

Engineering Management

Field Project

Operational Performance of Sedimentation Basins

By

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EXECUTIVE SUMMARY

ABC's Generating Station has low volume waste treatment ponds (LVWTP) that receive flow from plant floor drains, bottom ash overflow, boiler blowdown and equipment leaks. Bottom ash overflow makes up the majority of the influent to the LVWTP. The bottom ash overflow is also the primary source of solids settlement in the ponds. Approximately 7,000 cubic yards of solids are deposited in the ponds each year. The steep side slope of the pond berms, along with the inability to effectively dewater the settled solids makes periodic sediment removal a very difficult and costly operation.

A consulting firm was hired to design and oversee construction of a sedimentation basin that would remove the majority of sediment out of the waste stream before entering the treatment ponds. Two concrete basins were constructed with 50' x 20' at the bottom with 50' of ramp to access during cleaning.

The purpose of this paper is to summarize design and construction of the basins as well as testing that was conducted to determine how well the sediment basins perform. The basin testing was conducted on April 20, 2012. The waste flow was sampled for TSS upstream of the sediment basins and downstream of the basins in order to reach a percentage of TSS removed by the basins. Based on the April 20, 2012, testing, the sedimentation basins reduced the amount of TSS in the waste stream by 53%. For the test taken on April 20, the incoming TSS was 17.75 mg/L and the outgoing TSS was 9.5 mg/L.

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1.0 INTRODUCTION

ABC's Generating Station has low volume waste treatment ponds (LVWTP) that receive flow from plant floor drains, bottom ash overflow, boiler blowdown and equipment leaks. The first flush of storm water from the same area is also diverted to the LVWTP pond. The existing LVWTP consists of four holding cells that settle out the solids as well as treat the water for pH and aluminum content. The existing ponds are shown in Figure 1.1. The ponds have become ineffective due to high solids content as shown in Figure 1.2 and 1.3. The steep side slopes and the inability to effectively dewater solids has become an unnecessary operational cost for the plant. The plant currently utilizes the services of a subcontractor using trucks to vacuum out the solids and transport them to a disposal facility.



Fig 1.1 Existing Low Volume Waste Treatment Ponds



Figure 1.2 Existing Active Pond Cell



Figure 1.3 Existing Inactive Pond Cell

Consulting Firm was hired to design and oversee construction of sedimentation basins that would remove the majority of sediment out of the waste stream before entering the treatment ponds. Construction of the sedimentation basins was completed in October of 2011. This paper evaluates the design and the effectiveness of the sedimentation basins that were constructed in addition to providing a brief summary of construction of the basins.

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2.0 LITERATURE REVIEW

A literature review was conducted to get a basis for designing removal of the type of material that would be treated at the sediment basins and how it is formed at the power plant. The science of how the sediment will be removed from the waste stream was studied. A review of other technologies that would be available for TSS removal was also conducted. Finally, literature was reviewed to determine if others have attempted to quantify the success of sedimentation basins.

2.1 Plant Background

A bottom ash hopper is a large rectangular-shaped vessel used for the temporary collection and storage of bottom ash between the bottom of a boiler and a sluice system for eventual disposal. It is a refractory-lined steel structure, free standing, its only connection to the boiler being a water seal trough. This trough, which is continuous around the upper periphery of the hopper, allows the boiler to move freely in relation to the hopper. It allows for plus and minus boiler pressure, temperature expansion in all directions, sag, and minor construction differences. The trough is supplied with enough water to maintain a constant seal at a depth great enough to contain the boiler pressure at a low water temperature. Periodically, additional water is added to the trough to flush it of all sediment. The flushing can be manual or automatically operated, but should be done often enough to prevent any accumulation of material. With a completely automatic operating system, the flushing is normally activated once each operating cycle for a period of 5 to 10 minutes. Most systems are designed to operate three times per day. Flushing can be accomplished by agitation overboarding the excess water or preferably by draining the excess flushing water from the bottom of the trough. (Williams, 1983) This system of water and pumps overflows these basins and falls to the ground where it flows to drains on the ground and eventually gets treated at the waste treatment ponds.

2.2 Wastewater Background

A background of the characteristics of the general term “wastewater” is important to understand. An understanding of physical, chemical, and biological characteristics of wastewater is very important in design, operation, and management of wastewater. The nature of wastewater includes physical, chemical and biological characteristics which depend on the water usage in the community, the industrial and commercial contributions, weather, and infiltration/inflow. (Lee, 2007)

This project does not have a lot of the normal biological and chemical characteristics that would be found in residential wastewater treatment. However, most of the information and design of wastewater treatment stems from this type of wastewater. This project is focused on reducing the amount of solids in the wastewater stream.

Solids comprise matter that is suspended or dissolved in water. Solids are divided into several different fractions and their concentrations provide useful information for characterization of wastewater and control of treatment processes. (Lee, 2007)

2.2.1 Total Solids

Total solids (TS) is the sum of total suspended solids (TSS) and total dissolved solids (TDS). Total solids is the material left in the evaporation dish after it has dried for at least one hour or overnight in an oven at 103°C to 105°C and is calculated according to Standard Methods (Lee, 2007)

$$\text{Mg TS/L} = (A-B) \times 1000$$

Where A = weight of dried residue plus dish, mg

B = weight of dish, mg

1000 = conversion of 1000 mL/L

2.2.2 Total Suspended Solids

Total suspended solids (TSS) are referred to as a nonfilterable residue. The TSS standards for effluents are usually set at 30 mg/L and 12mg/L. (Lee, 2007). As a part of the National Pollution Discharge Elimination System (NPDES) permit for the ABC Generating Station, they are not allowed to exceed 30 mg/L before discharging to the River. TSS is determined by filtering a well-mixed sample through a 0.2 micron pore size, 24 MM diameter membrane; the membrane filter is placed in a Gooch crucible, and the residue retained on the filter is dried in an oven for at least one hour at a constant weight at 103°C to 105°C (Lee, 2007) It is calculated at:

$$\text{Mg TSS/L} = (C - D) \times 1000$$

Where A = weight of filter and crucible plus dried residue, mg

B = weight of filter and crucible, mg

1000 = conversion of 1000 mL/L

2.2.3 Settleable Solids

Settleable solids is the term applied to a material settling out of suspension within a defined time. It may include floating material. (Lee, 2007)

2.2.4 Temperature

Temperature and solids content in wastewater are very important factors for wastewater treatment processes. Temperature affects chemical reaction and biological activities. Solids, such as total suspended solids (TSS), volatile suspended solids (VSS), and settleable solids affect the operation and sizing of treatment units. (Lee, 2007)

2.2.5 Chemical Constituents of Wastewater

The dissolved and suspended solids in wastewater contain organic and inorganic material. For the purposes of this paper the organic constituents will be ignored although it is likely present in the wastewater that is ultimately treated at the plants primary wastewater treatment pond. The sediment basins will not be expected to remove any of the organic material.

2.3 Types of Grit Chambers (Sedimentation Basins)

Grit originates from domestic wastes, stormwater runoff, industrial wastes, pumpage from excavations and groundwater seepage. It consists of inert inorganic material such as sand, cinders, rocks, gravel and in our case coal fines. These substances can promote excessive wear of mechanical equipment and sludge pumps and clog pipes. (Lee, 2007)

Composition of grit varies widely, with moisture content ranging from 13 to 63 percent, and volatile content ranging from 1 to 56 percent. The specific gravity of clean grit particles may be as high as 2.7 and as low as 1.3. The bulk density of grit is about 100 lb/ft³. (Williams, 1983)

Grit chambers should be provided for all wastewater treatment plants, and are used on systems required for plants receiving sewage containing substantial amount of grit. Grit chambers are usually installed ahead of pumps. (Lee, 2007)

Generally an inorganic solid that is considerably denser than water can be removed with a grit chamber. A grit chamber works best when inlet flow is uniform. This is especially critical for a grit chamber because, if the flow is too large, grit will not be removed, and if the flow is too small, organic solids will settle with the grit, causing odors and making disposal more expensive. (Roberts, 2007) Odor and organic materials should not be a problem for our operations because they are not produced or treated in excess at the plant. Grit chambers for plants treating wastewater commonly have three types of grit settling chambers: hand cleaned, mechanically cleaned, and aerated or vortex-type de-gritting units. The chambers can be square, rectangular, or circular. A velocity of 1 ft/s is commonly used to separate grit from the organic material.

Grit chambers are commonly constructed as fairly shallow longitudinal channels to catch high specific gravity grit (1.65). The units are designed to maintain a velocity closest to 1.0 ft/s and to provide sufficient time for the grit particle to settle to the bottom of the chamber. (Lee, 2007)

2.3.1 Longitudinal Grit Chamber

The velocity of flow through a longitudinal grit chamber should be 0.5 to 1.0 ft/s. The detention time in a longitudinal grit chamber should be ½ to 1 minute. In order to limit velocity variations, an equalization basin can be used. (Roberts, 2007) The area required and expense to construct an equalization basin was not considered feasible for our design and therefore was not included.

2.3.2 Centrifugal Grit Chamber

A centrifugal grit chamber typically has a submerged tangential side entrance pipe and a surface exit pipe. The tangential velocity forces the solids to the walls and then to the bottom for removal from a centrally located bottom exit pipe. The slower moving solids in the center of the basin also will settle. The basin should have a surface area of approximately 2,000 gpd/ft² and the lower side slopes should be at least 60° from the horizontal. (Roberts, 2007)

2.3.3 Aerated Grit Chamber

The addition of coarse bubbles to a grit chamber will reduce the specific gravity of the wastewater so that the settling velocity of the grit is increased. The organic solids will tend to be suspended by the air bubbles and will not settle. The air flow should be adjustable or sized so that the water flow across the bottom is approximately 1 to 2 ft/s so that the grit is washed but not suspended. The total hydraulic detention time should be 5 to 10 min. and the air flow approximately 3 ft³/min/lf of tank width. (Roberts, 2007)

2.4 Sedimentation

Sedimentation is the process of removing solid particles heavier than water by gravity settling. It is the oldest and most widely used unit operation in water and wastewater treatments. The terms sedimentation, settling, and clarification are used interchangeably. The unit sedimentation basin may also be referred to as a sedimentation tank, clarifier, settling basin, or settling tank. (Lee, 2007)

In wastewater treatment, sedimentation is used to remove both inorganic and organic materials which are settleable in continuous-flow conditions. Based on the solids concentration and tendency of particle interaction, there are four types of settling which may occur in wastewater settling operations. The four categories are discrete, flocculent, hindered and compression settlings. They are known as types 1, 2, 3 and 4 sedimentation, respectively. (Eckenfelder, 2007)

This project was designed around the Discrete Particle Sedimentation and therefore it will be the only one described.

2.4.1 Discrete Particle Sedimentation (Type 1)

The plain sedimentation of discrete spherical particles, described by Newton's law, can be applied to grit removal in grit chambers and sedimentation tanks. In discrete settling, the particle maintains its individuality and does not change in size, shape, or density during the settling process. Particle settling, or sedimentation, may be described for a singular particle by the Newton equation for terminal settling velocity of a spherical particle. (Eckenfelder, 2009) Knowledge of this velocity is basic in the design and performance of a sedimentation basin.

The rate at which discrete particles will settle in a fluid of constant temperature is given by the equation:

$$V = [(4g (\rho_s - \rho) d) \ / \ (3 C_d \rho)]^{0.5}$$

where V = terminal settling velocity

g = gravitational constant

ρ_s = mass density of the particle

ρ = mass density of the fluid

d = particle diameter

C_d = Coefficient of drag (dimensionless)

The terminal settling velocity is derived by equating the drag, buoyant, and gravitational forces acting on the particle. At low settling velocities, the equation is not dependent on the shape of the particle and most sedimentation processes are designed so as to remove small particles, ranging from 1.0 to 0.5 micron, which settle slowly. Larger particles settle at higher velocity and will be removed whether or not they follow Newton's law, or Stokes' law, the governing equation when the drag coefficient is sufficiently small (0.5 or less) as is the case for colloidal products (Lee, 2007).

For small Reynolds number $R < 1$ or 2 with laminar flow, Stokes law can be derived which is:

$$V = \frac{g(\rho_s - \rho)d^2}{18\mu}$$

where

- V = terminal settling velocity
- g = gravitational constant
- ρ_s = mass density of the particle
- ρ = mass density of the fluid
- d = particle diameter
- μ = absolute viscosity of the fluid

This is the scenario that was analyzed for the design of the sedimentation basins.

The design of the sedimentation basin at the plant was based on the Stokes' Law equation given above.

The values to solve the equation for our scenario, expressed in SI units, were assumed to be:

$$g = 9.81 \text{ m}^2/\text{s} \text{ (32.2 ft}^2/\text{s)}$$

$$\rho_s = 1281 \text{ kg/m}^3 \text{ (80 lb/ft}^3\text{)}$$

$$\rho = 1,000 \text{ kg/m}^3 \text{ (62.4 lb/ft}^3\text{)}$$

$$d = D \text{ mm particle diameter}$$

$$\mu = .001792 \text{ poise (0}^\circ \text{ C)}$$

The basin size would be based on the flow of wastewater to be treated. Accurate measurements were required to obtain the optimum size of the basin. The flow of the wastewater at the plant was tested in the summer of 2010 from June 28 to July 28. A flowmeter was placed in a manhole close to where the sediment basin was to be placed. The flowmeter tested the wastewater for 28 days and took a reading every 15 minutes. The results were also compared against the rainfall in the area for that same period. The system receives stormwater from many inlets around the plant which impacts the flow entering the sediment basins. The results are listed in Figure 2-1 below.

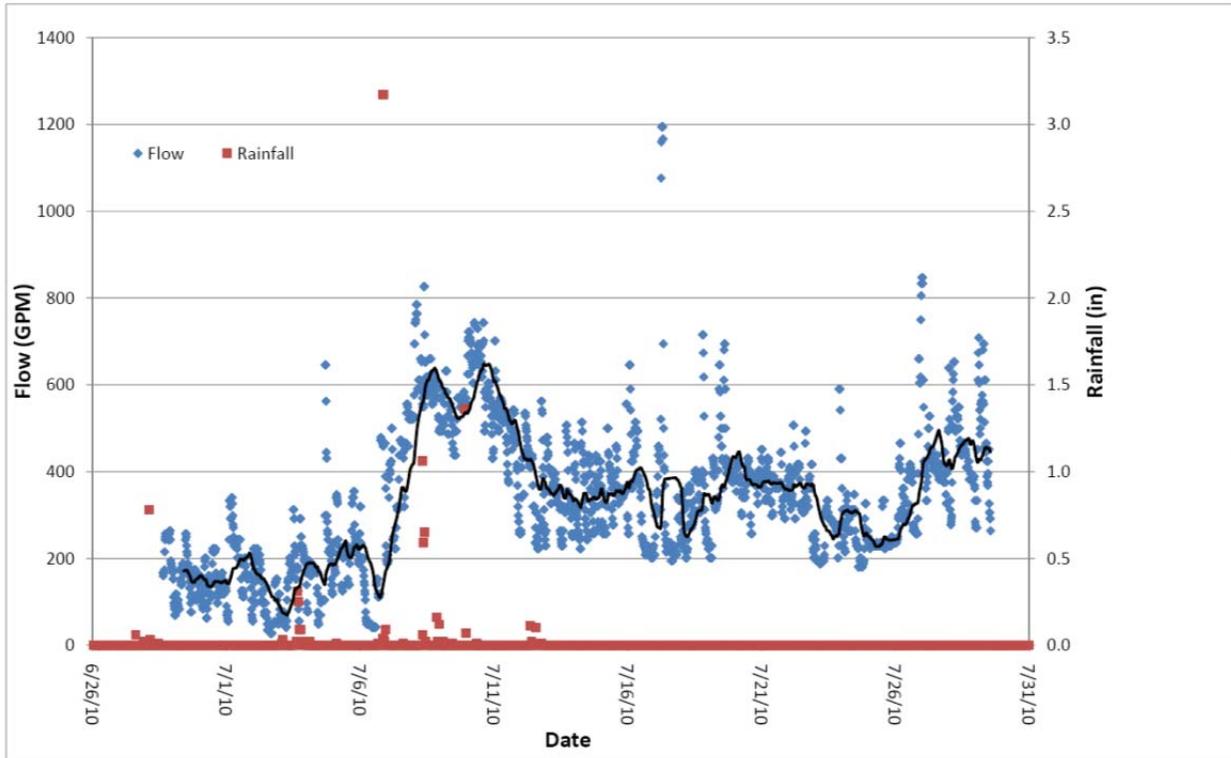


Figure 2-1 Flow Rate of Wastewater

Using the data shown above it was concluded that 1,000 gpm was a conservative flowrate to use for our calculation through the sediment basin.

2.5 Grit Removal

To understand how to remove grit from the wastewater most effectively, it is important to understand how grit behaves in that medium and how much grit is there in the first place. Surprisingly, there are no published standard methods for sampling and analyzing grit from wastewater treatment plants. (Wilson, 2007)

Grit is sediment, and sediment sampling is complex due to its dependence on flows. The speed at which water moves through a pipe affects how well particles can settle. For a grit particle to settle, its sinking speed, or settling velocity must be great enough to overcome the shear velocity of the water flows. The shear velocity is called the deposit limit. Particles with settling velocities in water greater than the deposit

limit will tend to deposit. Particles with settling velocities less than the deposit limit will be maintained in suspension. (Wilson, 2007)

Comparing the flowrate through the sediment basin and the settling vertical settling velocity of the sediment (using Stokes Law) it was concluded that a 40' x 10' basin would remove the size of sediment that was required.

2.6 Sediment Basin Performance

Grit chamber performance is not well documented for wastewater treatment plants. This is primarily due to the fact that the overall performance of a plant is the measured characteristic and not just the grit chamber. It was found that the primary clarification can be expected to achieve 50-70% suspended solids removal. (Hegg 1990)

2.7 Sediment Basin Design

The design basis for the basins is that when a basin is full it would be cleaned out by driving a bobcat or front end loader into the built up sediment and hauling it to a dump truck. The design called for a 40' x 10' basin. This would be too small for a bobcat or small front-end loader to operate when cleaning out the basin so the basin was designed to be larger. It was decided that the Sediment Basin would be 50' long by 20' wide. It was decided that two basins would be constructed, so that one could always be operational when the other was full and being dewatered or being cleaned. To accomplish the 40' of length that was desired, the basin needed to be longer because the inlet and outlet pipes needed to be offset from the end of the basin. The pipes were offset 5 feet from the ends making the basin length 50'. The basin was given a minimal slope so that the water gradually flowed to the outlet. This slope was set at 0.2%. When the basin is completely empty and using 1,000 gpm as the basis, it will take 15 minutes for the water to flow through the basin. This will vary once sediment buildup occurs in the basins.

The basins needed to be accessed with bobcats for clean out. The bottom elevation of the basin is 10' below the ground elevation where the trucks would be loaded by the bobcats. To access the basins the

bobcats would need a ramp to get in and out of. From experience, it was found that a 5:1 or 20% ramp was feasible for the bobcats to use.

The depth of the basin was calculated to be 2 feet from the calculations as discussed in Section 2.4. This was also the maximum depth that would be feasible for a bobcat to safely maneuver while cleaning out the basins. The flowline of the outlet pipe was set 2' above the floor of the basin; the inlet pipe was set 1' above the outlet pipe. This would allow for unobstructed flow of the inlet water into the basin when the basin was almost full to capacity with sediment.

The outlet of the sediment basin is an oil/water separator. This is for oil leaks and spills from the plant island. The design called for the majority of the sediment to be removed from the waste stream before entering the oil/water separator to avoid unnecessary accumulations in the separator. Oil/water separators do not function when oil has been emulsified. This will happen when water is sent through a pump. So, we needed to design our basin using gravity flow until after the wastewater had been treated through the oil/water separator.

The arrangement of the sediment basin is shown in Figure 2-2.

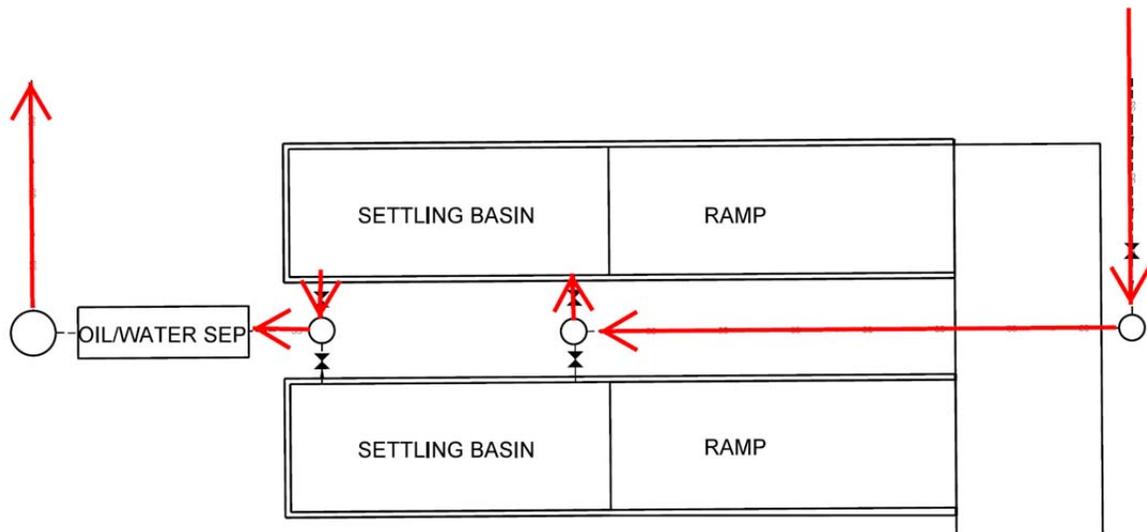


Figure 2-2 Sediment Basin Arrangement

A 12” pipe will come off of the main wastewater line 24” pipe. The 12” pipe will be 1’ lower than the 24” pipe flowline. The slope of this pipe was set to only allow 1,000 gpm of water through this pipe.

When this pipe is full the rest of the wastewater will continue down the main waste line bypassing the sediment basin. This should only occur during heavy rain events. Runoff from the rain does not contain the sediment that is desired to be captured so it is acceptable that this does not go through treatment.

The 12-inch line is sent to a manhole, MH-4, where it will be sent to either of the sediment basins depending on which one is active. The water is controlled by valves. Once the water has settled in the sediment basin it is discharged through another manhole and into the oil/water separator. The oil/water separator discharges to a lift station. The lift station contains two-7.5 HP pumps that pump the water back to the main 24” line and on to the LVWTP.

2.8 Sediment Basin Construction

The basins were designed with reinforced concrete. Construction of the forms for the basins began on June 26, 2011. The final concrete pour for the basins was August 19, 2011. Construction Company out of Texas performed the work using approximately 15 men working 50 hours/week. Daily highs in the 100's were common so productivity was very low in the afternoon. The concrete pours were started at 4 am because of the high temperatures. This was an effort to keep the concrete temperature as low as possible so that it would cure properly. It also allowed the workers relief from the heat while performing the strenuous task of pouring concrete.

The contractor elected to use a "seal slab" which is a 4" slump concrete placed at the bottom of the footer elevation. This prevented water from seeping up into the base and allowed for quick clean up after rainstorms.

The basin was approximately 10' below grade. The soil is a silty sand in this area so to allow for the area to be safely accessed the side slopes were cut back at a 1:1 slope. All concrete pours required a pumper truck to pump the concrete into the forms.

The footers were poured two at a time alternating between sections to allow for the joints to be formed. All combined the footers contain 300 cubic yards of concrete. Figure 2-3 is a picture of the footers being poured.



Figure 2-3 Footer Concrete Pour

The walls were also poured two at a time alternating between sections. All combined the walls contain 115 cubic yards of concrete. Figure 2-4 is a picture of the walls being poured.



Figure 2-4 Wall Concrete Pour



Figure 2-5 Completed Basin

When construction of the basin was completed the oil/water separator was constructed. The discharge from the basins will be conveyed to the oil/water separator. The oil/water separator was designed to handle 1,000 gpm of flow and holds 10,000 gallons of liquid. The basic design for the device is that oil contained in the water, which has a lower specific gravity than water and will therefore float, will rise to the top surface. When the oil has reached approximately 3” thick (equivalent to 1,000 gallons of oil) it triggers an alarm. The oil is suctioned out, and the oil/water separator is ready to receive flow again. This portion of the project was not analyzed in this paper. A picture of the oil/water separator is shown in Figure 2-6.



Figure 2-6 Oil/Water Separator

Following the oil/water separator is the lift station. The lift station contains two 7.5 gpm pumps that pump the water back into the main 24” wastewater line. The lift station is 7.5’ in diameter and 15’ deep. The pumps are at the bottom of the station. A system of 3 “floats” are connected to the electrical controls that operate the pumps. When the water reaches a certain level the floats are triggered to turn on the pumps

and drain the lift station. Figure 2-7 shows a picture inside the lift station of the pumps and guide bars used to lift the pumps in and out of the station. The pumps are lifted out frequently for maintenance.



Figure 2-7 Lift Station

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3.0 PROCEDURES AND METHODOLOGY

In order to test the performance of the sediment basins, samples for TSS were taken from the waste stream upstream and downstream of the sediment basin. This represents the pre-treatment and post-treatment condition. The samples were evaluated for concentration of TSS in mg/L. The pre-treatment and post treatment concentrations were compared to each other to get a percentage of removal of TSS.

A channel or pipe containing settleable solids at a velocity of less than approximately 2 fps will have a greater concentration of suspended solids closer to the bottom; therefore, neither the high bottom concentration nor the low top concentration will be representative. Accordingly, a sample should be taken in an area away from surfaces that is typical for the flow and well mixed. (Alley, 2007) The samples were consistently taken in the center of the pipe flow.

ABC station is also required by the Environmental Protection Agency through the National Pollution Discharge Elimination System to complete testing of its effluent into the River. The plant takes discharge values daily and reports an average for the month to the U.S. Environmental Protection Agency as a part of the plant's NPDES permit. These values were evaluated from July 2009 to July 2012 to evaluate if the overall TSS values for the plant had decreased due to the sedimentation basin.

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4.0 RESULTS

The basin was tested for TSS on April 20, 2012. The waste flow was sampled for TSS upstream of the sediment basins and downstream of the basins in order to estimate a percentage of TSS removed by the basins. It was estimated that the sedimentation basins reduced the amount of TSS in the waste stream by 53%. For the test taken on April 20, the incoming TSS was 17.75 mg/L and the outgoing TSS was 9.5 mg/L. This corresponds with the expected 50-70% removal as discussed in Section 2.6.

The plant is required as a part of their NPDES permit to report monthly values for TSS. These values are taken after the LVWTP and therefore after the main wastewater treatment. The values are taken just prior to the wastewater stream's discharge into the River. The values were analyzed to see if a decrease in TSS and therefore an increase in efficiency was noticed after the sedimentation basins were introduced into the wastewater treatment train. The values are available from July 2009 to July 2012. The sedimentation basins have been in service since January of 2012. The values were graphed to see if a noticeable difference could be discovered as shown below.

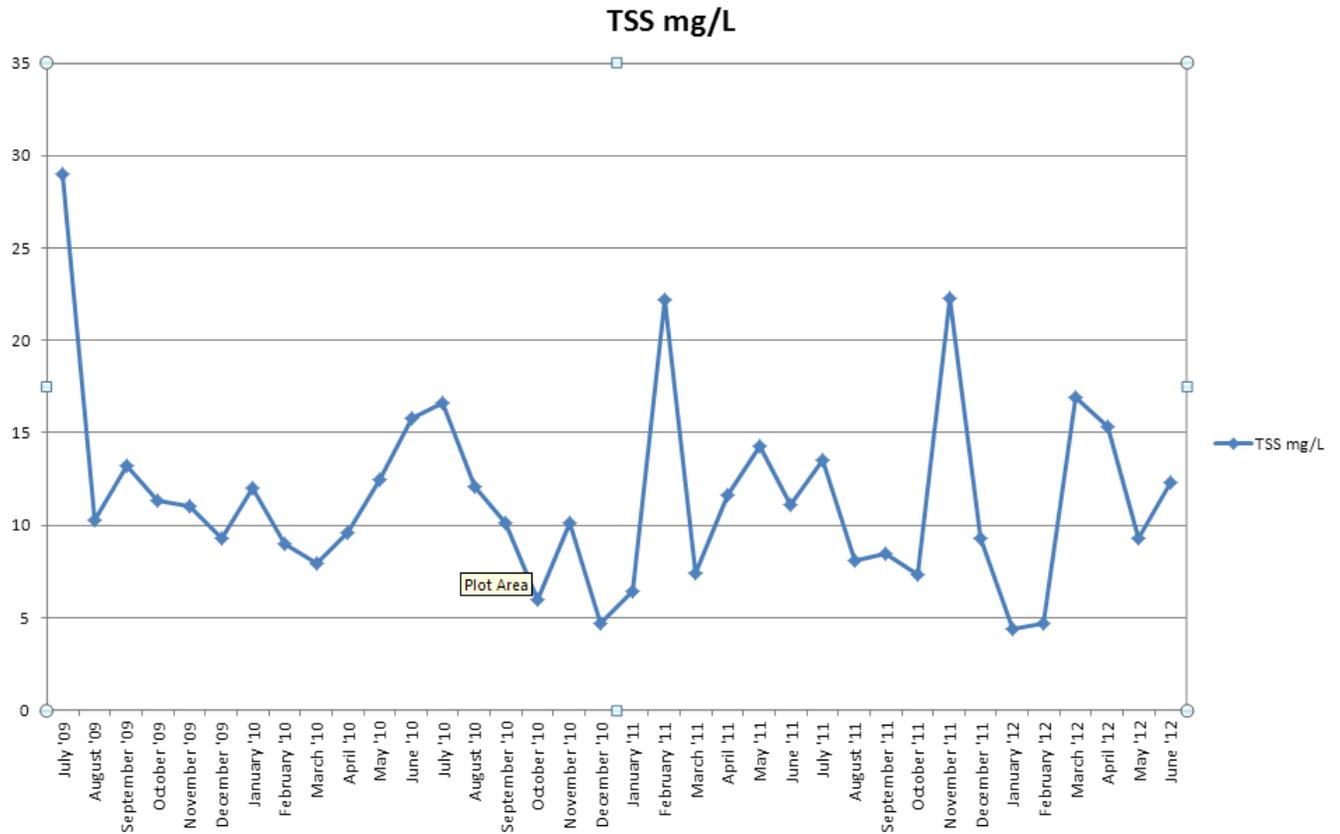


Figure 4.1 Graph of TSS from July 2009 to July 2012

The graph does not show a noticeable difference in values starting in January 2012. As a result, additional analyses were conducted.

The next analysis evaluated whether the total average of TSS decreased after the implementation of the sedimentation basins.

	TSS (mg/L)
July 2009 - December 2011	11.75
July 2009 - July 2012	11.54

3-Year Average TSS

So, this does show a slight decrease in TSS at the outfall of the plant and therefore an increase in efficiency of the system. This represents a 1.8% reduction in TSS. This may just be a result of a small

sample size so more data should be evaluated before drawing a complete conclusion. The next analysis compared the six month averages of the data we had available. The data that is available from when the sedimentation basins were in use is available between January to July 2012. The averages from 2010, 2011 and 2012 for this same six month period are given below.

	Average TSS (mg/L)
2010	11.13
2011	12.17
2012	10.48

6 Month Average TSS

This again shows a decrease in TSS and therefore an increase in efficiency of the total wastewater system for suspended solids removal. The 2012 value of 10.48 is a 14% decrease in TSS from 2011 and a 6% decrease from 2010.

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5.0 SUGGESTIONS FOR ADDITIONAL WORK

Additional testing is needed to provide a more comprehensive evaluation of the performance of the sediment basins. More testing is needed directly before and after the basins to evaluate the effectiveness of the treatment. At least 30 consecutive days of testing would provide more accurate measurements about the amount of TSS removed. This could be compared to the amount of power being produced to help operations make predictions on the amount of sediment they will need to dispose of each year.

It would also be informative to evaluate the residence time of the wastewater in the basins. The residence time is the amount of time the wastewater spends in the basins. This is important because there is a certain amount of time for the sediment to fall out of suspension and settle at the bottom of the basins. The calculations give in Section 2.4 could be validated if the residence time was known.

The plant will also need to know how much total sediment is being removed from the basins. This could be done simply by how often the basins need to be cleaned and evaluating if they need to be cleaned daily, monthly or quarterly. This will help with maintenance budgeting and planning.

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