Assessing the Effectiveness of a Storm Water Basin to Eliminate Wastewater Overflows

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Abstract

Wastewater treatment facilities are an important part of any urban community because they help decrease the amount of wastes entering waterways from homes and businesses. Yet due to increased flow associated with changes in population density and storm intensity, many wastewater treatment systems are becoming obsolete, frequently having no other option than to push untreated water into open waterways. This causes problems because the high levels of phosphorus in wastewater can alter aquatic ecosystems by causing algal blooms, and high levels of fecal coliform can ultimately contaminate the drinking water supply. One option of wastewater treatment plants is to use a storm water basin to collect and store excess inflow of wastewater until it can be treated by the plant. This would essentially increase the flow capacity of the plant without having to rebuild the existing wastewater facility. However, the effectiveness of this method remains unclear, and so the purpose of this study was to examine the efficiency of the storm water basin at the Wastewater Treatment Facility in Kenosha, WI (KWWTF). If the storm water basin at KWWTF is effective, then we would expect to see fewer instances of overflow when the basin is in use, as well as effluent phosphorus levels that meet EPA standards of less than 1ppm. To address this hypothesis, data were collected from 2006-2009, including total amount flowing through the plant, the number of pumps used (which is an indicator of the use of the basin), the total phosphorus and suspended solids in the effluent and the amount of wastewater released by overflows to Lake Michigan. It was found that when there were extremely high flows; more pumps were utilized, thus causing the basin to be used. It was also found that the basin was not 100% effective in eliminating the overflows, likely due to the patterns of rainfall. The basin utilized by the KWWTF, may reduce the number of annual overflows, but may not 100% eliminate them when storms intensify.

Introduction

Since 1960 the human population has doubled, and in well developed areas, the world's population is estimated to reach 12 billion people within the next thirty years. The sanitation and waste management services are well established in many of these well-developed areas, but added population and additional development can create environmental challenges for those trying to process and manage the waste produced and maintain clean water and natural resources. Along with the challenges produced from increasing population, large storm events can interfere with the sewer treatment processes. The large storm events, which are increasing in frequency and intensity as a result of global climate changes, can increase the overall flow entering and going through the system; thus reducing the ability to thoroughly treat the wastewater prior to releasing it into the nearest water body. Wastewater facilities must adapt their systems for an increase of flows and waste product, or the quality of natural waterways quality will begin to decrease. Even with the current population and climate, storm water can be problematic.

Wastewater treatment is an important process to understand, because if water is not able to be treated before its release due to increased flows, there can be a problem with overflows that enter water bodies untreated. The extra nutrients that can enter the waterways pose problems for the already existent ecosystem. A main problem, which directly affects the general public, is disease. Untreated wastewater can contain pathogens that can enter the drinking water supply undetected (Kerri, 1993). In the case that the water is not sanitized, pathogens can enter the water way and essentially contaminate the drinking water supply for a city. Disease, such as typhoid, cholera, dysentery, polio and hepatitis, can follow after consuming contaminated water (Kerri, 1992). The diseases that can be found in ‘dirty’ water can be deadly if not caught. An example of this is the outbreak of cryptosporidium in Milwaukee, WI in 1993 (Geiman, 1993). Cryptosporidium is usually found in rivers and lakes that are contaminated with animal feces (Wisconsin DNR). The bacterium can also be found in rivers and lakes that receive wastewater from treatment facilities. This specific outbreak was due to treatment of drinking water that was inadequate. There was not a specific source identified (WI DNR). During 1993, the cryptosporidium bacterium was not removed from the drinking water in Milwaukee. The bacteria outbreak caused there to be a ‘don’t drink the water’ order put in place. This meant that residents needed to boil any water used in the household to ensure that the cryptosporidium bacteria was killed, therefore leaving the water safe to use. This outbreak was not a part of the waste water treatment facility, but still caused a questioning in the water quality in Milwaukee. Cryptosporidium is a bacterium that causes illness in humans. According to Bruce Clark, a Seattle lawyer, the outbreaks focus on the bacterium invading the water source. He also states that due to its infectious capabilities, Cryptosporidium must be reported to public health officials after diagnosis.

Other diseases can be caused from wastewater treatment problems. In another case, Milwaukee’s sewerage district was under fire due to the contamination of the Milorganite produced. Milorganite is a fertilizer made from dried and dewatered microorganisms found in the aeration tanks in the Milwaukee Metropolitan Sewerage District’s treatment facility on Jones Island (www.mmsd.com) The Milorganite was tainted with harmful Polychlorinated biphenyls (PCBs). The PCBs found in the Milorganite can cause cancerous cells to form in humans. The PCBs were knocked off of older sewer pipes during a mandatory cleaning of the sewer lines (JSOnline 2007). Because of the event, numerous parks, and school fields needed to be closed down due to the harmful chemicals being placed onto the grass.

While the addition of extra, carcinogenic nutrients can be detrimental to the health of humans, there are still problems with the addition of extra nutrients entering waterways, therefore causing disruptions in the ecosystems. Nutrients such as phosphorus, fecal coliform, nitrogen and suspended solids occasionally enter the waterways during the event of an overflow. Phosphorus is a nutrient used by plant life, such as algae, when going through growth periods. When more phosphorus is added to a waterway, the algae begins to grow more, which therefore causes there to be a higher amount of oxygen used. The lack of oxygen in the water damages the other life that is in the waterway's ecosystem (Aquatic Ecology, Carthage College, 2009).

The extra nitrogen entering the ecosystem also damages the aquatic ecosystem. The nitrogen entering the waterways can also deplete the oxygen in the water, as well as be at highly toxic pH levels (Magnaye, 2009). The excess nitrogen in the water can affect the way food is produced and increase eutrophication (Magnaye, 2009). The extra nitrogen can also turn into ammonia, thus raising the pH levels. The anaerobic and aerobic processes aid in the removal of nitrogen.

Fecal coliform and suspended solids can damage the ecosystem in similar ways. The fecal coliform can contain non-recommended nutrient levels as well as other toxins and diseases from humans. The suspended solids are materials that continue to stay suspended within the water. The amount of solids increases as the size of each particle decreases. The suspended solids are removed by sedimentation. As the water is slowed, the particles begin to fall to the bottom of the tanks from gravity.

While protecting the people that live in the area from disease is important, there needs to be something done to protect the waterways that the treated water enters. Each year, overflows can be detrimental to the receiving waterways by loading extra nutrients into the water. How can wastewater treatment facilities store the water during a storm event to minimize the amount of overflows that occur in a year? The detention of water during storm events can minimize the amount of water entering the facility as well as decrease the amount of water and pressure found in the sewers.

Storm events as well as precipitation, due to a warming climate, are increasing. While the changes in increasing precipitation are not uniform across the entire United States, the majority of the increases are located in the upper Midwest (Hatfield, 2004). With the storms increasing in intensity and precipitation, overflows from wastewater treatment facilities are occurring. A solution in preventing overflows is a storm water basin.

In Chemnitz, Germany, a study was conducted by M. Ahnert (2009) on similar problems found in storm water overflows from wastewater treatment systems. In the study, three ways to reduce overflows were suggested. The first suggested that the water from the storm water basin begin to be diverted to the secondary clarifier (Ahnert, 2009). The water would have already gone through a semi-primary treatment process, so the secondary clarifier would not be overloaded with extra sediments. The second option, for the cases in which a storm water basin is not available, diverted the pre-treated wastewater entering the facility to the secondary clarifier prior to sending it to water body (Ahnert, 2009). The final option was to send wastewater from the sewer straight into the secondary clarifier, all together skipping the pre-treatment process. The first two options were looked at more in depth in the study. The results suggested that bypass approach during high flows were uncommitted to being good or bad (Ahnert, 2009). The bypass, according to Ahnert, is effective during times of high flow, but extreme caution has to be taken in order to not cause the system to hydraulically overload (Ahnert, 2009). Ahnert (2009) concludes that the bypass after the water being held in the basin allows for the flows entering the facility to increase.

The study in Germany shows the vital use of a basin to hold water prior to treatment (Ahnert, 2009). The sewer system in Chemnitz, is substantially large, so more basins are put into service and are used more frequently to hold water prior to it reaching the facility. In Berlin, Germany, the River Panke has frequent problems surrounding hydraulic peak loads and pollutant loads from separated sewers and combined sewer overflows (CSOs) (Peters, 2007). Due to the numerous separate sewers and CSOs, the river Panke has been structurally degraded and has had problems with flooding (Peters, 2007). The city’s center utilizes combined sewers while the suburban areas use separate sewers. This has resulted in a high hydraulic peak during storm events (Peters, 2007). After adjusting pump stations and working with methods to separate urine from the sewage in the sewer systems, it was concluded that the pressures in the pipes can influence the wastewater treatment facilities (Peters, 2007). The goal to separate the urine in the system would have allowed for the treatment processes to occur quicker. According to Peters, the urine separation worked the best in the combined sewers rather than the separated sewers. Also, the changes made to the pumping stations greatly reduced overflows into the river Panke.

This study, like the previous studies in Germany, focuses on the utilization of a structure, like a basin, to store water during storm events until the flows decrease in the wastewater treatment facility, therefore decreasing the amount of overflows occurring annually. Specifically, the Kenosha Waste Water Treatment Facility (KWWTF) was chosen as the case study site. The KWWTF uses a storm water basin during periods of high flow.

Case Study Site: Kenosha Waste Water Treatment Facility

Figure 1: Aerial Photo of KWWTF. Source: Google Maps

The Kenosha Waste Water Treatment Facility (KWWTF) is located on the western shore of Lake Michigan in the city of Kenosha, Wisconsin. Roughly, the water utility services about 100,000 customers located in Somers, Bristol, Pleasant Prairie and Kenosha; all are located in Kenosha County (www.kenoshawaterorg). The water that is treated is put directly back into the lake. The KWWTF is an activated sludge facility, which means that it has a biological treatment that uses live microorganisms to break down any organic matter still within the water after the primary treatment process, in addition to physical and chemical processes. The facility layout is essential to making the treatment process work. On the north side of the facility, there is the administration building and preliminary treatment building while on the south side of the facility, there are secondary clarifiers and chlorination channels (Figure 1). Currently, the KWWTF has a capacity of 72.0 million gallons per day (MGD). The facility treats on average, anywhere between 20.0 and 28.0 MGD and has been able to treat 90.0-100.0 MGD in the past. The larger MGD treated is the result of high flows entering the facility. The amount of water that enters the facility on any given day is dependent on the flows and how much precipitation falls. Daily, there are outputs of sediments removed from the sewage as well as how much air is pushed into the aeration tanks to keep the microorganisms alive (Table 1).

In order to go through the treatment process, the water must travel through the sewer system. Two types of sewers are used in Kenosha, sanitary sewers and storm sewers. The sanitary sewers, specifically, are designed to handle the fecal materials. Opposite from the sanitary sewers are storm sewers. The storm sewers are designed for storm water flows. Carthage College has a series of sanitary sewers running through the campus (Figure 2). Carthage added new dormitories on the southern end of the campus, so the sewer connections are fairly new. The map is showing where the new connections meet up with the previously existing sewer lines prior to hooking up to the main sewer line for the city. The sanitary sewers all connect at one larger sewer pipe that meets up with the main line under Sheridan Road. The green arrows represent which way the sewage is flowing throughout the campus. Once in the main sewer line, the sewage runs south until it reaches the KWWTF.

Table 1: Major Process Elements in the Kenosha Facility (Source: Kenosha Water Utility, www.kenoshawater.org)

Each day, the KWWTF treats millions of gallons of wastewater, which in turn produces numerous products. These products are measured and put onto the water utility website for public access

Pumping	22.0 Million gallons per day
Grit Removal	54.0 cubic feet per day
Primary Settling	50,000 gallons of sludge per day
Aeration	18.0 Million cubic feet of compressed air per day
Sludge Thickening	Uses air flotation to thicken the sludge from 1.00% -4.00%
Sludge Dewatering	Dewaters the digested sludge to 40% solids. About 80.0 tons of sludge is taken to a landfill each day.
Final Clarification	7.60 Million gallons of sludge is returned to the aeration tanks.
Disinfection	Water is chlorinated at discharged into Lake Michigan, 1,200 feet out in the lake

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Figure 2: Map of Carthage College campus sewer lines. Source: Kenosha Water Utility, 2009.

The sewage is pumped from the wet wells that store water coming in from the sewers by using 1-6 pumps. As the flows entering the wells reach heights of 220.0” for more than one minute, more pumps begin to turn on. Each well has a depth of 235.0 inches. After 4-6 pumps are turned on, the basin may be put into use. The pumps automatically turn on, but it is up to the facility operators to manually adjust the pumps and turn off any extra pumps if the weather forecast indicates the weather to be slowing. The flows are calculated by a meter (NJDWM) that records how much wastewater is entering the facility.

According to Bruce Rabe, the Laboratory Supervisor at KWWTF, during normal flows the facility uses two pumps to lift the water into the facility from the sewers. When precipitation begins to occur, a third pump turns on automatically. It is up to the operators to determine whether the third pump is actually needed, or if two pumps are sufficient enough to handle the incoming flows of water. When a third pump is needed, administrators are alerted. During events in which four or more pumps are needed to push water into the facility, the basin is turned on to help handle the larger flows.

Once in the facility, the water goes first goes through a physical treatment process. The physical treatments surround the primary treatment process wastewater goes through. Prior to the primary treatment phase, the wastewater enters the facility and goes through a bar rack to remove any large pieces of debris from the channel. The large debris get caught on the bar rack and is eventually ground up and removed from the water and disposed of. The wastewater then goes through the grit removal process. The smaller particles that were not caught by the bar rack are removed from the water. This is done by slowing the water down, through the use of flumes, to a point where the small particles are able to settle. The water then goes into the primary clarifiers. There are many types of clarifiers used in the primary treatment process, but the KWWTF uses rectangular bays. The water sits in the bays for a period of time that is specific to the type of bay. The facility uses the height, length and width to determine how long the water is detained in the bays before going to the next process (Kerri, Kenneth D. *Operation of Wastewater Treatment Plants*, 1992). The KWWTF normally runs four of the primary clarifier bays. During higher flows, more bays are put into use. While the water is being detained in the clarifier bays, the solids continue to settle. The lighter solids, such as oils, greases, and soaps, float to the surface and are skimmed off by the use of skimmers, while the heavier solids fall to the bottom of the bay where they are scraped into a pip that leads to the digesters. The effluent water, after being detained for about an hour or so, is pushed into the biological treatment process.

After leaving the clarifier bays, the water travels through channels until it reaches the aeration tanks. There, the water is mixed with activated sludge to break down any organic matter that is still within the water. This is done by bacteria and microorganisms. According to Bruce Rabe, the laboratory supervisor at KWWTF, the activated sludge has a live stock of microorganisms that are able to survive with the organic materials still dissolved in the water. The microorganisms are also dependant on the amount of dissolved oxygen present in the water. At the KWWTF there are large motors and compressors that push oxygen into the activated sludge bays. The motors on the compressors are adjusted with the temperature and amount of water flowing through the facility. During times of higher flows, the “blowers” (compressors) may be turned down or off completely to protect the supply of microorganisms present in the bays.

After being detained within the aeration tanks, the water is pushed out to the final clarifiers. The final clarifiers allow for the activated sludge to settle out of the treated water. The sludge settles to the bottom of the clarifiers and is transported back to the aeration tanks. The KWWTF uses circular clarifiers for the secondary clarifying process. After leaving the final clarifier, the water goes through a chlorination channel to be disinfected. According to Bruce Rabe, the chlorine disinfects the water and kills the majority of organisms that could potentially cause hard to the water environment. The water is not sterilized because it can cause harm to the ecology of the water body, but enough of the pathogens are killed to meet the standards set by the Environmental Protection Agency (EPA). The chlorine is then removed before the water enters Lake Michigan.

Sludge that is collected in the primary clarifiers is sent to be thickened, dewatered and pressed. This is done in the digesters. Microbes are digested and water is removed from the sludge. The sludge is then stored. Another process that occurs within the facility is adding chemicals, mainly ferric chloride ($FeCl_3$) to the wastewater. The ferric chloride added reduces the phosphorus found within the water to levels that are acceptable to the EPA.

The EPA uses guidelines set in the National Pollutant Discharge Elimination System (NPDES) for wastewater treatment facilities' effluent discharge (EPA, 2009). The discharge permits are set so the nutrients still found in the water after treatment are at low enough levels so they don't damage the ecosystems.

The storm water basin utilized by the KWWTF is located on 80th Street in Kenosha, WI. A large pipe running under 80th Street connects the basin to the facility. The basin was built to hold up to 30.0 million gallons of water in the event of high flows. The basin is split up into four compartments. The smaller three compartments are large enough to hold a capacity of 6.00 million gallons of water and the larger, fourth compartment is able to hold up to 12.0 million gallons of water. When in use, the majority of water stored in the basin is storm water. The basin is used when 4-6 pumps are pushing water through the facility. Once the pumps turn on, some of the water is diverted to the basin. Like at the facility, there are six pumps that can push water into the basin. Once the water is diverted, it goes through bar racks to prevent any large materials from entering and potentially damaging the basin. When water enters the basin, the bar rack automatically turns on (Rabe, 2009). The water then settles while being held in the basin. To put it simply, the basin acts as a primary clarifier while water is being detained. Once the period of higher precipitation and high flows has concluded, the water in the basin drains and goes to the facility for treatment. During non-severe storm events, where the basin is used, usually only the first two compartments are used. After the first compartment is filled, the water will reach a spill divide and begin to fill the second compartment, and so on. If only two are used, then it normally takes about a day to empty and treat the water. In cases where all four compartments are used, it can take up to a week to empty. Emptying the basin is also dependant on the rain cells coming into the area. When a string of storm cells enters the treatment area, operators may decide to keep the facility running as if there is a severe storm present and keep diverting water to the basin. The basin prevents water from backing up into home and business owners basements.

Operations

At the KWWTF, the facility operators maintain a high amount of control of what goes on within the facility. The facility is of an older model, therefore leaving the operators to control how it runs each day. The city of Kenosha began building the facility in 1938. In 1940, the facility was put into full service (Kenosha Water Utility).

During each shift, operators walk around to every portion of the facility to monitor the engines and flows. The first building the operator goes into is the pump station. The operator checks the bar screens to make sure they are running correctly, and makes any adjustments to the chains that scoop the large material out of the water. The operator then checks the pumps to make sure that they are running efficiently enough for the flow entering the facility. If another pump turns on, it is up to the operator to manually turn it off. This can occur if the flows are low enough or holding at a steady rate. The operator then check pressure meters on sludge pipes and, he measures the amount of sludge that is in each primary clarifier bay. This is done by a sonic wave meter and a light meter. The operator has to measure how much gas there is in the operating digesters. The operator then goes below the digesters to release moisture in the gas lines. The operator also checks the meters of the gas and of the water. The operator also takes a sample of the sludge that is settling in the primary clarifiers. It is at this point where the operator can make the decision to open another primary clarifier bay. The operator also checks the meters in the building containing the blowers and engines used to push oxygen into the aeration tanks. From there, the operator checks the operations in the building where the sludge is thickened over time, on top of the water. The operator then goes into the sludge press building to check on operations with the person operating the press. It is the duty of the person working on the press to determine how much lime and ferric chloride is added to the sludge during the dewatering and pressing process. After completing rounds, the operator heads back to the administration building to call in any information that is needed at any other facilities. The operator also takes in phone calls from any of the pumping stations in the city if there are problems with the stations. The operator then heads back outside to do another wave of rounds throughout the facility.

Operators have to handle precipitation events throughout the year that affect the way sewage is treated. Each year, storms entering the area dump inches of water onto the treatment area, causing sewer flows to rise. Storm water is classified as the water that enters an area from a precipitation event, like a thunderstorm. The water can become a nuisance to wastewater treatment facilities because it adds to the flows already entering the facility. To a wastewater treatment facility, like KWWTF, a storm event is classified as an event that produces 1.00” or more of rainfall. According to Wes, an operator at the KWWTF, the extra inch of rain can be the deciding factor as to whether or not the facility has to make changes in the way the water is treated. The KWWTF handles the higher flows with six pumps that are capable of pushing the water into the facility at a safe rate. During a normal day of operation, the facility runs two pumps to push the average amount of water through the facility (Rabe, 2009). When rainfall begins, the flows generally begin to pick up about two hours later. During that lag time between the beginning of the rain and when the flows noticeably increase, the operators and supervisors look at the weather radar to try and estimate whether or not there will be a large change in the way the facility treats the water. At the KWWTF, the wet wells hold up to 235.0” of water (Rabe, 2009). The minute timer is set through the programmable logic computer (PLC). The use of three or more pumps is classified as a non-standard operation (Rabe, 2009). If the water level in the wet well does not significantly decrease once the third pump is turned on, more pumps are turned on. While the pumps turn on automatically, they have to be manually shut down or adjusted to accommodate the flows. When the last three pumps are turned on, the basin, located in Kenosha, WI, may be automatically turned on to hold the excess water found in the sewers. When the facility is running with five or six pumps, the biological treatment process is shut down to protect and preserve the microbiological organisms found in the activated sludge. The water is just processed with the primary treatment and chlorination (Rabe, 2009).

When the basin is in use, other options can be utilized to help decrease the amount of water found in the sewer systems. For example the voluntary bypass is used to pump water out of the sewers and to the curbs. The Kenosha Water Utility (KWU) locates sewers that are surcharged use a portable pump to remove the water from the sewers (Rabe, 2009). This conscious choice allows the utility to ensure that the sewage does not back up into the basements of residents that are at lower elevations. The involuntary bypass that the facility occasionally utilizes is to also allow untreated wastewater to be released into Lake Michigan directly. The involuntary bypass occurs when the pressure within the sewers elevates to the point where the water automatically is released. The KWU does not have a monitoring device alerting them to any overflows that occur. When these non-standard operations, due to an increase of flows turn on three or more pumps at the KWWTF, supervisors are called. After the flows increase, forcing the facility to use 4 pumps, the facility supervisors are called. The general manager of the KWU is also informed of the non-standard operations. The general manager then sends workers out into the city to check for surcharged manholes as well as if there are any involuntary overflows. In the case of five or more pumps being turned on during a period of high flows, the aeration tanks are turned off.

Aeration tanks are turned off in extreme measures. Utilizing the storm water basin as flows entering the facility get higher helps to try to keep all processes at the facility running. Although looking at the storm water basin is important, other factors, such as precipitation may give a clearer look into whether or not the facility is able to manage flows during events. Factors such as phosphorus and suspended solids levels are considered secondary factors. After looking at the flows and overflows going in and out of the facility during precipitation events, the phosphorus and suspended solids will give an idea of what is actually entering the waterways. It is expected that the flows will increase in the warmer months and decrease during the colder months. It is also predicted that if the basin is effective, then there won't be any overflows occurring. But if the basin is not 100% effective, other factors will be examined to see why the basin failed. The phosphorus is expected to follow the same pattern as flows. As the flows increase, ideally, the phosphorus levels will increase due to the extra amount of water. Suspended solids is predicted to have an inverse pattern to the flows. The suspended solids should decrease as the flows increase due to the extra amount of water.

Methods

Data were collected for daily precipitation for January 2006 through September 2009. Daily precipitation includes snow as well as rain that falls in the area. The data collected were measured at the Kenosha Regional Airport, and was obtained from the National Oceanic and Atmospheric Administration (NOAA) website. The precipitation data were gathered to show how much precipitation is needed in order for the basin to essentially fail, thus causing an overflow to occur within the city. Only portions of the precipitation data were examined included the week prior to overflows as well as two days afterwards. The purpose of going through the precipitation data is to show how much precipitation is needed before an overflow occurs. The precipitation amount can hinder and cause a disadvantage to the KWWTF by causing the ground to be saturated. Saturated ground causes more water to enter the sewers instead of being absorbed into the ground. When the ground is saturated, it only takes a small amount of rain to cause an overflow. Another way an overflow can occur is when a storm drops a large amount of rain in a short period of time. During a situation like this, the high precipitation amount flows quickly to the facility, causing the facility to have to quickly adjust the pumps.

The amount of flow through the plant was monitored from the Kenosha Wastewater Treatment Facility (KTTWF) in late 2009 for the monthly span of January 2006 through September 2009. Average and total, in millions of gallons (MGD), for each variable was calculated for each month. Phosphorus and suspended solids data were collected to show what enters the lake during overflows. When and overflow occurs, extra nutrients, that on a normal operating day would be removed from the water, are pushed into the lake with the extra water.

Overflow data were collected also including dates of the overflows, how much sewage had been pushed out of the system, as well as fecal, total suspended solids and biochemical oxygen demand data. The fecal, suspended solids and biochemical oxygen demand data were only collected for the last two years. Overflows were shown to occur in the spring, summer and, at times, in the winter. In 2006, there were four overflows, while from 2007-2009, there were five annual overflows. From the estimated gallons that overflowed, a total amount per year as well as standard deviations was calculated.

As flows increase and overflows potentially occurring, it is important to have data on how many pumps were used and whether or not the basin was used. Flow data was compiled into a new spreadsheet to show the date, the influent flow, how many pumps were used, and if the basin was used. For this particular analysis, the use of three or more pumps was only significant. This is because the use of only one or two pumps signifies a normal flow day. The use of three or more pumps signifies higher flows and abnormal operation for the facility. After calculating the average flow and standard deviations of each year's flow, in correlation to the pumps used, a figure was made to show the amount of average flow per pump.

Calculations were also completed to show the percentages of days that the pumps were used as well as the percentage of times in the 45 month study period that there were recorded overflows.

Calculations:

Percentage of Days that had Overflows: 19/ ((365*3 days) + (14843 days)) *100= percentage

Percentage of Days the Basin was in Use: (40 days basin was in use/ 15938 days in data collection period)*100

Results

Overflows were not prevented over the course of the four years studied. Though, overflows have not increased much at all over the last four years. The only tiny increase of four annual overflows to five annual overflows was between 2006 and 2007; the annual overflows increased by 1. The total gallons overflowed in the last four years does not reflect the number of annual overflows. In 2006 and 2008, the amount of sewage that overflowed was significantly lower than the amounts recorded for 2007 and 2009. In figure 4, the graph showing total amount of water that overflowed shows that more water overflowed in 2007 and 2009 in comparison to 2006 and 2008.

The precipitation data, however, showed that more precipitation fell in 2007 and 2009, causing there to be higher flows and therefore more overflows. The ranges of precipitation values were examined as well. The maximum rainfall from 2006-2009 peaked in 2007 at 2.73” and then began to decrease. The second year, 2007, was the only year to go above the maximum amount of precipitation of the previous year. Another aspect examined was the precipitation that fell prior to the dates of the overflows as well as two days after the overflows occurred. Once again, nothing was out of the ordinary, with the exception of the date, August 20, 2007. The week prior to the overflow on August 20, 2007, 5.01” of precipitation fell. The week prior to March 13, 2006 had 2.04” and the week prior to April 11, 2008 had 1.98”. The dates in 2009 had less than 1.00” of precipitation. In the 45 month data period, there were nineteen days where there were recorded overflows. This is 0.12% of the data period. The low percentage of days that had overflows from the sewers is minimal compared to the days that the basin was used. Out of the 45 month period, there were 40 days (0.67%) the basin was in use. Every time six pumps were in use, the basin was also in use. The use of the pumps helps the efficiency of the facility use. The basin on the other hand, may not have been used enough to prevent the overflows. According to Bruce Rabe (2009) the entire basin is not even used when water is pumped into the chambers.

The flows increased during the summer months and decreased during the colder, winter months during each year sampled and there is an overall increase of flows over the entire data period (Figure 3). The phosphorus had an inverse relationship with the level of flows. There was a steady linear trend over the data period (Figure 3). There are also spikes and drops occurring every other month while others are occurring over a few months. In 2008, there was a large spike during winter months. This could be due to the quick temperature rise in January, causing the snow to melt quickly (Figure 3). The suspended solids had increases and decreases throughout the years sampled. There was not a direct relationship to flows. There were points where the flows would increase, and a few data points later, the suspended solids would increase as well.

Over the last four years, the numbers of times the pumps have been used compared to the flows entering the KWWTF have all increased. The pattern seen, however, in the pump and average flow portion of figure 3, the pump usage in 2006 and 2008 have a smaller standard deviation than the years 2007 and 2009.

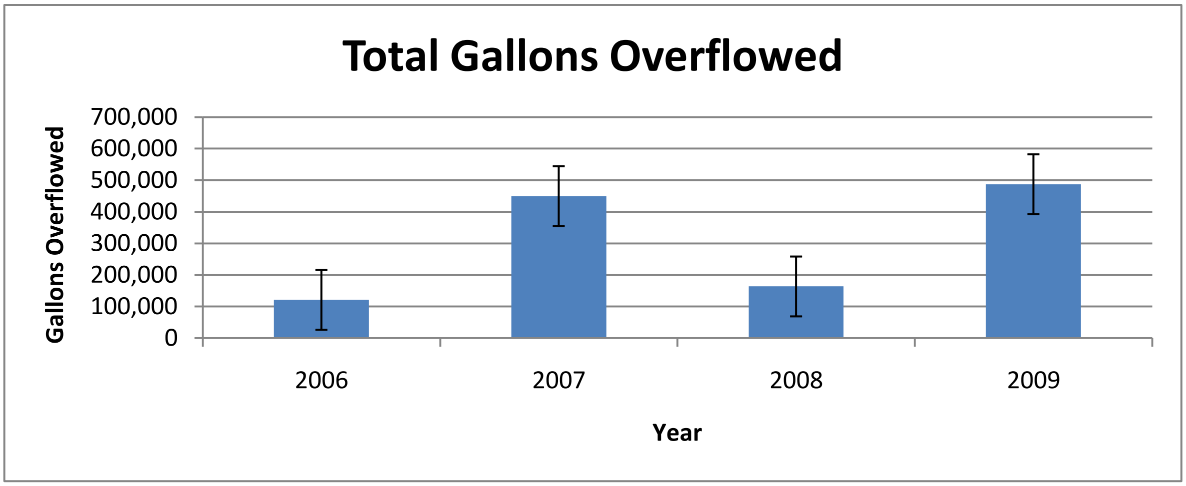

Figure 3: The total amount water that overflowed each year in gallons. Source: Kenosha Waste Water Treatment Facility.

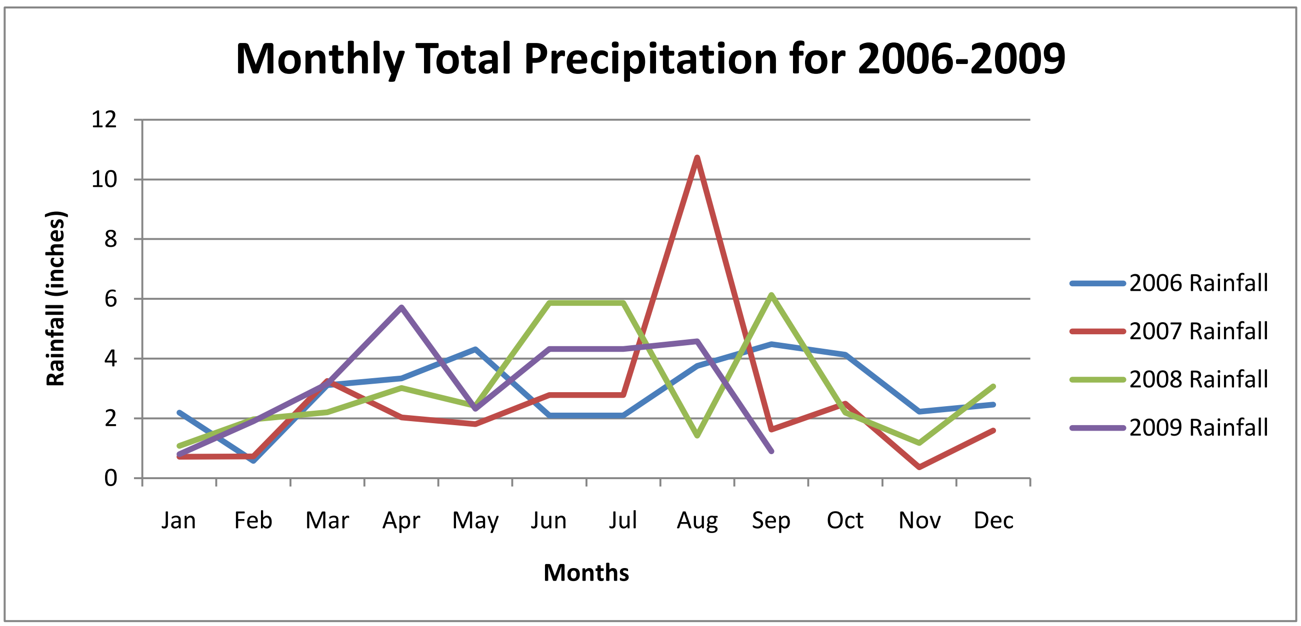

Figure 4 : Is showing monthly total precipitation for 2006-2009. The peaks and drops can be compared for each month. Source: National Oceanic and Atmospheric Administration (NOAA

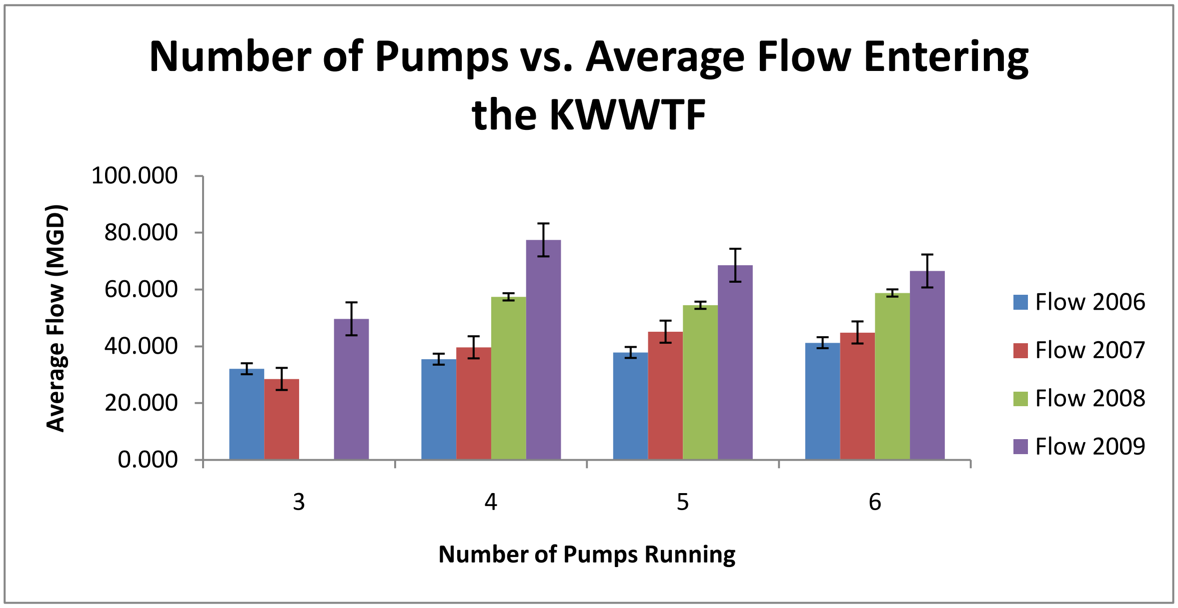

Figure 5: Is showing the total flow over time. This is showing where there are peaks and drops throughout the year.

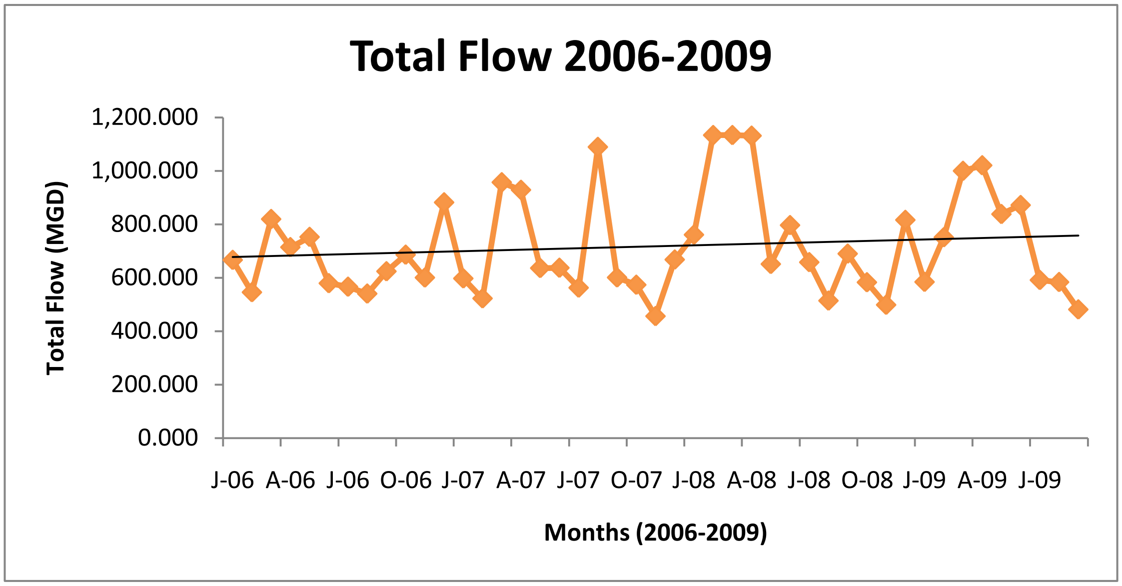

Figure 6a: shows the average flow entering the facility each year, and how many pumps are needed to push that flow through.

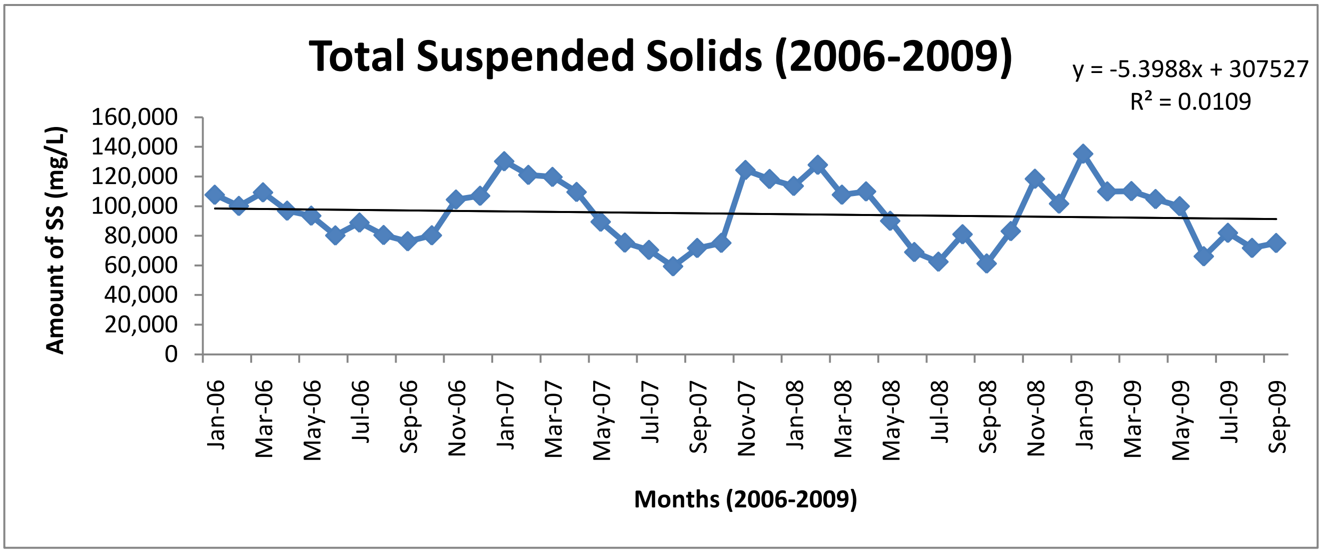

Figure 6b: The total suspended solids measured from 2006-2009 is being shown above.

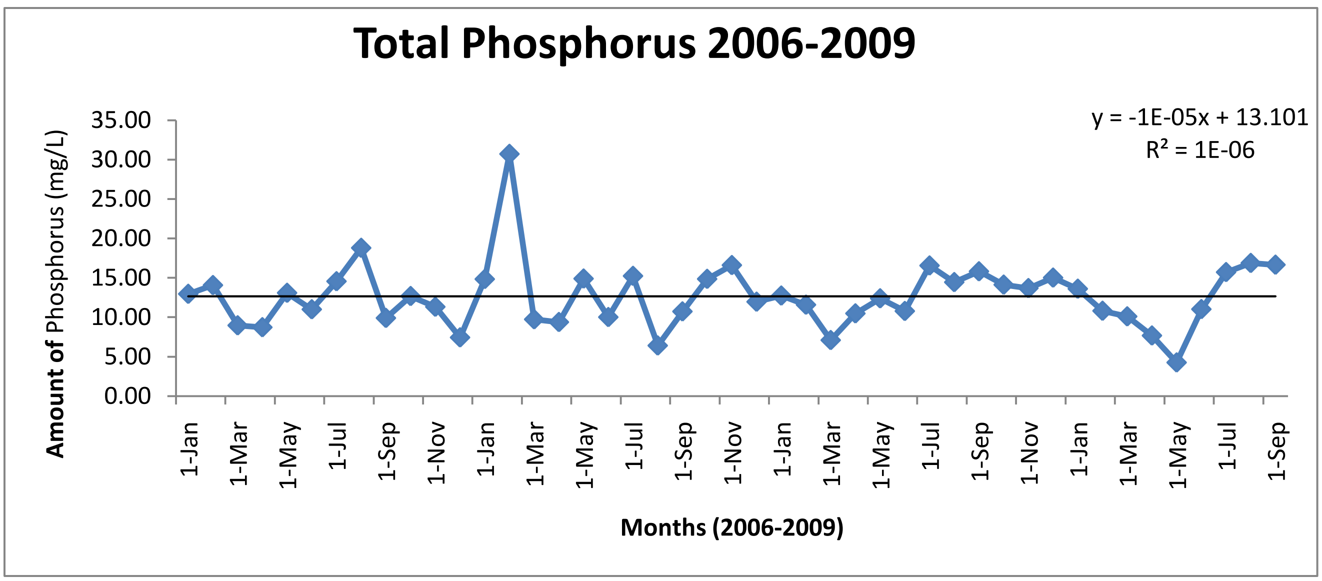

Figure 6c: The figure above is showing the total phosphorus levels from 2006-2009

Discussion

The basin was shown to not be 100% effective in preventing overflows in the last four years. Since the basin wasn't 100% effective, the precipitation data were looked at to see if there was any significant precipitation causing there to be higher flows, therefore leading to more overflows. There was a maximum peak of precipitation in 2007, and then the maximum peak decreased for the next two years. The most logical reasoning to explain the higher flows and overflows is the time of year the overflows are occurring. The precipitation data on the day of actual overflows, with the exception of one date (June, 19 2009), shows that less than 1.00" of precipitation fell in the Kenosha area. June 19, 2009 was the only date to exceed 2.00" with having 2.26" of rain falling. The other dates of overflows, however, had a considerable amount more precipitation falling the week prior to the overflow. In the cases of there being precipitation falling during the week prior to the overflow can cause flows to increase over that week, then when rain falls on the day of the overflow, the sewers cannot handle the extra pressure, leading to overflows. The time of year also plays a part in the overflows. The overflows occurring in December can be related to how saturated the ground already is. The snow cover saturates the ground, therefore making it difficult for any water to be absorbed in the case of a heavy precipitation, mainly rain, event. Because the water doesn't have anywhere else to go, it enters the storm sewers, causing flows to rise quickly. From looking at the monthly flow data, it is not understood why the pumps were used more in 2007 and 2009 rather than 2006 and 2008.

As expected, total flow increased during the summer months and decreased during the winter months over the 45 month period with an overall increase. This could be due to the increase in population density, increase of service area as well as climate change. The increase of population density in Kenosha, Somers, Bristol and Pleasant Prairie creates a higher waste source. There is about 100,000 customers in the Kenosha Metropolitan Area. Higher usage of water and creation of waste will increase flows overall. The increase of service area has to deal with the increase of population density as well, but it also has to deal with the politics of money within the county. Originally, the KWWTF was treating water from the city of Kenosha, but as time continued to pass, other cities in the county, such as Pleasant Prairie and Bristol decided to send their wastewater to Kenosha to be treated (Rabe, 2008). Climate change is also a factor in the overall increase of flows. The climate of Wisconsin has been increasing in temperature over the last few decades, causing there to be an increase of stronger storms. Thunderstorms are formed when a mass of warm air meets a mass of cold air. The warm, wet air mass rises and becomes to intensify (Sloan, 2006). The flow data supported the prediction by showing an increase during the summer months and a decline in the winter months in some cases. In 2008, there was a period where the temperatures warmed enough in January through March to melt the snow. This snow melt increased the flow to its highest point that year. In 2006, the highest flow recorded was in December. It was only slightly higher than the flows that peaked in April. The peak in December could be due to a climate shift where the winter didn't begin to get colder until January. In 2007, the flows rose and fell throughout the time period with the highest point being in the month of August. There were also large differences between the values. Every two to three months the flows would rise drastically or fall drastically.

The average flow data were compared to the data collected on the usage of three or more pumps. Three or more pumps signified non-standard operations. In 2006, the numbers of pump usage to flow increased exponentially. Six pumps were used on numerous occasions throughout the year. The average flow recorded for the time periods where six pumps were used was about 40.0 MGD. This is relatively low when compared to the other years. In 2007, there was also an increase of pumps used, as well as average flows. Figure 5 shows the usage of five and six pumps is about equal, with flows at roughly 45.0 MGD. In 2008, there wasn't any usage of three pumps. In 2008 was a high amount of precipitation was recorded, and is shown by the flows measured while four through six pumps were used. There were not any records of there being three pumps in use during non-standard operations in 2008. In 2009, the flows were also high. Figure 5 also shows that flow was higher than any other year per pump. The highest average flow recorded was about 80.0 MGD in pump 4. The fifth and sixth pumps were about equal at about 70.0 MGD. The third pump was even high at about 50.0 MGD.

The changes in flow and pump usage can be due to the same reasons that the flows are high; population density increase, climate change, and service area increase. The climate change, like stated earlier helps produce larger storms that can produce more precipitation in an area; thus increasing flows. The increase in population and service area can also increase the original flow, but also cause large increases in the flows during non-standard operations.

Phosphorus enters the facility at levels higher than the recommended amount allowed to enter a waterway. The DNR allows about less than or equal to 1.00 part per million (ppm) of phosphorus to enter water ways (KWWTF 2008). Extra phosphorus that enters the water way can affect the ecosystems already in existence; such as causing there to be an algae bloom. Algae blooms affect the water way by decreasing the amount of available oxygen found in the water. Looking at figure 6c, the trend stays the same throughout the entire data period. There are increases and decreases that are above and below the trend line. When the phosphorus data is compared to the flow data, as done in chart 4, a more definite relationship is formed. The top line shows the flows while the bottom line shows the phosphorus levels. Prior to receiving the data, Bruce Rabe mentioned that the data would most likely show the levels of phosphorus decreasing during times of higher flows. Figure 6c also shows that there is a decrease in the phosphorus found in the wastewater when the flows increased, and an increase when the flows decreased. This relationship between the phosphorus and the flows can be related to the storm water. Storm water, once it has entered the sewers dilutes the wastewater already flowing to the facility. The diluted storm water and wastewater lowers the amount of phosphorus seen in the samples tested. When the flows decrease, more phosphorus is found in samples.

Total suspended solids are measured during the primary treatment process. The solids are materials that continue to stay suspended in the water. There is evidence that the solids increase during the winter months and decline during the summer months. The increase during the winter months may be due to the temperatures. Molecules, when cold, compress together, making the solid more compact. This compacting of the solids may allow there to be more free space in the sewers; thus allowing more solids to enter the sewer at a given time. During the summer months, the solids may become less compacted, making it harder for large amounts of solids to pass through the sewers and into the facility at one time.

Overall the data collected and analyzed on phosphorus and suspended solids is showing what is entering the lake during overflows. The phosphorus and suspended solids is prone to enter the water ways as overflows occur, so therefore the data is being shown as an example of what and how much is entering the waterways during overflows. There is staff that is required to take samples of the water that is overflowing to be analyzed. There is biochemical oxygen demand, suspended solids, and fecal materials data within the data collected on overflows.

Unfortunately, the data on the features of the water only date back to the beginning of 2008. Therefore this data could not be added to the results of phosphorus and suspended solids exiting the facility. This is due to there not being enough data to compare over the 2006-2009 data period. The data on biochemical oxygen demand, suspended solids, and fecal materials found within the overflows can be better examined after a few more years of data are collected. As a future study, looking at the biochemical oxygen demand, suspended solids and fecal materials will allow for there to be a more in depth look at what is entering the lake during overflows.

Conclusions

After looking at all the pieces of data collected from the Kenosha Waste Water Treatment Facility (KWWTF), it is seen that the basin is not 100% effective in eliminating any storm water overflows. The overflows, while not being large in number, still allow thousands of gallons of water to not be treated prior to leaving the sewers. This large amount of water lost can still harm the ecosystem it enters.

From the data gathered and analyzed, flows do directly influence how much phosphorus enters the facility. When the storm water flows increase at the KWWTF, phosphorus levels begin to decrease. This is due to the dilution of the water that goes through the facility. The phosphorus levels begin to rise again as the flow levels begin to decline. The suspended solids is affected by the flows but not as greatly as the phosphorus. As the storm water increases the flows entering the facility, suspended solids rise slightly. Due to there not being a strong relationship between flows and suspended solids, it is important to look at other factors. The levels of suspended solids over time are more influential to gather conclusions from. The suspended solids begin to increase and peak in the late winter months and decline during the summer months. This could be due to temperature in the sewers as well as outside. Climate changes could also be a factor influencing the suspended solids. The climate changes are causing there to be a rise in temperature in the area. Increased temperature could be the cause for a decline in the amount of suspended solids recorded in the facility.

A future study of the Kenosha storm water basin compared to other wastewater treatment facility storm water management practices would greatly influence what type of management practice works better over others. Other storm water- high flow management practices include an underground tunnel, such as the deep tunnel in Milwaukee, WI, and wetlands specially designed to handle storm water flows.

Budget

Access to Facility Data	$0 (Public Records)
Gas for Transportation	$10 / week
Program Licensing (Excel, Word Perfect)	$500
Time to analyze data collected	$100/ Day it Takes to Complete Analysis
Time for consultations with facilities	$20/hour

Works Cited

"2008-2009 Muskegon Wastewater Treatment Ponds Weekly Waterfoul Count Estimates." Chart. *Muskegon Wastewater Treatment Facility*. Print.

Ahnert, M., J. Tranckner, N. Gunther, S. Hoeft, and P. Krebs. "Model-based Comparison of Two Ways to Enhance WWTP Capacity Under Stormwater Conditions." *Water Science & Technology* (2009): 1875-883. Print.

Bartlett, Jerry. "Storm Water Treatment Options at Composting Facilities." Feb. 2006: 23-27. Print.

"CDC - Costs of Illness in the 1993 Waterborne Cryptosporidium Outbreak, Milwaukee, Wisconsin." Message to the author. 26 Jan. 2010. E-mail.

"DB2 Universal Database." *IBM Support & Downloads - United States*. Web. 21 Jan. 2010. <http://publib.boulder.ibm.com/infocenter/db2luw/v8/index.jsp?topic=/com.ibm.db2.udb.doc/admin/c0006909.htm>.

Direxion Funds. Web. 22 Jan. 2010. <http://www.direxionfunds.com>.

"EPA - Pretreatment Standards & Limits." *U.S. EPA ColdFusion Server*. Web. 22 Mar. 2010. <http://cfpub.epa.gov/npdes/pretreatment/pstandards.cfm#prohibited>.

Gaigger, Glen T. "Wastewater Management in the 21st Century." *Journal of Environmental Engineering* (2007): 671-80. Print.

Geiman, Ron. "'Crypto' and Controversy in Milwaukee Water Debacle." Print.

Hatfield, J.L., and J.H. Prueger. "Impacts of changing precipitation patterns on water quality." *Journal of Soil and Water Conservation* 59.1 (2004): 51+. *Academic OneFile*. Web. 20 Mar. 2010

Harper, Kristine. *Weather by the Numbers the Genesis of Modern Meteorology*. Cambridge, Mass: MIT, 2008. Print.

Henson, Robert. *The Rough Guide to Weather*. New York: Rough Guides, 2002. Print.

Hsieh, Chi-hsu, and Allen P. Davis. "Evaluation and Optimization of Bioretention Media for Treatment of Urban Storm Water Runoff." *Journal of Environmental Engineering* (2005): 1521-531. Print.

Kerri, Kenneth D. *Operation of Wastewater Treatment Plants*. New York: Csus Foundation, 1992. Print.

Ludlum, David. *National Audubon Society Field Guide to North American Weather*. New York: Knopf, 1991. Print.

Magnaye, Florante A., Pag-asa D. Gaspillo, and Joseph L. Auresenia. "Biological nitrogen and COD removal of nutrient-rich wastewater using aerobic and anaerobic reactors." *Journal of Water Resource and Protection* [JWARP] 1.5 (2009): 376+. *Academic OneFile*. Web. 21 Mar. 2010.

Mannina, Giogio, and Gaspare Viviani. "Separate and Combined Sewer Systems: A Long-term Modelling Approach." *Water Science & Technology* (2009): 555-65. Print.

Milwaukee Metropolitan Sewerage District |. Web. 06 Nov. 2009. <http://www.mmsd.com>.

MMSD May Require Cities to Test Pipes for PCBs [Milwaukee, WI] 6 Sept. 2007. Print.

"Page Title Here - WDNR." *Wisconsin Department of Natural Resources*. Web. 18 Mar. 2010. <http://dnr.wi.gov/org/water/dwg/Crypto.htm>.

Peters, C., S. Keller, H. Sieker, and M. Jekel. "Potentials of Real Time Control, Stormwater Infiltration and Urine Separation to Minimize River Inpacts: Dynamic Long Term Simulation of Sewer Network, Pumping Stations, Pressure Pipes and Waste Water Treatment Plant." *Water Science & Technology* 56.10 (2007): 1-10. Print.

Pitt, Robert, and Shirley E. Clark. "Integrated Storm-Water Management for Watershed Sustainability." *Journal of Irrigation and Drainage Engineering* (2008): 548-55. Print.

Reynolds, Ross. *Cambridge Guide to the Weather*. Cambridge, U.K: Cambrige UP, 2000. Print.

Sloane, Eric. *Eric Sloane's Book of Storms Hurricanes, Twisters and Squalls*. Minneapolis: Dover Publications, 2006. Print.

Smith, B. R. "Re-thinking Wastewater Landscapes: Combining Innovative Strategies to Address Tomorrow's Urban Wastewater Treatment Challenges." *Water Science & Technology* (2009): 1465-473. Print.

Zhou, Yongchau, and Tian Li. "Case Study: the Performance and Design Outline of a Buffering Stormwater Drainage System for a Low-lying Area." *Water and Environment Journal* (2008): 199-205. Print.