Two Channels (ft/s)	1.83
Maximum Design Velocity for Three Channels (ft/s)	0.91
Velocity Through Bars for One Channels, One Screen (ft/s)	4.74
Velocity Through Bars for Two Channels, Two Screens (ft/s)	2.37
Redundancy: Velocity Through bars for Three Channels, Three Screens (ft/s)	1.18
Headloss Through Bar Screen (in)	2.44

Grit Removal

The Huber Vortex Grit Chamber is specified to hold 20 MGD. The capacities of each unit were compared and appropriately duplicated based on the maximum design flow. For Phase 2, the facility will need to implement two units of the vortex grit chamber to support the maximum design flow of 20 MGD and allow for redundancy. For Phase 3, the facility will need to add one additional vortex grit chamber to support the maximum design flow rate of 33 MGD and allow for redundancy.

Table 34: Phase 2 - Grit Chamber Expansion

Phase 2: Vortex Grit Chamber Influent Parameters	
Flow (MGD)	20
Flow (cfs)	30.9
BOD (lb/day)	37,113.89
COD (lb/day)	67,479.81
TSS (lb/day)	28,046.30
TDS (mg/L)	780.95
Phase 2: Vortex Grit Chamber Expansion	
Maximum Flow Rate (MGD)	20
One Unit (MGD)	20
Redundancy: Two Units (MGD)	40
Phase 2: Vortex Grit Chamber Effluent Parameters	
Flow (MGD)	20
Flow (cfs)	30.9
BOD (lb/day)	37,113.89
COD (lb/day)	67,479.81
TSS (lb/day)	28,046.30
TDS (mg/L)	780.95

Table 35: Phase 3 - Grit Chamber Expansion

Phase 3: Grit Chamber Influent Parameters for 2037-2050	
Flow (MGD)	33
Flow (cfs)	51.1
BOD (lb/day)	62,169
COD (lb/day)	113,035.51
TSS (lb/day)	46,980.38
TDS (mg/L)	941.50
Grit Chamber Expansion for 2037-2050	
Maximum Flow Rate (MGD)	33
One Unit (MGD)	20
Two Units (MGD)	40
Redundancy: Three Units (MGD)	60
Phase 2: Vortex Grit Chamber Effluent Parameters	
Flow (MGD)	33
Flow (cfs)	51.1
BOD (lb/day)	62,169.0
COD (lb/day)	113,035.51
TSS (lb/day)	46,980.38
TDS (mg/L)	941.50