JOY CONE INDUSTRIAL WASTEWATER PRETREATMENT SYSTEM

FINAL PRESENTATION
CENE 486C
4/28/2023

Honeycomb Engineering

HONEYCOMB ENGINEERING INC.

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INTRODUCTION

- Joy Cone Ice Cream Cone Factory
  - produces 585,000,000 cones per year on-site
  - 500,000 gallons per year of industrial wastewater
  - Wastewater currently discharged to public sanitary sewer

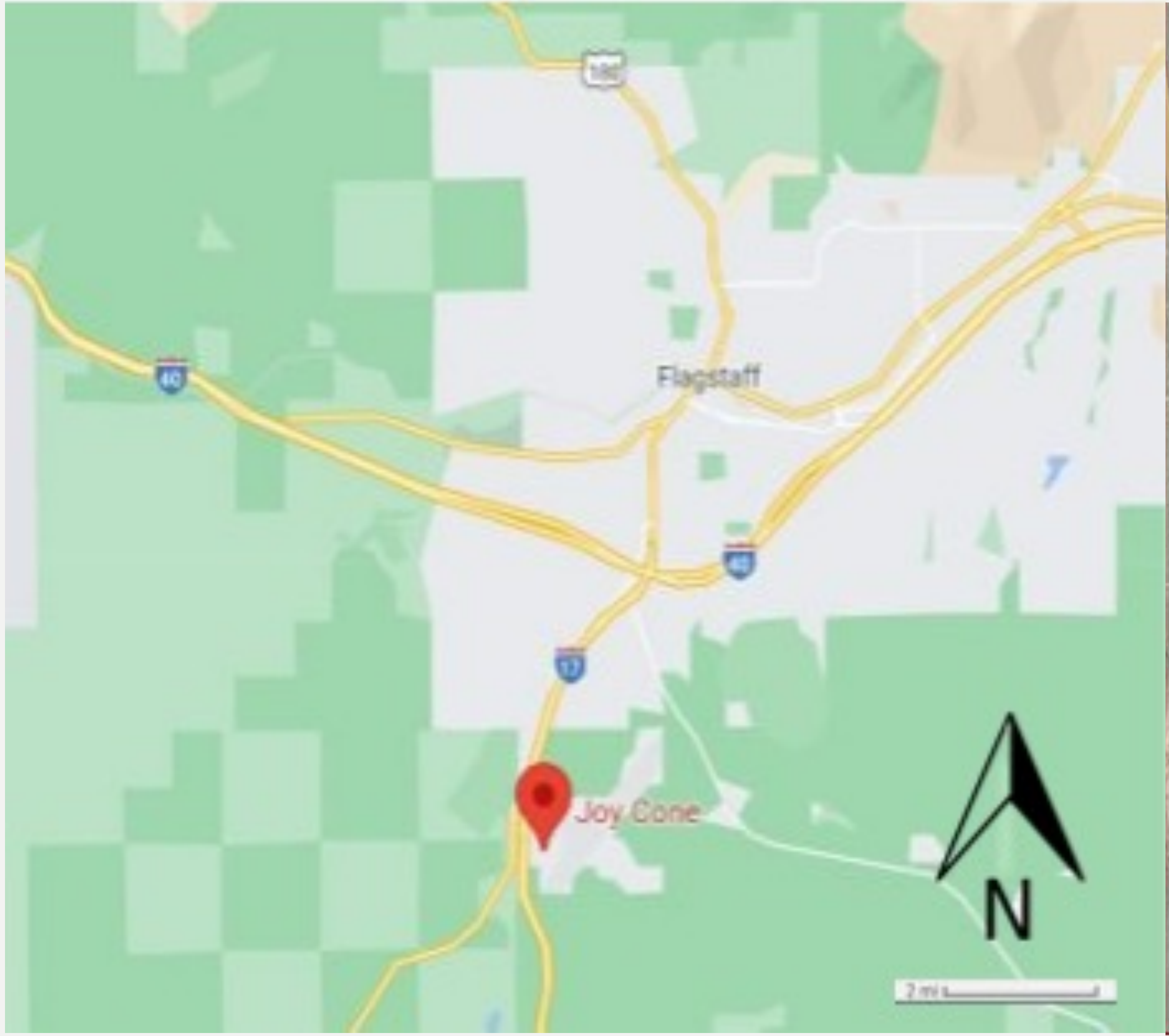
- Client: Lane Fisher (Plant Engineer)

- Purpose: Design a new pretreatment system to reduce:
  - Total Kjeldahl Nitrogen (TKN)
  - Biological Oxygen Demand (BOD)
  - Total Suspended Solids (TSS)

- Interested in using existing detention basin in new treatment design

Figure 1: Joy Cone Ice Cream Cone

PROJECT LOCATION



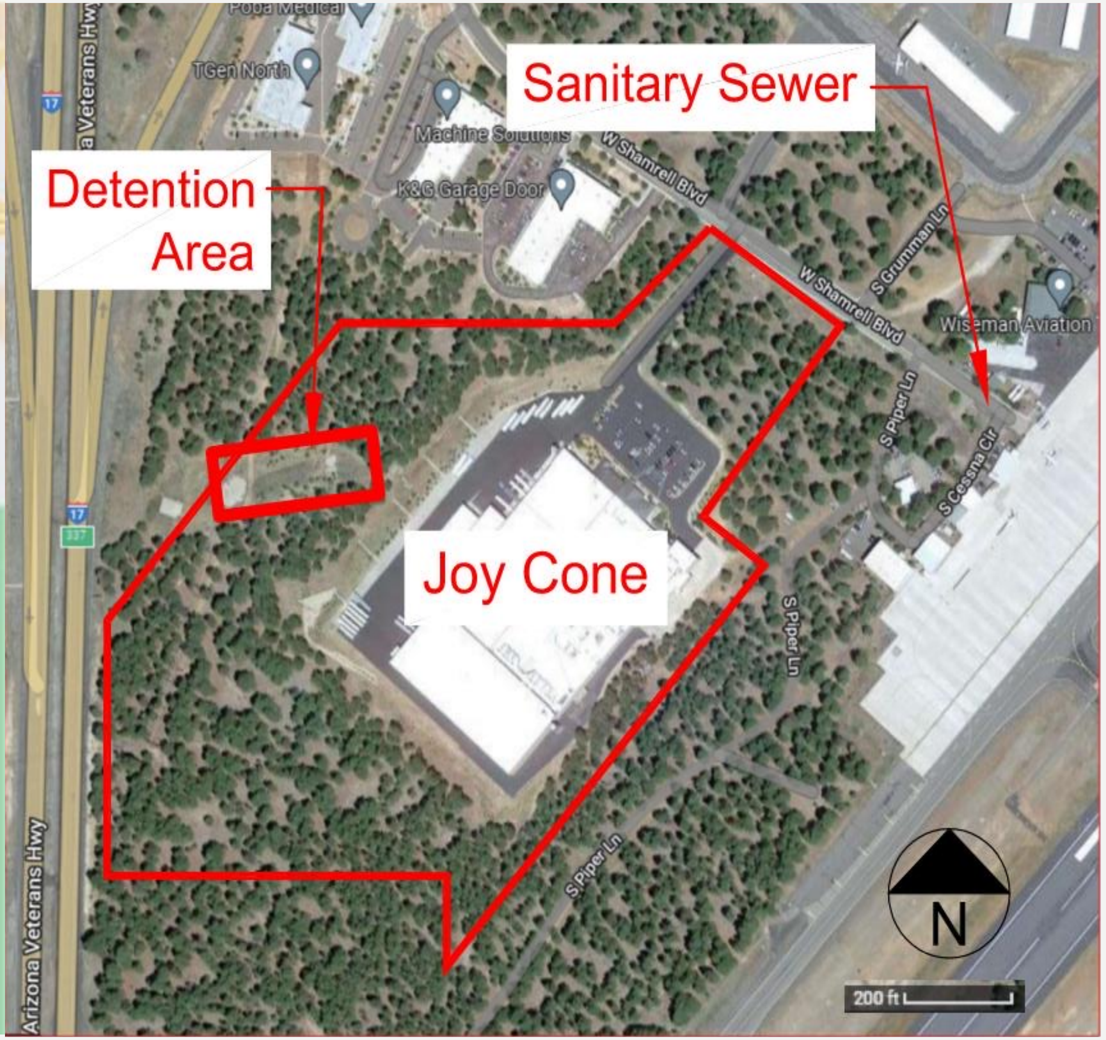


Figure 2: Joy Cone Factory location in Flagstaff [2]

Figure 3 : Joy Cone Factory Land Parcel

CONSTRAINTS AND LIMITATIONS

- Land Use
  - Integrity of the land and trees
  - Reduce noise during construction
- Cleaning Process
  - Chlorinated detergent and liquid acid sanitizer used to maintain equipment
  - Could impact biological treatment processes
- Available Area
  - Limited space in facility and detention basin

Figure 4: Joy Cone factory

REGULATIONS RESEARCH

- Facility currently has City of Flagstaff Industrial Pretreatment Permit
  - Required for discharge to publicly owned treatment works
- National Pollutant Elimination Discharge System (NPDES) Permit
  - Required for discharge to waters of the U.S.
- Aquifer Protection Program (APP) Permit
  - Required for discharges that may enter aquifer/vadose zone [4]
- No new permit is required

Table 1: City of Flagstaff Industrial Pretreatment Standards [3]

Parameter Maximum	Concentration
BOD	700 lb/day
TSS	130 lb/day
TKN	173 mg/L

INDUSTRIAL PROCESS FLOW DIAGRAM

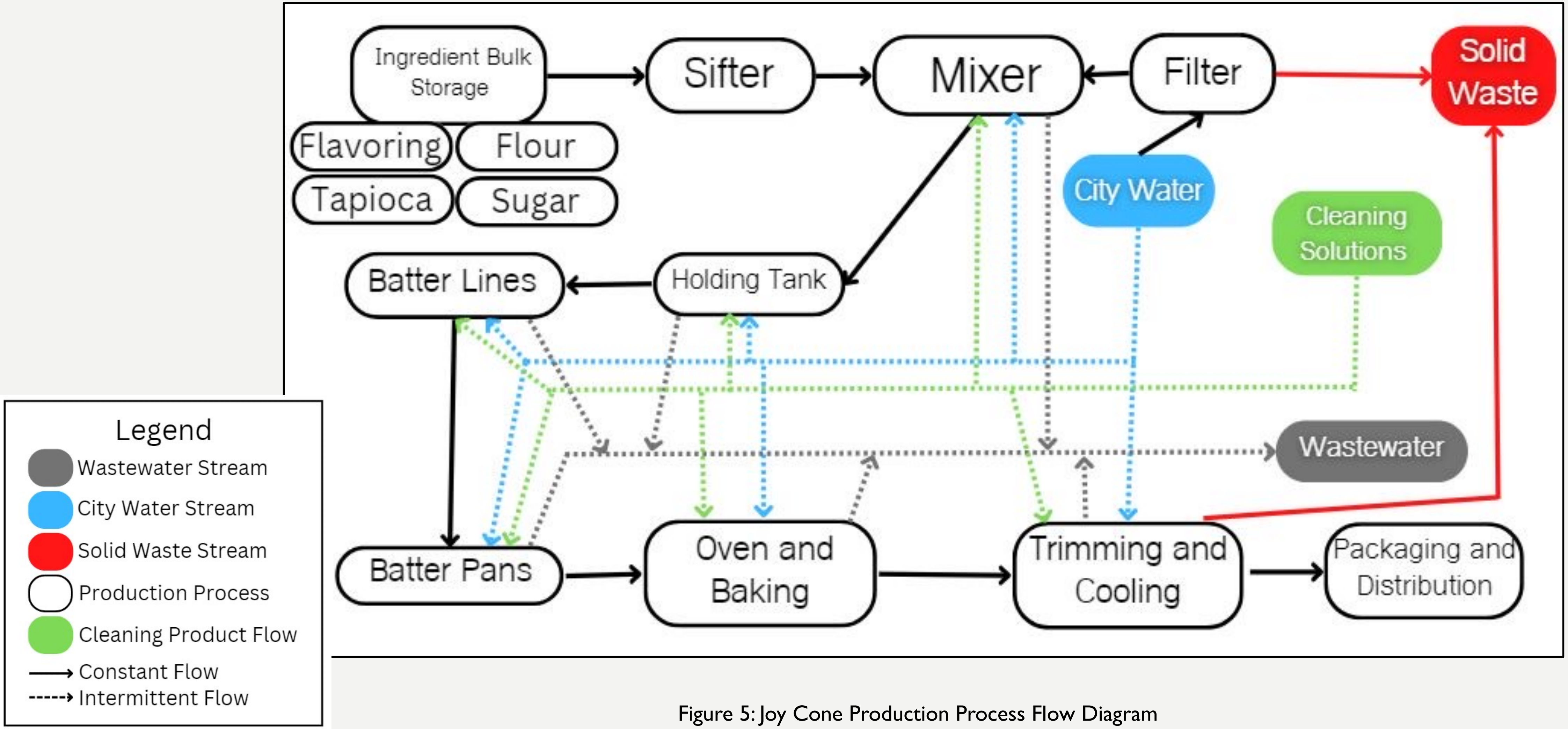


Figure 5: Joy Cone Production Process Flow Diagram

TREATMENT PROCESS BLOCK DIAGRAM

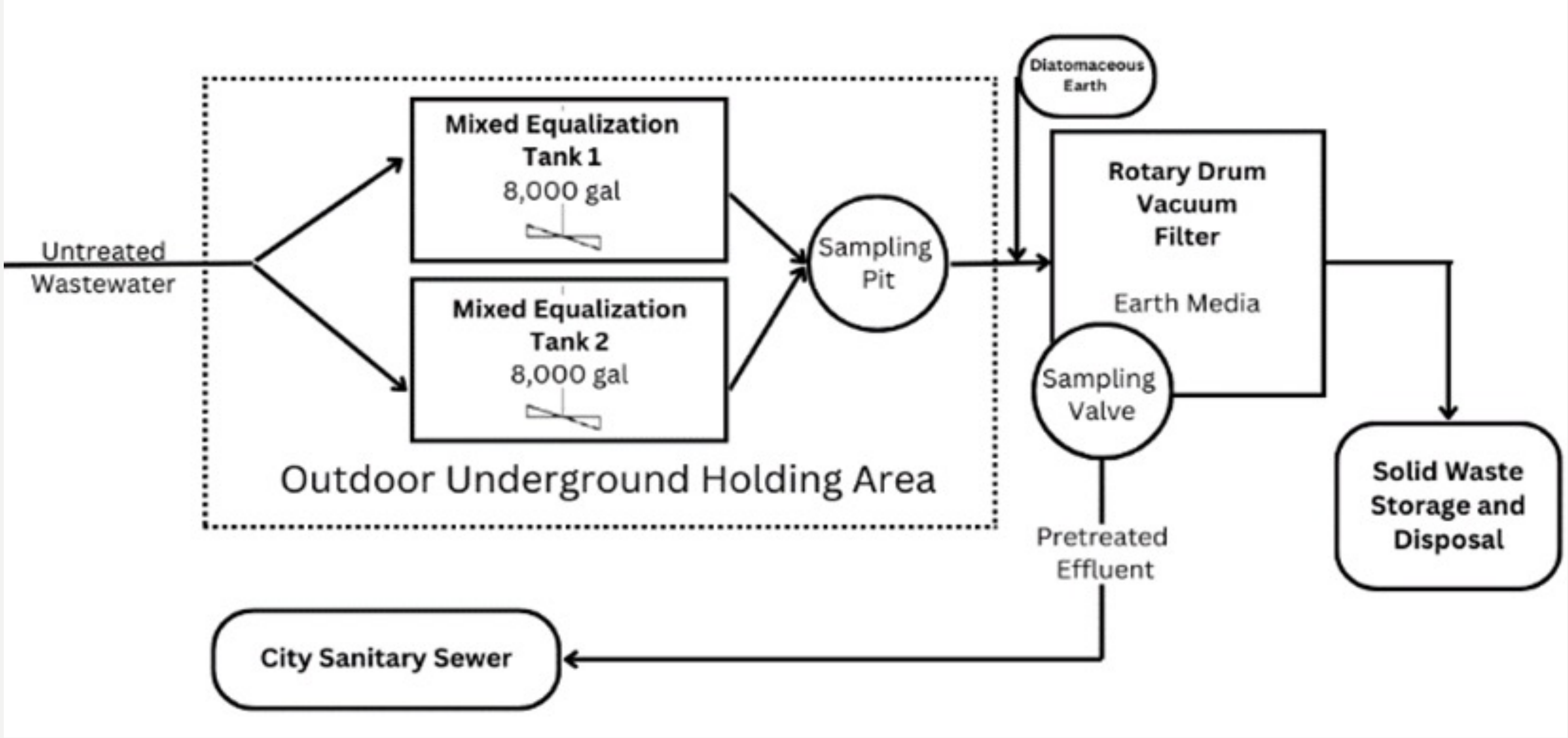


Figure 6: Joy Cone Wastewater Treatment System Block Diagram

TREATMENT AREA PLAN VIEW

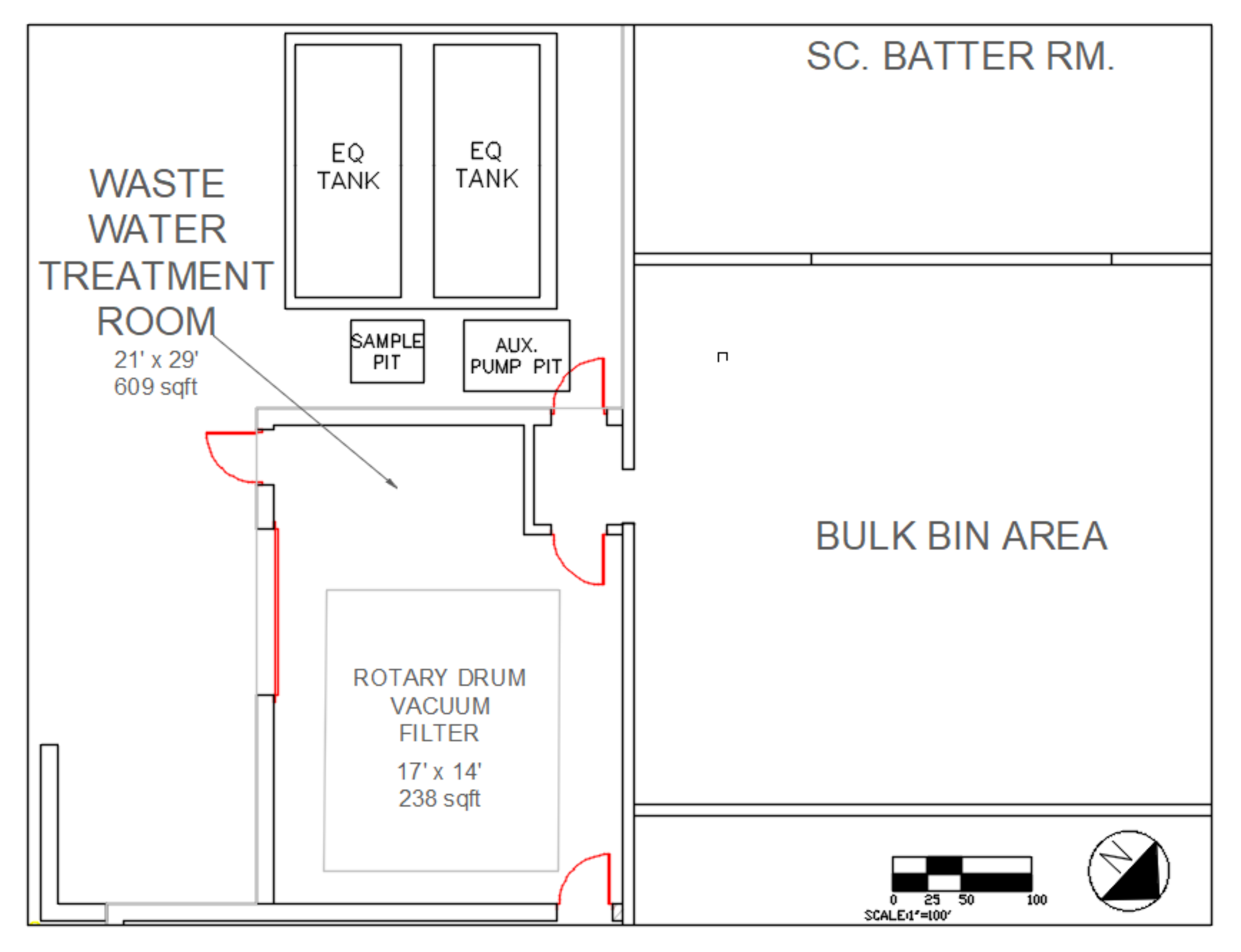


Figure 7: Plan View of Current Treatment Room at Joy Cone Co.

CURRENT TREATMENT SYSTEM

- Vacuum drum rotary filter using diatomaceous earth media
- Solid waste disposed of using dumpster to landfill

Figure 8: Current Rotary Drum Filter

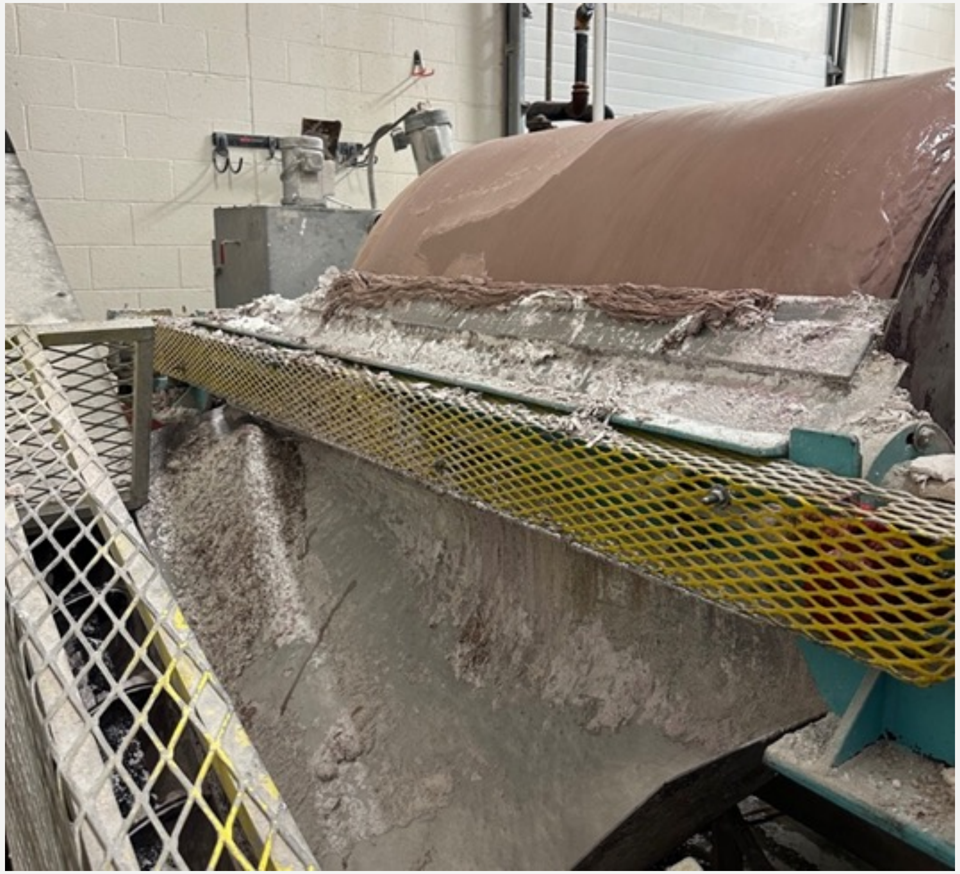


Figure 9: Rotary Drum Filter Blade

DETENTION BASIN

Figure 10: Joy Cone Basin #1

Figure 11: Joy Cone Basin #2

DATA ANALYSIS

- 2022 pretreated effluent data from Joy Cone tested by Inner Basin Laboratories

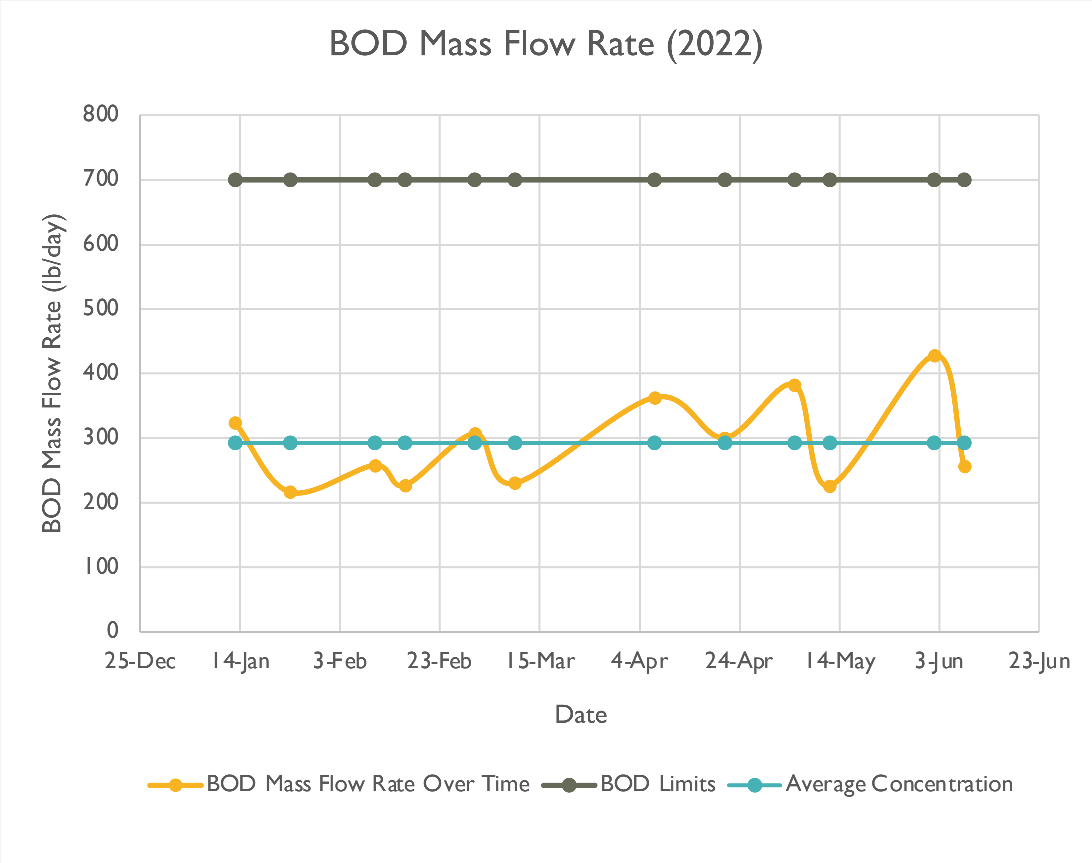


Figure 12: BOD Mass Flow Rate (2022)

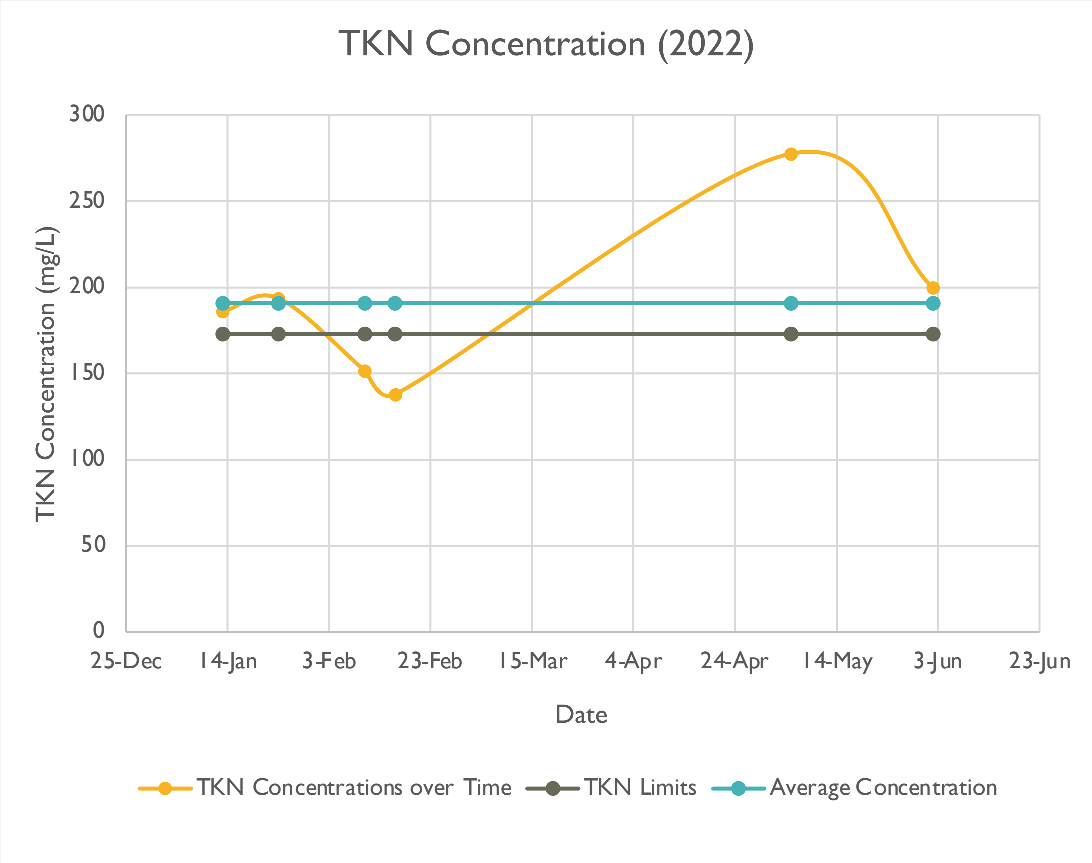


Figure 13: TKN Concentration (2022)

DATA ANALYSIS

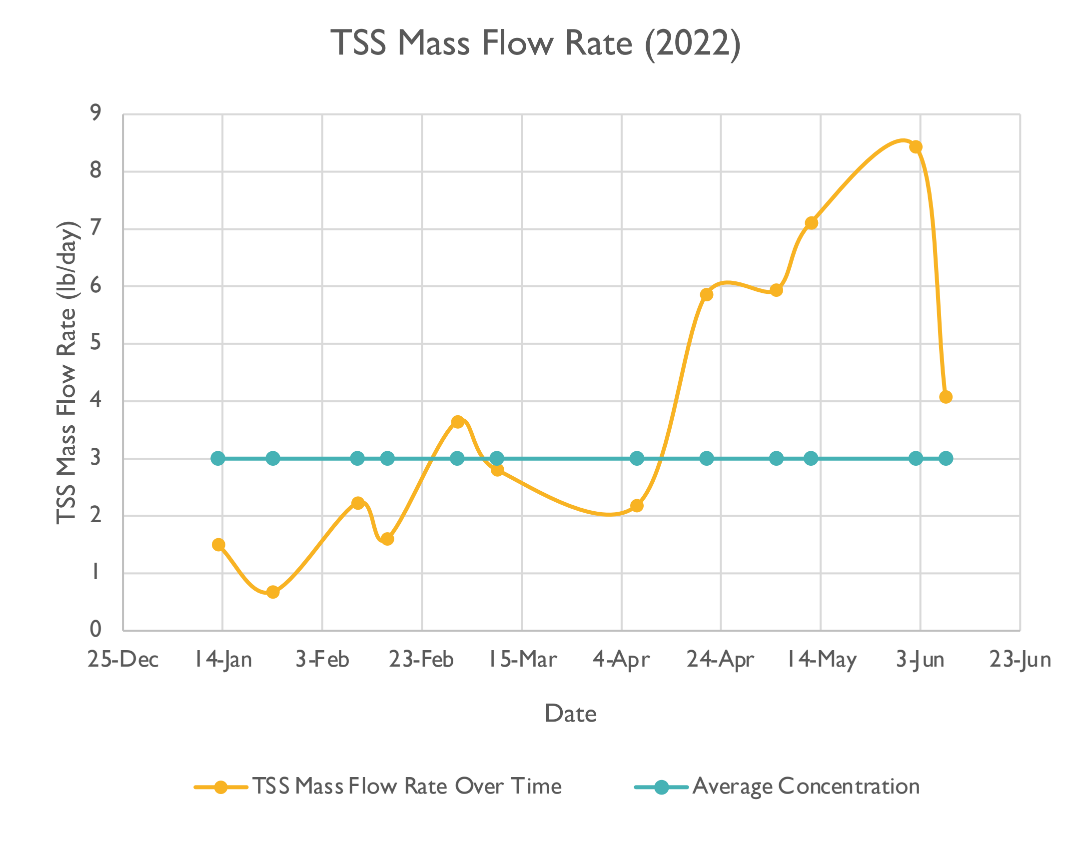


Figure 14: TSS Mass Flow Rate (2022)

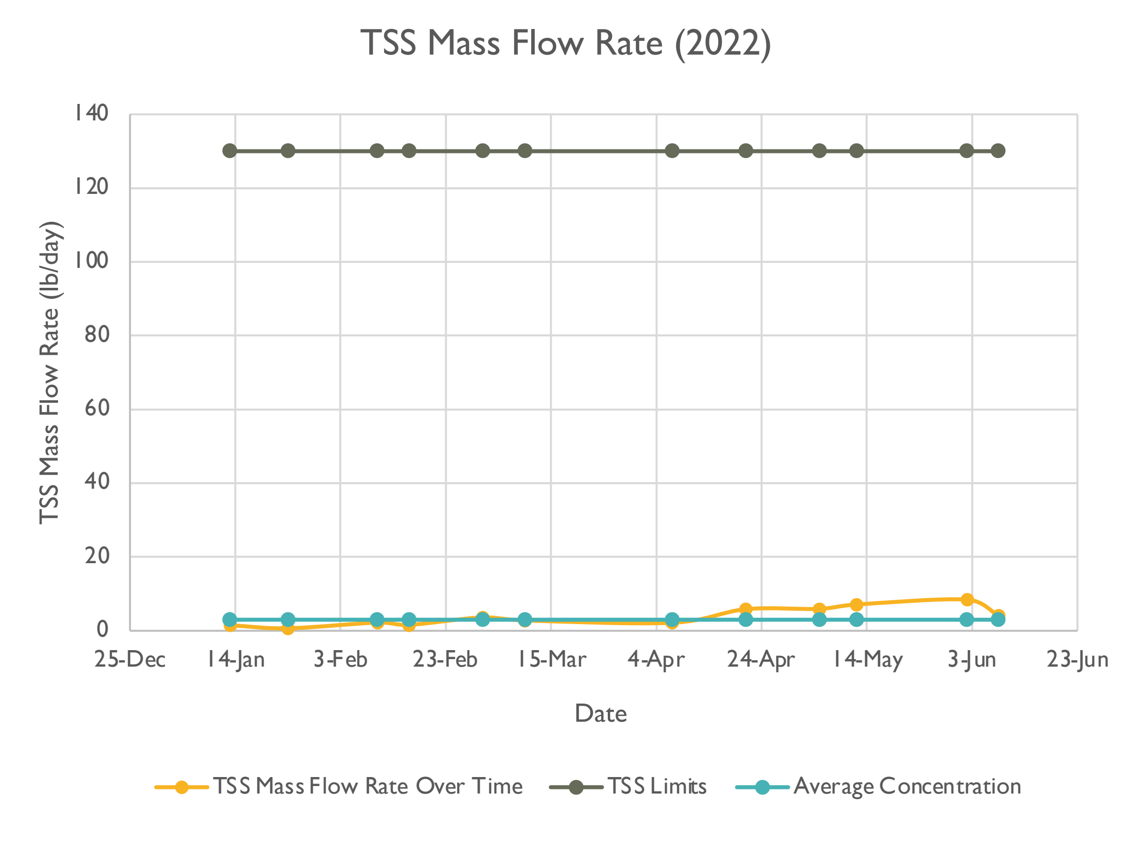


Figure 15: TSS Mass Flow Rate and limits(2022)

DATA ANALYSIS

Table 2: 2022 Data Analysis

Contaminant	Average Concentrations (mg/L)	Average Concentrations (lb/day)	Permit Levels
BOD (N=12)	23440 ± 5335	293 ± 5	700 lb/day
TKN (N=6)	191 ± 45	2 ± 0.04	173 mg/L
TSS (N=12)	307 ±189	3 ± 0.2	130 lb/day

TOPOGRAPHIC MAP

- Separation of Stormwater and Wastewater

  275,000 cubic feet for stormwater detention

  535,000 cubic feet for wetland design

  810,000 cubic feet total

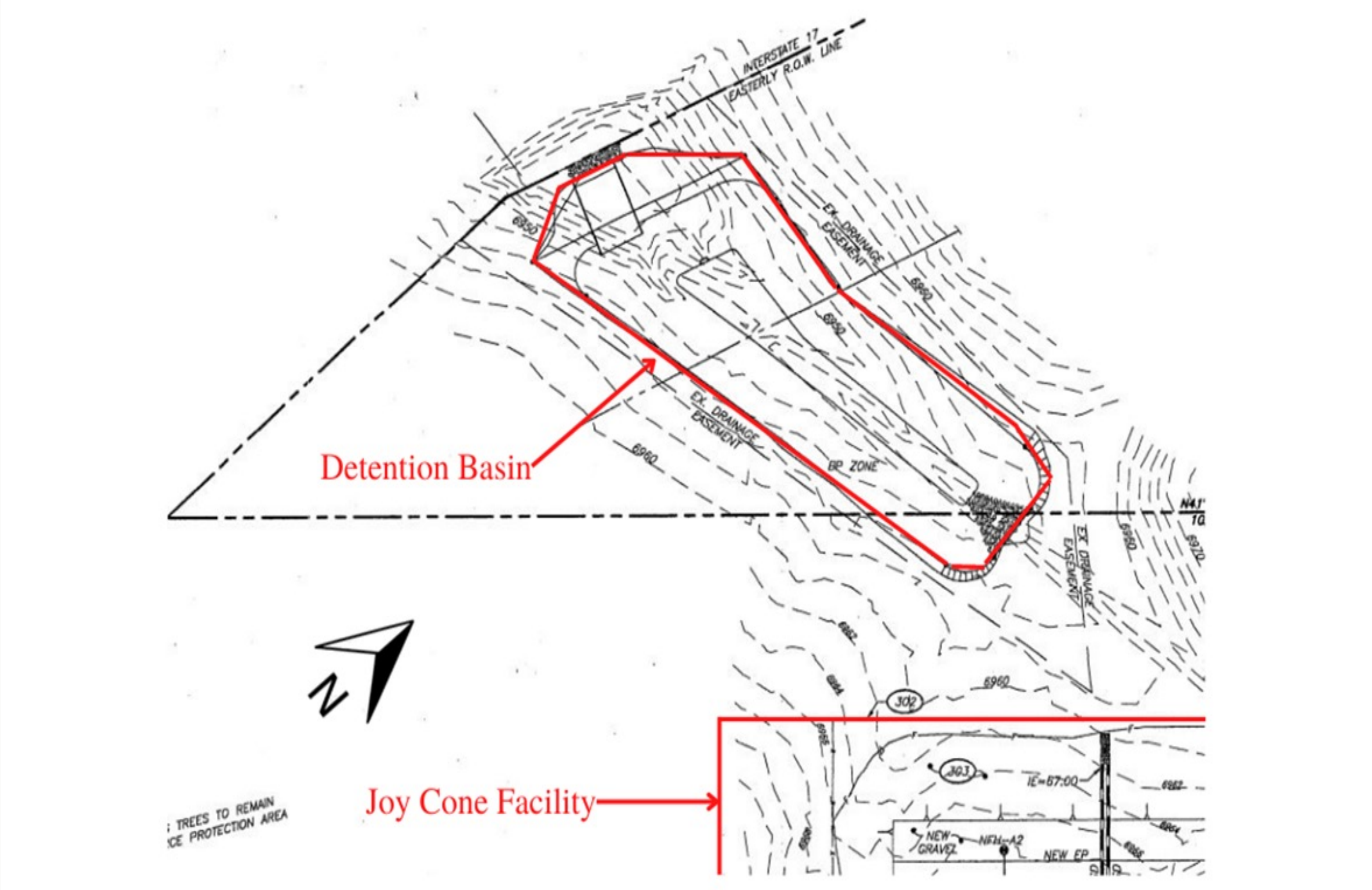


Figure 16: Topographic Map of Joy Cone Property Provided by the City of Flagstaff

WATERSHED DELINEATION

- Delineation completed using ArcMap GIS
- LiDAR data from Coconino County collected in 2019

Figure 17: GIS Watershed Delineation

WATERSHED CALCULATIONS

- TOC is 10 minutes
- The peak flow is approximately 167.8 cfs
- The storm water volume to be detained is approximately 90,000 cf.

Table 3: Results from Rational Method Tool

Parameter	2-Year	10-Year	100-Year
Discharge-Q (cfs)	57.7	96.0	167.8
Rational Coefficient-C	0.58	0.59	0.61
Rainfall intensity-i (inches/hour)	2.36	3.87	6.54
Subbasin Total Area-A (acres)	42.05	42.05	42.05
Computed Time of Concentration-Tc (minutes)	6.3	5.1	4.1
Applied Time of Concentration-Tc (minutes)	10	10	10

DESIGN ASSUMPTIONS

- System will operate at a 1,500 gallon per day flow rate
  - Based on 500,000 gallon per year flow
- All designs will include discharge to the public sanitary sewer
  - Current permit levels will govern target outlet concentrations
- Inlet concentrations based on 2022 data provided by Joy Cone

Table 4: Minimum influent contaminant concentration

Contaminant	Average Concentrations		Permit Levels	Design Concentration	
	(mg/L)	(lb/day)		(mg/L)	(lb/day)
BOD	23440	293	700 lb/day	30000	376
TKN	191	2	173 mg/L	210	3
TSS	307	3	130 lb/day	337	4

Two Phase Treatment design:

- Phase I: Pretreatment
  - BOD & TSS
- Phase II: Wetland
  - TKN

PHASE I DESIGN ALTERNATIVES

1. Fill and Draw System
    - Acts as Sequencing Batch Reactor (SBR)
    - Agitation process is followed by the settling process
    - One tank fills while the second tank treats effluent

For all alternatives:
- Ammonia free and biodegradable cleaning solution
- Plate and frame filter press for sludge handling

2. Rotary Drum Filter with Moving Bed Biological Reactor
    - Rotary drum installed in 2002 and update needed
    - Use perlite to create filter slurry in updated drum filter
    - No changes in sludge disposal

3. Fill and Draw with Rotary Drum Filter
    - Upgraded rotary drum paired with fill and draw system

PHASE I SCORING SYSTEM

Table 5: Scoring System

Criteria	1	2	3
Treatment Efficiency	≥80% removal of 1 contaminant	≥80% removal of 2 contaminants	≥80% removal of 3 contaminants
Footprint (area required)	>400sqft of indoor space	300 - 399sqft of indoor space	<300sqft of indoor space
Total Costs (capital and maintenance)	costliest design	second most costly design	most cost-effective design
Maintenance Required	>8 hours per day Difficult sludge/residual disposal	6 - 8 hours per day Moderately difficult sludge/residual disposal	<6 hours per day Easy disposal of sludge/residuals

PHASE I EVALUATION

Table 6: Criteria and team scoring

Criteria	Weight of Criteria (%)	Option A: Fill and Draw Alone	Option B: Rotary Drum Filter with Moving Bed Biological Reactor	Option C: Fill and Draw with Rotary Drum Filter
Treatment Efficiency	40%	2	3	3
Footprint (area required)	15%	3	1	2
Total Costs (capital and maintenance)	25%	3	1	2
Maintenance and Operation	20%	3	1	2
Total Score	100%	**2.6**	1.8	2.4

PHASE II DESIGN ALTERNATIVES

1. Vertical Subsurface Flow (VSFF)
   - Batch or continuous process
   - HRT controlled by porosity and depth of media from top to bottom
   - Aeration possible

2. Horizontal Subsurface Flow (HSFF)
   - Singular inlet and outlet
   - HRT controlled by slope and length
   - Less required equipment

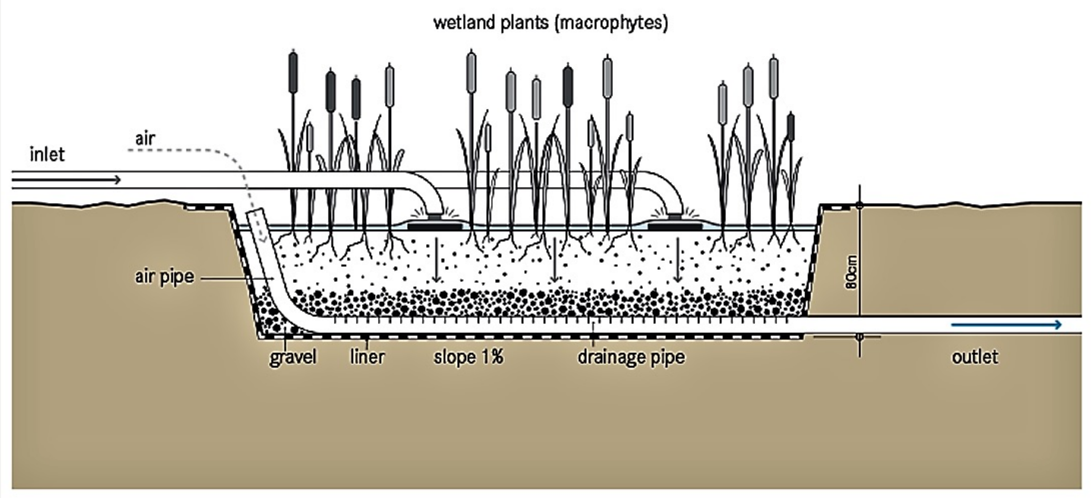


Figure 18: Example of VSSF Constructed Wetland

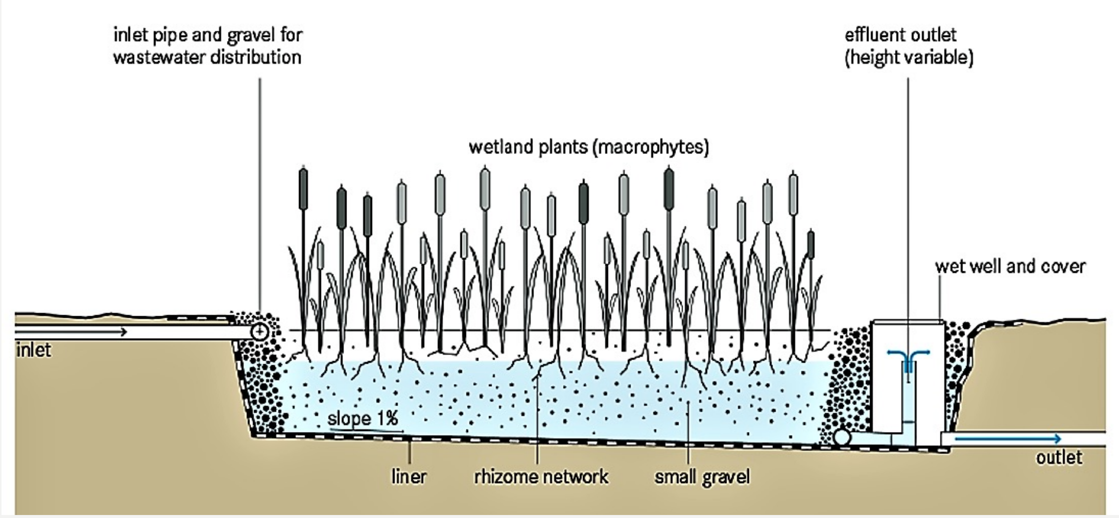


Figure 19: Example of HSFF Constructed Wetland

PHASE II SCORING SYSTEM

Table 7: Phase II Scoring System

Criteria	1	2	3
TKN Treatment Efficiency	Below 65%	Between 65-75%	Above 75%
BOD Treatment Efficiency	Below 70%	Between 70-80%	Above 80%
TSS Treatment Efficiency	Below 75%	Between 75-89%	Above 90%
Costs (capital and maintenance)	Most expensive	Both Alternatives are equal	Least expensive
Maintenance Required	Most maintenance	Both Alternatives are equal	Least maintenance

PHASE II EVALUATION

Table 8: Phase II criteria and team scoring

Criteria	Weight of Criteria (%)	Vertical Subsurface Flow	Horizontal Subsurface Flow
TKN Treatment Efficiency	30%	3	1
BOD Treatment Efficiency	25%	3	2
TSS Treatment Efficiency	20%	2	2
Costs (capital and maintenance)	15%	1	3
Maintenance Required	10%	1	3
Total	100%	**2.30**	1.95

PHASE I FINAL DESIGN

- Two 8,000-gallon existing tanks
  - Fill and Draw system
  - Q = 1,500 gal/day
  - HRT = 7 days (3.5 days of agitation and 3.5 days of settling)

- One additional tank will be aboveground
  - 13.5 ft long x 10 feet wide x 8 feet deep

- 6,000-gallons will be treated in each tank

- Centrifugal pumps with 25 gal/min pump capacity

- Level sensors in each tank control valves on inlets

Table 9: Design Parameters for tanks

Design Parameters for Tanks	
Flow (gpd)	1,500
Influent BOD (mg/L)	30,000
Influent TSS (mg/L)	337
% BOD Removal	90
% TSS Removal	80
Effluent BOD (mg/L)	140
Effluent TSS (mg/L)	27
Hydraulic Retention Time (days)	7

PHASE I FINAL DESIGN

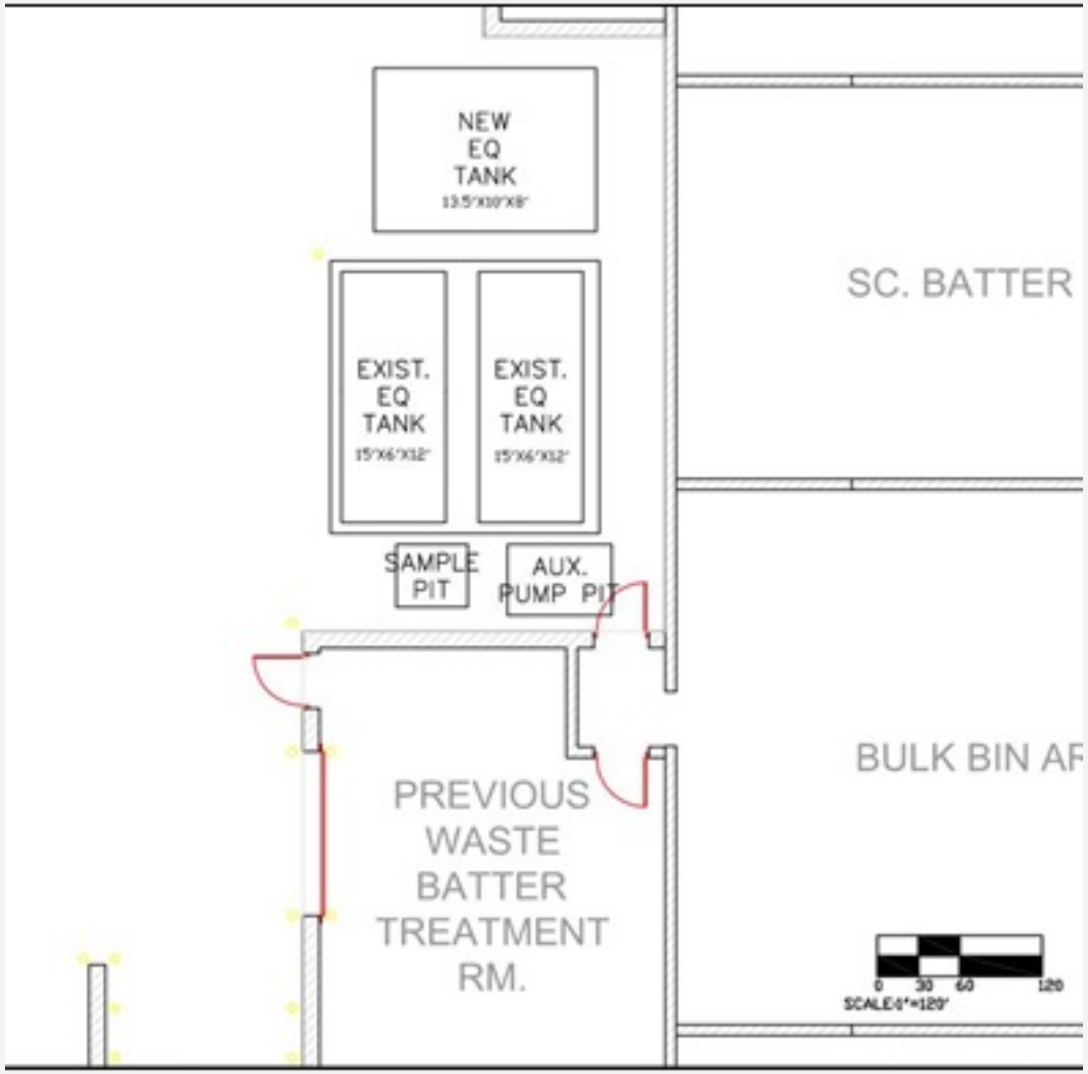


Figure 20: AutoCAD with new tank

- Rotary drum filter will be retired
- Plate and frame filter press added for sludge processing and disposal

PHASE II DESIGN PARAMETERS

Table 10: Phase II Final Design Parameters

Parameter	Variable	Value	Units	Notes
Flow In	Qin	1500	gal/day	Inlet flow controlled by discharge from 3rd tank in phase I every four days as batch process Total flow every four days: 22.7 m3
Flow Out	Qout	1088	gal/day	Outlet flow controlled by automated pump using wetwell system and accounting for hydrologic losses
Overall Flow	Q	1294	gal/day	Average of inlet and outlet flows
Length	L	130	ft	Length of wetland
Width	W	17	ft	Width of wetland
Depth	d	2	ft	Depth of media
Length to width ratio	L:W	8:01	-	ratio of length to width
Total Volume	Vt	31700	gal	Total volume of wetland including media
Void Volume	Vv	11359	gal	Volume available for water (excluding media)
Hydraulic Retention Time	HRT	8.7	days	Length of time water will take to travel through media from surface to bottom

- $Q = \frac{Qin+Qout}{2}$
- $HRT = \frac{nLWd}{Q}$
- $Vv = nVt$
- $Vw = \frac{Tpq}{4}$

PHASE II FINAL DESIGN

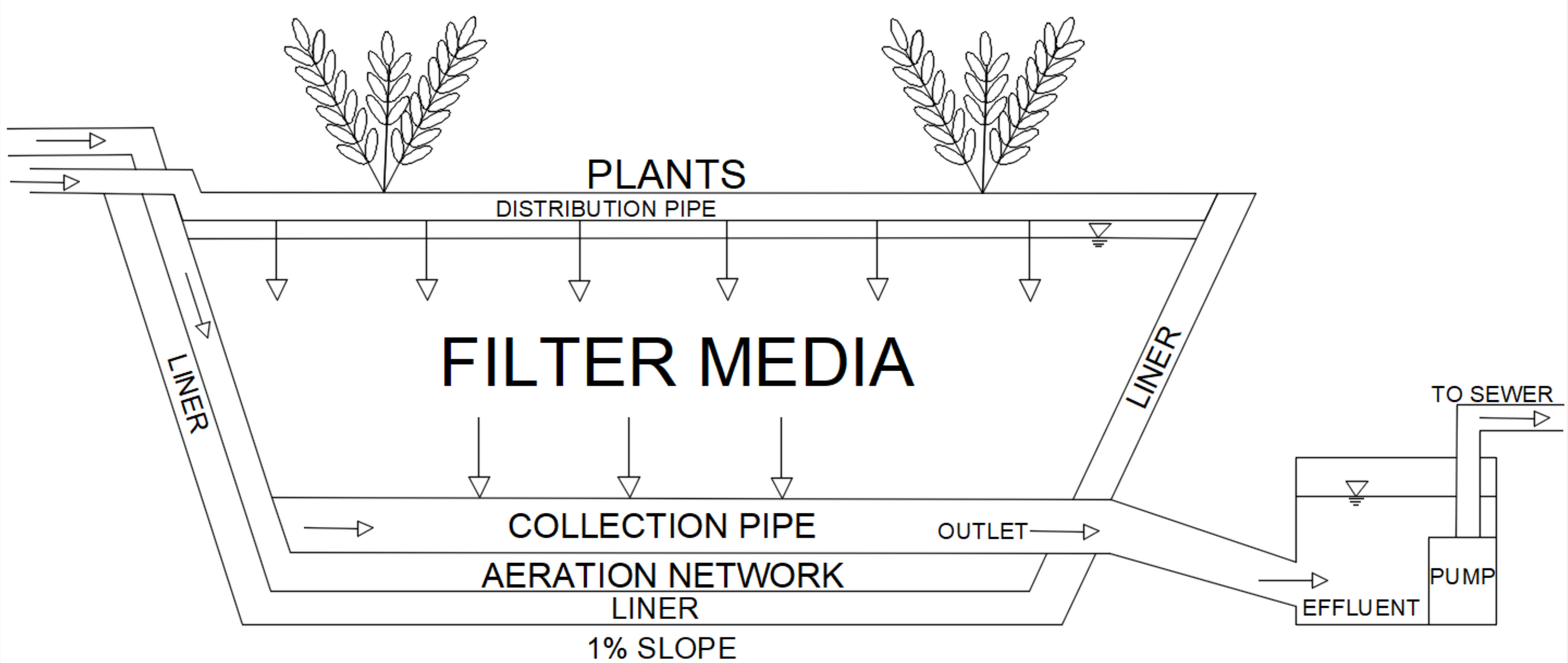


Figure 21: Phase 11 Final Design Profile View

PHASE II WETLAND MEDIA DESIGN

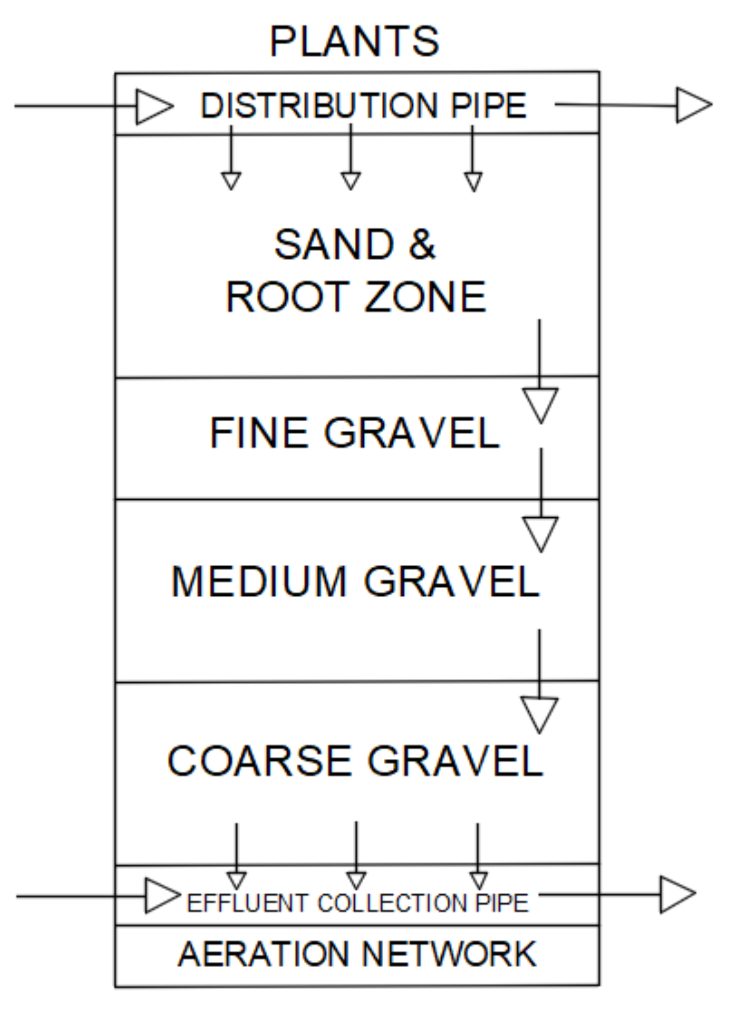


Figure 22: Phase II Final Design Media Parameters

Table 11: Phase II Final Design media Parameters

Media Type	Depth (m)	Porosity
Sand	0.23	0.300
Fine Gravel	0.07	0.365
Medium Gravel	0.15	0.380
Coarse Gravel	0.15	0.415
Total	0.60	0.357

PHASE II FINAL DESIGN

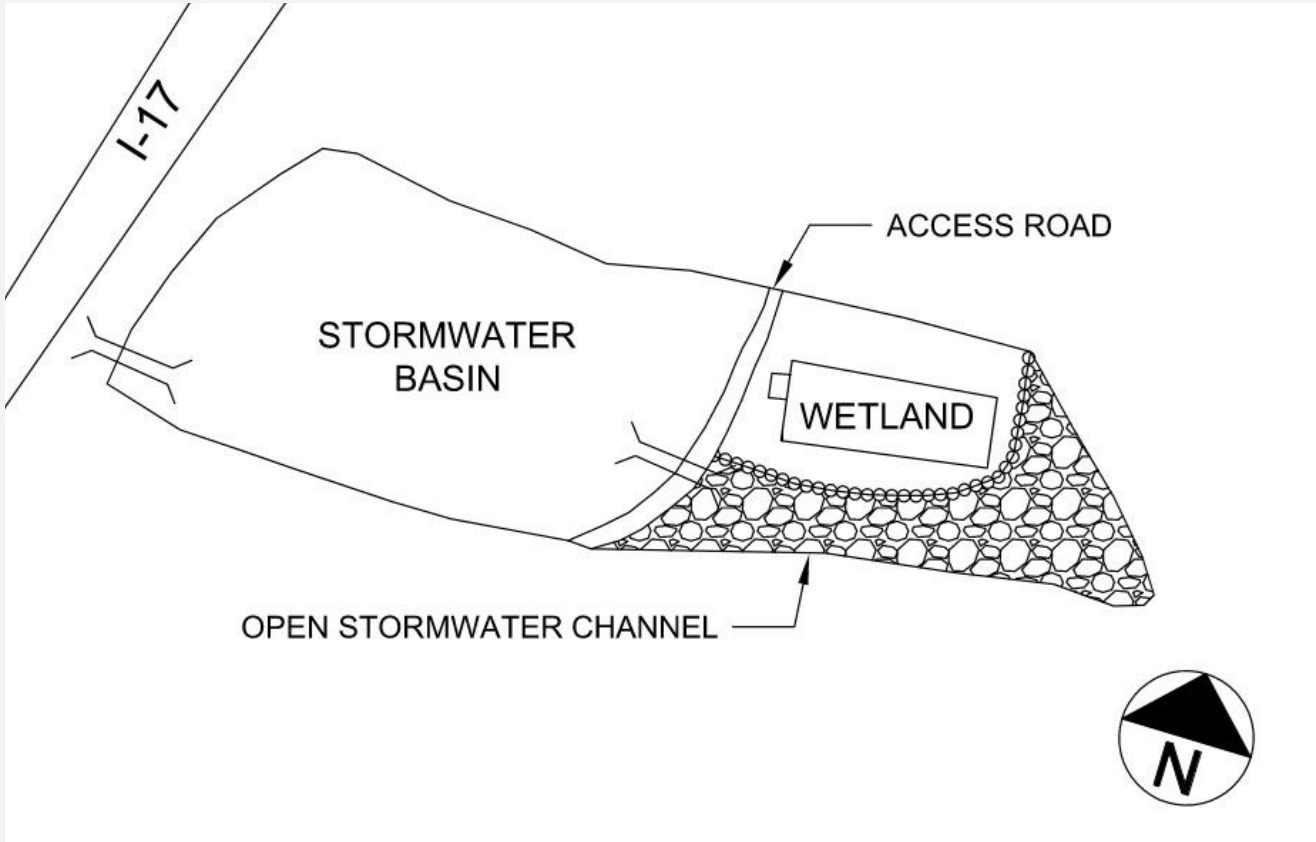


Figure 23: Phase 11 Final Design Plan View

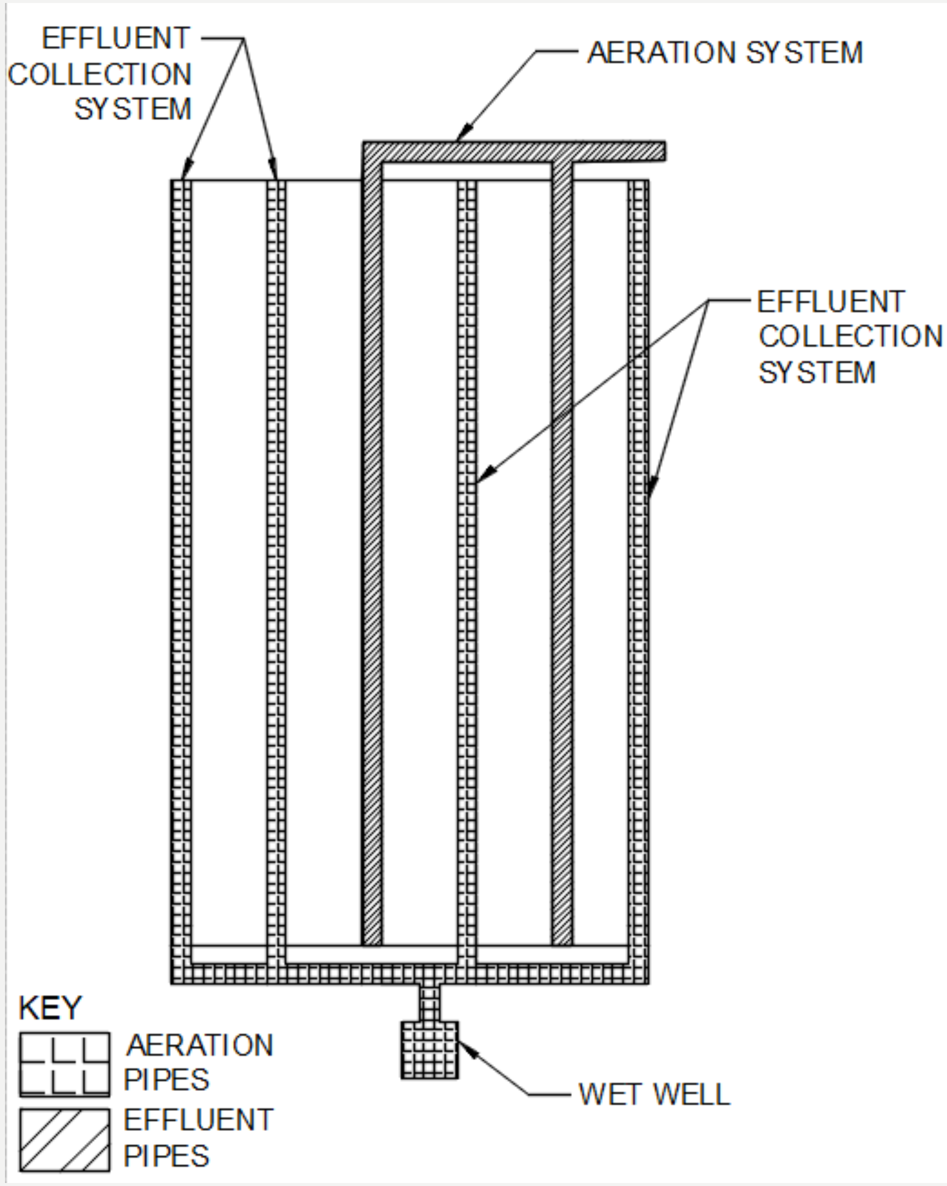


Figure 24: Phase 11 Final Design Pipe Plan View

PHASE II REACTION EQUATIONS

- $C_e = e^{(-K_T * t)} C_i$
  - C_e = Effluent Concentration
  - C_i = Inlet Concentration
  - K_T = 1st order reaction rate constant
  - t = hydraulic retention time (days)

- $K_T = K_{20}\theta^{(T-20)}$
  - Θ = 1.056 when T= 0-20C
  - Θ = 1.047 when T = >20C
  - K_{20} = 0.23/day
  - T = temperature (C)

- $K_T = 0.1367(1.15)^{(T-10)}$
  - K_T = first order reaction rate constant for TKN (1/day)
  - T < 10C

- $K_T = 0.2178(1.048)^{(T-20)}$
  - K_T = first order reaction rate constant for TKN (1/day)
  - T > 10C

FINAL DESIGN – EFFLUENT CONCENTRATIONS

Table 12: Final Design Effluent Concentrations

Contaminant	Outlet Levels		Permit Limits	Overall Design Removal Efficiency	
	Winter	Summer		Winter	Summer
BOD	0.134 lb/day	0.020 lb/day	700 lb/day	0.99797	0.9997
TKN	125 mg/L	15 mg/L	173 mg/L	0.40476	0.92857
TSS	0.001 lb/day	0.001 lb/day	130lb/day	0.9984	0.9984

COST ANALYSIS

Table 13: Design Costs

Cost Analysis	
Item	**Cost**
8,000-gallon Aeration Tank	$ 7,500.00
25-gallons/min Centrifugal Pump (3)	$ 2,400.00
Raidan Standard 2 HP Plate Mount Top Entry Mixer (6)	$ 40,134.00
6" Eccentric Plug Valve, Full Port, Mechanical Joint, Resilient Seated (3)	$ 2,040.00
Advanced Wireless Fully Automatic Water Level Controller with Indicator (3)	$ 19,500.00
Plate and Frame Filter Press	$ 30,000.00
Maintenance and Operation (per year)	$ 5,000.00
Phase I total	**$ 106,574.00**
Earthwork	$ 15,000.00
PVC Liner	$ 1,200.00
Filter Media	$ 12,000.00
Plants	$ 1,000.00
50gmp Centrifugal Pump	$ 1,100.00
PVC Piping	$ 21,000.00
Construction	$ 12,000.00
Pipe Installation	$ 48,000.00
Maintenance and Operation (per year)	$ 6,000.00
Phase II Total	**$ 117,300.00**
Total Cost	**$ 223,874.00**

PROJECT IMPACTS

Environmental

- Habitat for toads, insects and plants
- Less solids sent to landfill
- Removal of trees

Economic

- Large investment for Joy Cone Co.
- Jobs and economic stimulation
- Removes fees for TKN exceedances
- Fees due to lag time

Societal

- Adds to aesthetic value
- Encourages upkeep of paths and extension of Flagstaff Urban Trails System (FUTS)
- Improves public image for Joy Cone
- Green space for workers
- Reduces contaminant load

REFERENCES

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QUESTIONS?

THANK YOU