Spring 2017

Vrishabhavathi Valley Wastewater Treatment Plant System Upgrade

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SANTA CLARA UNIVERSITY

Department of Civil Engineering

I HEREBY RECOMMEND THAT THE THESIS PREPARED
UNDER MY SUPERVISION BY

Vijay Chellaram & Christian Miller

ENTITLED

Vrishabhavathi Valley Wastewater Treatment Plant System Upgrade

BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

BACHELOR OF SCIENCE
IN
CIVIL ENGINEERING

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Vrishabhavathi Valley Wastewater Treatment Plant System Upgrade

By

Vijay Chellaram & Christian Miller

SENIOR DESIGN PROJECT REPORT

Submitted to
the Department of Civil Engineering

of

SANTA CLARA UNIVERSITY

in Partial Fulfillment of the Requirements
for the degree of
Bachelor of Science in Civil Engineering

Santa Clara, California

Spring 2017

Acknowledgements

The proposed project required collaboration between two parties. The success of this project is due in large part to the efforts of the following entities: Santa Clara University School of Engineering and Bangalore Water Supply and Sewerage Board (BWSSB). Additionally, we would like to thank the following groups and individuals:

Dr. Steven Chiesa (Faculty Advisor) for providing constant support and critical technical guidance throughout the design phase of the project.

Dr. Hisham Said (Faculty Advisor) for providing constant support and critical technical guidance throughout the cost estimation and scheduling phase of the project.

Karen Pachmayer (Thesis Advisor) for providing guidance while writing this thesis.

BWSSB for providing us with the information needed to design the system upgrade.

DESIGN OF THE EXPANSION OF THE VRISHABHAVATHI WASTEWATER TREATMENT FACILITY IN BANGALORE, INDIA

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Department of Civil Engineering
Santa Clara University, Spring 2017

Abstract

Sixteen activated sludge tanks, eight secondary clarifiers, and four return pump stations were designed for the Vrishabhavathi Wastewater Treatment plant in Bangalore India. The design included tank dimensions, mechanical equipment associated with each component, pipe sizes for the piping system, and a cost estimate with a construction schedule. The activate sludge tanks were designed to be made of reinforced concrete with a mechanical air diffuser system installed for oxidation purposes. The secondary clarifiers were designed using reinforced concrete and a mechanical sweeping mechanism to scrape up the sludge as it settles to the bottom of the tank. Return pump stations were designed to transport the sludge into recirculation pipes or to a waste activated sludge stream. The treated water from the expanded facility will be discharged back into the river or transported to a tertiary treatment facility on site. The effluent will act as a source of non-potable water for local urban and agricultural use. Construction of the proposed facility will not interfere with the operation of the existing plant. This expansion to the existing facility will provide the city of Bangalore with an additional 71.33 million gallons per day of fresh, not-potable water.

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Project Background

Background Information and Location

The population of the South Indian city of Bangalore is about 10.8 million according to estimates from 2017 (Population City), making it the third largest populated city and the fifth largest urban city in India. The city is home to a number of different hi-tech industries and is dubbed as the 'Silicon Valley of India'. The Vrishabhavathi River, a tributary of the Arkavathi River which later joins the Cauvery River, flows through these industrial areas.

The city of Bangalore has a current wastewater requirement of 1720 million liters per day (MLD) which is approximately 454.4 million gallons per day (mgd). This gives an average daily water use of 42 gallons per person per day, which is far less than the average daily water consumption in the USA, which is in the range of 80-100 gallons per person per day. The city has a safe yield of 396.25 mgd from groundwater aquifers. To meet the demand for freshwater, an overdraft is becoming increasingly evident in the city.

The city's wastewater treatment plants are collectively capable of treating only 190.48 mgd of wastewater across the city's 14 existing treatment plants whereas, the current estimated flow of sewage is estimated to be 369.86 mgd. The demand for freshwater is expected to increase to 561.4 mgd in 2021 and 673.68 mgd in 2036 (The Hindu). This shows that Bangalore has a huge demand for freshwater and additional sewage treatment. The additional sewage treatment and wastewater reclamation capacity proposed by this project can offset some of the groundwater needs, thereby reducing stress of the groundwater aquifers.

Figure 1 shows the geographic location of the treatment plant to be upgraded as part of this project. The image to the left shows an aerial view of the Western region of Bangalore. The yellow box is zoomed in on the right, where the yellow outline shows the treatment plant's site boundary, and the highlighted blue region shows the portion of the site that was allocated for the purpose of this project.

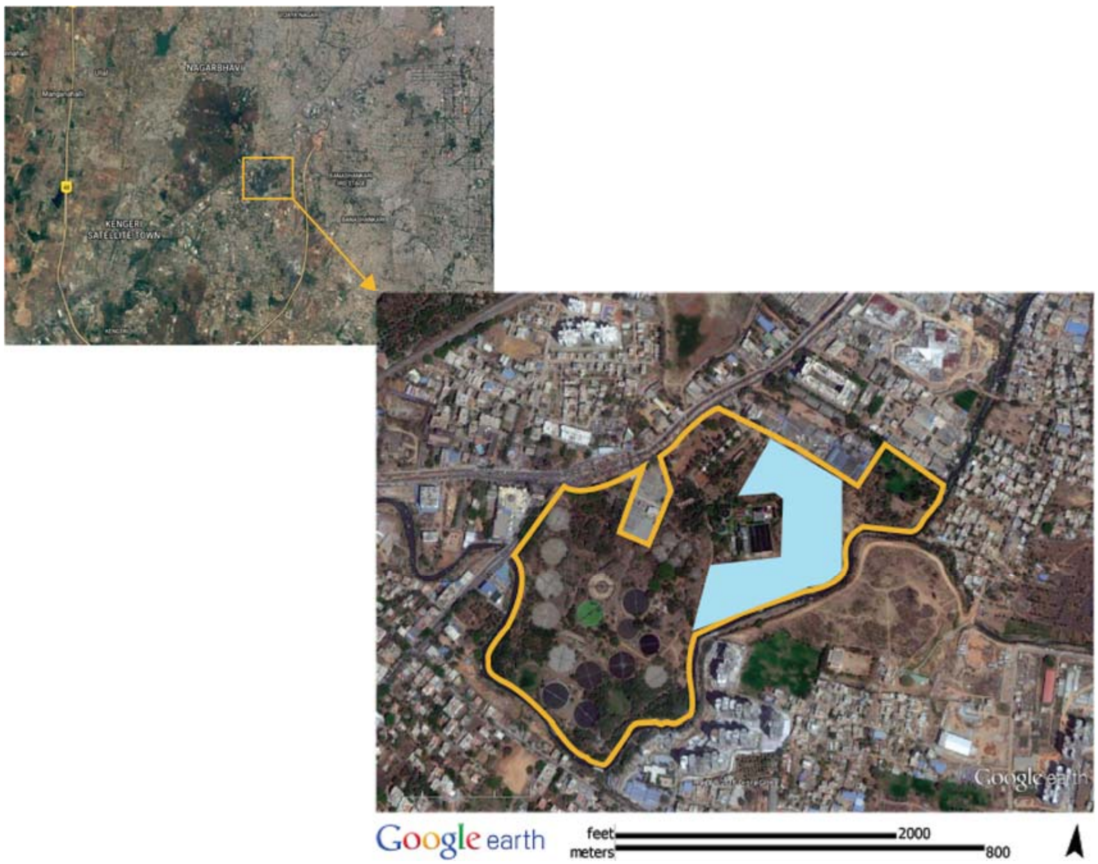

Figure 1: Vrishabhavathi Valley Wastewater Treatment Plant located in West Bangalore.

Existing Conditions of the Vrishabhavathi River

Many local industries dump their waste products directly into the river, which causes pollution and increases the stress on the river. The wastewater treatment plant capacity serving the area does not meet the demand, which further adds stress on the river. Figure 2 shows industrial waste flowing in the Vrishabhavathi River in Bangalore, Karnataka.

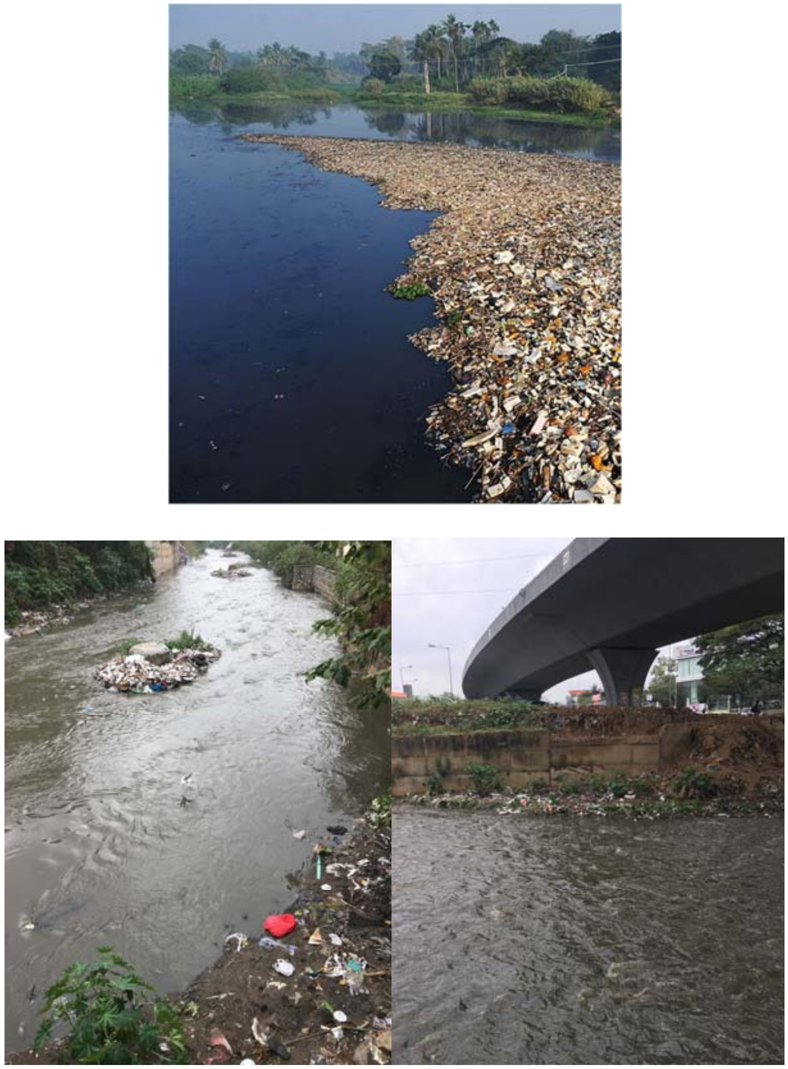

Figure 2: Pollution in the Vrishabhavathi River in Bangalore, India.

The distribution of wastewater to the different treatment plants in Bangalore can be seen in Figure 3 below.

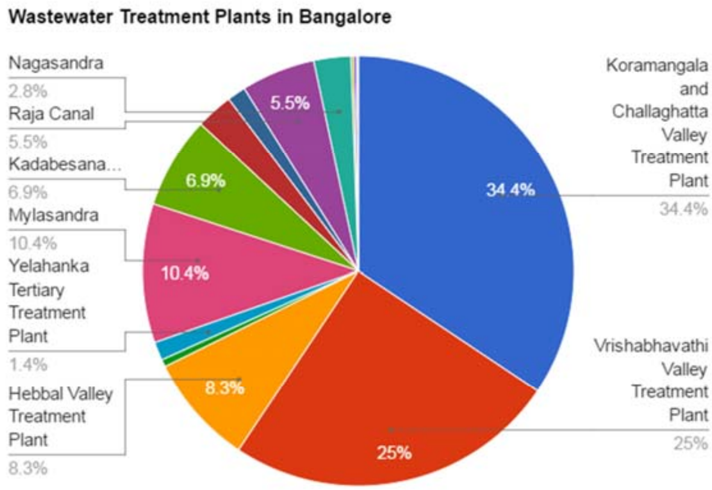

Figure 3: Percentage of sewage flow that each plant is responsible for.

Additionally, Table 1 provides information regarding the treatment processes used by each treatment plant. Note that the Vrishabhavathi Valley treatment plant is responsible for the second highest amount of wastewater to be treated.

Table 1: Information on the 14 existing treatment plants in Bangalore.

Plant	Capacity in MLD	Treatment process adopted
1) Vrishabhavathi Valley	180	Secondary: Trickling filters
2) K & C Valley	248	Secondary: Activated sludge process
3) Hebbal Valley	60	Secondary: Activated sludge process
4) Madivala	4	Secondary: UASB + oxidation ponds + constructed wetlands
5) Kempambudhi	1	Secondary: Extended aeration
6) Yelahanka	10	Tertiary: Activated sludge process + filtration + chlorination
7) Mylasandra	75	Secondary: Extended aeration
8) Nagasandra	20	Secondary: Extended aeration
9) Jakkur	10	Secondary: Upflow anaerobic sludge bank + Extended aeration
10) K. R. Puram	20	Secondary: Upflow anaerobic sludge bank + Extended aeration
11) Kadubeesanahalli	50	Secondary: Extended aeration
12) Raja Canal	40	Secondary: Extended aeration
13) Cubbon Park	1.5	Membrane Bioreactor
14) Lalbagh	1.5	Extended Aeration + Plate Settlers + UV disinfection
Total	721	

www.bwssb.gov.in

The current treatment process at the Vrishabhavathi Valley Wastewater Treatment Plant consists of:

- Preliminary Treatment
    - Screening: Screening is adopted to remove larger floating solids and organic solids, which do not become septic. The screens are made up of flats welded to the horizontal bars at 40mm and 20mm spacing. These screens are placed perpendicular to the direction of flow, and floating matter stuck to the screens are removed manually. The screenings are disposed of in a local landfill.
    - Grit removal: The heavier inorganic matter is removed during this process. The heavier inorganic matter such as grit, sand, eggshells, gravel etc., are removed by rapid sedimentation of the particles, which can settle in a timeframe of 60 seconds. The settled matter is pushed to the sides and classifiers will transport the matter to the required location. Ultimately, the grit is disposed of in the same local landfill as the contents from the screening process.
- Primary Treatment
    - Primary clarification: Primary clarifiers consist of a settling basin where inorganic matter will settle. The detention time in this tank is 2 to 2.5 hours. The clarifiers may be circular or rectangular in shape. The settled matter will be scraped to the center by the raker arms and the primary sludge will be taken to the primary sludge pump house to pump the sludge to sludge digesters. According to data available on the Bangalore Water Supply and Sewerage Board (BWSSB) website, in primary clarification, about 30–35% of the BOD_5 and 60–65% of the suspended solid are removed.
- Secondary Treatment

- Trickling filter process: The wastewater is sprinkled over a rock medium and microorganisms grow on the surface of the medium. The grown microorganisms will absorb the organic matter in the wastewater and multiply to grow on the surface. When the self-weight increases, growth will fall down and be carried away with the water. This will be removed in the secondary clarifiers and recycled continuously.
- Secondary clarification: Secondary clarifiers consist of a settling basin where sloughed biomass will settle. The detention time in this tank is 1.5 to 2 hours. The clarifiers are circular in shape. The settled matter will be scraped to the center by the raker arms, the secondary sludge will be taken to the recirculation sludge pump house to pump the sludge to the aeration tank or trickling filters, and excess sludge is pumped to sludge thickeners. According to data available on the BWSSB website, in secondary clarification about 80 – 90% of the BOD_5 and 80 – 90% of the suspended solid are removed.

➔ Sludge Management

- Sludge Thickening: Sludge thickeners are used to separate excess water content in the sludge produced by primary and secondary techniques. The effluent will be taken back to the detritor and thickened sludge will be pumped to the sludge digester.
- Sludge digestion: The sludge digester system is an anaerobic tank where sludge is digested. The digested sludge is taken to the drying beds for drying.
- Sludge Drying Beds: The digested sludge will be spread over a flat surface for drying. The dried sludge will be disposed of as landfill.

➔ Tertiary Treatment

- The Vrishabhavathi Valley Wastewater Treatment Plant has a tertiary treatment facility that is capable of treating 33.33% of the plant's existing treatment capacity of 47.5 mgd. Since there currently is not a high demand for tertiary treated water, most of the water from this plant is discharged back into the river.

It is not clear exactly how much of the wastewater that enters the plant is residential or industrial. There is no available information on industrial pretreatment of water.

Figure 4 shows a schematic drawing of the existing system at the Vrishabhavathi Valley Wastewater Treatment Plant. It shows that 104 MLD (27.47 mgd) enters the plant from the river itself and 26 MLD (6.89 mgd) enters the plant from the sewage system. This adds up to a total inflow of 130 MLD (34.34 mgd). The outflow of the plant into the river is 127 MLD (33.55 mgd), and only three MLD (0.79 mgd) is recycled from the plant. The flow of the river is approximately 600 MLD (158 mgd). Water is taken from the river to be treated since local industries use it for waste disposal. It is imperative to treat the river water because the population downstream depends on the water from the river for both industrial and agricultural uses.

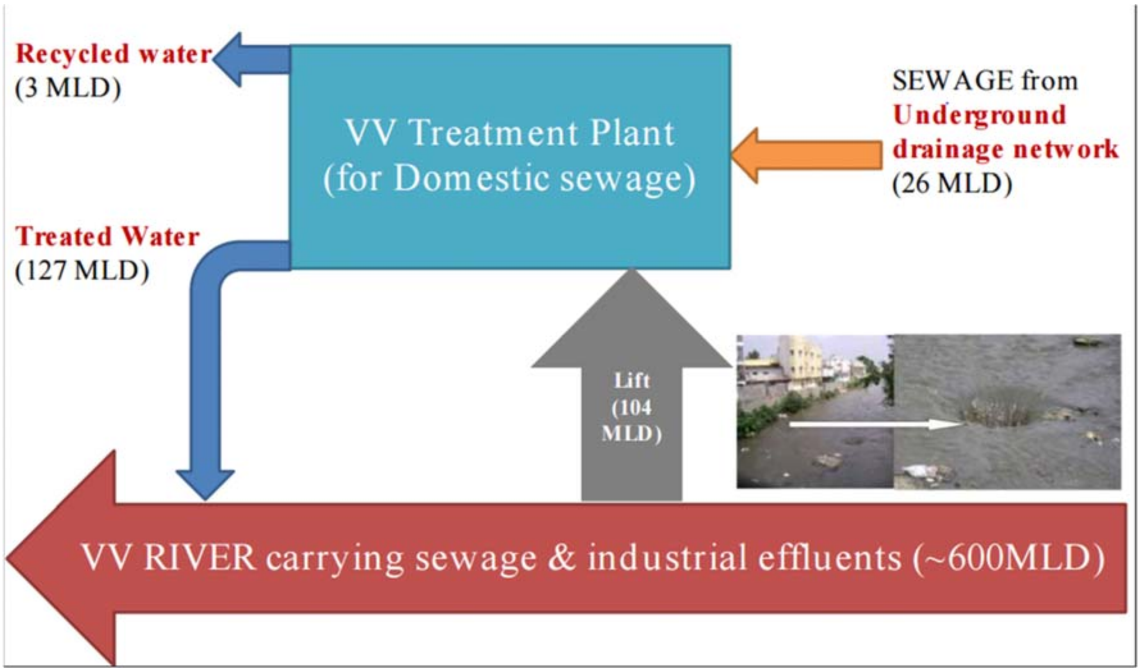

Figure 4: Schematic of the existing system.

Current Status

The Vrishabhavathi Valley Wastewater Treatment Plant is responsible for treating 47.5 mgd and uses the rock trickling filter process for secondary treatment. This translates to 25% of Bangalore City's sewage, as shown in Figure 3. The average treated effluent BOD_5/COD ratio was less than 0.2, which suggests that the plant is receiving too many incompatible pollutants that are non-biodegradable. This suggests that there is a high level of industrial pollution in the river. While there is no explicit statement, the reason for the plant's current inadequacies could be due to the following:

- The flow is greater than the plant capacity
- Higher pollutant loading than the current capacity
- Poor operation and maintenance of the plant and treatment process

- Power failures

Problem to be addressed

The ultimate goal of this project was to increase the treatment capacity of the existing facility to satisfy both current and future demands for freshwater. The overall capacity of the facility will be increased by 71.33 mgd. The treated water from the expanded facility will act as a source of non-potable water for local agricultural and industrial uses. Increasing the available non-potable water will offset the groundwater needs in the area as well.

Strategy

In order to achieve the increased capacity of 71.33 mgd, the team designed activated sludge aeration basins (not currently used at the existing facility), additional secondary clarifiers to accompany those already on-site, and return pump stations to direct the flow of sludge. In order to complete this project, the appropriate design criteria and constraints were first identified. From there, the size and capacity of individual system components were calculated. Once the design parameters were set, detailed design drawings of each component were created using AutoCAD. Lastly, the team provided a preliminary cost estimate and construction schedule for the proposed project.

Performance Goals

The two major performance goals of the project were an effluent biochemical oxygen demand (BOD_5) of 20 milligrams per liter (mg/L) and an effluent total suspended solids (TSS) of 22 mg/L. This goal was set in order to meet the Bangalore equivalent NPDES 30/30 requirement, which states that over a 30-day average, both of these values must be under 30 mg/L. It was decided to aim for the 20 mg/L range, in order to account for a factor of safety.

Project Alternatives & Best Alternative

Alternative 1

The first solution considered for this project was an expansion of an existing wastewater treatment facility. This would allow the choice of an existing facility and determine if any additional treatment techniques were needed, as well as the ability to determine what could be done to improve the capacity of the systems currently in place. This solution allowed the team to make use of available space on site that was not currently being used, and allows the use of existing infrastructure for collection, treatment, and reclamation of wastewater. This particular system was suitable for large tributary area, due to its larger size and capacity.

Alternative 2

The second solution investigated was a decentralized wastewater treatment system. This system included a network of satellite wastewater treatment facilities along the river. This approach is suitable for newly developed areas. This solution was attractive because it minimized the need to construct extensive pipeline systems for transporting untreated wastewater. These systems are less expensive than a larger, centralized facility. Table 2, below, represents a summary and comparison of the two alternatives discussed for completing this project.

Table 2: Summary of centralized treatment vs. decentralized treatment.

Centralized Treatment	Decentralized Treatment
Large amount of land required	Small amount of land required
Large tributary area	Small tributary area
Large treatment capacity	Small treatment capacity
Economies of scale	Minimal pipeline infrastructure

Best Apparent Alternative: Alternative 1

Upon evaluation of the two alternatives, it was determined that a centralized wastewater treatment plant was more suitable to the project area. The area being looked at is particularly large, and expanding an existing facility would allow the use of current infrastructure to meet both the current demands and the demands over the next 20 years. This solution was also more suitable because it was possible to make a site visit to the facility in December, 2016 and gather information rather than having to choose multiple locations along the river and perform multiple site visits overseas. Lastly, the tributary area being looked at is already developed and not suitable for satellite treatment plants.

Design Criteria & Constraints

The design of the treatment plant took into consideration the cost and availability of local materials and equipment, construction planning, accessibility and physical site parameters for the plant. Research was conducted and a long list of equipment manufacturers in India was found, however, an in-depth research effort on the same was conducted to choose the best and most cost effective option(s).

Site-Specific Constraints

The treatment plant has 33.2 acres of unused land that is available to use for the expansion project. This project will have to be scheduled and coordinated in such a way that it will not interfere with any of the plant's existing treatment processes, in order to maintain the plant's existing capacity during the construction process. Since the plant is situated along the river, levees will have to be constructed to protect the plant from any flooding that might occur during the seasonal monsoons.

Codes and Standards

The project wastewater treatment design voluntarily complies with the:

- National Pollutant Discharge Elimination System Permit (NPDES)
- US Environmental Protection Agency-Secondary Treatment Requirements (US EPA)

The structural design must comply with the Indian Standards Institution (ISI) Building Codes. India-specific treatment requirements are very similar to those set by the US EPA.

Design Criteria and Summary

Activated Sludge Aeration Basins

Table 3 shows the design criteria used to design the activated sludge tanks for this project. The table shows typical design criteria values for non-nitrifying activated sludge tanks and were taken from *Wastewater Engineering* by Metcalf and Eddy.

Table 3: Design Criteria for Activated Sludge Tanks.

Capacity (mgd)	**71.33**
Primary Effluent BOD_5 (mg/L)	**140**
Temp (ºC)	**26**
MLVSS/MLSS	**0.85**
Return Sludge Concentration (mg/L of SS)	**10000**
MLVSS (mg/L)	**2500**
Mean Cell Residence Time (days)	**5**
Peak Flow Factor	**2.5**
Field O_2 Transfer Efficiency	**15%**
F/M Ratio	**0.2-0.35**

Table 4 shows the summary of the designed activated sludge aeration basin. A total of eight tanks were designed, of which only seven would be used at any time. One tank would be in place in case of any redundancies in the system.

Table 4: Summary Design of Activated Sludge Tanks.

Number of Tanks	8 (7 in use)
Capacity per Tank	10.19 mgd
Tank Dimensions	118’x118’x16’- 4”
Number of 8” Diffusers per Tank	1444

Secondary Clarifiers

Table 5 shows the design criteria values used to design the secondary clarifiers for the project. The table shows typical design criteria values for circular secondary clarification tanks and were taken from *Wastewater Engineering* by Metcalf and Eddy, 1991.

Table 5: Design Criteria for Secondary Clarifiers.

Criteria	Acceptable Range	Calculated Value
Surface Overflow Rate ($gal/ft^2 \bullet d$)	400 - 800	629
Weir Overflow Rate (gpd/ft)	<20,000	14,945
Solids Loading Rate ($lbs/solids/day/ft^2$)	12 - 30	21.6
Detention Time (hrs)	≤4	4.0

Table 6 shows the summary of the designed secondary clarifiers. Circular secondary clarifiers were chosen to avoid any sludge build up in the corner of tanks, as can typically be seen in any square shaped clarifiers. A total of 16 circular secondary clarifiers were designed, where of 14 clarifiers would be used at any time and two tanks would be in place to provide mechanical redundancy. The influent flow rate for each tank included the 40% recirculation rate for each clarifier.

Table 6: Summary Design of Circular Secondary Clarifiers.

Number of Tanks	16 (14 in use)
Influent Flow Rate per Tank	7.14 mgd
Recirculation Rate	40%
Tank Diameter	95’
Tank Depth	14’

Pump Stations

A total of four pump stations were designed, where each pump station would serve a battery of four clarifiers. Each clarifier would be served by two Return Activated Sludge (RAS) pumps and two Waste Activated Sludge (WAS) pumps. Only one RAS and WAS pump will be used at any one time, while the other pump will be available to provide for redundancies in the system. Table 7 shows the design criteria used for designing the pump stations.

Table 7: Design Criteria for Pump Stations.

Design Criteria	Return Activated Sludge Pump	Waste Activated Sludge Pump
Total Dynamic Head (ft)	30	29.7
Pump Capacity (gpm)	1240	75

Civil Drawings

The following images were produced using the software AutoCAD 2016. All dimensions are in US customary units. Figure 5 represents an aerial view of the proposed system configuration and site layout. Figures 6-10 contain plan and section views for the activated sludge tanks and secondary clarifiers, and a plan view of the return pump station, respectively.

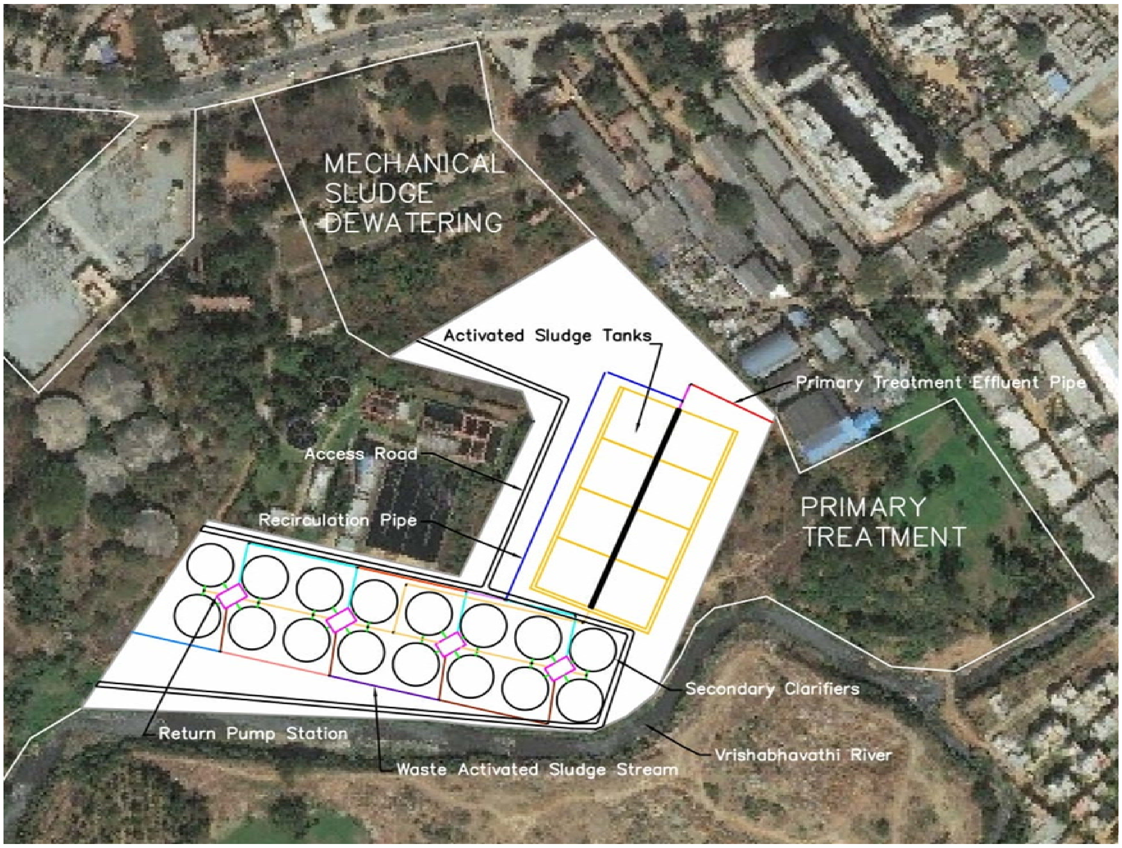

Figure 5: Site Layout & Secondary System Configuration.

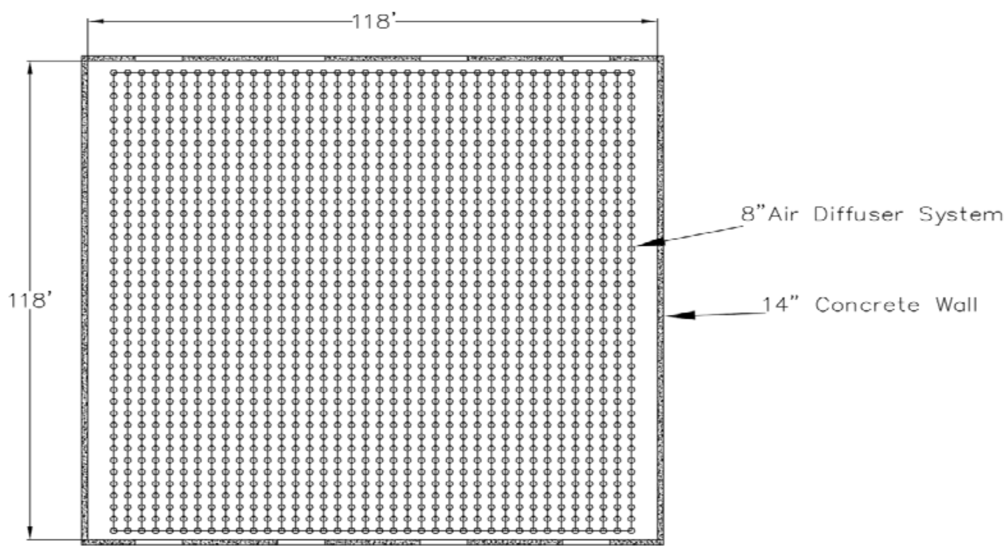

Figure 6: Plan View of Activated Sludge Tank.

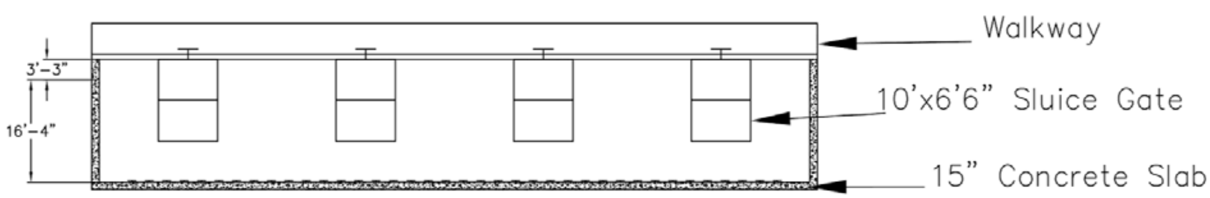

Figure 7: Section View of Activated Sludge Tank.

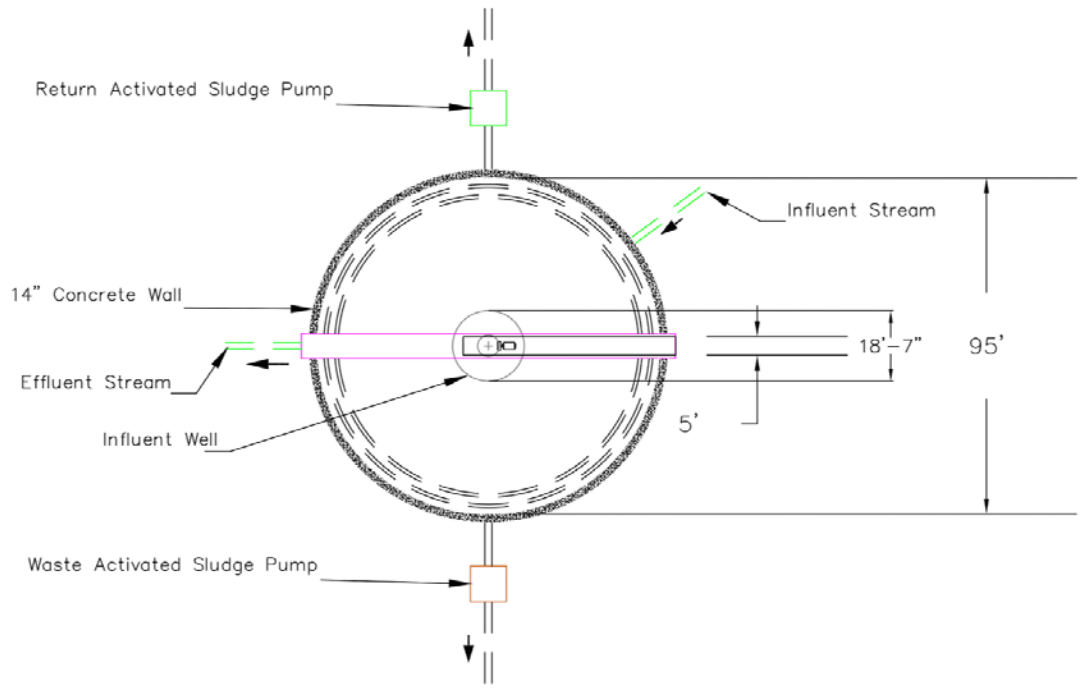

Figure 8: Plan View of Secondary Clarifier.

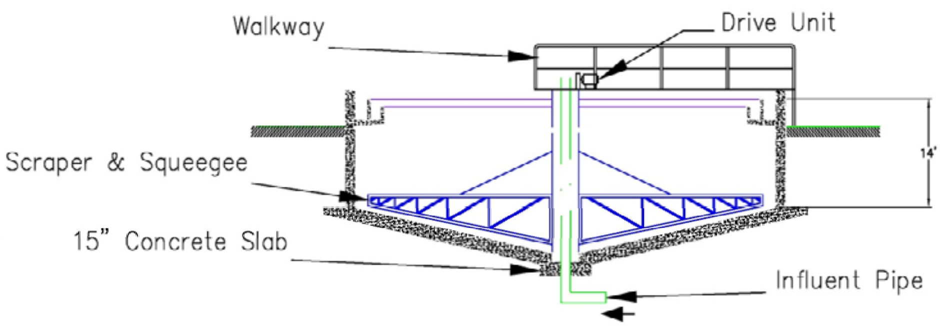

Figure 9: Section View of Secondary Clarifier.

- **Key Features:**
    - Gate valve on each side of each pump
    - Check valve on discharge side of each pump
    - Flow meter on discharge side of each pump for process control
    - Flex connectors at key points to account for any pipe alignment issues
    - Flanged, ductile iron pipes

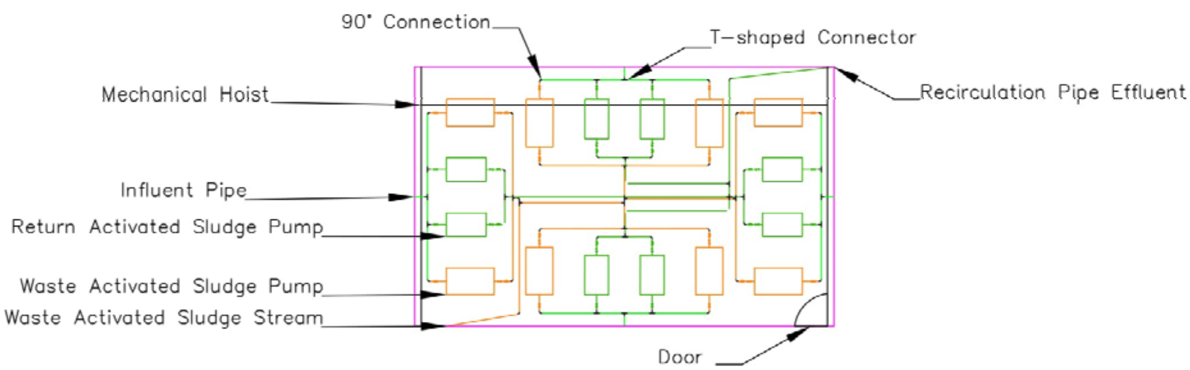

Figure 10: Plan View of Pump Station.

Non-Technical Considerations

For this project, there were a variety of non-technical issues that are important to consider. Listed below are some of the issues considered.

Political Issues

- Bureaucracy

  India has an extremely large bureaucratic system. Getting approval from all of the various authorities could affect the project completion time.

- Public Pressure

  The Bangalore Water Supply and Sewerage Board (BWSSB) and The Government of Karnataka already face a great deal of public pressure due to the increasing freshwater needs, the city's inability to treat the existing sewage flow, and the pollution in the river. The project would also involve deforestation on the 33.2 acres of undeveloped land on the site, which could also be another issue since the city is also known as the "garden city of India".

- Since there is little demand for recycled water in India, the BWSSB and the Government would be apprehensive to invest a great deal of money into an expansion project since there would be a very small Return on Investment (ROI) as compared to a ROI on a toll road project.

- The BWSSB is a separate entity from the Government of Karnataka. This means that they would be responsible to source funding for a portion of the project from external sources such as the World Bank. The central and state governments are only responsible for funding up to 50% of the project costs. The BWSSB will also be responsible for funding any maintenance and operation costs for the project.

Ethical Issues

- Equitable distribution of benefits

  Who would benefit from this project? There is an extremely large need for freshwater for domestic purposes, for agricultural purposes downstream, and for industrial use.

- Development vs. environment

  The project could spark additional growth in the area, which could add stress on the area's infrastructure. The project could also affect the aesthetics of the area. This project will improve the state of the river but will create some odor issues in the area.

Environmental Impact

- Site clearing may disturb wildlife
- Heavy construction produces temporary industrial waste
- Increase water quality of river
- Reduce groundwater overdraft

The benefit to the community of having access to cleaner river water and less groundwater overdraft outweigh the temporary negative impacts related towards waste and habitat removal.

Cost Estimate & Scheduling

In order to complete the cost estimate and construction schedule, first a work-breakdown structure was created for each individual task associated with this project. Once all tasks were defined, quantity take-offs were performed in phases using the AutoCAD drawings. Construction would be phased by constructing two activated sludge tanks, four clarifiers, and one pump station all simultaneously. Once that construction is complete, the next series of two sludge tanks, four clarifiers, and one pump station would begin. This phasing of construction allows the construction team to efficiently use the mechanical equipment available on site. Once all quantities were determined, the *Heavy Construction RSMeans, 2017* textbook was used to attain information regarding the following for each task: crew sizes/number of crews, daily output per crew, and cost rate per unit. The line cost of each item was calculated by multiplying the quantity by the cost rate per unit. The duration of each task was calculated by dividing each quantity by the daily output per crew. A 15% construction contingency was also assumed to account for the lack of information for some parts that the team did not design in details, or the unforeseen soil conditions, or permitting issues. More detailed information regarding the schedule and cost estimate can be found on the sheet included in Appendix A. Table 8 provides a breakdown of the engineer's estimate of the most probable cost in both U.S. dollars and in Indian National Rupees (INR) which was found by converting the total cost in USD.

Table 8: Engineer's Estimate of Most Probable Cost.

Task	Cost (USD)	Cost (INR)
Eight (8) Activated Sludge Tanks	**$21,010,000**	**₹1,353,000,000**
16 Secondary Clarifiers	**$3,080,000**	**₹198,000,000**
Four (4) Return Pump Stations	**$2,100,000**	**₹135,000,000**
General Construction	**$5,100,000**	**₹328,000,000**

Total Cost	**$35,980,000**	**₹2,320,000,000**

- **All costs were obtained from *Heavy Construction Costs with RSMeans Data*, 31st annual edition, 2017**
- **Estimate only includes secondary treatment process**

After communication with a cost-estimator from the wastewater manufacturing company called DN Tanks, the team was told that the final price estimated by the team falls into the acceptable range for the plant of the chosen size. Figure 11 provides a graphical illustration of the duration of each phase of the project.

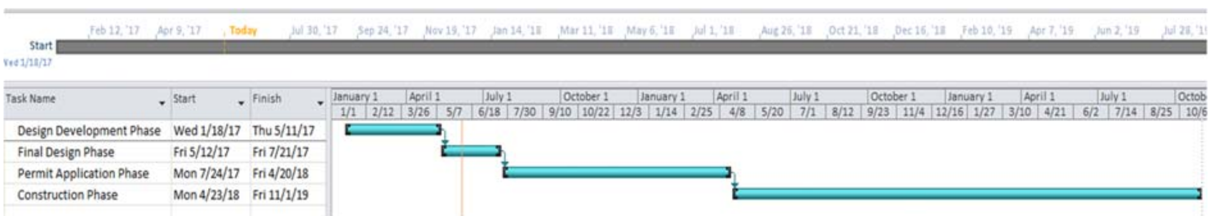

Figure 11: Schedule Breakdown.

Table 9 shows the calculated durations for each phase of the project.

Table 9: Schedule Breakdown for the Project.

Design Development Phase	80 days
Final Design Phase	90 days
Permit Application Phase	6 months
Construction Phase	1 year, 7 months
Total Duration	2 years, 6 months

- **All times assuming construction five days a week, 8:00am - 5:00pm**
- **Weekends and Indian national holidays were accounted for**

Conclusion

Take Aways

This project helped improve the team's skills in designing various secondary treatment processes, choosing the most appropriate solution for the project, and determining the construction scheduling process in different phases. The project also helped develop the team's skills in AutoCAD, Microsoft Excel and Project.

Final Solution

If implemented, this project would give the population of Bangalore access to an additional 71.33 mgd of freshwater. The constructed project would also increase the water quality in the river, while using existing resources, thereby benefiting the entire community. The supply of freshwater will meet the growing demand of water through the year 2036. The tensions created throughout Bangalore regarding the lack of freshwater will be better improved from the proposed design.

References

"About Bwssb | BWSSB - Bangalore Water Supply and Sewerage Board". *www.bwssb.gov.in*. N.p., 2017. Web. 9 Nov. 2016.

"Bangalore Population." *Population.city*. Population.city, 2015. Web. 5 May 2017. <http://population.city/india/bangalore/>.

Hale, Derrick. *Heavy Construction Costs with RSMeans Data*. 31st ed. Rockland: Gordian Group, 2016. Print.

"Study Foresees Spike in City Water Shortage." *The Hindu*. The Hindu, 12 Mar. 2014. Web. 05 June 2017.

Tchobanoglous, George. *Wastewater Engineering Treatment, Disposal, and Reuse*. 3rd ed. N.p.: Metcalf & Eddy, 1972. Print.

Appendix A

Design Parameters and Calculations

Aeration Tank Design	
Given:	
Capacity(mgd)	**71.33**
BOD5 (mg/L)	**140**
Effluent BOD5 (mg/L)	**20**
Temp (degC)	**26**
Given:	
Influent volatile suspended solids	**Negligible**
MLVSS/MLSS	**0.85**
Return Sludge Concentration Xw (mg/L SS)	**10000**
MLVSS (mg/L)	**2500**
Cell Residence Time (days)	**5**
Effluent Biological Solids (mg/L)	**22**
%Biodegradable	**0.65**
BOD5/BODL	**0.68**
Peak Flow	**2.5*avg flow rate**
Biodegradble portion of effluent	14.3
Ultimate BODL	20.31
Effluent BOD5	13.81
Effluent soluble BOD5 escaping treatment	6.19
Treatment efficiency E	
Efficiency of soluble BOD5	95.58
Overall Plant Efficency	85.71
Reactor Volume (mil gallons)	11.46
Depth(m)	5
L:W Ratio	1
Width(m)	36
Length(m)	36
Number of Tanks	8
Volume(m^3)	51840
HRT of Reactor (days)	0.16
in hours	3.86
Yobs	0.46

Px(SS)(lb/day)	43222.47
g of MLVSS/day	3240000
kgs of MLVSS/day	50849.97
QwXw	30134.84
Xw in MLVSS	8500
Qw (m^3/day)	6656
Mass to be wasted(lb/day)	30134.84
Recirculation Rate	0.4
Mass of BODL utilized (lb O2/day)	117060.86
O2 Requirements (lb/day)	64891.34
Assume O2 transfer efficiency	0.15
safety factor for design volume for sizing blowers	2
Air Density (lb/ft^3)	0.08
% by weight of oxygen in air	0.23
Air Requirement (ft^3/day)	1864693.55
	12431290.35
ft^3/min	8632.84
Design Air requirments (ft^3/min)	17265.68
F/M Ratio	0.35
Volumetric Loading(lb BOD5/d/1000ft^3)	54.36
F/M Ratio (lb BOD5/d/lb MLVSS)	0.2-0.35
Organic Loading (lb BOD5/d/1000ft^3)	20-100
	inches
Length of tank (inches)	1377.6
Area (in^2)	1897781.76
Diameter of diffuser (in)	8
Spacing between each diffuser(in)	27
Distance on center(in)	35
Length of pipe (in)	1330
Diffusers in a row	38
Number of rows	38
Number of diffusers	1444
Power (BHP)	68.59

Secondary Clarifier Design		
Required data entry cells		
Calculated cells		
Circular Secondary Clarifier	**Values**	**Units**
Influent flow rate	49,535	**gpm**
Influent flow	71.3	**mgd**
Influent flow	2,972,083	**gph**
MLSS concentration	2,941	**mg/L**
RAS flow rate	19,814	**gpm**
RAS flow rate per clarifier	1,238	**gpm**
RAS flow rate	28.5	**mgd**
RAS flow rate percentage	40.00%	**percent of influent**
Total flow	99.9	**mgd**
Actual Secondary Clarifier Dimensions		
Tank diameter	95	**ft**
Tank depth	14	**ft**
Calculate surface area (per tank)	7,085	**ft2**
Calculate clarifier volume (per tank)	99,185	**ft3**
Calculate clarifier volume (per tank)	741,902	**gal**
Weir length (per tank)	298	**ft**
Number of clarifiers in service	16	
Total secondary clarifier surface area	113,354	**ft2**
Total secondary clarifier volume	1,586,956	**ft3**
Total secondary clarifier volume	11,870,431	**gal**
Total weir length	4,773	**ft**
Calculated surface overflow rate	629	**gal/ft2•d**
		gal/ft2•d
Calculated weir overflow rate	14,945	**gpd/ft**
Calculated solids loading rate	21.6	**lbs/solids/day/ft2**
		lbs/solids/day/ft2
Calculated detention time	4	**hrs**

Appendix B

Construction Cost Estimate and Schedule

2 Activated Sludge Tanks									
#	**Task**	**Duration**	**Quantity**	**Unit**	**Crew**	**Daily Output**	**O & P Cost Rate**	**Line Cost**	**RSMeans Number**
1	Excavation	5.42	18957.795	cy	B-10V	3500	$1.89	$35,830.23	31 23 16.46 - 6000
2	Backfill	0.38	417.5525	cy	B-10L	1110	$1.28	$534.47	31 23 23.14 - 2000
3	Formwork-Slab	2.33	817.21	sf	C-1	350	$7.55	$6,169.94	03 11 13.65 - 3060
4	Pouring-Slab	0.52	1306.8	cy	C-14F	2505	$8.50	$11,107.80	03 30 53.40 - 4950
5	Formwork-Walls	27.77	33323.4	sf	C-2 (2)	1200	$6.95	$231,597.63	03 11 13.85 - 8060
6	Install Ceramic Air Diffuser System	0.15	2	systems	2 Plum	13.41	$511,560.00	$1,023,120.00	46 51 36.10 - 0100
7	Install Sluice Gates	16.00	16	gates	E-20 (2)	1	$154,500.00	$2,472,000.00	35 20 16.26 - 0250
8	Pouring-Walls	14.74	1439.9	cy	C-14D (2)	97.7	$515.00	$741,548.50	03 30 53.40 - 4500
9	Walkways	1.60	816.37	sf	B-24	510	$6.60	$5,388.04	32 06 10.10 - 0400
10	Electrical	3.00	-	-	-	-	-	$685,089.24	Assume 15%
11	Paint and Finishes	0.41	816.37	sf	2 Psst	2000	$1.01	$824.53	09 97 13.23 - 6910
12	Waterproofing	15.26	2746.7	cy	C-1	-	$14.25	$39,140.48	03 05 13.80 - 0050
13	Waterproof Testing	2.00	2	tanks	-	-	-	$0.00	-
Total								**$5,252,350.86**	

4 Secondary Clarifiers									
#	**Task**	**Duration**	**Quantity**	**Unit**	**Crew**	**Daily Output**	**O & P Cost Rate**	**Line Cost**	**RSMeans Number**
1	Excavation	4.20	14693.53	cy	B-10V	3500	$1.89	$27,770.77	31 23 16.46 - 6000
2	Backfill	1.13	1250.85	cy	B-10L	1110	$1.28	$1,601.09	31 23 23.14 - 2000

3	Install 24" effluent pipes	2.76	276.415	ft	B-14	100	$55.50	$15,341.03	33 41 13.60 - 1080
4	Install Mechanical Equipment	4.00	-	-	-	-	-	$225,622.61	-
5	Formwork-Slab	7.06	4939.43	sf	C-1 (2)	700	$7.55	$37,292.70	03 11 13.65 - 3060
6	Pouring-Slab	0.51	1288.12	cy	C-14F	2505	$8.50	$10,949.02	03 30 53.40 - 4950
7	Formwork-Walls	27.52	33028.63	sf	C-2 (2)	1200	$6.95	$229,548.98	03 11 13.85 - 8060
8	Pouring-Walls	3.64	177.9	cy	C-14D	48.85	$515.00	$91,618.50	03 30 53.40 - 4500
9	Walkways	2.20	1120.8	sf	B-24	510	$6.60	$7,397.28	32 06 10.10 - 0400
10	Electrical	6.00	-	-	-	-	-	$100,374.72	Assume 15%
11	Paint and Finishes	0.56	1120.8	sf	2 Psst	2000	$1.01	$1,132.01	09 97 13.23 - 6910
12	Waterproofing	4.16	1466.02	cy	C-1	-	$14.25	$20,890.79	03 05 13.80 - 0050
13	Waterproof Testing	4.00	4	tanks	-	-	-	$0.00	-
Total								**$769,539.49**	

1 Pump Station									
#	**Task**	**Duration**	**Quantity**	**Unit**	**Crew**	**Daily Output**	**O & P Cost Rate**	**Line Cost**	**RSMeans Number**
1	Excavation	0.05	158.6225	cy	B-10V	3500	$1.89	$299.80	31 23 16.46 - 6000
2	Formwork- Slab	0.99	213.88	sf	C-1	215	$13.55	$2,898.07	03 11 13.65 - 2000
3	Formwork-Walls	5.86	3514.15	sf	C-2	600	$6.95	$24,423.34	03 11 13.85 - 8060
4	Formwork- Roof	0.66	142.58	sf	C-1	215	$13.55	$1,931.96	03 11 13.65 - 2000

5	Pour Slab	0.86	78.73	cy	C-14E	92	$222.00	$17,478.06	03 30 53.40 - 4700
6	Pour Walls	2.71	73.87	cy	C-14D	27.26	$810.00	$59,834.70	03 30 53.40 - 4250
7	Pour Roof	0.86	52.49	cy	C-14E	60.75	$264.00	$13,857.36	03 30 53.40 - 4650
8	Backfill	0.11	131.27	cy	B-10L	1150	$1.28	$168.03	31 23 23.14 - 2000
9	Install Pumps	1.00	16	pumps	-	-	$16,176.26	$258,820.28	-
10	Install 12" WAS pipes	3.82	183.4305	ft	Q-3	48	$217.00	$39,804.42	22 13 16.20 - 2260
11	Install 10" RAS pipes	2.94	158.52	ft	Q-3	54	$164.00	$25,997.28	22 13 16.20 - 2240
12	Install 24" effluent from clarifier pipes	0.90	89.6425	ft	B-14	100	$55.50	$4,975.16	33 41 13.60 - 1080
14	Install Mechanical Hoist	1.00	1	hoist	-	-	$2,850.00	$2,850.00	41 22 23.10 - 2200
15	Electrical	1.00	-	-	-	-	-	$68,301.09	Assume 15%
16	Paint and Finishes	0.99	1982.34	sf	2 Psst	2000	$1.01	$2,002.16	09 97 13.23 - 6910
17	Commissioning & Testing	1.00	1	station	-	-	-	$0.00	-
	Total							**$523,641.71**	

General Construction

#	Task	Duration	Quantity	Unit	Crew	Daily Output	O & P Cost Rate	Line Cost	RSMeans Number
1	Site Clean Up	0.33	16.47	acre	B-10M	50	$60.00	$988.20	31 11 10.10 - 9030
2	Mobilization and Erosion Control Systems	0.50	2	cranes	1 Eqhv	4	$169.00	$338.00	01 54 36.50 - 1700
3	Equipment Setup	2.00	1	trailer	2 Skwk	0.5	$35,700.00	$35,700.00	01 52 13.20 - 0500
4	Order Concrete Piping	45.00	4240.97	ft	-	-	-	$0.00	-
5	Order Mechanical Equipment- Activated Sludge Tanks	30.00	8	systems	-	-	-	$0.00	-
6	Fabricate Sluice	128.00	64	gates	4	0.5	-	$0.00	-

	Gates				crews				
7	Order Mechanical Equipment-Secondary Clarifiers	30.00	16	systems	-	-	-	$0.00	-
8	Order Pump Station Piping	25.00	1726.372	ft	-	-	-	$0.00	-
9	Order Pumps	25.00	64	pumps	-	-	-	$0.00	-
10	Order Mechanical Hoist	20.00	4	hoist	-	-	-	$0.00	-
11	Pipework-Trenching	7.63	4120.24	cy	B-12B	540	$4.11	$16,934.19	31 23 16.13 - 0130
12	Install 96" inflow pipe	7.70	184.77	ft	B-13B	24	$625.00	$115,481.25	33 41 13.60 - 2140
13	Install 96" total inflow pipe	2.42	58.08	ft	B-13B	24	$625.00	$36,300.00	33 41 13.60 - 2140
14	Install 60" recirculation pipes	14.83	711.65	ft	B-13B	48	$270.00	$192,145.50	33 41 13.60 - 2090
15	Install 30" recirculation pipes	8.45	743.95	ft	B-13	88	$94.00	$69,931.30	33 41 13.60 - 2050
16	Install 42" downstream recirculation pipe	3.21	231	ft	B-13B	72	$160.00	$36,960.00	33 41 13.60 - 2070
17	Install 48" downstream recirculation pipe	1.28	81.74	ft	B-13B	64	$189.00	$15,448.86	33 41 13.60 - 2080
18	Install 18" pipe to digester	1.60	231	ft	B-14	144	$42.50	$9,817.50	33 41 13.60 - 1060
19	Install 24" pipe to digester	2.31	231	ft	B-14	100	$55.50	$12,820.50	33 41 13.60 - 1080

20	Install 30" pipe to digester	2.11	186.05	ft	B-13	88	$94.00	$17,488.70	33 41 13.60 - 2050
21	Install 12" digester pipe	3.12	623.77	ft	B-14	200	$28.00	$17,465.56	33 41 13.60 - 1040
22	Install 96" aeration basin to clarifier pipe	19.96	957.96	ft	B-13B (2)	48	$625.00	$598,725.00	33 41 13.60 - 2140
23	Pipework-Backfill	1.25	1373.41	cy	B-10L	1100	$1.28	$1,757.96	31 23 23.14 - 2000
24	Topsoil Stripping & Stockpiling	2.72	8161.97	cy	B-10M	3000	$1.00	$8,161.97	31 14 13.23 - 0200
25	Electrical	8.00	-	-	-	-	-	$195,634.18	Assume 15%
26	Roads	0.95	3500	sy	B-25	3700	$18.30	$64,050.00	32 11 26.13 - 0550
27	Finish Grade	7.09	63124.67	sy	B-11L	8900	$0.21	$13,256.18	31 22 16.10 - 3300
28	Commissioning & Testing	30.00	-	-	-	-	-	553639.8052	Assume 2%
29	Landscaping	7.00	-	-	-	-	-	$31,810.44	01 11 31.30 - 0800
30	Site Clean Up	8.24	16.47	acre	B-84	2	$525.00	$8,646.75	31 13 13.10 - 1020
Total								**$2,053,501.84**	
Sub Total								**$28,235,630.07**	

Project Schedule			
Task Name	Duration	Start	Finish
Design Development Phase	80 days	Wed 1/18/17	Thu 5/11/17
Final Design Phase	50 days	Fri 5/12/17	Fri 7/21/17
Permit Application Phase	180 days	Wed 1/18/17	Wed 10/4/17
Site Clean Up	1 day	Thu 10/5/17	Thu 10/5/17
Mobilization and Erosion Control Systems	1 day	Fri 10/6/17	Fri 10/6/17
Equipment Setup	2 days	Mon 10/9/17	Tue 10/10/17
Order Concrete Piping	45 days	Mon 7/24/17	Tue 9/26/17
Order Pump Station Piping	25 days	Mon 7/24/17	Tue 8/29/17
Order Mechanical Equipment-Activated Sludge Tanks	30 days	Mon 7/24/17	Tue 9/5/17
Fabricate Sluice Gates	128 days	Fri 5/12/17	Mon 11/13/17
Order Mechanical Equipment-Secondary Clarifiers	30 days	Mon 7/24/17	Tue 9/5/17
Order Pumps	25 days	Mon 7/24/17	Tue 8/29/17
Order Mechanical Hoist	20 days	Mon 7/24/17	Mon 8/21/17
Excavation	6 days	Wed 10/11/17	Wed 10/18/17
Formwork-Slab	3 days	Thu 10/19/17	Mon 10/23/17
Pouring-Slab	1 day	Tue 10/24/17	Tue 10/24/17
Formwork-Walls	28 days	Wed 10/25/17	Fri 12/1/17
Install Ceramic Air Diffuser System	1 day	Mon 12/4/17	Mon 12/4/17
Install Sluice Gates	16 days	Mon 12/4/17	Tue 12/26/17
Pouring-Walls	15 days	Wed 12/27/17	Wed 1/17/18
Backfill	1 day	Thu 1/18/18	Thu 1/18/18
Walkways	2 days	Fri 1/19/18	Mon 1/22/18
Electrical	3 days	Tue 1/23/18	Thu 1/25/18
Paint and Finishes	1 day	Mon 1/29/18	Mon 1/29/18
Waterproofing	16 days	Tue 10/24/17	Tue 11/14/17
Waterproof Testing	2 days	Tue 1/30/18	Wed 1/31/18
Excavation	5 days	Wed 10/11/17	Tue 10/17/17
Install 24" effluent pipes	3 days	Wed 10/18/17	Fri 10/20/17
Formwork-Slab	8 days	Mon 10/23/17	Wed 11/1/17
Pouring-Slab	1 day	Thu 11/2/17	Thu 11/2/17
Formwork-Walls	28 days	Fri 11/3/17	Tue 12/12/17
Pouring-Walls	4 days	Wed 12/13/17	Mon 12/18/17
Backfill	2 days	Tue 12/19/17	Wed 12/20/17
Install Mechanical Equipment	4 days	Tue 12/19/17	Fri 12/22/17
Walkways	3 days	Tue 12/26/17	Thu 12/28/17
Electrical	6 days	Fri 12/29/17	Mon 1/8/18
Paint and Finishes	1 day	Tue 1/9/18	Tue 1/9/18
Waterproofing	5 days	Thu 11/2/17	Wed 11/8/17
Waterproof Testing	4 days	Wed 1/10/18	Mon 1/15/18
Excavation	1 day	Wed 10/11/17	Wed 10/11/17
Formwork- Slab	1 day	Thu 10/12/17	Thu 10/12/17
Pour Slab	1 day	Fri 10/13/17	Fri 10/13/17
Formwork- Walls	6 days	Mon 10/16/17	Mon 10/23/17
Pour Walls	3 days	Tue 10/24/17	Thu 10/26/17
Install Pumps	1 day	Fri 10/27/17	Fri 10/27/17

Install 12" WAS pipes	4 days	Mon 10/30/17	Thu 11/2/17
Install 10" RAS pipes	3 days	Fri 11/3/17	Tue 11/7/17
Install 24" effluent from clarifier pipes	1 day	Wed 11/8/17	Wed 11/8/17
Formwork- Roof	1 day	Thu 11/9/17	Thu 11/9/17
Pour Roof	1 day	Fri 11/10/17	Fri 11/10/17
Backfill	1 day	Mon 11/13/17	Mon 11/13/17
Install Mechanical Hoist	1 day	Mon 11/13/17	Mon 11/13/17
Electrical	1 day	Tue 11/14/17	Tue 11/14/17
Paint and Finishes	1 day	Wed 11/15/17	Wed 11/15/17
Commissioning & Testing	1 day	Thu 11/16/17	Thu 11/16/17
Excavation	6 days	Thu 2/1/18	Thu 2/8/18
Formwork-Slab	3 days	Fri 2/9/18	Tue 2/13/18
Pouring-Slab	1 day	Wed 2/14/18	Wed 2/14/18
Formwork-Walls	28 days	Thu 2/15/18	Mon 3/26/18
Install Ceramic Air Diffuser System	1 day	Tue 3/27/18	Tue 3/27/18
Install Sluice Gates	16 days	Tue 3/27/18	Wed 4/18/18
Pouring-Walls	15 days	Thu 4/19/18	Fri 5/11/18
Backfill	1 day	Mon 5/14/18	Mon 5/14/18
Walkways	2 days	Tue 5/15/18	Wed 5/16/18
Electrical	3 days	Thu 5/17/18	Mon 5/21/18
Paint and Finishes	1 day	Tue 5/22/18	Tue 5/22/18
Waterproofing	16 days	Wed 2/14/18	Wed 3/7/18
Waterproof Testing	2 days	Wed 5/23/18	Thu 5/24/18
Excavation	5 days	Tue 1/16/18	Mon 1/22/18
Install 24" effluent pipes	3 days	Tue 1/23/18	Thu 1/25/18
Formwork-Slab	8 days	Mon 1/29/18	Wed 2/7/18
Pouring-Slab	1 day	Thu 2/8/18	Thu 2/8/18
Formwork-Walls	28 days	Fri 2/9/18	Tue 3/20/18
Pouring-Walls	4 days	Wed 3/21/18	Mon 3/26/18
Backfill	2 days	Tue 3/27/18	Wed 3/28/18
Install Mechanical Equipment	4 days	Tue 3/27/18	Mon 4/2/18
Walkways	3 days	Tue 4/3/18	Thu 4/5/18
Electrical	6 days	Fri 4/6/18	Fri 4/13/18
Paint and Finishes	1 day	Mon 4/16/18	Mon 4/16/18
Waterproofing	5 days	Thu 2/8/18	Wed 2/14/18
Waterproof Testing	4 days	Tue 4/17/18	Fri 4/20/18
Excavation	1 day	Fri 11/17/17	Fri 11/17/17
Formwork- Slab	1 day	Mon 11/20/17	Mon 11/20/17
Pour Slab	1 day	Tue 11/21/17	Tue 11/21/17
Formwork- Walls	6 days	Wed 11/22/17	Wed 11/29/17
Pour Walls	3 days	Thu 11/30/17	Mon 12/4/17
Install Pumps	1 day	Tue 12/5/17	Tue 12/5/17

Install 12" WAS pipes	4 days	Wed 12/6/17	Mon 12/11/17
Install 10" RAS pipes	3 days	Tue 12/12/17	Thu 12/14/17
Install 24" effluent from clarifier pipes	1 day	Fri 12/15/17	Fri 12/15/17
Formwork- Roof	1 day	Mon 12/18/17	Mon 12/18/17
Pour Roof	1 day	Tue 12/19/17	Tue 12/19/17
Backfill	1 day	Wed 12/20/17	Wed 12/20/17
Install Mechanical Hoist	1 day	Wed 12/20/17	Wed 12/20/17
Electrical	1 day	Thu 12/21/17	Thu 12/21/17
Paint and Finishes	1 day	Fri 12/22/17	Fri 12/22/17
Commissioning & Testing	1 day	Tue 12/26/17	Tue 12/26/17
Excavation	6 days	Fri 5/25/18	Fri 6/1/18
Formwork-Slab	3 days	Mon 6/4/18	Wed 6/6/18
Pouring-Slab	1 day	Thu 6/7/18	Thu 6/7/18
Formwork-Walls	28 days	Fri 6/8/18	Tue 7/17/18
Install Ceramic Air Diffuser System	1 day	Wed 7/18/18	Wed 7/18/18
Install Sluice Gates	16 days	Wed 7/18/18	Wed 8/8/18
Pouring-Walls	15 days	Thu 8/9/18	Wed 8/29/18
Backfill	1 day	Thu 8/30/18	Thu 8/30/18
Walkways	2 days	Fri 8/31/18	Mon 9/3/18
Electrical	3 days	Tue 9/4/18	Thu 9/6/18
Paint and Finishes	1 day	Fri 9/7/18	Fri 9/7/18
Waterproofing	16 days	Thu 6/7/18	Thu 6/28/18
Waterproof Testing	2 days	Mon 9/10/18	Tue 9/11/18
Excavation	5 days	Mon 4/23/18	Fri 4/27/18
Install 24" effluent pipes	3 days	Mon 4/30/18	Fri 5/4/18
Formwork-Slab	8 days	Mon 5/7/18	Wed 5/16/18
Pouring-Slab	1 day	Thu 5/17/18	Thu 5/17/18
Formwork-Walls	28 days	Fri 5/18/18	Tue 6/26/18
Pouring-Walls	4 days	Wed 6/27/18	Mon 7/2/18
Backfill	2 days	Tue 7/3/18	Wed 7/4/18
Install Mechanical Equipment	4 days	Tue 7/3/18	Fri 7/6/18
Walkways	3 days	Mon 7/9/18	Wed 7/11/18
Electrical	6 days	Thu 7/12/18	Thu 7/19/18
Paint and Finishes	1 day	Fri 7/20/18	Fri 7/20/18
Waterproofing	5 days	Thu 5/17/18	Wed 5/23/18
Waterproof Testing	4 days	Mon 7/23/18	Thu 7/26/18
Excavation	1 day	Wed 12/27/17	Wed 12/27/17
Formwork- Slab	1 day	Thu 12/28/17	Thu 12/28/17
Pour Slab	1 day	Fri 12/29/17	Fri 12/29/17
Formwork- Walls	6 days	Tue 1/2/18	Tue 1/9/18
Pour Walls	3 days	Wed 1/10/18	Fri 1/12/18
Install Pumps	1 day	Mon 1/15/18	Mon 1/15/18
Install 12" WAS pipes	4 days	Tue 1/16/18	Fri 1/19/18
Install 10" RAS pipes	3 days	Mon 1/22/18	Wed 1/24/18
Install 24" effluent from clarifier pipes	1 day	Thu 1/25/18	Thu 1/25/18
Formwork- Roof	1 day	Mon 1/29/18	Mon 1/29/18
Pour Roof	1 day	Tue 1/30/18	Tue 1/30/18

Backfill	1 day	Wed 1/31/18	Wed 1/31/18
Install Mechanical Hoist	1 day	Wed 1/31/18	Wed 1/31/18
Electrical	1 day	Thu 2/1/18	Thu 2/1/18
Paint and Finishes	1 day	Fri 2/2/18	Fri 2/2/18
Commissioning & Testing	1 day	Mon 2/5/18	Mon 2/5/18
Excavation	6 days	Wed 9/12/18	Wed 9/19/18
Formwork-Slab	3 days	Thu 9/20/18	Mon 9/24/18
Pouring-Slab	1 day	Tue 9/25/18	Tue 9/25/18
Formwork-Walls	28 days	Wed 9/26/18	Fri 11/2/18
Install Ceramic Air Diffuser System	1 day	Mon 11/5/18	Mon 11/5/18
Install Sluice Gates	16 days	Mon 11/5/18	Mon 11/26/18
Pouring-Walls	15 days	Tue 11/27/18	Mon 12/17/18
Backfill	1 day	Tue 12/18/18	Tue 12/18/18
Walkways	2 days	Wed 12/19/18	Thu 12/20/18
Electrical	3 days	Fri 12/21/18	Tue 12/25/18
Paint and Finishes	1 day	Wed 12/26/18	Wed 12/26/18
Waterproofing	16 days	Tue 9/25/18	Tue 10/16/18
Waterproof Testing	2 days	Wed 10/17/18	Thu 10/18/18
Excavation	5 days	Thu 12/27/18	Wed 1/2/19
Install 24" effluent pipes	3 days	Thu 1/3/19	Mon 1/7/19
Formwork-Slab	8 days	Tue 1/8/19	Thu 1/17/19
Pouring-Slab	1 day	Fri 1/18/19	Fri 1/18/19
Formwork-Walls	28 days	Mon 1/21/19	Wed 2/27/19
Pouring-Walls	4 days	Thu 2/28/19	Tue 3/5/19
Backfill	2 days	Wed 3/6/19	Thu 3/7/19
Install Mechanical Equipment	4 days	Wed 3/6/19	Mon 3/11/19
Walkways	3 days	Tue 3/12/19	Thu 3/14/19
Electrical	6 days	Fri 3/15/19	Fri 3/22/19
Paint and Finishes	1 day	Mon 3/25/19	Mon 3/25/19
Waterproofing	5 days	Fri 1/18/19	Thu 1/24/19
Waterproof Testing	4 days	Tue 3/26/19	Fri 3/29/19
Excavation	1 day	Tue 2/6/18	Tue 2/6/18
Formwork- Slab	1 day	Wed 2/7/18	Wed 2/7/18
Pour Slab	1 day	Thu 2/8/18	Thu 2/8/18
Formwork- Walls	6 days	Fri 2/9/18	Fri 2/16/18
Pour Walls	3 days	Mon 2/19/18	Wed 2/21/18
Install Pumps	1 day	Thu 2/22/18	Thu 2/22/18
Install 12" WAS pipes	4 days	Fri 2/23/18	Wed 2/28/18
Install 10" RAS pipes	3 days	Thu 3/1/18	Mon 3/5/18
Install 24" effluent from clarifier pipes	1 day	Tue 3/6/18	Tue 3/6/18
Formwork- Roof	1 day	Wed 3/7/18	Wed 3/7/18
Pour Roof	1 day	Thu 3/8/18	Thu 3/8/18

Backfill	1 day	Fri 3/9/18	Fri 3/9/18
Install Mechanical Hoist	1 day	Fri 3/9/18	Fri 3/9/18
Electrical	1 day	Mon 3/12/18	Mon 3/12/18
Paint and Finishes	1 day	Tue 3/13/18	Tue 3/13/18
Commissioning & Testing	1 day	Wed 3/14/18	Wed 3/14/18
Trenching	8 days	Fri 10/19/18	Tue 10/30/18
Lay Concrete Pipes	73 days	Wed 10/31/18	Fri 2/8/19
Backfill-Pipes	2 days	Mon 2/11/19	Tue 2/12/19
Strip Topsoil	3 days	Wed 2/13/19	Fri 2/15/19
Finish Grade	8 days	Mon 2/18/19	Wed 2/27/19
Roads	1 day	Thu 2/28/19	Thu 2/28/19
Commissioning & Testing	30 days	Wed 2/13/19	Tue 3/26/19
Landscaping	7 days	Wed 3/27/19	Thu 4/4/19
Site Clean Up	9 days	Fri 4/5/19	Wed 4/17/19