PERFORMANCE EVALUATION OF EXISTING WASTEWATER TREATMENT PLANT AND SUBSEQUENT FUTURE EXPANSION TO MEET STRINGENT NUTRIENT GOALS

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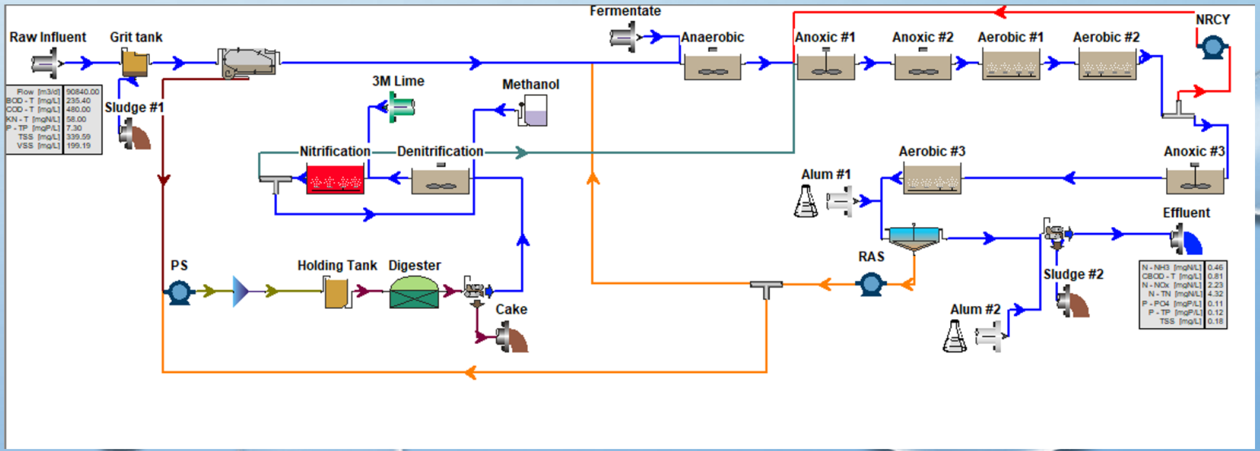


PROBLEM STATEMENT

<u>Step1</u>: Performance evaluation of existing wastewater treatment plant

<u>Step2</u>: subsequent future expansion to meet stringent nutrient goals.

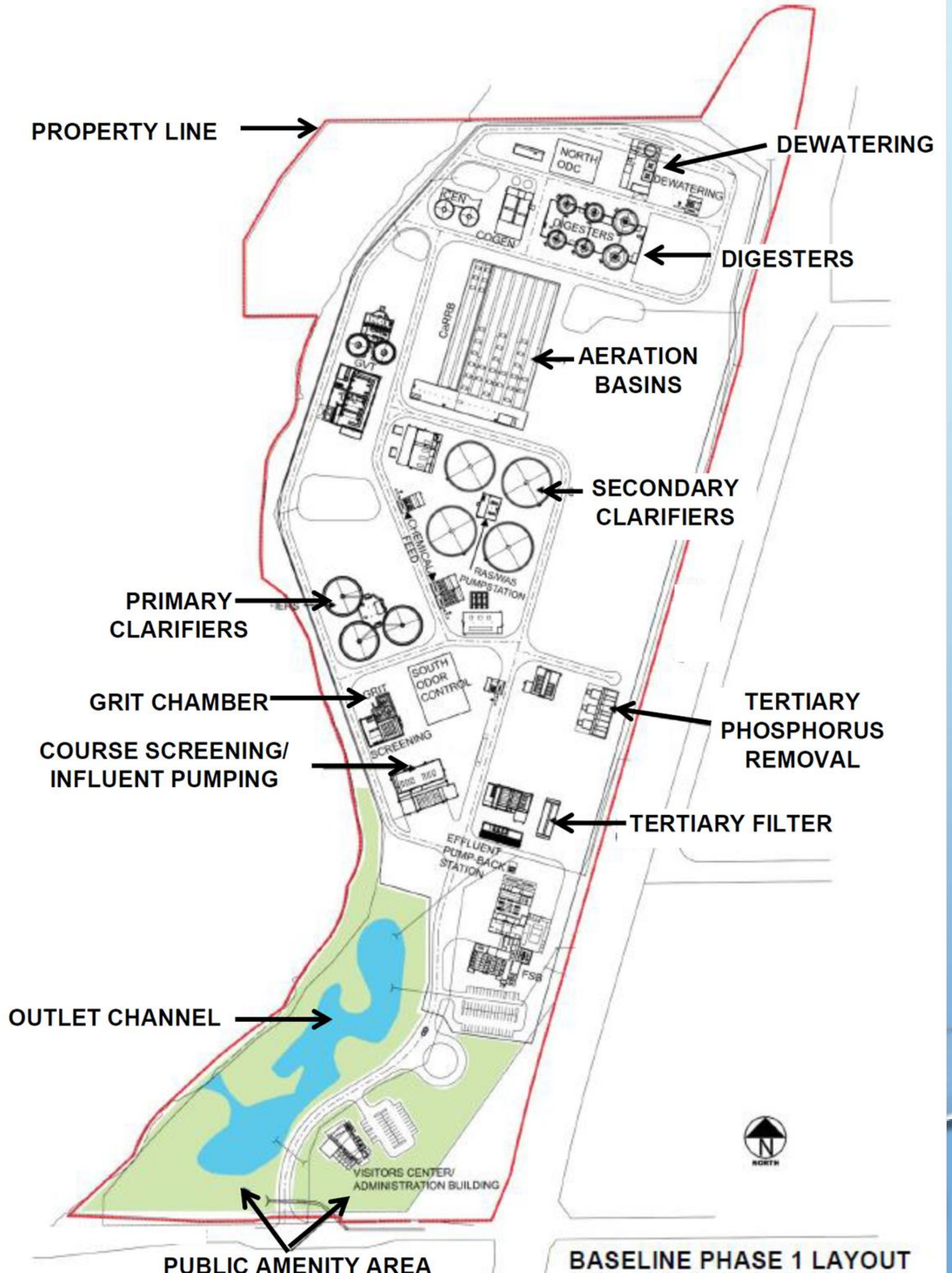
Design Parameter	Units	Present Treatment Goals	Future Treatment Goals
BOD			
Monthly (30-day average)	g/m^3	<10	<10
TSS			
Monthly (30-day average)	g/m^3	<10	<10
E -coli			
Monthly (30-day average)	$No./m^3$	1.26×10^6	1.26×10^6
Total Nitrogen			
Monthly (30-day average)	g/m^3	4.8-8	2.4
Nitrate-N and Nitrite-N			
Daily maximum	g/m^3	8	8
Ammonia-N			
Daily Max – Winter Low (February)	g/m^3	4.9	1.8-2.2
Daily Max – Summer Low (August)	g/m^3	1.8	
30-day Average – Winter Low	g/m^3	3.8	0.21
30-day Average – Summer Low	g/m^3	1.6	
Total Phosphorus			
Annual Average	g/m^3	0.06	0.03

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM PERMIT LIMITS

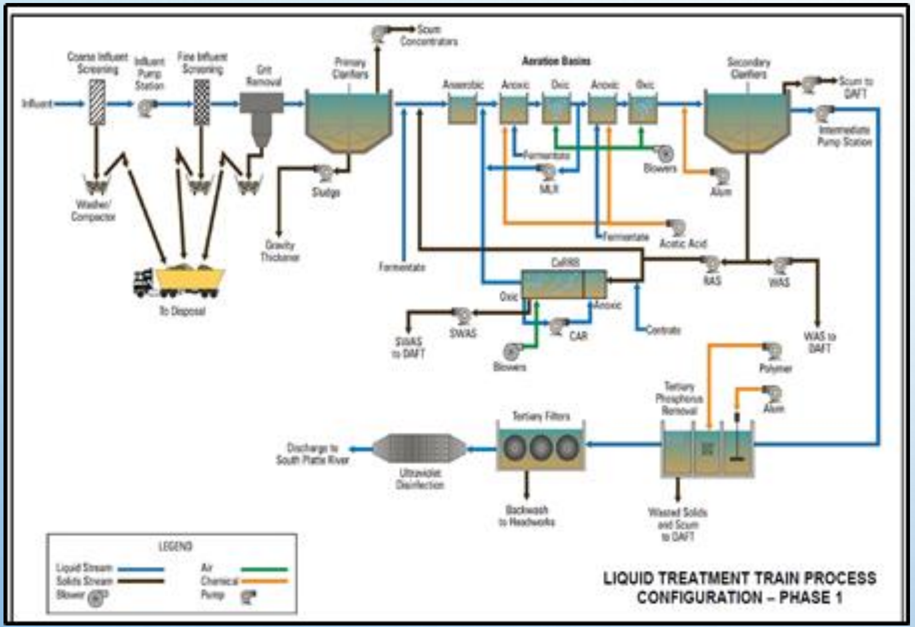
Design Parameter	Units	Present Criteria	Future Criteria
BOD			
Monthly (30-day average)	g/m^3	17	17
TSS			
Monthly (30-day average)	g/m^3	30	30
E -coli			
Monthly (30-day average)	$No./m^3$	1.26×10^6	1.26×10^6
Total Nitrogen			
Monthly (30-day average)	g/m^3	6 to 10	3
Nitrate-N and Nitrite-N			
Daily maximum	g/m^3	10	10
Ammonia-N			
Daily Max – Winter Low (February)	g/m^3	6.1	2.28-2.9
Daily Max – Summer Low (August)	g/m^3	2.28	
30-day Average – Winter Low	g/m^3	4.78	0.26
30-day Average – Summer Low	g/m^3	1.95	
Total Phosphorus			
Annual Average	g/m^3	0.1	0.04

PERFORMANCE EVALUATION OF EXISTING FACILITIES

- Existing WWTP is located in a western part of the usa
- WWTP has two distinct treatments
  - Liquid steam train
  - Solid stream train
- Existing treatment plant
  - Average Day Annual Flow (ADAF)
    - 90840 m^3/d
  - Average Day Maximum Month Flow (ADMMF)
    - 109008 m^3/d
  - Peak Instantaneous Flow (PIF)
    - 208932 m^3/d

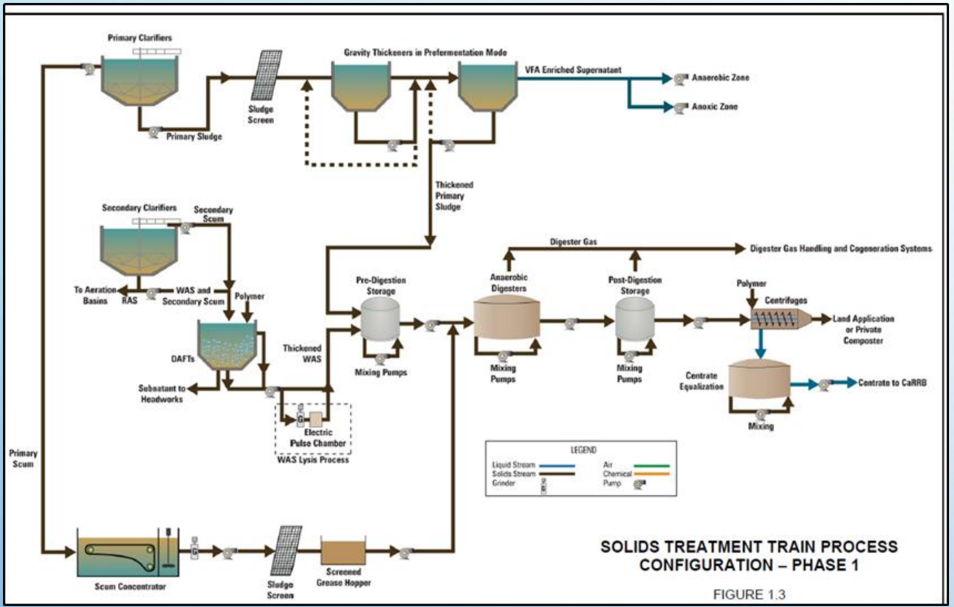


LIQUID TREATMENT UNITS OF THE WWTP



Treatment Process	Design Definition Process or Equipment Recommendation
Influent screening	2-stage screening with 2-inch climber-type coarse screens before influent pumps, and 1/4-inch (6-mm) fine screens after influent pumps. District preference for climber-type units on coarse screens.
Grit basins	Sloped-floor mechanical vortex grit basins
Grit handling	Coanda grit washer
Primary clarifiers	Circular primary clarifiers with low-profile dome covers
Aeration basins	Modified five-stage Bardenpho
Side-stream centrate treatment	Centrate and RAS reaeration basins (CaRRB) with MLE recycle
Aeration blowers	Single-stage centrifugal blowers
Secondary clarifiers	Circular secondary clarifiers
Intermediate pump station	Vertical mixed flow pumps with VFDs
Tertiary filters	Chemical addition/flocculation/sedimentation basin followed by disk filters
Disinfection	Open-channel low-pressure/high output (LP/HO) UV disinfection
Wetlands/natural channel system	Lined wetland/natural channel with grouted sloping boulder-type level control structure
Effluent pump-back station (as part of pump-back system)	Vertical turbine pumps with VFDs

SOLID TREATMENT UNITS OF THE WWTP

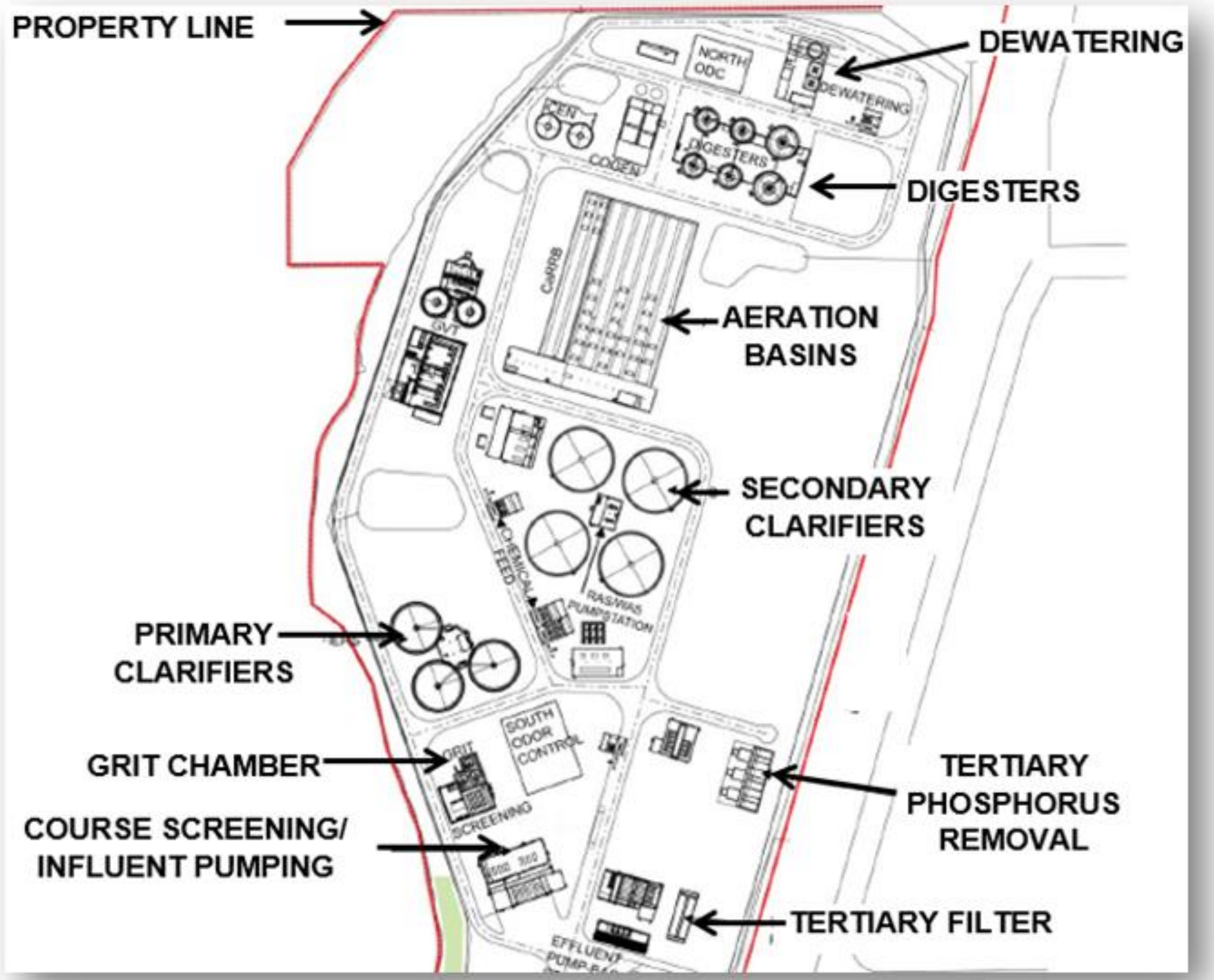


Treats Class B Bio Solids

Treatment Process	Design Definition Process or Equipment Recommendation
Primary sludge screening	Open channel
Sludge grinding	In-line
Primary sludge thickening	Gravity thickeners
Primary sludge fermentation	Unified fermentation and thickening (UFAT) process
Primary scum handling	Scum concentrator
WAS thickening	Dissolved air flotation (DAF) thickeners
Sludge blending mixing	External pumped mixing
Polymer system	Emulsion polymer, bulk chemical storage
Digestion	Conventional anaerobic digesters
Digester sludge mixing	External recirculation pump
Digester heating	Spiral heat exchangers (for recirculation heating only
Digested sludge dewatering	Centrifuges
Dewater sludge conveyance	Belt conveyors
Digester gas handling	Low emission waste gas burners,gas utilization for co generation
Cogeneration	Conventional reciprocating engines utilizing digester gas

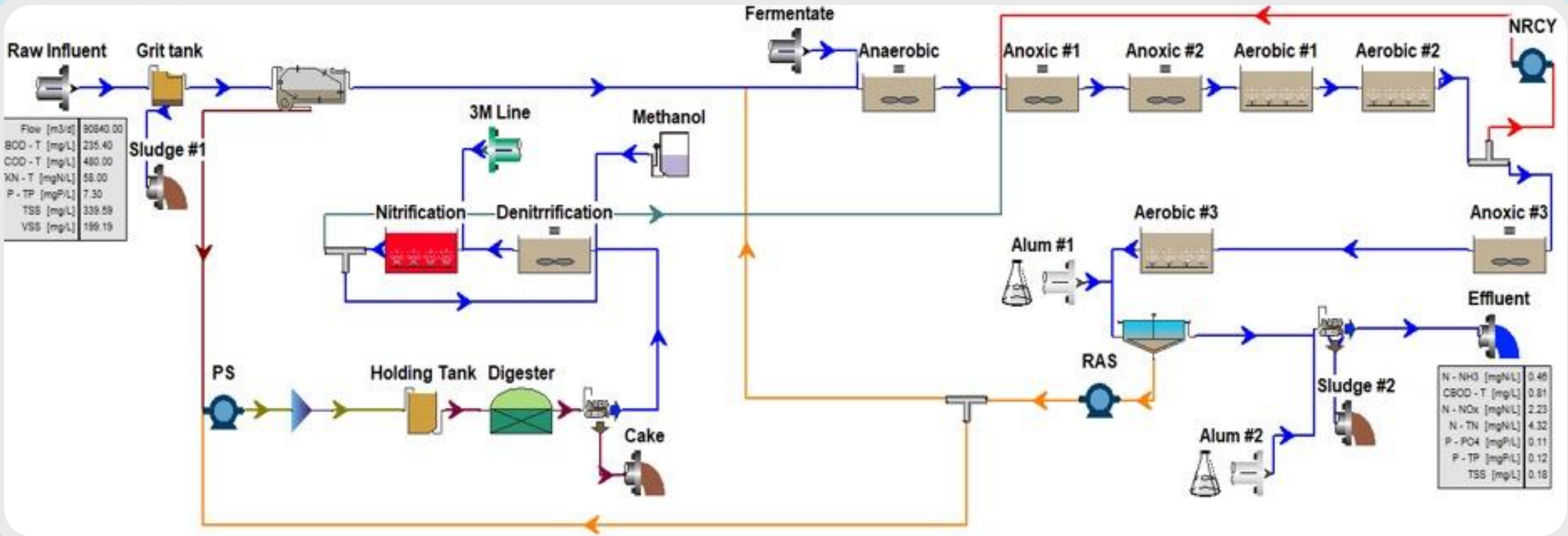
PROCESS DESIGN

1. BIOLOGICAL NITROGEN AND PHOSPHORUS REMOVAL
2. TERTIARY TREATMENT.
3. SLUDGE TREATMENT.



EVALUATION OF EXISTING CONDITION

BioWin 06 was used to create the proposed model



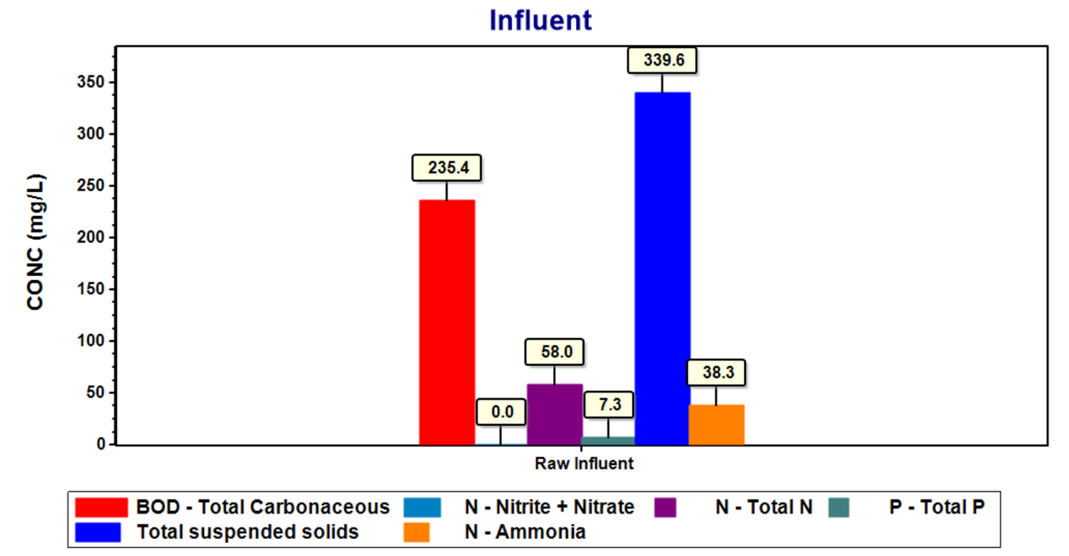
INFLUENT FOR PRESENT TREATMENT

Element name	Raw Influent
Flow	90840
COD - Total mgCOD/L	480
N - Total Kjeldahl Nitrogen mgN/L	58
P - Total P mgP/L	7.3
S - Total S mgS/L	10
N - Nitrate mgN/L	0
pH	7.3
Alkalinity mmol/L	6
ISS Total mgISS/L	140.4
Metal soluble - Calcium mg/L	160
Metal soluble - Magnesium mg/L	25
Gas - Dissolved oxygen mg/L	0

TREATMENT OBJECTIVES

1. Total Nitrogen (TN) <4.8 to 8 mg/L
2. Biological Oxygen Demand (BOD)<10 mg/L
3. Total Suspended Solids (TSS)<10 mg/L
4. Total Phosphorus (TP)<0.1 mg/L
5. Ammonia-N< 1.6 to 3.8 mg/L
6. Nitrate+Nitrite< 1.6 to 3.8 mg/L

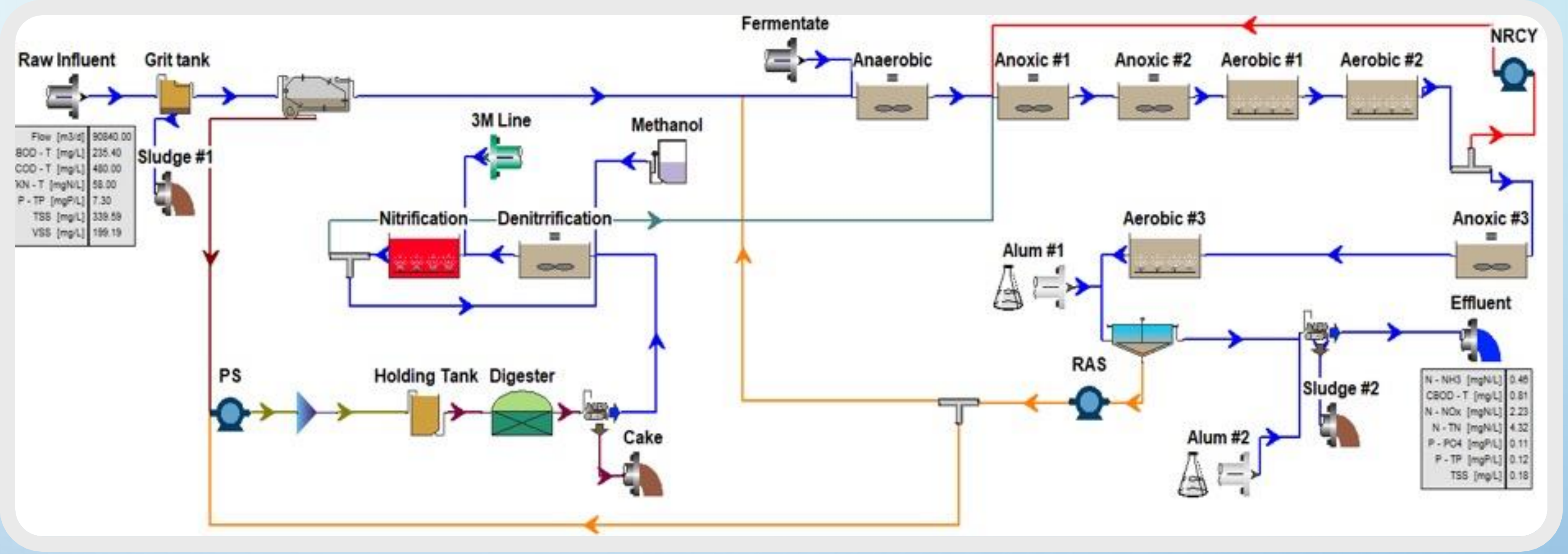
Influent Concentrations (at ADAF*)		
BOD	g/m^3	240
TSS	g/m^3	240
TKN	g/m^3	35
NH_4-N	g/m^3	23.1
TP	g/m^3	7.3



DIFFERENT TREATMENT UNITS OF TREATMENT PLANT (MODEL)

- Grit Tank
- Primary Clarifier
- 5- Stage Bardenpho (Anaerobic, Anoxic 1 & 2, Aerobic 1 & 2,

  Anoxic 3 & Aerobic 3)
- Secondary Clarifier
- Digester Tank
- Side Stream Treatment: Nitrification/Denitrification



Tanks	Name	Volume
	Grit tank	5,000.0
	Holding Tanks	1,000.0
	Group Total	**6,000.0**

Clarifiers	Name	Volume
	Primary Clarifier PST	9,691.7
	Secondary Clarifier FST	24,596.0
	Group Total	**34,287.7**

Reactors	Name	Volume
	Aerobic #1	11,420.0
	Aerobic #2	9,514.5
	Aerobic #3	1,903.0
	Anaerobic	5,709.0
	Anoxic #1	3,806.0
	Anoxic #2	3,806.0
	Anoxic #3	3,805.0
	Denitrrification	3,482.6
	Nitrification	6,965.2
	Group Total	**50,411.3**

Anaerobic Digesters	Name	Volume
	Digester	6,016.0
	Group Total	**6,016.0**

Total Volume for All Units	**96,715.0 m^3**

FIRST STAGE

RAW INFLUENT

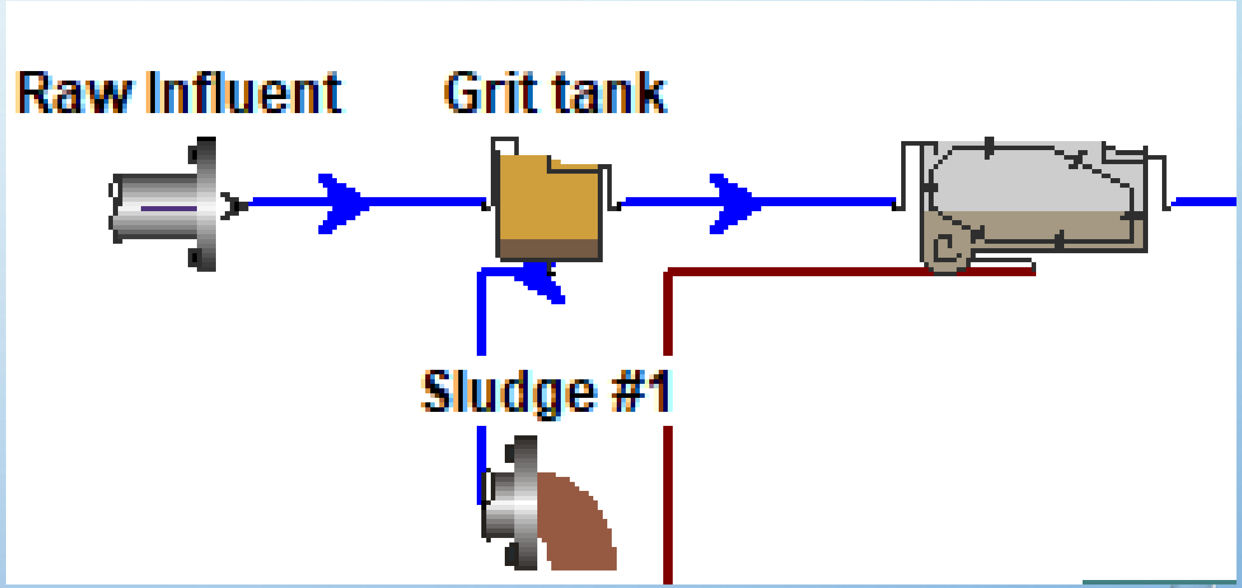
- Wastewater enters the system from homes and business into the treatment plant

GRIT TANK

- Used to remove solids and grit from the raw water before entering the primary clarifier.

PRIMARY CLARIFIER

- Used a settler as a replacement, removes additional grit in the water and creates a hydraulic line and sludge line



SECOND STAGE

5 STAGE BARDENPHO (REMOVAL OF NITROGEN AND PHOSPHORUS)

- **ANAEROBIC;**

  Polyphosphate accumulating organism (PAOs)

  Release phosphorus and volatile fatty acids.

- **ANOXIC 1 & 2, AEROBIC 1 & 2, ANOXIC 3 & AEROBIC 3;**

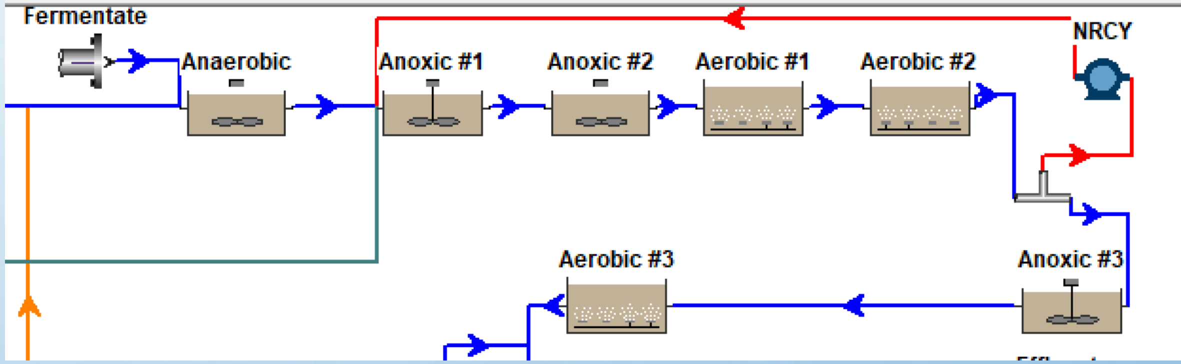
  Absorb phosphorus and release volatile fatty acids

- **INTERNAL RECYCLING RATIO 11[3];**

  With help of pumps

- **FEMENTATE;**

  Used as an extra source for carbon; no methanol was used since carbon in the tanks



THIRD STAGE

- **ALUM;**

  Aluminium Sulfate was added to the treatment plant to remove excess phosphorus

  Alum #1 : 190.4 kg/d

  Alum #2 : 5.8 kg/d

- **SECONDARY CLARIFIER;**

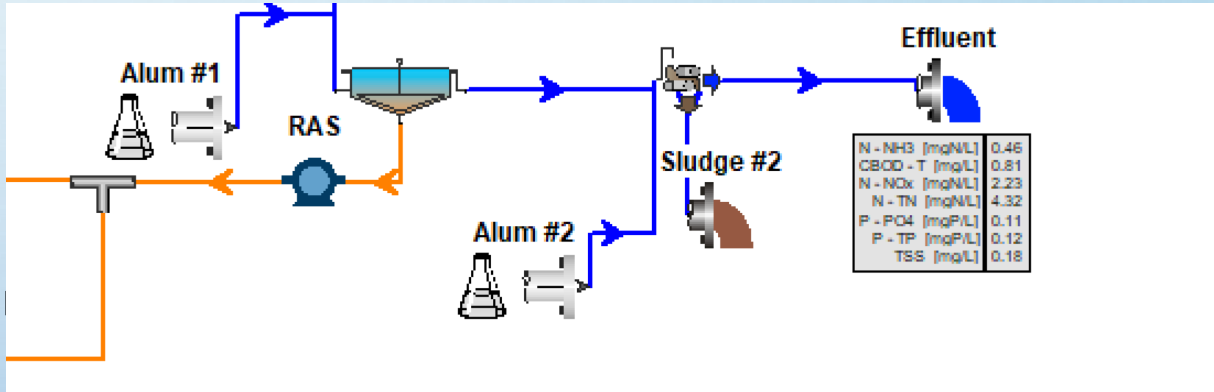
  Used to remove extra sediment and grit from the tank for final effluent and sludge processing.

- **DEWATERING UNIT;**

  Remove remaining sludge

- **EFFLUENT;**

  Water successfully treated



SLUDGE PROCESSING STAGE

- **PUMPS;**

  All sludge in the treatment plant is sent to pumps to direct it to digester

- **HOLDING TANK;**

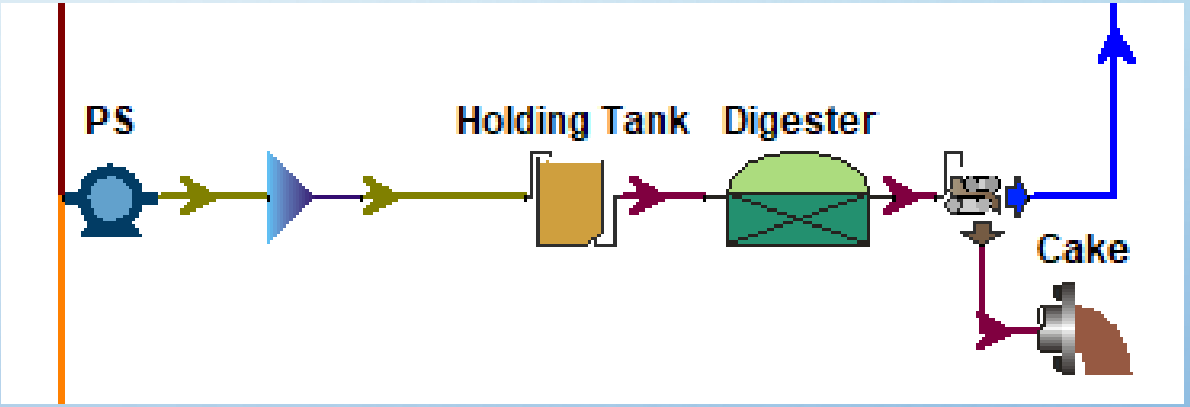
  Store the sludge to not overwhelm the digester system.

- **DIGESTER;**

  Breakdown organic waste (sludge) from clarifiers

- **DEWATERING UNIT;**

  Separate excess liquid to be sent to nitrification and denitrification process. Sludge is remove from the treatment plant.



SIDE STREATM TREATMENT: NITRIFICATION AND DENITRIFICATION STAGE

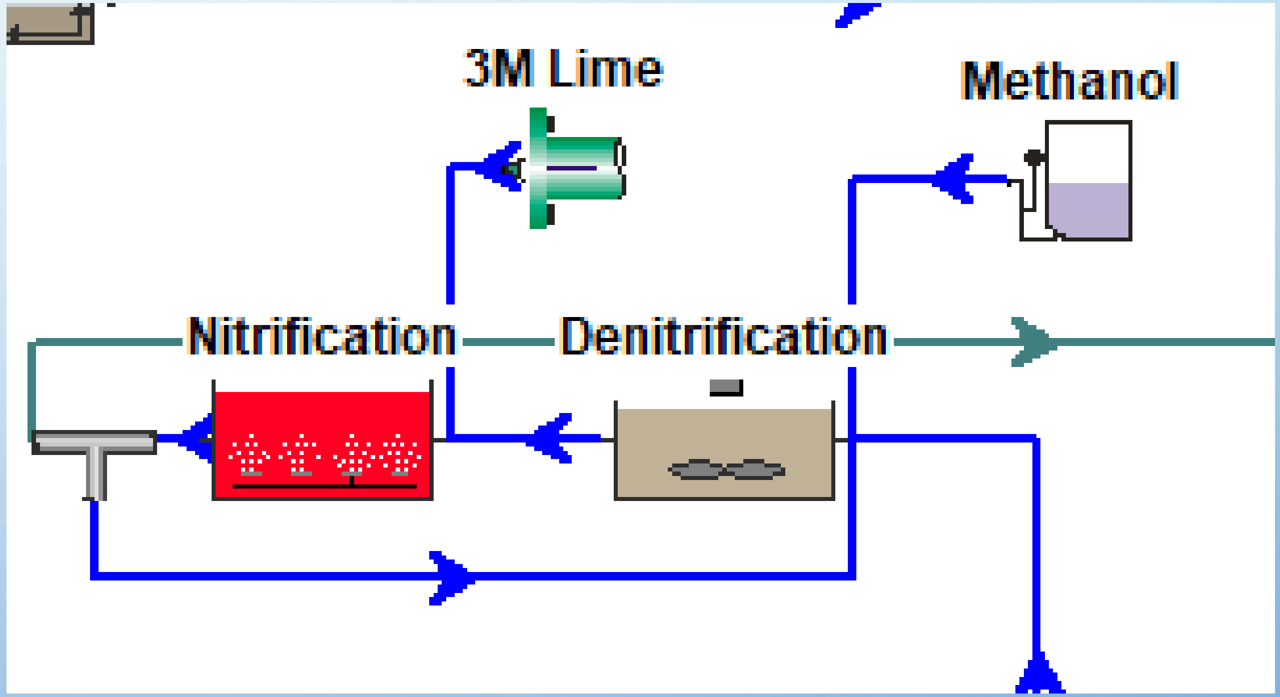
- **NITRIFICATION/DENITRIFICATION;**

  Remove nitrogen from the treatment plant from the sludge and recycled back to the first stage (Bardenpho)

- **METHANOL;**

  17,820 kg/d added to provide additional carbon denitrification

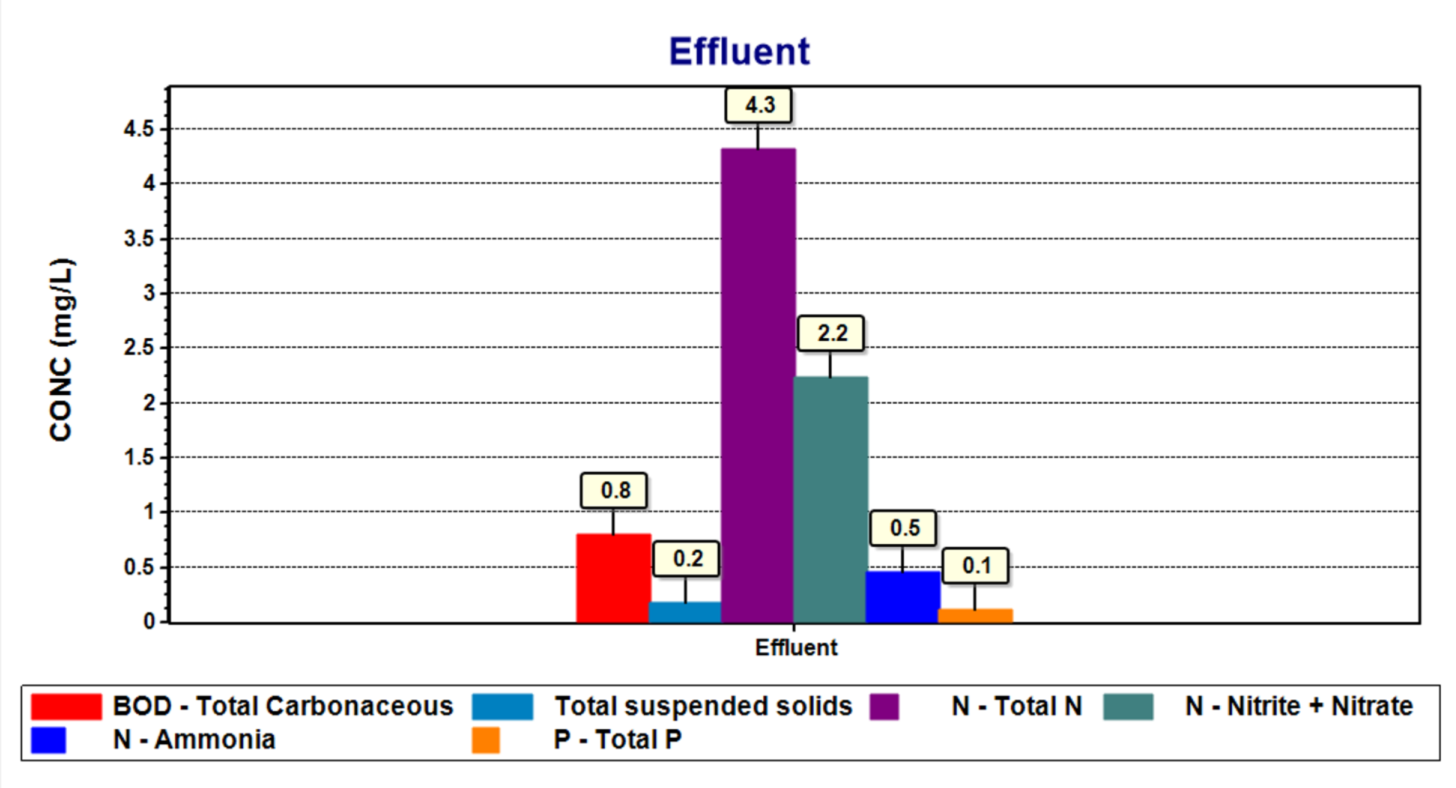
- **3M LIME;**



EFFLUENT PRESENT TREATMENT GOALS MET

TREATMENT OBJECTIVES

1. Total Nitrogen (TN) <4.8 to 8 mg/L
2. Biological Oxygen Demand (BOD)<10 mg/L
3. Total Suspended Solids (TSS)<10 mg/L
4. Total Phosphorus (TP)<0.1 mg/L
5. Ammonia-N< 3.8 mg/L
6. Nitrate+Nitrite< 3.8 mg/L



SOLID RETENTION TIME AND HYDRAULIC RETENTION TIME

SRT (Solid Retention Time) = $\sum \frac{VX}{Q_W X_R + Q_e X_e}$

V=Volume of the reactor, m^3
X= Aeration tank solids concentration, mg/L
Q_W= Waste sludge flowrate from the return sludge line, m^3/d
X_R=Concentration of sludge in the return sludge line, mg/L
Q_E=Effluent flowrate from the secondary clarifier, m^3/d
X_E=Effluent TSS concentration, mg/L

SRT Results ** (BioWin)

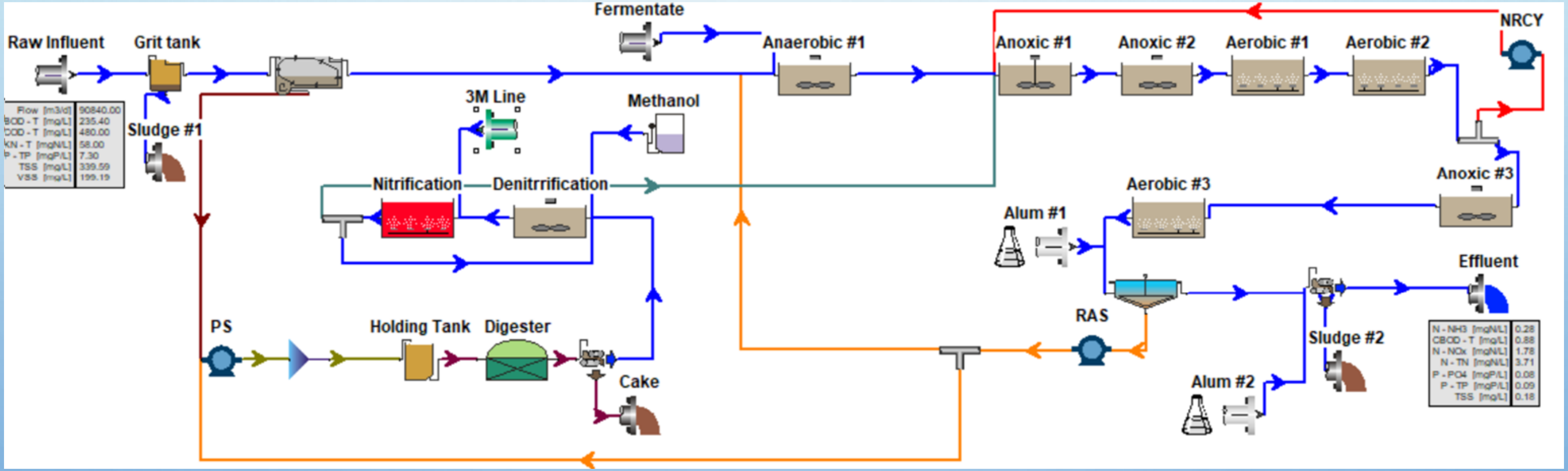
SRT Calculators Summary	
Name	Value (days)
Total SRT	4.98
Aerobic SRT	2.82

HRT (Hydraulic Retention Time) = $\sum \frac{V}{Q}$

V= Volume of Aeration Tank, m^3
Q= Influent flow rate, m^3/h

HRT Calculators Summary	
Name	Value (hours)
Total HRT	10.56

DESIGN MODEL TO MEET FUTURE CRITERIA



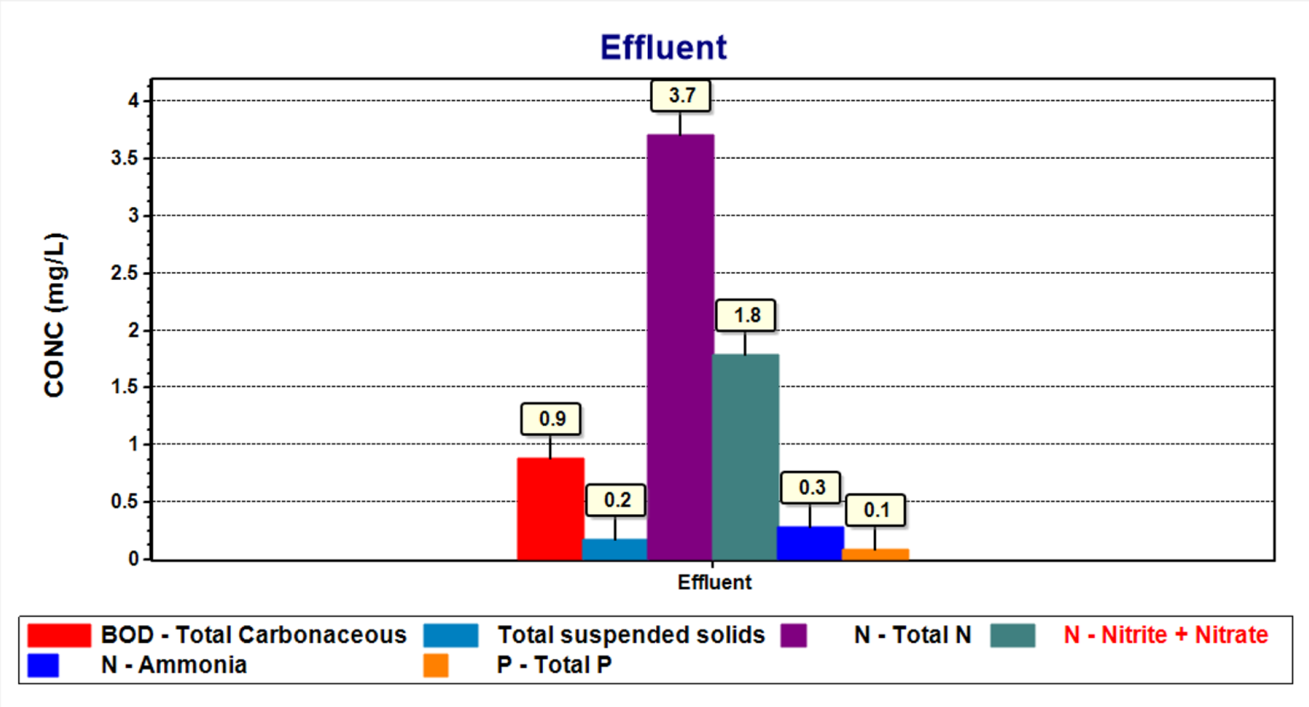
DESIGN MODEL TO MEET FUTURE CRITERIA: CHEMICAL ADDITION

	Present Mass Flow Rate	Future Mass Flow Future
Methanol Influent Name	COD kg/d	COD kg/d
Methanol	17,820	11,880
Alum #1	190.4	230.8
Alum #2	5.8	5.8

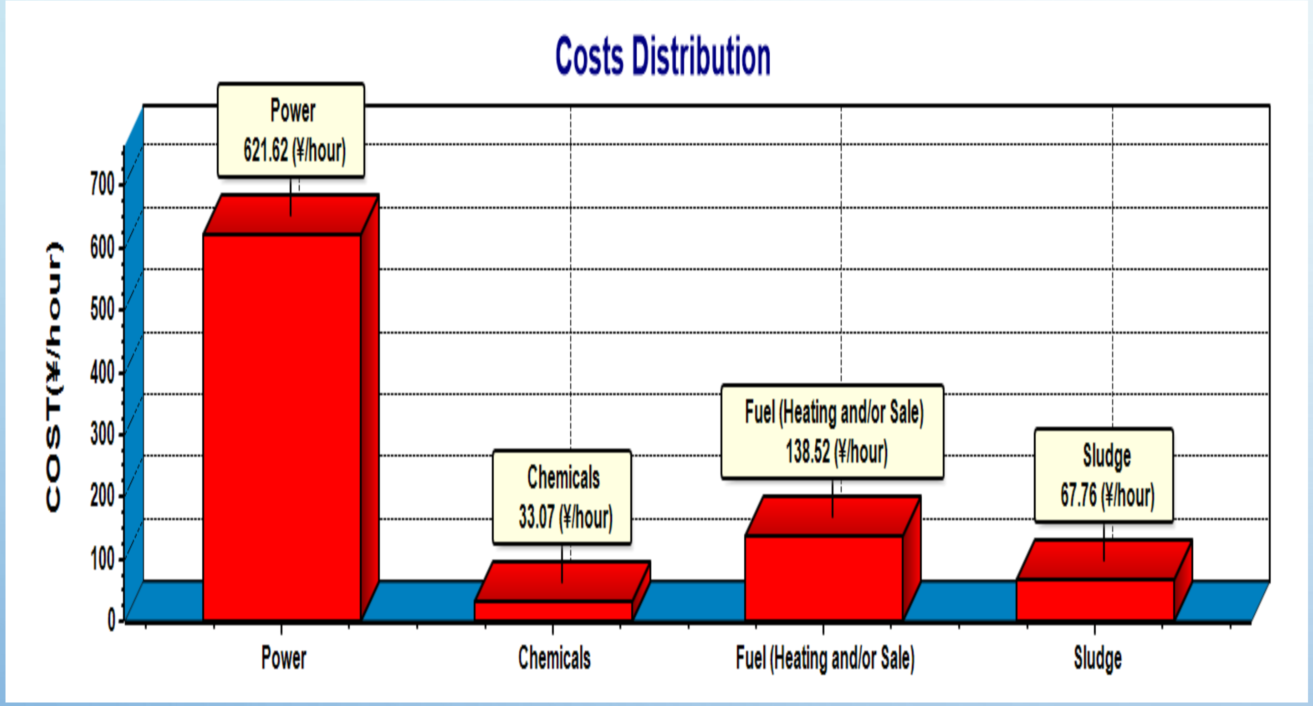
EFFLUENT FUTURE TREATMENT GOALS MET

TREATMENT OBJECTIVES

1. TN< 2.4 mg/L
2. BOD<10 mg/L
3. TSS<10 mg/L
4. TP<0.1 mg/L
5. Ammonia-N< 0.21 mg/L
6. Nitrate+Nitrite< 1.8 mg/L



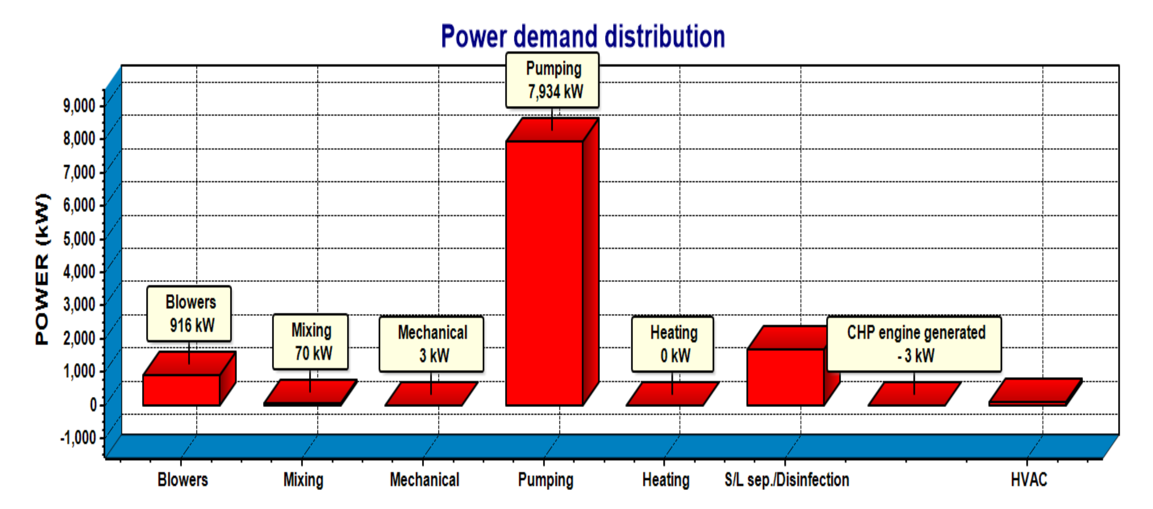
COSTS DISTRIBUTION



Categories	Cost [$/hour]	Cost [$/year]
Power	$621.62	$5,445,391.20
Chemicals	$33.07	$289,693.20
Fuel (Heating and/or Sale)	$138.52	$1,213,435.20
Sludge	$67.76	$593,577.60
Total	$860.98	$7,542,184.80

COST ANALYSIS FOR POWER DEMAND

POWER DEMAND DISTRIBUTION



Power Categories	Power Demand [kW]	Cost (Power Consumption) [$/hour]	Cost (Power Consumption) [$/year]
Blowers	916.39	$53.03	$464,542.80
Mixing	69.99	$4.05	$35,478.00
Mechanical	3.00	$0.17	$1489.20
Pumping	7933.88	$459.13	$4,021,978.80
Heating	-----		
S/L sep./Disinfection	1668.44	$96.55	$845,778.00
Total of tabulated	10591.69	$612.93	$5,369,266.80
HVAC	110.00	$6.37	$55,801.00
Service Charge	-----	$0.05	$438.00
Peak Demand Charge	-----	$1.34	$11,738.40
System total	10720.72	$621.79	$5,446,880.40
Power (CHP)	-2.90	---	
System Net	10710.82	$621.62	$5,445,391.20

Note: 1 year = 8760 hours thus to convert $/hour to $/year multiply $/hour x 8760 hours/1 year = $/year **

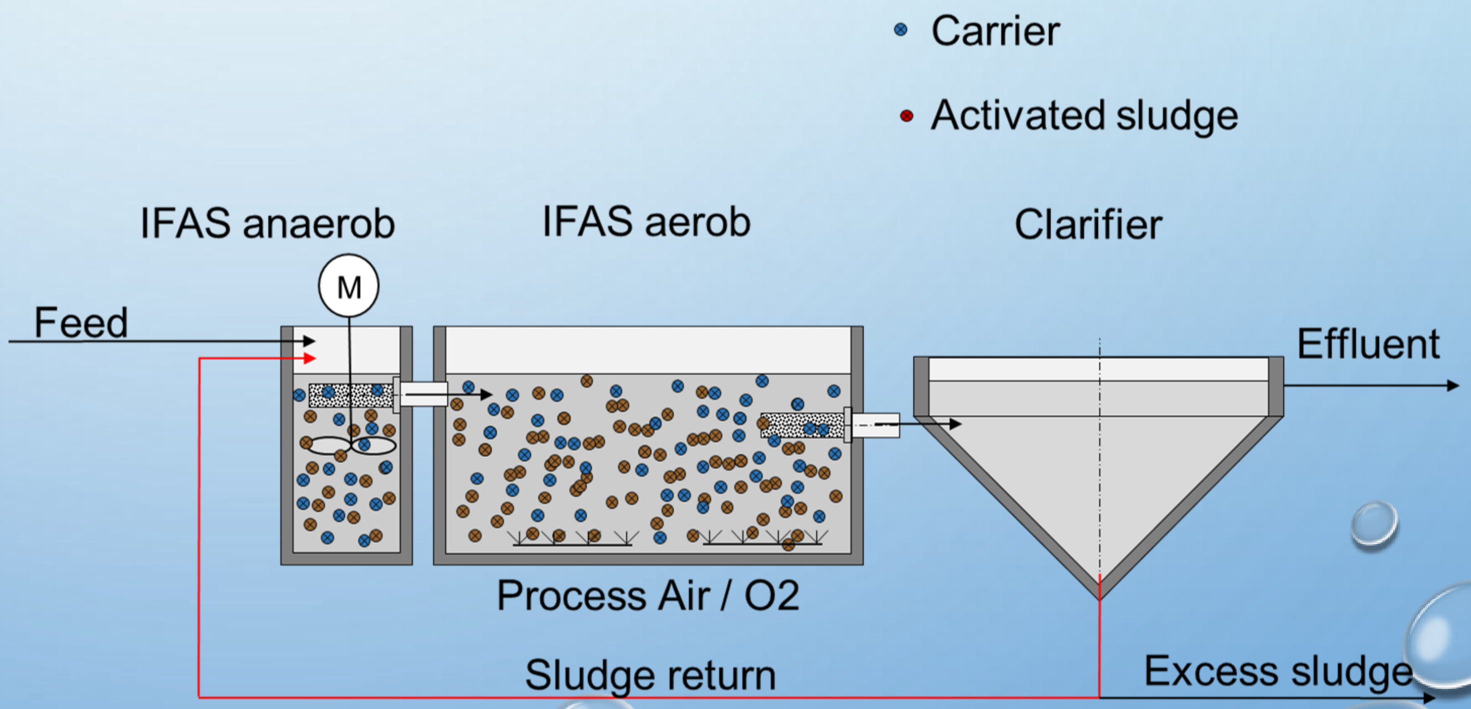
ALTERNATIVE TECHNIQUES

1. **IFAS** (Integrated Fixed Activated Sludge)
2. **SHARON** (Single Reactor System for High Activity Ammonium Removal Over Nitrite)
3. **ANAMMOX** (Anaerobic Ammonium Oxidation)
4. **ANITA™ MOX** (Anammox Process)
5. **MBR** (Membrane BioReactor)
6. **Ostara Pearl Reactor**
7. **PHOSTRIP Process**

INTEGRATED FIXED ACTIVATED SLUDGE (IFAS)

•A fixed or free floating media to an activated sludge BASIN that helps enhance the treatment process by stimulating through the growth of biomass.

•AERATION is used during the Activated sludge process. It is when air is added to water to help promote the microbial growth.



INTEGRATED FIXED ACTIVATED SLUDGE (IFAS)

ADVANTAGES

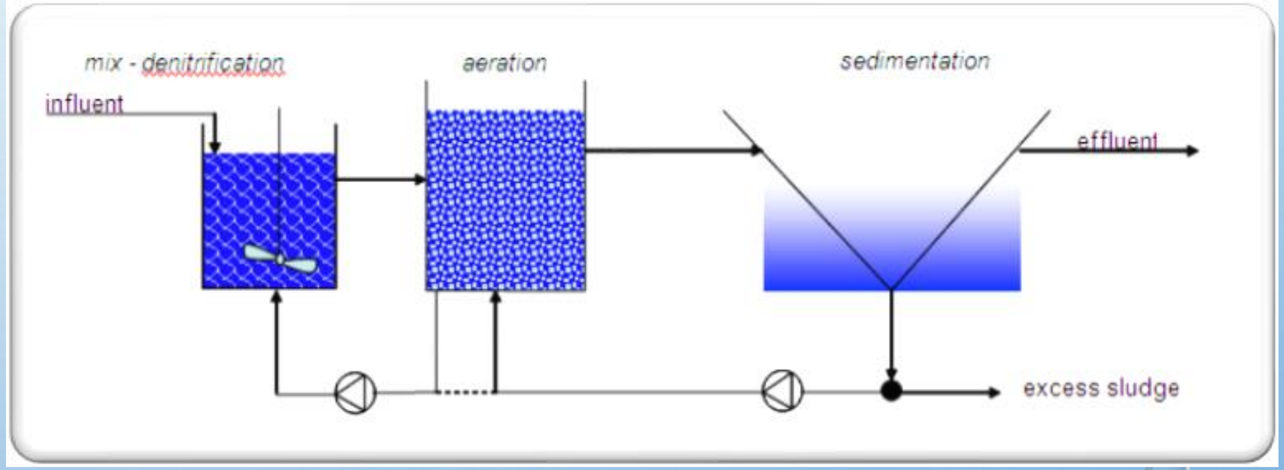
- Increased process stability.
- Reduced production of sludge.
- Improve nitrification through the aerobic, anaerobic, and anoxic zones.
- Improve sludge retention time.
- Faster restoration of system nitrification due to the large mass of nitrifiers on the fixed film.

DISADVANTAGES

- High energy requirements, such as for aeration.
- High costs for construction and operation.
- The need for expert, specialized knowledge.
- Challenges in finding mechanical spare parts locally.

SINGLE REACTOR SYSTEM FOR HIGH ACTIVITY AMMONIUM REMOVAL OVER NITRITE (SHARON)

- Sharon is a method used to help remove nitrogen from wastewater. It is the best cost effective system for sewage treatment PROCESS. The process is used for treatment of high strength ammonia liquors such as sludge dewatering liquors and the liquid fraction of pig manure.



SINGLE REACTOR SYSTEM FOR HIGH ACTIVITY AMMONIUM REMOVAL OVER NITRITE (SHARON)

ADVANTAGES

- The process is suitable for wastewater flows with high amounts of ammonium content (>100mg/l) or low organic matter (c/n<0.15).
- Activated sludge systems for nutrient removal are flexible, robust, and cost effective treatments for household and industrial wastewater.

DISADVANTAGES

- Biological nutrient removal is a tedious process and requires the main parameters to be constantly supervise Such as, the Sedimentation parameter must be checked on a daily basis.

ANAEROBIC AMMONIUM OXIDATION (ANAMMOX)

•Discovered in 1999, anaerobic ammonium oxidation (anammox) is a microbial process in which nitrite and ammonium ions are converted directly into diatomic nitrogen

•Anammox is a two-step process

1. partial nitrification of half of the ammonium present

$$NH_4^+ + NO_2^- \rightarrow N_2 + 2H_2O$$

2. Conversion of resulting ammonium and nitrite into dinitrogen:

$$NH_4^+ + NO_2^- \rightarrow N_2 + 2H_2O$$

ANAEROBIC AMMONIUM OXIDATION (ANAMMOX)

ADVANTAGES

- conventional nitrogen removal, mediated by aerobic bacteria, is accomplished in two separate steps: nitrification and denitrification
- requiring only a single-stage and no aeration, anammox consumes less energy, produces less excess sludge, and emits fewer green-house gasses such a CO_2 and N_2O and ozone-depleting NO

DISADVANTAGES

- Slow doubling time (10 to 14 days)
- By effect, a longer recovery time after loss of sludge in comparison to conventional systems

ANITA™ MOX

- Anitamox is a single-stage nitrogen removal process based on the MBBR (moving bed biofilm reactor) technology
- It combines aerobic nitritation and and anoxic ammonia oxidation (anammox)
- The anitamox process was specially developed for treatment of streams highly loaded with ammonia, including effluents from anaerobic sludge digestion, industrial wastewaters, and landfill leachates

ANITA^{TM} MOX

ADVANTAGES

- More economical
- 90% less sludge production
- 60% less energy consumption
- No Carbon source needed

DISADVANTAGES

- Higher initial investment

MEMBRANE BIOREACTOR (MBR)

- Combination of membrane process (e.g. microfiltration, ultrafiltration) with biological treatment process (activated sludge)
- Widely used due to recent cost reduction in membrane cost
- Could be coupled with newer technologies such as anammox to increase efficiency

MEMBRANE BIOREACTOR (MBR)

ADVANTAGES

- Independent HRT and SRT, since sludge solids are completely retained in the bioreactor
- High quality effluent
- Consistent performance
- Low sludge production
- Less sludge dewatering

DISADVANTAGES

- High capital and operational cost
- Operational is complex and needs a specialize trained personnel.

OSTARA PEARL REACTOR

OSTARA PEARL REACTOR

ADVANTAGES

DISADVANTAGES

PHOSTRIP PROCESS

- PhoStrip Process is an method, where microorganisms in the activated sludge are bioaccumulate and secrete phosphate. Phostrip is the “sidestream process” where only a part of the recirculated sludge is passed through the anaerobic tank and “mainstream “ is where all sewage is passed through anaerobic tank.
- The main purpose of PhoStrip Process combines both biological and chemical processes for the removal of phosphorus.

PHOSTRIP PROCESS

ADVANTAGES

- No additional heavy metals contamination of sludge
- No negative effect on acid capacity
- No additional salinization of the receiving watercourse
- no or less chemical cost
- no or less chemical storage and handling
- unaffected by fluctuations in treatment plant influent

DISADVANTAGES

- Filamentous bacteria with a tendency towards scum formation are suppressed.

SUMMARY AND FINAL RECOMMENDATION

In our two-in-one design system that was accomplished by BIOWIN 6.0, we were able to meet all present criteria and future criteria minus the phosphorus limits for future limits. For this reason, if we get selected for the next round, we can use an alternative technique to compensate for the phosphorus limits. This can reduce the cost and increase efficient of the design system.

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  - Students

- UDC
  - Faculty and Staff members
  - Students
  - Civil Engineering Director
    - Dr. Pradeep K. Behera

Special Acknowledgment

To our Advisor

Dr. Hossain Azam

THANK YOU FOR LISTENING

ANY QUESTIONS?

APPENDIX

Design Parameter	Units	Present Criteria	Future Criteria
Flow Peaking Factors			
Minimum Flow/ADAF*	....	0.3	
ADMMF/ADAF*	....	1.2	
PDF/ADAF*	....	1.75	
PHF/ADAF*	....	2.14	
PIF/ADAF*	....	2.3	
Design Flows			
Minimum Flow at Startup	m^3/d	10976.5	33686.5
Minimum ADAF* at Startup	m^3/d	36714.5	112793
ADAF*	m^3/d	90840	181680
ADMMF*	m^3/d	109008	218016
PDF*	m^3/d	158970	317940
PHF*	m^3/d	194549	388719.5
PIF*	m^3/d	208932	417864
Load Peaking Factor (ADMML*:ADAL*)			
Biochemical Oxygen Demand (BOD)	....	1.15	
Total Suspended Solids (TSS)	....	1.19	
Total Kjeldahl Nitrogen (TKN)	....	1.15	
Ammonia-Nitrogen (NH4-N)	....	1.15	
Total Phosphorus (TP)	....	1.15	
Ortho-Phosphorus (OP)	....	1.15	
Load Peaking Factors (PDL*:ADMML*)			
Total Kjeldahl Nitrogen (TKN)	....	1.15	
Influent Wastewater Temperature			
Minimum 30-day average	deg C	14	
Influent Concentrations (at ADAF*)			
BOD	g/m^3	240	
TSS	g/m^3	240	
TKN	g/m^3	35	
NH_4-N	g/m^3	23.1	
TP	g/m^3	7.3	
OP	g/m^3	3.6	