United States Environmental Protection Agency

Wastewater Management Fact Sheet
In-Plant Wet Weather Peak Flow Management

INTRODUCTION

Managing sewage flows resulting from wet weather events presents numerous challenges at wastewater treatment plants (WWTPs). It involves the integration of planning, design, operation, and maintenance of not only the treatment system but the collection system as well (WEF Guide to Managing Peak Wet Weather Flows, 2006). When wet weather events contribute flows to a WWTP that exceed the capacity of one or more treatment units at the plant, inadequate treatment, operational difficulties, and/or National Pollutant Discharge Elimination System (NPDES) permit violations can result. These problems may include overflows, diversions in violation of the bypass provision of the permit, and exceedences of effluent limitations. A WWTP utilizing biological treatment requires a certain concentration of pollutants to operate effectively. Therefore these treatment plants can be severely impacted when dilute flows enter the treatment train. This can impact operations beyond the timeframe of the wet weather event. Addressing such peak flow problems typically involves a comprehensive solution that reduces flows in the collection system, provides storage to dampen peak flows, and increases the treatment capacity at the plant. Wet weather events can impact both combined and separate sewer systems. Though the peak flows at combined sewer systems will typically be greater, there are many similarities in how a treatment plant with combined or separate sewer systems can deal with the issue. This fact sheet describes possible treatment technologies and measures for managing WWTPs during wet weather peak flow events.

DESCRIPTIONS

Several options are available for facilities that pursue improved in-plant peak flow management. These management approaches generally involve either providing or increasing storage capacity, decreasing the volume of water entering the WWTP through rectifying infiltration/inflow issues, improving the storage of excess influent prior to primary clarification, or increasing the capacity of the existing treatment process by chemical and/or mechanical means or constructing additional treatment units.

Prior to selecting a technology, it is important to first characterize the existing conditions at the WWTP.

Assessment and Planning

If peak flows are presenting difficulties at a WWTP, it will be difficult to address those issues without proper planning, development, and evaluation of a peak wet weather treatment strategy. It is first necessary to characterize the existing conditions. This involves understanding the existing service area, the flows generated during peak events, operational techniques, monitoring requirements, and the collection and treatment systems. The characterization of existing conditions involves gathering known information, collecting missing information, and conducting an analysis of the system and its performance.

For the collection system, this analysis includes defining the service area, quantifying flows, and determining component capacity and limits. Possible causes of collection system performance difficulties include blockages in the system, high levels of infiltration and inflow, overflows, and infrastructure decay (pipe corrosion, etc.) (WEF, 2006).

For the treatment system, it is necessary to understand peak flow intensity, volume, and the corresponding wasteloads at the headworks of the WWTP. Not all treatment plants perform the same; therefore site specific information is crucial in order to determine the course of action for a particular WWTP. The treatment plant's ability to handle increased flows and loadings vary depending on the facility's permitting requirements, design preferences, and the levels of operation and maintenance performed at the facility (WEF, 2006).

A WWTP is comprised of numerous treatment units that combine to form the treatment system. It is necessary to understand the capacities of individual units and how they relate to the treatment system as a whole. It is also important to understand the design performance of a particular unit, the dry weather performance of that unit, and the wet weather performance of the unit. This can be a time and labor intensive task but is vital in properly understanding how peak flows impact the WWTP as a whole and which individual units of the plant may be stressed in these peak flow events.

A key component of the planning process is not only determining present conditions, but forecasting future needs. This can involve predicting future growth in the service area, assessing the impact of collection system modifications, evaluating the timeframes for the replacement of treatment units or collection system components, or anticipating future regulatory requirements.

Several techniques for addressing wet weather peak flows are presented below. It is expected that one or more of these practices or technologies will be applicable to a particular WWTP and understood that site-specific conditions will determine the best course of action.

Assessment of Existing Capacity

According to the Water Environment Research Federation's (WERF) report entitled *Research Priorities for Debottlenecking, Optimizing, and Rerating Wastewater Treatment Plants* (WERF 1999), the available capacity in WWTPs can be increased as much as 20 percent due to existing design and operation related inefficiencies. The report identifies three types of opportunities to achieve capacity gains within existing treatment facilities. These are:

- Debottlenecking: This involves the identification and removal of individual bottlenecks within a facility that can limit the overall capacity of the WWTP.
- Optimization: Reconfiguring an existing unit process to boost its capacity, or otherwise improve its performance, for example.
- Rerating: Reassessing a unit's capacity based on actual performance. Historical information or stress testing is used to redefine loading and flow capabilities.

Operational Procedures to Increase Capacity of Existing Units

Use of Existing and New Storage

Storage or flow equalization is used to lessen operational problems caused by flow rate variations, to improve the performance of downstream processes, and to reduce the size and cost of downstream facilities. This can also be an effective utilization of capacity which does not require construction of additional treatment capacity for infrequent events.

Storage is a means to reduce the magnitude of peak flow events and to spread the loading to the WWTP over a period of time. However, storage does not lessen the volume of water that will need to be treated. Flow equalization basins, tunnels, and converted abandoned treatment facilities are potential methods available to attenuate peak flow loadings conveyed to WWTPs.

Storage capacity should be evaluated for the necessary volume needed based on storm frequency, duration, and intensity. Determining the total volume of water to be treated and subtracting the design volume of the WWTP will indicate the needed capacity. If possible, initial removal of solids, mixing of the water, and flushing of the basin post storm event will lessen operational difficulties (WEF, 2006).

Storage can be applied upstream, midstream, or downstream (Field & O'Connor, 1997). In-sewer storage and use of unused treatment units for water storage will be the least expensive.

Solids Removal

Solids removal can greatly impact treatment plant performance. The performance of both primary and secondary clarification plays a large part in the overall efficiency of the biological treatment system at publicly owned treatment works (POTWs). Optimizing the performance of clarifiers during wet weather events will improve the ability of the treatment systems to respond to peak wet weather flows and improve the effluent quality of the discharge. There are a number of options that can be applied to both the primary and secondary clarifiers. Some of these include:

- Chemical Enhancement. Chemical Enhancement involves adding coagulant and flocculant chemicals to wastewater in order to accelerate the process of separating and removing solids. Coagulants are chemicals that help to form larger, heavier particles. Flocculants aid coagulants in the clarification process by bridging and binding solids together, thereby enhancing their settling capabilities.
- Baffle Installation in Clarifiers. Density currents can channel solids through a clarifier and over a weir, reducing effluent quality. These density currents can occur in both circular and rectangular clarifiers. Dye testing can be used to identify if such density currents exist and to assist in the placement of baffles.

Operational Control

In addition to solids removal, modifications to the biological treatment units can greatly improve peak flow performance. For those WWTPs employing suspended growth biological treatment, possible operational approaches include:

- Biosolids Control. Maintaining the proper mixed liquor suspended solids (MLSS) concentration for the type of treatment system being utilized can lessen the potential for washout during peak flows. The goal is to eliminate the build up of excessive solids (MLSS) in aeration basins to lessen the potential for washout and to maintain only a MLSS concentration that results in adequate treatment.
- Return Activated Sludge Rate Control. Regulating the rate of return of biosolids from the secondary clarifier to the biological treatment unit(s) can ensure proper solids content in the aeration basins and sludge blanket in the clarifier. This is vital to ensuring that wash out of microorganisms does not occur during peak flow events.
- Aeration Control. A low level of dissolved oxygen (DO) during periods of peak flow can result in lower effluent quality and promote filamentous growth which can affect solids removal during secondary clarification. The DO concentration can be increased through surface aeration as well as diffused air equipment.

Aeration Basin Configuration

Plant performance during peak flow events can often be improved by modifying the flow of water through the aeration basin with different configurations, including:

- Step Feed. The step feed process introduces wastewater following primary clarification into the aeration basin at several points in the basin. Since this could lower removal efficiencies for organics, it is recommended this only be used during peak flow events. The advantages to utilizing a step feed approach during wet weather events include equalizing the food-to- microorganism ratio and dispersing shock loads to the biological treatment system.
- Contact Stabilization. Contact stabilization is a modification of the traditional activated sludge treatment process. The return activated sludge is reintroduced to the aeration basin downstream of the conventional point. The return activated sludge is aerated prior to being blended with the influent to the basin. Again, this should only be utilized during peak flow conditions since it may reduce organic treatment efficiencies. Use of contact stabilization during peak flow conditions can help reduce solids losses during hydraulic surge events since the return activated sludge is introduced to the aeration basin at a different location than the direct influent flow.

For those facilities using fixed film biological treatment systems, there are also operational modifications that can be made to better manage peak flow conditions, such as the following:

- Reduce/Stop Trickling Filter or Rotating Biological Contactor Recirculation Flows. The recirculation of wastewater in trickling filters is commonly used to ensure adequate wetting of the media. For rotating biological contactors, recirculation is often used to promote biological growth. During peak flow conditions, recirculating water is not necessary and can be temporarily reduced or halted to allow for increased hydraulic capacity throughout the treatment system.
- Adjust Trickling Filter Distributor Arm Speed. Some distributor arms for trickling filters are hydraulically driven. During peak flow events, this may result in arm speeds that are problematic due to too much rotational speed. Nozzles can be installed on the distributor arm that discharges in the opposite direction of the normal nozzles thus slowing down the rotational speed of the arms. The new nozzles can be capped to return the arm to normal operation once the peak flow has passed and operations return to normal.

Chemical Disinfection

During times of peak flow conditions, the contact time of wastewater to chemical disinfectants such as chlorine or bromine may not be adequate for disinfection. It is important to ensure the influent that flows to the contact chamber, and the chemical disinfectant, are completely mixed before entering the chamber. High rate disinfection processes that have been shown to be successful include (Field and O'Connor):

- Increased mixing intensity;
- Increased disinfectant concentration (Care must be taken not to overdose, unless you use UV or ozone. If disinfectants are used in sensitive waters you have to disinfect or chlorinate and dechlorinate with care, as some disinfectants are toxic to aquatic life);
- Two stage dosing; or
- A combination of the above.

Advanced Physical – Chemical Processes

During peak flows, wastewater volumes can exceed the capacity of treatment units at WWTPs. These flows are typically intermittent, of a generally short duration, high volume, and may have a lower concentration of pollutants than a dry weather flow entering the WWTP. Physical-Chemical processes can help to mitigate the impact of peak flow conditions.

Installing Parallel Treatment Processes

The installation of parallel treatment trains to handle peak flow volumes can be a viable option to WWTPs. A physical-chemical system has the advantage of being able to be used intermittently and handle more dilute concentrations of pollutants.

Options for primary physical parallel processes include microscreens, plate settlers, and screening followed by dissolved air flotation, among others (Field & O'Connor). Effluent from the parallel process can either be discharged back to the WWTP headworks or, if all NPDES permit limitations and conditions are met, discharged directly to the receiving water.

Chemically Enhanced Primary Treatment (CEPT). CEPT is one type of chemical enhancement process that employs coagulants and flocculants in conventional primary clarifiers.

CEPT allows the sedimentation basins to operate at higher overflow rates, while still maintaining high removal rates of total suspended solids (TSS) and biochemical oxygen demand (BOD). Hence the treatment infrastructure can be smaller, which reduces capital costs.

Table 1. Performance data summary for select supplemental treatment technologies: Hydraulic Capacities and Removal Efficiencies.

Technology	Source(s)	Hydraulic Capacity (gpd/ft^2)	BOD Removal (Percent)	TSS Removal (Percent)
Primary Clarification	Metcalf and Eddy 1991; NEIWPCC 1998; WEF 1996	600-3,000	25-40	50-70
Screening	Metcalf and Eddy 1991			
Coarse (5-25 mm)		21,000-86,000	Not Available	15-30
Fine (0.1-5 mm)		150-1,400	Not Available	40-50
Micro (less than 0.1 mm)		150-1,400	Not Available	40-70
Vortex Separation	EPA 1996; Boner *et al.* 1995; WERF 2002	Up to and greater than 100,000	Up to 55 [a]	5-60
Ballasted Flocculation	Radick *et al* .2001; Scruggs *et al.* 2001; Vick 2000; Poppe *et al.* 2001	Up to 90,000	65-80	70-95
Chemical Flocculation	Metcalf and Eddy 1991; Moffa 1997	Up to 20,000	40-80	60-90

Table 2. Cost data summary for select supplemental treatment technologies: Capital and O& M Costs.

	Capital Costs ($/10^{3}m^3/d)	O&M Costs ($/10^{6}m^3)	Total Costs ($/10^{6}m^3)
Conventional Primary Treatment	3.1 — 4.2	0.8 — 0.9	1.7 — 2.1
Conventional Primary Plus Biological Secondary Treatment	9.1 — 9.8	1.2 — 1.6	3.5 — 4.3
Chemically Enhanced Primary Treatment	4.2 — 5.3	0.9 — 1.1	2.1 — 2.6

Additionally, CEPT provides the opportunity for either reducing the size of subsequent treatment units, or increasing the capacity of existing conventional treatment plants, such as activated sludge basins. The addition of metal salts and/or a polymer will only require tanks for the chemicals and injection equipment. Tables 1 and 2 present performance and cost data comparing for several technologies and operational measures.

Vortex/Swirl Separators

Vortex/Swirl Separators use centripetal force, inertia, and gravity to send heavier solid particles to the center and bottom of the swirling flow. When configured to operate within a WWTP, vortex/swirl separators help to remove solids prior to primary treatment. This existing technology has been successfully used at treatment plants for many years for wet weather flow treatment. Vortex/swirl separators are compact systems that provide flow regulation and some removal of solids and floatable material. The flow in vortex/swirl devices initially travels around the perimeter of the unit.

Flow is then directed into an inner swirl pattern with a lower velocity than the outer swirl (Figures 1 and 2).

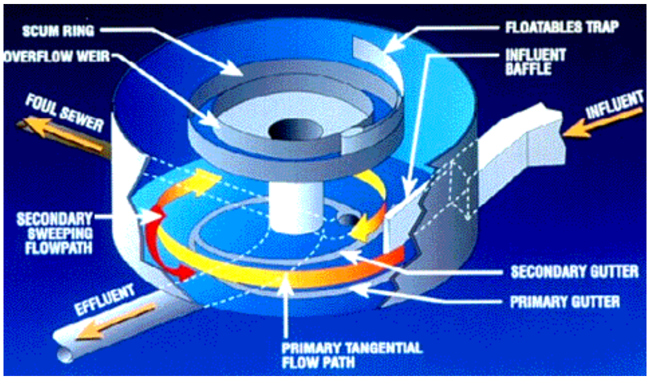

Figure 1. Onondaga Lake Improvement Project (2005), New York, Schematic Diagram

Figure 2. Hydro-International (2007)

The concentrated underflow passes through an outlet in the bottom of the vessel while the treated effluent flows out of the top of the vessel (i.e., "overflow water" flows down through central pipe to outlet "effluent" at bottom). Vortex/ swirl separators for wet weather flow treatment typically would be installed offline and would be empty at the start of a wet weather event.

One technology that uses vortex–swirl systems in wet weather applications is the Hydro Stormwater Management System offered by Hydro International (Portland, Maine). The system consists of three basic phases:

- a high-rate rotary-flow vortex separator to achieve clarification of excess flow (an example would be at a CSO point in a combined sewer system);
- an off-line storage system for clarified effluent; and
- controlling the flow from the catchment to the collection system and on to the treatment plant.

Vortex units have the primary advantage of operating at surface-overflow rates ranging from 5,000 gallons per day per square foot (gpd/sf) to 100,000 gpd/sf. This technology removes floatables and settleable solids by directing the flow tangentially into a cylindrical tank, creating a vortex (Figure 1). The vortexing action tends to concentrate settleable solids towards the center of the tank and removes the concentrated solids through a foul sewer outlet located at the bottom of the tank. The vortex separator has no moving parts and is designed to operate under high surface loading rates. Power is not required for operation of the unit, although influent, effluent and underflow pumping may be required depending on the hydraulics of the specific installation. Operation and maintenance requirements are low since the majority of the captured settleable solids and floatables are flushed into the foul sewer during the storm event.

Ballasted Flocculation. Ballasted flocculation is a high-rate sedimentation process that introduces coagulation and flocculation agents during high speed mixing to promote settlement and enhance solids removal (Figure 3). In the process, flow enters the first zone of the facility where the coagulating agent is added and mixed with diffused air. The coagulating agents are typically metal salts and/or polymer. The flow then enters the second zone where the flocculating agent together with a flocculating aid, either recirculated sludge or sand, is added. In this area, gentle mixing occurs to promote the formation of suspended floc particles. The flow then enters the settlement zone where the dense flocs settle out and are concentrated at the bottom of the basin. Clarified effluent passes through a lamellar settling zone to remove residual floc particles and the final effluent is discharged. The concentrated sludge is either recycled back to the second zone or wasted. Sludge from technologies utilizing sand as a flocculating aid are conveyed through a separation process whereby the sand is separated from the waste sludge and recycled back into the process or stored for future flow events (Onodaga Lake Improvement Project, 2005).

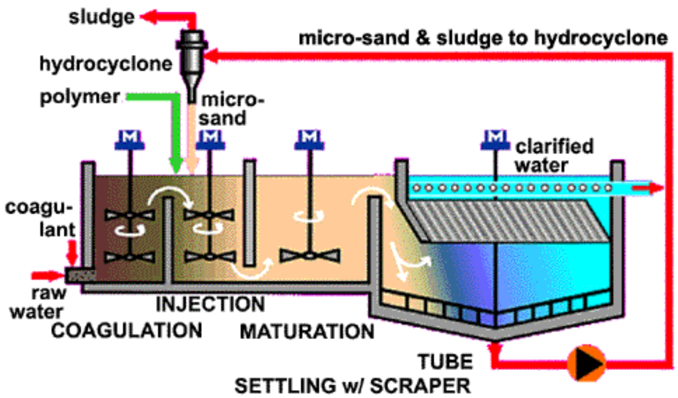

Figure 3. Ballasted Flocculation

(Onondaga Lake Improvement Project, N.Y., 2005)

Chemically Enhanced Clarification (CEC), also known as High Rate Clarification, is another type of chemical enhancement process that involves using coagulant and flocculant media in high-rate clarifiers such as DensaDeg® and Actiflo® to form dense, high settling velocity flocs. Certain CEC systems will operate as either chemical flocculation processes or ballast flocculation processes to settle effluent solids. Chemical flocculation relies on metal salt coagulants and anionic polymers for solids removal; whereas ballast flocculation relies on metal salt coagulants and anionic polymers coupled with materials such as microsand or chemically enhanced sludge for solids removal.

ADVANTAGES & DISADVANTAGES

Storage

Storing effluent in either a flow equalization basin or a converted, formerly abandoned treatment process can provide WWTP operators the ability to manage and store excess flows. This helps maintain treatment efficiency and allows for a greater volume of flow to receive more treatment.

Availability for expanding other treatment processes on the WWTP site should be taken into account when considering constructing on-site storage systems. In addition, restored facilities used as on-site storage systems, depending on their age, may deteriorate faster than a newly constructed flow equalization basin. Finally, on-site storage systems have finite capacity, which may not be sufficient to prevent combined sewer overflows (CSOs) or sanitary sewer overflows (SSOs) from occurring. In considering storage, factor in the impacts of weak (diluted) influent on the capability of the plant to consistently achieve permit limits.

Vortex/Swirl Separators

The major advantage of using vortex/swirl separators is their ability to remove suspended solids and floatables in effluent while dampening volumetric surges. In addition, vortex/swirl separators require little maintenance, as they contain no moving parts. Furthermore, these devices require only a small footprint for placement and installation. Additional advantages include no external power source requirements and low system headloss.

Limitations of the vortex/swirl separator are their inability to: remove fine and soluble products: disinfect excess wet weather flow (some newer systems can provide disinfection capabilities): process floatables during extreme wet weather flows; and maintain efficiency when equipped with sump systems.

Chemical Enhancement

Chemically Enhanced Primary Treatment, when implemented, has the potential to increase TSS removal efficiencies from a range of 55 to 65 percent to a range of 75 to 85 percent. Similar improvement potential exists for BOD removal. As a result, this technology may offer downstream processes (i.e., aeration basins, secondary clarifiers) greater latitude to operate efficiently under increased flow conditions.

While CEPT offers greater removal efficiencies of organic matter, its surface overflow rates function under a similar range to that of conventional primary clarifiers (3000 to 3500 gpd/ft^2 [122 to 143 L/m^2·d]). Consequently, CEPT requires a footprint similar to conventional primary clarifiers.

"Chemically Enhanced Clarification" systems achieve TSS removal efficiencies in the range of 80 to 95 percent. In addition, CEC systems operate at surface overflow rates 20-to-50 times greater than conventional gravity settling, while requiring a footprint that is typically only 5 to 15 percent of the space required for installing conventional primary clarifiers. In other words, CEC systems remove solids at faster rates and with a smaller footprint compared to conventional clarification systems. On the other hand, CEC systems have a limited ability to remove soluble pollutants. The greater the ratio of soluble to solid BOD, the greater the likelihood of expecting reduced BOD removal rates. In addition, CEC systems incur higher operational costs compared to conventional treatment systems due to cost of using and disposing of chemicals and sludge.

"Ballasted flocculation" has been reported to be capable of removing nearly 100% of settlable solids, up to 84% of TSS, 54% of BOD, 25% of TKN, and 90% of TP in CSO applications. However, it has been reported that the process requires approximately 10 to 30 minutes of startup time in order to stabilize before it is able to accomplish the above-stated pollutant removal efficiencies. In addition, preliminary screening is required before the flow is treated with ballasted flocculation. The operation and maintenance concerns associated with the system are high, due to the requirements for screenings disposal, chemical addition, sludge processing and disposal and the relatively high consumption of power.

The advantage of a ballasted flocculation system is that it provides a high degree of treatment. One disadvantage of this process is the physical size of the facility required. Ballasted flocculation facilities would cover approximately twice the surface area of vortex facilities. Other disadvantages are the time required to stabilize the system and high operation and maintenance concerns. As such, this technology is not considered feasible for remote, unmanned CSO treatment sites.

Unit cost data for these technologies is presented in Table 3.

Table 3. Performance data summary for select supplemental treatment technologies: Unit Capacities, Capital Costs, and Unit Costs

Technology	Source(s)	Capacity (MGD)	Estimated Total Capital Cost [a]	Unit Cost [a] (Per Gallon / Day of Capacity)
Primary Clarification	Hufford 2001	78	$11.0 million	$0.14
Screening	EPA 1999	0.75 - 375	$40,800 - $2.2 million	$0.01 - $0.05
Vortex Separation	Sacramento 1999	1.8 - 16.2[b]	$10,000 - $50,000	$0.01
Vortex Separation with Blending	Sacramento 1999	0.71 - 194	$13,000 - $630,000	$0.01 - $0.02
Ballasted Flocculation	Wendle 2002	15	$5.5 million	$0.37
	Hufford 2001	78	$12.4 million	$0.16
	WERF 2002	100	$20.0 million	$0.20
	Bremerton 2002	20	$4.0 million[c]	$0.20
Chemical Flocculation – Aluminum as Additive	Hewing *et.al,* 1995	Not Available	$0.50 (cost per pound)	$0.04 (per gallon treated)[d]
Chemical Flocculation – Ferrous Sulfate as Additive	Hewing *et.al.* 1995	Not Available	$0.17 (cost per pound)	$1.03 (per gallon treated)[d]

[a] Costs in 2002 dollars.
[b] Vortex separator capacities are hydraulic capacities. Manufacturer recommended design capacities for optimal TSS removal are generally 25 percent of the hydraulic capacities.
[c] Includes costs for a 20 MGD Ultraviolet (UV) disinfection process. Cost for ballasted flocculation alone was not available.
[d] Capital costs for chemical feed mechanisms not available. Treatment costs include chemical costs and sludge handling costs.
Ferrous sulfate generates larger sludge volumes than aluminum, significantly increasing treatment costs.

IMPLEMENTATION

Vortex/Swirl Separators

The City of Columbus, Georgia has installed several treatment systems as part of an evaluation and demonstration study conducted through a Congressional appropriation and EPA grant. Several technologies have been evaluated, including vortex separators. Managing and controlling flows upstream of the treatment plant can lessen the need for collection system infrastructure construction. That can result in large cost savings for municipalities. The five year program of operations and performance testing of the full-scale facilities has shown that the system demonstrated at full scale in Columbus is equivalent to, or better than, primary clarification. Cost savings can be up to one-half that of primary clarification and occupy one-tenth the footprint of conventional systems (Andoh, et al. 2002).

Chemical Enhancement

In January 2006, the City of Tacoma, Washington, began construction of a 75 mgd ballasted flocculation process at the City's Central Treatment Plant (CTP) to parallel existing primary clarification systems at the plant during wet weather events. The peak wet weather flow component is a portion of a much larger upgrade to the entire facility. The city developed a plan for maintaining adequate capacity at the CTP since the current separate sanitary sewer system was capable of delivering up to 110 MGD to the CTP. The existing primary treatment and disinfection processes can handle a capacity of 103 MGD and the existing biological treatment processes can handle a daily load of 78 MGD.

Cost became another factor in deciding to supplement Tacoma's CTP with ballasted flocculation systems and related wet weather processes as its estimated construction costs ($50.7 million) were less in comparison to the cost of expanding just the existing activated sludge processes onsite ($130 million).

Pilot tests demonstrated effluent TSS concentrations below 30 mg/L (with the exception of the first day of testing) and TSS removals ranging from 79 to 92 percent as well as effluent BOD concentrations ranging from 20 to 42 mg/L and BOD removals ranging from 63 to 73 percent.

The commissioned ballast flocculation process was scheduled to operate in parallel with the existing processes employed at Tacoma's CTP but only during wet weather events. The city anticipates the commissioned system to operate a maximum of 5.5 days in a row, 8 days in a month, and 21 days per year.

Other Sources of Information

The Office of Wastewater Management has developed additional fact sheets on storm water technologies that are available. These fact sheets can be found at http://www.epa.gov/owm/mtb/mtbfact.htm.

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