Supplemental Documentation Volume 11

Analysis of Wet Weather Treatment Alternatives for Southwest WPCP

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Final Tech Memo

Wet Weather Treatment Alternatives at Northeast, Southeast and Southwest WPCPs

SW2: Analysis of Wet Weather Treatment Alternatives for Southwest WPCP

Prepared for

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Executive Summary

Background and Project Summary

As part of the series of memoranda prepared for the Philadelphia Water Department's (PWD) Combined Sewer Overflow (CSO) Long Term Control Plan (LTCP) update, this report presents the conceptual design and cost analyses for four wet weather treatment alternatives for the Southwest Water Pollution Control Plant (SW WPCP). The wet weather treatment technologies for the SW WPCP evaluated in this report are as follows:

1. Vortex Swirl Concentrators
2. Conventional Clarifiers
3. Chemically Enhanced Primary Treatment (CEPT) with Conventional Clarifiers
4. Ballasted Flocculation (includes fine screening)

Conceptual treatment trains were developed for each treatment technology at various wet weather flows ranging from 220 million gallons per day (mgd) to 1740 mgd and cost curves for capital, operations and maintenance (O&M), and lifecycle costs were generated for each treatment train alternative.

Existing Plant and the New Wet Weather Treatment Facility

Currently, the SW WPCP has a flow capacity of 400 mgd. With several process and hydraulic modifications, as identified in the 2001 Stress Testing Report, the capacity of the existing plant can potentially reach 540 mgd (CH2M HILL, 2001). In sizing the wet weather treatment trains, it was assumed that these upgrades, costing $64.6 million, will have been completed, increasing the plant's capacity to a minimum of 540 mgd (Section 2). Any wet weather flow in excess of 540 mgd would be diverted to the new wet weather facility.

The new wet weather facility is sited in two tracts of land currently utilized by the Biosolids Recycling Center (BRC), the Upper and Lower BRC areas. Due to the likely infeasibility in routing a new outfall conduit from the BRC area through the Philadelphia International Airport to the Delaware River, a new outfall conduit to the Schuylkill River is proposed to be constructed for the new wet weather treatment facility. Unlike the Southeast and Northeast WPCPs, effluent from the wet weather facility will not commingle with the effluent from the conventional plant. This means that the regulating agencies may view the new facility as a separate wet weather treatment facility requiring a new discharge permit.

If blending of the two plant effluents is required or desired, the outfall for the existing plant could be relocated to the Schuylkill by constructing a new outfall conduit. The cost of this conduit, and thus comingling, is estimated at $155 million. Despite the difference in outfall locations, this report assumes that the SW WPCP and its new wet weather facility will operate as one system.

Flow Scenarios

Conceptual designs and cost estimates were developed for the design flows for each wet weather treatment train under evaluation (Exhibit ES-1). These flows were selected based on the ability to meet permit requirements (assuming commingling with existing plant), the capacity of the existing collection system, the land area available at the Upper and Lower BRC sites, and the maximum expected flow from the upgraded collection system, as described in Section 4.

EXHIBIT ES-1
Design Flows Evaluated for each Wet Weather Treatment Train

Treatment Train	Design Flows Evaluated (mgd)
#1) Vortex/Swirl Concentrators	220, 702
#2) Conventional Clarifiers	220, 600, 1200
#3) CEPT w/ Conventional Clarifiers	220, 550, 1000
#4) Ballasted Flocculation	220, 980, 1740

Comparison of Treatment Alternatives

Effluent Water Quality

Due to the varying removal efficiencies of each candidate treatment train, the resulting water quality differs widely between different trains. The TSS and cBOD concentrations of the effluent for each wet weather treatment train and flow scenario is presented under Section 10 in Exhibits 10-1 and 10-2, respectively. In general, ballasted flocculation provides the best treatment, achieving TSS and cBOD concentrations even lower than the existing plant.

Capital and O&M Costs

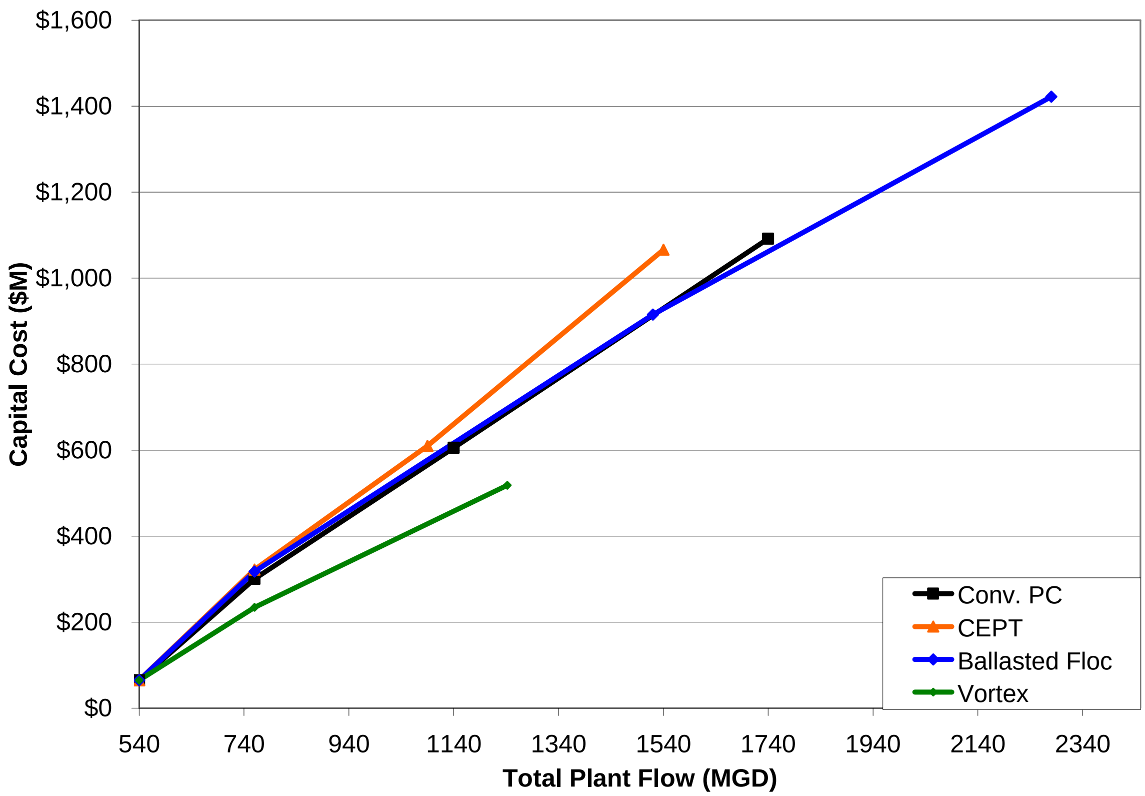
The capital cost estimates for the four treatment trains are shown in Exhibit ES-2. Train #3, CEPT, is the most expensive, followed by Trains #2 and #4, Conventional Clarification and Ballasted Flocculation, which appear similar in cost. The cost of Train #1, Vortex/Swirl, is significantly less expensive than the other three trains. Translated into capital cost per volume treated, all trains appear to become more cost effective as flow capacity increases (Exhibit ES-3).

The reason that CEPT is more expensive than Ballasted Flocculation for the SW WPCP wet weather facility is likely due to the limited length and increased number of its clarifiers, as described in Section 7.2, as well as the increased cost for piles.

The comparison of O&M costs for each treatment train is shown in Exhibit ES-5. As expected, the O&M costs for vortex swirls and conventional clarifiers, which do not require chemical settling aids, are the lowest. Ballasted Flocculation has the highest O&M costs due to its chemical usage and the complexity of its system.

Taking construction, non-construction, and O&M costs into consideration, Exhibit ES-6 shows the present value of the total cost of each wet weather treatment train. Again, CEPT and Ballasted Flocculation remain most costly due to their high capital and O&M costs. Train #1, vortex/swirl concentrators, is significantly less expensive compared with other technologies from the life-cycle cost perspective. This is due to its low chemical usage and minimal operations and maintenance needs.

EXHIBIT ES-2
Comparison of Capital Costs for All Treatment Trains



Note: Capital cost presented includes cost of improvements recommended in the Stress Testing Report ($64.6 million). Total plant flow includes flow from both the conventional plant and the wet weather treatment facility.

EXHIBIT ES-3
Comparison of Capital Cost Effectiveness for all Treatment Trains

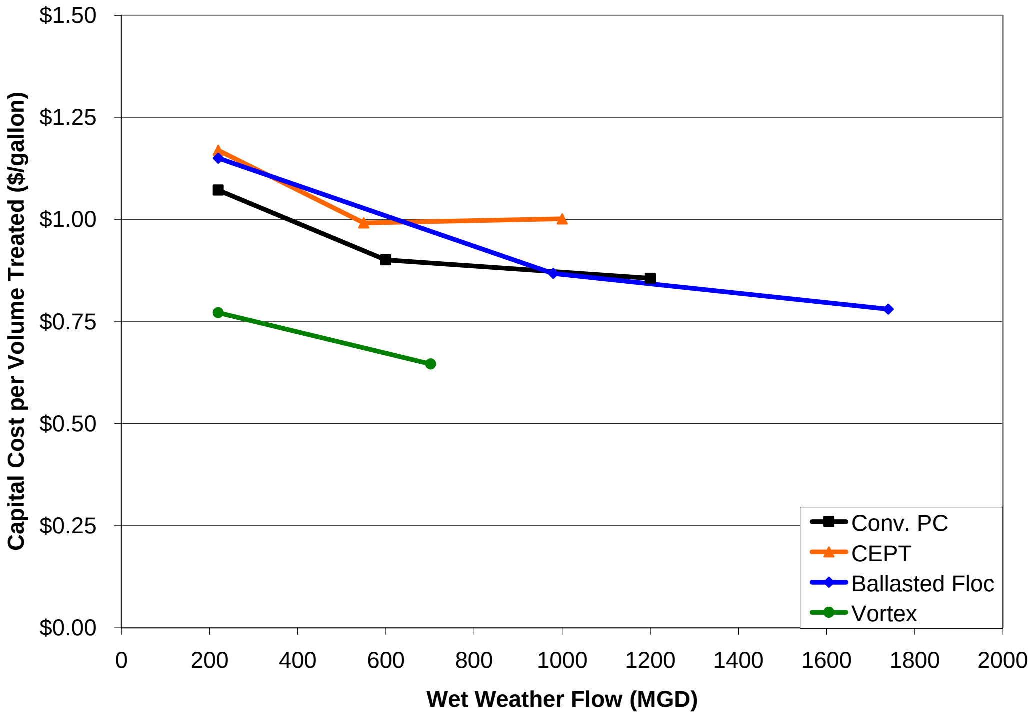


EXHIBIT ES-4
Comparison of Operations and Maintenance Costs for all Treatment Trains

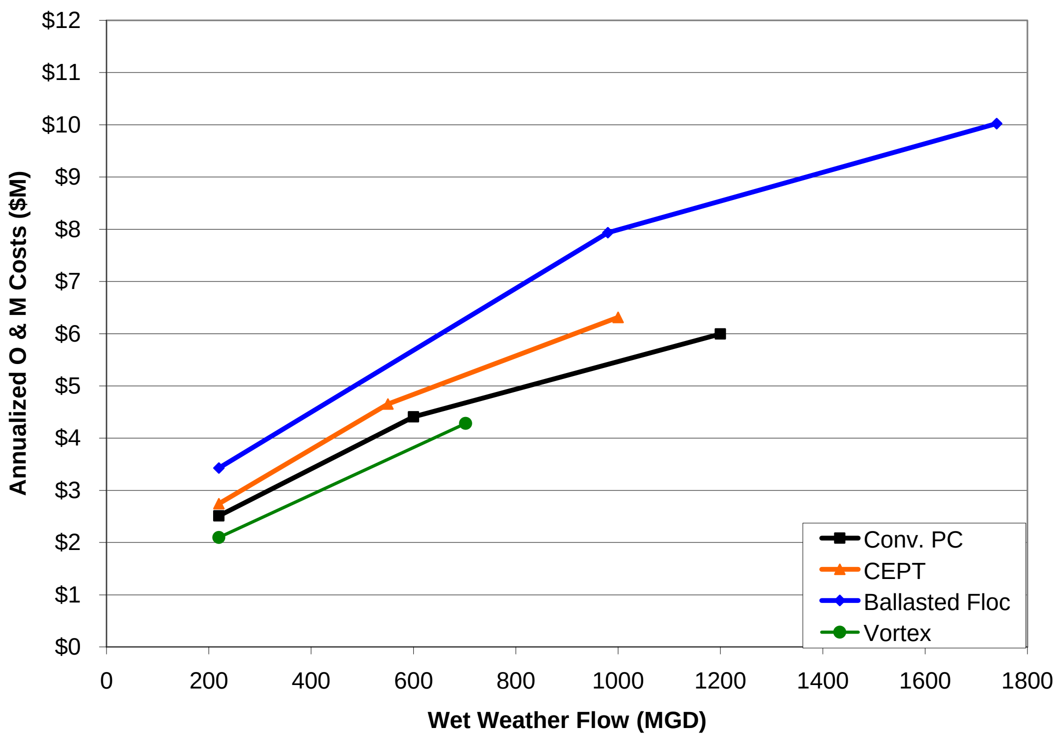
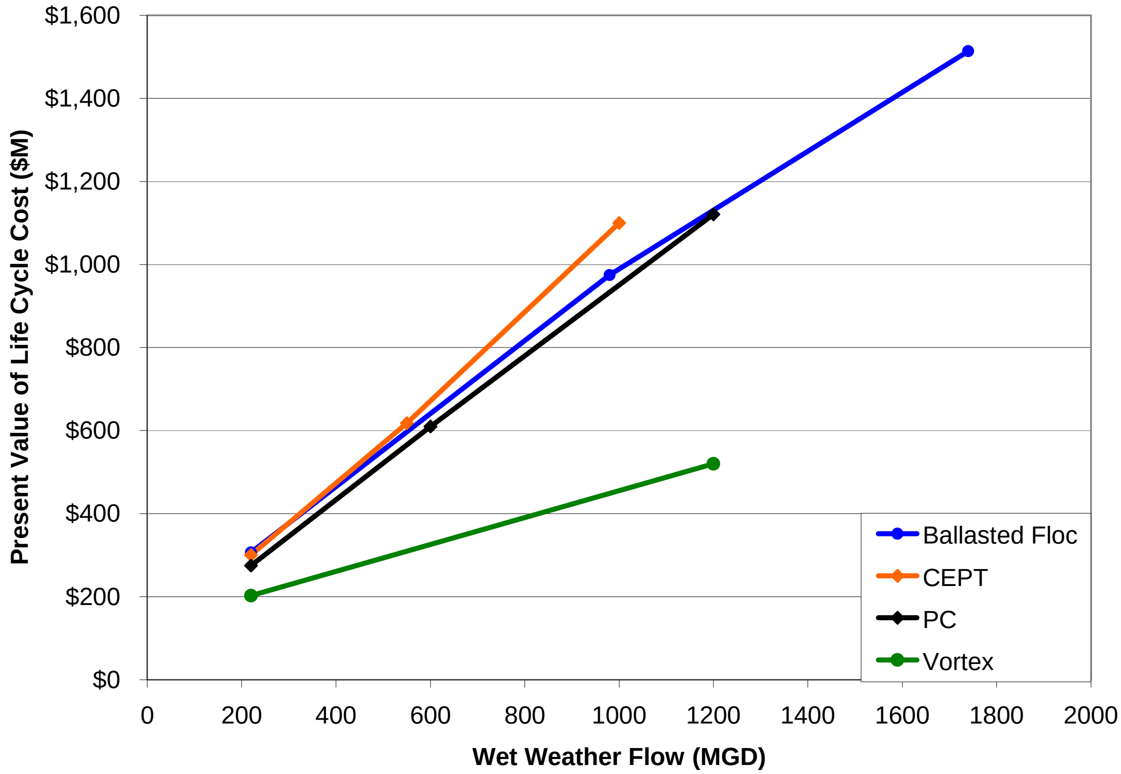


EXHIBIT ES-5
Comparison of Life-Cycle Costs for all Treatment Trains



Overall Comparison

Aside from capital, O&M, and lifecycle costs, there are numerous other criteria by which the treatment trains should be evaluated, including system reliability, community impacts, the ability to handle large variations in flow, land requirements, constructability, requirements for maintenance and operator attention, and sustainability. The main advantages and disadvantages for Treatment Trains #1 - #4, as evaluated in this report, are described in Exhibit ES-6.

EXHIBIT ES-6
Summary of Pros and Cons for Each Wet Weather Treatment Train

Treatment Train	Pros	Cons
Train #1: Vortex/Swirl Concentrators	• Simple operation • Low maintenance requirements – no moving parts	• Maximum design flow may decrease if the assumed number of operating days per month is greater than 7. • Unless operated at lower loading rates, removal efficiency may not be high enough to operate alone without blending effluent with main plant effluent.

EXHIBIT ES-6
Summary of Pros and Cons for Each Wet Weather Treatment Train

Treatment Train	Pros	Cons
Train #2: Conventional Clarifiers	• Simple operation • Same technology as existing plant –operators familiar with equipment	• Space limited • Maximum design flow may decrease if the assumed number of operating days is greater than 9 per month.
Train #3: CEPT	• Lower chlorine dose possible due to high TSS removal efficiencies • May be operated as Conventional Clarifiers if chemicals found to be unnecessary	• Operators unfamiliar with technology • Space limited • Can treat less flow on land available than conventional clarifiers • Uses two additional chemical systems for coagulation and flocculation
Train #4: Ballasted Flocculation	• Can treat up to 1740 mgd with available land on site • Highest removal efficiencies • Unlimited number of operating days per month • Lower chlorine dose possible due to high TSS removal efficiencies	• Operators unfamiliar with technology • Most labor intensive and complex system • Uses two additional chemical systems for coagulation and flocculation

The costs for wet weather treatment at the SW WPCP should be analyzed with the costs of other wet weather treatment alternatives, such as improvements in the collection system, to determine which treatment train alternatives and flow regimes should be evaluated further. Treatment trains that are selected for further evaluation should undergo more detailed design and costing methods, water quality sampling, and bench and pilot scale testing, so that removal efficiencies, land requirements, capital costs, and O&M costs can be further refined.

Contents

Exhibits

1.0 Introduction

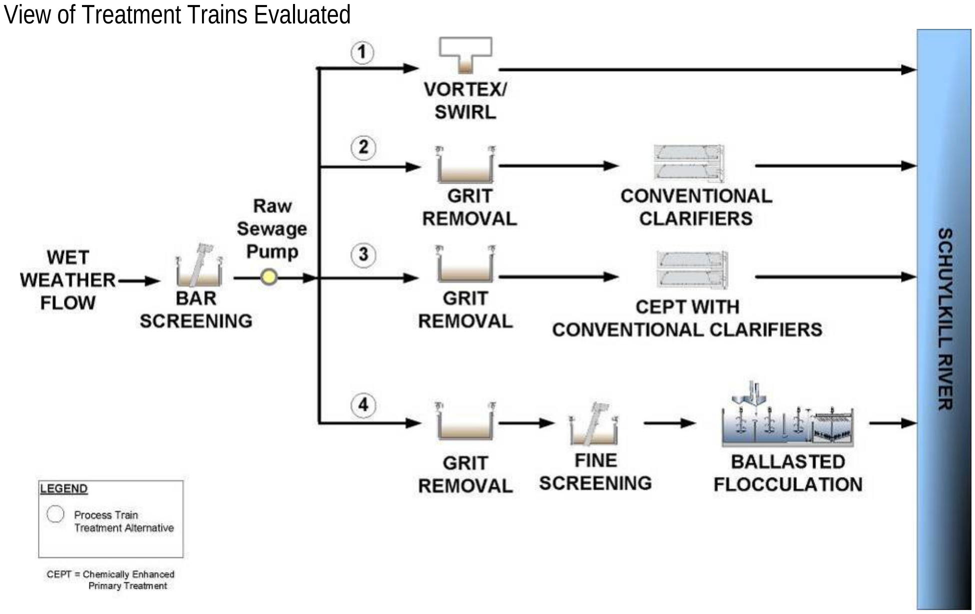
As part of the series of memoranda prepared for the Philadelphia Water Department's (PWD) Combined Sewer Overflow (CSO) Long Term Control Plan (LTCP) update, this report presents the conceptual design and cost analyses for four wet weather treatment alternatives for the Southeast Water Pollution Control Plant (SW WPCP). These treatment alternatives were short listed from previous evaluations by the LTCP team (PWD, CDM, and CH2M HILL) based on information from: water quality data analysis and review of available land for SW WPCP; survey of various potential wet weather treatment technologies; and site visits to three existing wet weather treatment facilities in Ohio (CH2M HILL, 2008b). A treatment train utilizing CEPT with Plate Settlers was evaluated for the Southeast WPCP, but was subsequently eliminated due to its extremely high cost (CH2M HILL, 2008c).

The wet weather treatment technologies for the SW WPCP evaluated in this report are as follows:

1. Vortex Swirl Concentrators
2. Conventional Clarifiers
3. Chemically Enhanced Primary Treatment (CEPT) with Conventional Clarifiers
4. Ballasted Flocculation (includes fine screening)

Conceptual treatment trains were developed for each treatment technology at various wet weather flows ranging from 220 million gallons per day (mgd) to 1740 mgd (Exhibit 1-1). Cost curves for both capital and operations and maintenance (O&M) costs were generated for each treatment train alternative. This report presents the conceptual design parameters, site layouts, cost estimates, and potential issues of each treatment train alternative.

EXHIBIT 1-1
Schematic View of Treatment Trains Evaluated



2.0 Improvements to Existing Plant

In order to increase the flow capacity of the SW WPCP for wet weather conditions, the potential of maximizing flow through the existing plant was evaluated. From 2004 to 2007, the SW WPCP treated an average daily flow of 193 mgd, a maximum daily flow of 432 mgd, and an instantaneous peak flow of 489 mgd. The maximum plant flow sustained over 12 hours was 466 mgd (CH2M HILL, 2008b).

According to stress testing results and recommendations, the SW WPCP's firm capacity can potentially reach 540 mgd with several process and hydraulic modifications (Exhibit 2-1). The necessary improvements to achieve this flow were identified in the 2001 Stress Testing Report and are based on results of stress tests on unit processes, long-term monitoring of the plant, hydraulic modeling, and input from SW WPCP plant staff (CH2M HILL, 2001).

In sizing the wet weather treatment trains, it was assumed that the upgrades proposed in the Stress Testing Report and identified in Table 2-1 will have been completed, increasing the plant's capacity to a minimum of 540 mgd. Thus, the baseline cost that is used in the wet weather treatment train cost estimates is $64.5 million (Exhibit 2-1). This is reflected in the cost curves for each treatment train, presented in latter sections of the report.

EXHIBIT 2-1
Cost Summary of Potential Improvements for Existing SW WPCP

	Improvement Description	Cost[1]
1	Replace caulking on secondary clarifier launders to improve flow distribution	Complete
2	Provide preliminary treatment for the BRC centrate that is recycled to the plant	$17,585,962
3	Modify existing RAS system in the secondary clarifiers	$8,717,624
4	Provide four gravity thickeners for thickening of primary sludge (tentative location west of the Final Sedimentation Tanks)	$25,165,565
5	Resolve hydraulic limitations between primary clarifiers and aeration basin	$11,121,009
6	Provide an additional effluent pump at the effluent pumping station	$1,981,532
	TOTAL	$64,571,692

(1) Assume escalation factor of 19.8% - based on 9/1/2009 start date and 2-year construction duration.

3.0 New Facility Location

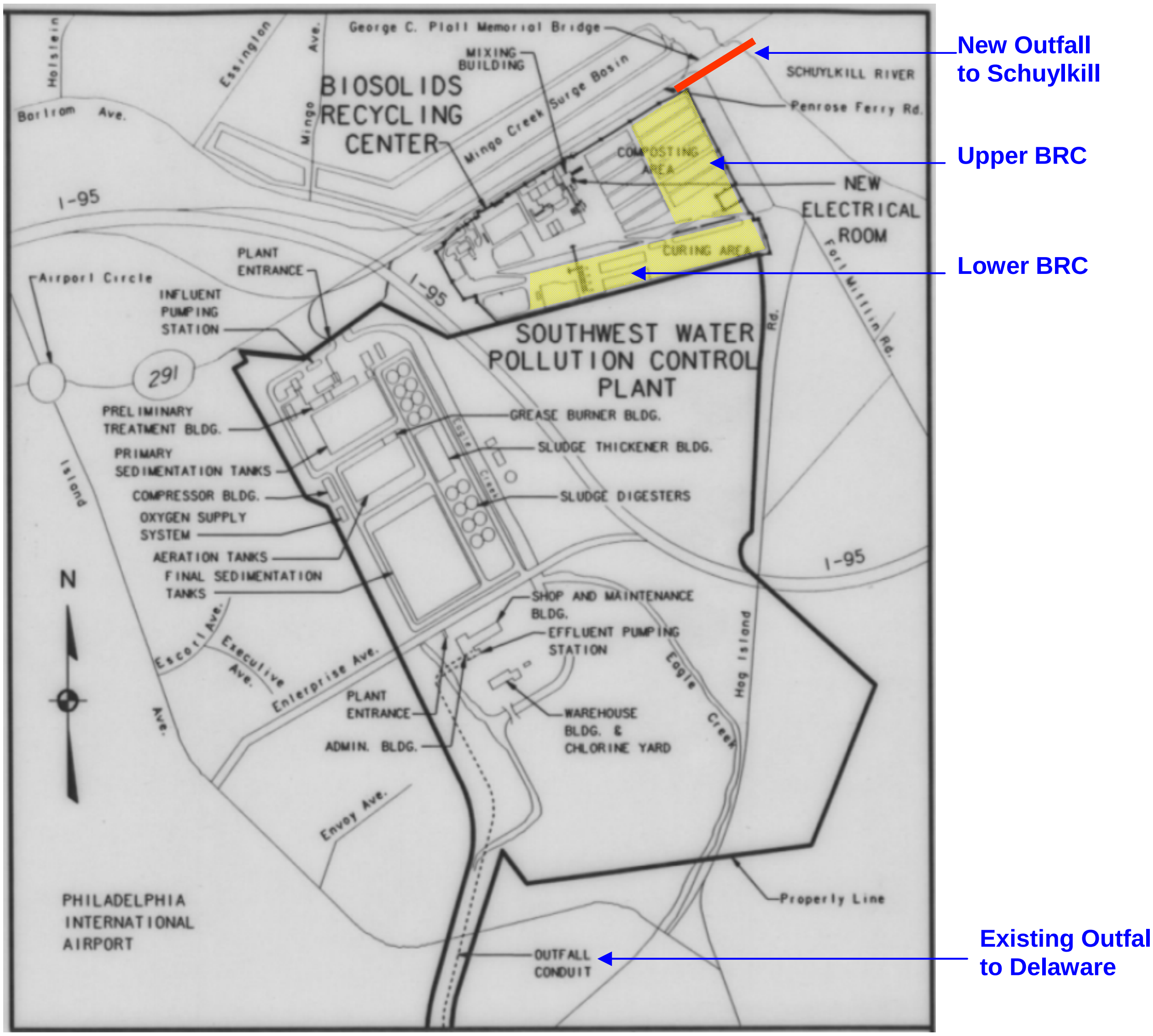
The existing SW WPCP is located east of the Philadelphia International Airport, near the confluence of the Schuylkill and Delaware Rivers. Due to proposed construction activities by both the Federal Aviation Authority (FAA) and the Army Corps of Engineers (ACOE) in the vicinity, the land area available for plant expansion is limited. While the impact of the proposed projects by the FAA and the ACOE is presently undetermined, it was decided that the wet weather treatment facility should be located in an area least likely to be affected by projects proposed by those entities. The area north of the lagoons, currently utilized by the Biosolids Recycling Center (BRC) for composting and curing, was chosen as a suitable location for the new wet weather treatment facility. This L-shaped area is comprised of two tracts of land referred to as the Upper BRC and the Lower BRC (Exhibit 3.1).

3.1 New Outfall to the Schuylkill

The outfall conduit for the existing SW WPCP passes underneath the airport as it runs southward from the plant to the Delaware River. Since it runs under an airport runway on FAA property, the expansion of this existing conduit is considered infeasible. Alternate routes to the Delaware also appear difficult for construction. Given the new wet weather facility's proximity to the Schuylkill River, the most logical alignment for the new outfall conduit is eastward along Penrose Avenue, terminating at the Schuylkill River near the George Platt Memorial Bridge (Figure 3.1).In order to construct a new outfall to the Schuylkill, a new discharge permit will need to be negotiated for the new wet weather treatment facility. Unlike the Southeast and Northeast WPCPs, effluent from the wet weather facility will not commingle with the effluent from the conventional plant. This means that the regulating agencies may view the new facility as a separate wet weather treatment facility, not as an expansion of a WPCP requiring secondary treatment.

If blending of the two plant effluents is required or desired, the outfall for the existing plant could be relocated to the Schuylkill by constructing a new outfall conduit. The cost of this conduit, and thus comingling, is estimated at $155 million. Since the value of comingling is questionable, the cost of this blending option is not included in the cost curves. In terms of plant operation, this report will treat the new wet weather facility as part of the SW WPCP, despite the difference in outfall locations.

EXHIBIT 3-1
New Wet Weather Facility Location for the SW WPCP



4.0 Wet Weather Treatment Alternatives: Evaluation Methodology

As described above, the new wet weather facility for the SW WPCP will be designed to treat all flows that cannot be treated by the conventional plant. As such, wet weather flows in excess of 540 mgd will be diverted to the new facility. The four wet weather treatment trains under evaluation for the new facility are:

1. Vortex Swirl Concentrators
2. Conventional Clarifiers
3. Chemically Enhanced Primary Treatment (CEPT) with Conventional Clarifiers
4. Ballasted Flocculation (includes fine screening)

Conceptual designs and cost estimates were performed for each treatment train at different design flows. This section describes the development of the various design flows and the key assumptions for design and cost estimating.

4.1 Design Flows

The design flows that were selected for evaluation for each treatment train are shown in Exhibit 4-1 and are described below in further detail.

EXHIBIT 4-1
Design Flows Evaluated for each Wet Weather Treatment Train

Treatment Train	Design Flows Evaluated (mgd)
#1) Vortex/Swirl Concentrators	220, 702
#2) Conventional Clarifiers	220, 600, 1200
#3) CEPT w/ Conventional Clarifiers	220, 550, 1000
#4) Ballasted Flocculation	220, 980, 1740

4.1.1 Minimum Design Flow: 220 MGD

The 220 mgd flow point reflects the capacity of the wet weather treatment train required to bring the treatment capacity of SW WPCP to the same level as the existing collection system capacity. In a technical memorandum provided by CDM, it was noted that the existing collection system can deliver 760 mgd to the SW WPCP assuming all process and hydraulic limitations in the plant are removed (Myers, 2007). With the assumption that 540 mgd can be treated by upgrading the existing plant, the new wet weather treatment train will need a minimum capacity of 220 mgd.

4.1.2 Design Flow by Permit Limits: 702 MGD

Unlike the Northeast and Southeast plants, no physical blending of the effluents from the conventional and wet weather plants at SW WPCP will actually occur (Section 2). For the purposes of this evaluation, we have considered the existing plant and its new wet weather facility as one system and have based the maximum allowable system flows on the water quality of the commingled flow. This allows for the determination of the maximum allowable flow through each wet weather treatment train for the system to continue meeting NPDES permit limits for weekly and monthly TSS and cBOD concentrations (Exhibit 4-2, CH2M HILL, 2008b).

With the exception of the Vortex/Swirl train, the flows through the candidate wet weather treatment trains were unlimited by permit requirements, assuming that the wet weather treatment facility operates for no more than seven days per month. The maximum allowable flow through the Vortex/Swirl train is 702 mgd. The maximum flows for the “unlimited” trains are bounded by other conditions as described in Sections 4.1.4 and 4.1.5.

It should be noted that if PWD were to negotiate a new discharge permit to the Schuylkill for the wet weather treatment facility, the maximum allowable flows through each wet weather treatment train would also need to be negotiated. Thus, the flow points analyzed in this report were used for the development of cost curves, but may not reflect what will be allowable under the regulatory framework.

EXHIBIT 4-2
Maximum Allowable Flow of Wet Weather Treatment Trains to Meet NPDES Permit Requirements

Treatment Train	TSS Removal Efficiency(1) (%)	Achievable Effluent TSS Concentration of Wet Weather Train(2) (mg/l)	Maximum Allowable Flow Through Wet Weather Train(3) (mgd)
#1) Vortex/Swirl Concentrators	30%	158	702
#2) Conventional Clarifiers	55%	102	Unlimited*
#3) CEPT w/ Conventional Clarifiers	80%	45	Unlimited*
#4) Fine Screening -> Ballasted Floc	91%	21	Unlimited*

*These flows are unlimited assuming the wet weather treatment train operates for no more than seven days per month, an estimate provided by CDM (CH2M HILL, 2008b).

(1) TSS removal efficiencies are based on industry standards. Specific references are provided in TM-SE2 (CH2M HILL, 2008a).

(2) Achievable effluent concentrations based on 95th percentile influent wet weather TSS concentration (226 mg/L)

(3) Maximum flow determined by NPDES Monthly TSS Limit assuming blending between conventional and wet weather plant. The allowable daily “blended” effluent TSS concentration during wet weather was calculated to be 99 mg/L (CH2M HILL, 2008b).

4.1.3 Design Flows by Available Land – Upper BRC: 550 MGD, 600, 980 MGD

While both the Upper and Lower BRC areas are available for the new wet weather facility, the two strips of land are separated by Penrose Ferry Road. To keep both the new wet weather facility and the BRC on the same side of the road, the use of the Upper BRC alone was assessed. It was found that a 550-mgd CEPT facility, a 600-mgd Conventional Clarification facility, or a 980-mgd Ballasted Flocculation could fit on the Upper BRC site alone. The 702-mgd vortex facility described above is also able to fit on this site.

4.1.4 Design Flows by Available Land – Upper and Lower BRC: 1000, 1200 MGD

Making full use of the land available in both the Upper and Lower BRC areas, it was found that either a 1000-mgd CEPT facility or a 1200-mgd Conventional Clarification facility could fit on the entire site.

4.1.5 Maximum Design Flow: 1740 MGD

According to CDM's assumptions on the capacity of the upgraded collection system, the collection system capacity for the SW WPCP could reach 2,280 mgd after transmission improvements, equivalent to three times the existing collection system capacity. Assuming the existing plant will be able to handle 540 mgd, the maximum flow to the new wet weather facility will be 1,740 mgd. The maximum design flow point used for the ballasted flocculation was thus 1,740 mgd. This facility will be able to fit on the Upper and Lower BRC areas.

4.2 Key Design Assumptions

4.2.1 Average Design Flow

In the previous section, the design flow capacities were identified for each treatment train based on permit limits, available land area, and collection system capacity. These flows are the peak flows that the wet weather facilities are designed to treat under each scenario.

The average flow that the wet weather facility will receive, however, depends on conditions in the collection system. Preliminary model simulations have been performed for the Southwest Drainage district (SWDD) under several deep tunnel and plant expansion scenarios (CDM, 2008). Simulation results suggest that the average flow delivered to the wet weather facility increases as the capacity of the facility increases, and is not highly sensitive to the volume of storage in the collection system (Exhibit 4-3).

Model runs for a 540-mgd and a 1,080-mgd wet weather facility generated an average flow of 362-mgd and 472-mgd, respectively, assuming the largest storage tunnel scenario. Based on these model results, the maximum average design flow assumed for the new wet weather treatment trains evaluated in this report is 472-mgd. For the Conventional Clarification 600-mgd and the CEPT 550-mgd scenarios, an average flow of 362-mgd was assumed. For trains with peak capacities less than 362 mgd, the average flow is assumed to be equivalent to the peak flow of the facility (Exhibit 4-4).

EXHIBIT 4-3
Average Annual Wet Weather Treatment Rates Under Various Deep Tunnel and Plant Expansion Scenarios

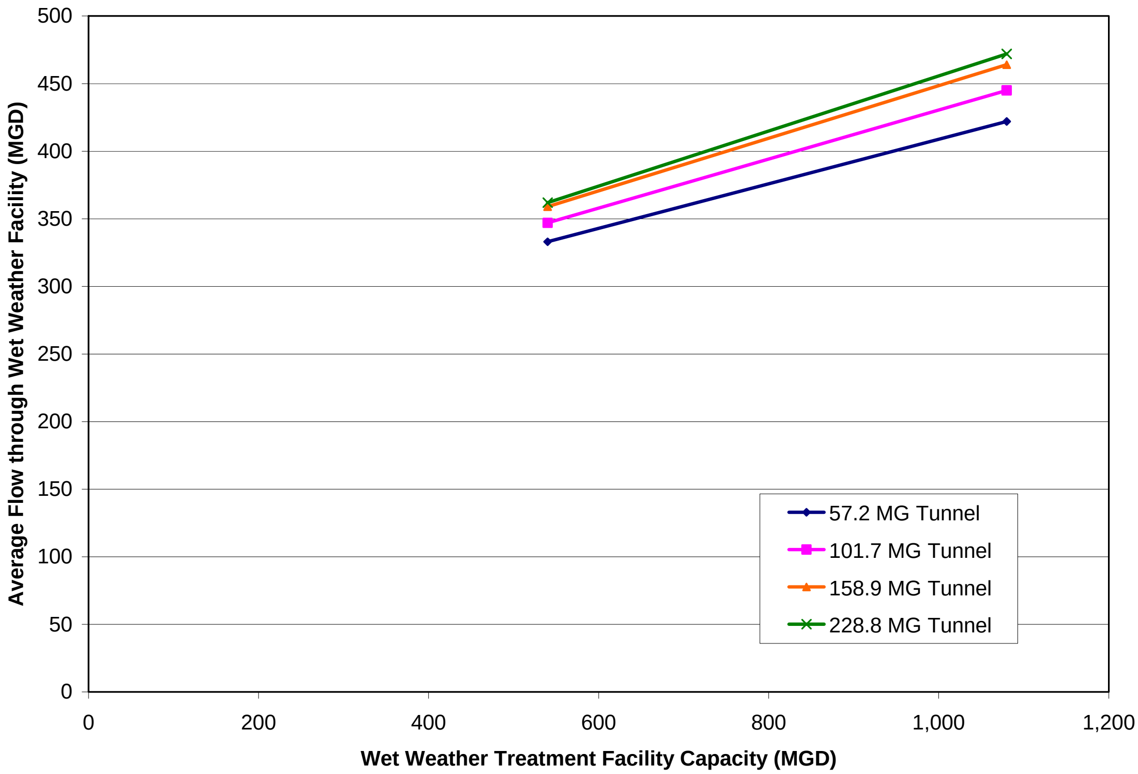


EXHIBIT 4-4
Average Design Flows

Maximum Design Flow (mgd)	Average Design Flow (mgd)
220	220
550, 600	362
980, 1000, 1200, 1740	472

4.2.2 Process

The process design described herein is based on conceptual design parameters and will require refinement as the planning and design efforts progress. For the purposes of developing capital costs, sizing of most facilities was based on maximum design flows. The average design flow, as described above, was used for sizing chemical storage facilities, storage for screenings and grit, and sludge handling facilities.

Preliminary Treatment

Each wet weather train evaluated in this report was sized to treat influent flow in excess of the plant's flow capacity of 540 mgd. A new influent conduit will divert excess wet weather flow to the new preliminary treatment building (PTB) of the wet weather treatment facility. The new PTB will contain an influent wet well at a similar elevation to the existing wet well, bar screens, influent pumps, and screenings and grit handling systems. The influent pumps were designed to increase the hydraulic grade line so that the wet weather flow can discharge to the river outfall by gravity from the wet weather treatment facilities. The screenings and grit handling systems include screenings washers and compactors, as well as grit concentrators and classifiers. This system will handle screenings from both the bar screens and the fine screens when required.

From the PTB, the wet weather flow will continue on to further treatment through processes dependent on each treatment train. These are described in further detail in Sections 5 through 8.

Disinfection

The final process of all treatment trains is chlorination and dechlorination. The wet weather flow will be dosed with sodium hypochlorite at the head of the new chlorine contact chamber. For all facilities with capacities of 600-mgd or less, the chlorine contact chamber is sized to provide a 20-minute detention time at peak flow. For facilities with higher capacities, the chamber is sized for a 10-minute detention time at peak flow, and it is assumed that the chlorine dosage will be increased correspondingly to provide adequate disinfection. Sodium bisulfite is then used for dechlorination at the end of the chlorine contact chamber. A new 700-ft long outfall conduit will convey the treated effluent to the Schuylkill River.

Chemical Feed

For CEPT and Ballasted Flocculation, which provide chemically-enhanced clarification, a coagulant and flocculant are added as settling aids. For CEPT, Train #3, these chemicals are added to a rapid mixer and flocculation basin upstream of the sedimentation tank. In the ballasted flocculation, Train #4, the settling aids are added to mixing zones that are part of the ballasted flocculation unit.

Ferric chloride was selected as the coagulant for all trains since it is currently used at PWD's water treatment plants. However, if there are concerns with the iron affecting the digestion process downstream, aluminum sulfate (alum) can be used as a substitute. Liquid polymer is used as the flocculant for all trains.

Ten-day storage at average flow was assumed for all chemicals.

Sludge Handling

Primary sludge from all treatment trains is pumped to gravity thickeners, where the solids concentration is expected to increase to a minimum of 3 percent. The thickeners are sized to handle the average wet weather flow (as presented in Exhibit 4-4) with a 95 percentile influent solids concentration (226 mg/L) for a continuous period of 24 hours.

The thickened sludge will be pumped to the plant's digesters for treatment. The sludge will be screened through StrainPress® sludge cleaners to remove inert solids before entering the digesters. Capital costs for each treatment train include the cost of extra digesters that may be required at the SW WPCP, assuming a maximum of seven wet weather days in one month. The digesters were sized to provide 20-day storage for solids, assuming average flow, a 95 percentile influent solids concentration (226 mg/L), an average wet weather event duration of five hours, and five events in 20 days. The new digesters will be located in the vacant area south of the existing digesters at the SW WPCP. The digesters needed for the SE WPCP wet weather facility will also be located in this area.

The design parameters that were assumed for all the treatment train processes are summarized in Exhibit 4-5. The process flows are described in further detail in each of the treatment train sections.

EXHIBIT 4-5
Key Process Design Assumptions for Wet Weather Treatment Trains(1)

Preliminary Treatment			
Bar Screens	Opening Size	15	mm (0.59 in)
	Screenings Production(2)	3.5	cf/mg
Influent Pumps	Type	Vertical End-Suction	
	Total Dynamic Head (TDH)	60	ft (match SW WPCP wet well elevations)
Fine Screens	Opening Size	6	mm (0.24 in)
	Screenings Production(2)	2.5	cf/mg
	Screenings Compaction Factor	2	
Grit Removal	Type	Vortex Grit Unit	
	Grit Production(2)	4	cf/mg
Screenings and Grit	Number of Days Storage	1	day
Primary Clarifiers	Type	Rectangular Basin	
	Sludge Collection Mechanism	Chain-and-flight	
Flocculation Tank	Detention Time (at max flow)	10	min
	Number of Stages	3	
Wet Weather Treatment Technology	**Surface Overflow Rate (gpd/sf)**		
Vortex/Swirl	36,000 (25 gpm/sf)		
Conventional Clarifiers	2,400 (3)		
CEPT	3,000		
Ballasted Flocculation	84,600 (60 gpm/sf)		
Chlorine Contact			

EXHIBIT 4-5
Key Process Design Assumptions for Wet Weather Treatment Trains(1)

Chlorine Contact Chamber	Detention Time (at avg flow)	20	min
Chemical Feed			
Chemical	**Purpose**	**Concentration**	**Storage (at avg flow)**
Ferric Chloride	Coagulation	60 mg/L	10 days
Liquid Polymer	Flocculation	2 mg/L	10 days
Sodium Hypochlorite	Chlorination	5 mg/L	10 days
Sodium Bisulfite	De-chlorination	1.5 mg/L(4)	10 days
Primary Sludge Generation(5)			
Train	**% TSS Removal**	**% Solids in Sludge**	
#1: Vortex/Swirl	30%	0.07%(6)	
#2: Conventional Clarifiers	55%	0.5%	
#3: CEPT	80%	0.5%	
#4: Ballasted Floc	90%	0.3%	
Sludge Thickening			
Gravity Thickeners	Max Hydraulic Loading Rate (limiting factor for Trains #1 and #5)	900	gal/sf/day
	Max Solids Loading Rate (limiting factor for Trains #2, #3, and #4))	30.7	lb/sf/day
	% Solids of Thickened Sludge	3	% minimum
StrainPress® Sludge Screens	Sludge Throughput	200 – 400	gpm
Digesters			
Anaerobic Digesters	Detention Time	20	days
	Diameter	115	ft
	Side Water Depth	25	ft
	Volatile Solids Destruction	50	%

(1) Unless otherwise noted, all design parameters are based on standard textbook values.

(2) Estimated from 2004-2005 grit and screenings disposal records from the SE WPCP (CH2M HILL, 2008c).

(3) Based on stress testing results on existing primary clarifiers

(4) Assumes 1 mg/L residual chlorine concentration at the end of the chlorine contact chamber

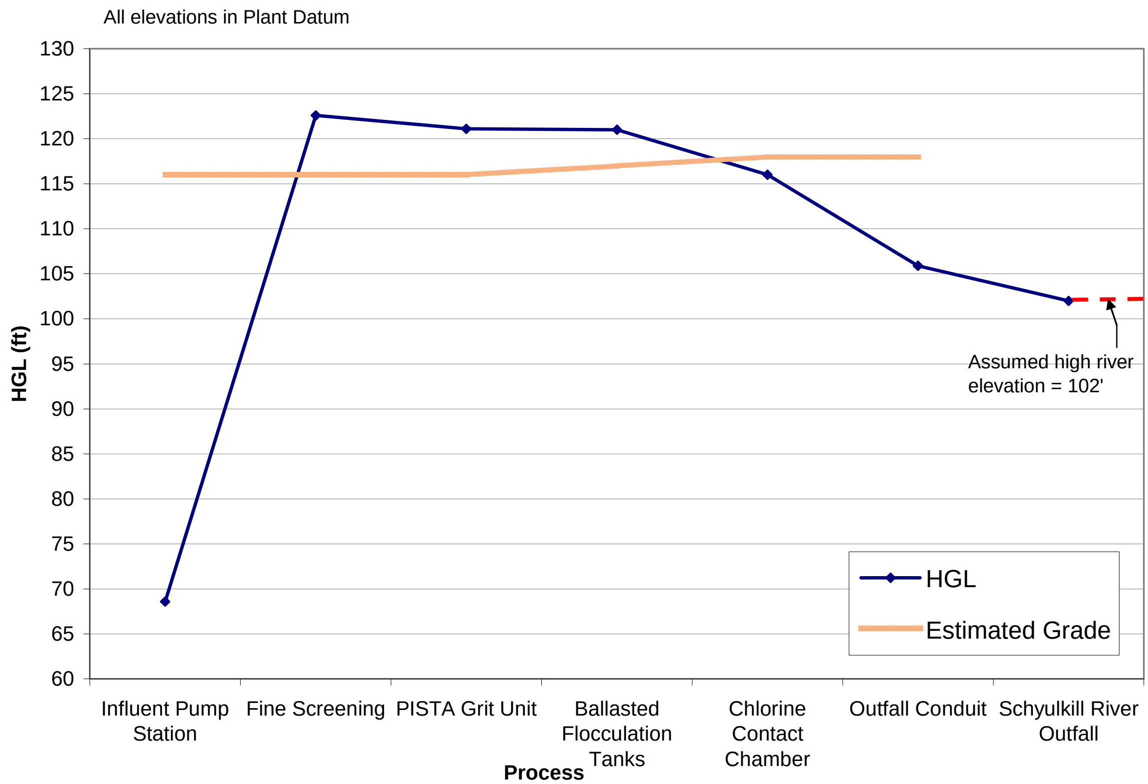
(5) Assumes 95 percentile influent TSS concentration of 226 mg/L, and volatile solids percentage of 70%

(6) Based on a 10% underflow from the vortex/swirl concentrator

4.2.3 Hydraulics

To eliminate the need for a new effluent pump station, the elevations of the new wet weather treatment trains were set to allow gravity flow to the new Schuylkill River outfall. A preliminary hydraulic profile for the ballasted flocculation train at 980 mgd is shown in Exhibit 4-6.

EXHIBIT 4-6
Preliminary Hydraulic Gradeline for the Ballasted Flocculation Treatment Train at 980 MGD



As an initial condition, the high river elevation was assumed to be 102 feet. This is similar to the assumption made for the Delaware River in the Southeast WPCP memo (CH2M HILL, 2008c). It is also based on the assumption that the Schuylkill River levels and the Delaware River levels are equal at their point of confluence.

The water surface level of the chlorine contact chamber was assumed to be 2 feet below grade (116 feet). Since the ground elevation at the Upper BRC site is much higher than the maximum river level, there is an approximate 10-ft drop between the chlorine contact chamber and the beginning of the outfall conduit. Headloss through the outfall conduit is estimated at 3.9 ft (using Manning's Equation).

The elevation of the chlorine contact chamber sets the elevations of the upstream unit processes. As shown in Exhibit 4-6, the tank walls may rise above grade by several feet. To be conservative, however, the capital cost estimates assume complete burial of all tanks.

4.2.4 Site Conditions

Two main assumptions were made on the site and soil conditions at the Upper and Lower BRC sites:

- Piles will be needed for foundations of all structures. A pile density and depth of 0.069 piles/sf and 30 feet were used for all water-bearing structures on site. A pile density and depth of 0.089 piles/sf and 50 feet were used for the outfall conduit going out to the Schuylkill River. These numbers were based on existing pile plans for the Northeast WPCP, since there are no similar structures at the existing BRC (CH2M HILL, 2008d). A pile density and depth of 0.0006 piles/sf and 30 feet were used for all other structures, based on drawings of the existing sludge dewatering facility at the BRC.
- Dewatering will be required for most buried structures. According to plant drawings, the groundwater elevation is approximately 10 to 15 feet below grade at the SW WPCP.

4.3 Cost Estimating Assumptions

CH2M HILL's costing model was used to develop conceptual level estimates of both capital and life-cycle costs for each of the treatment trains and flows. This tool was supplemented by budgetary quotes from vendors for all major pieces of equipment. These estimates are defined as Class 4 estimates by the Association for the Advancement of Cost Engineers (AACE) and have an expected level of accuracy of +50 to -30 percent.

4.3.1 Capital Costs

Construction Costs

Construction costs were developed using the costing model for each building or unit process of a treatment train, and were based on estimated materials, labor, equipment, and installation costs. Contractor markups applied to the construction subtotal costs are presented in Exhibit 4-7. The percentages used are industry standards and are in agreement with CDM's assumptions. The escalation factors applied are based on a construction start-date of September 1, 2009, and the estimated construction duration of each scenario (Exhibit 4-8). This start-date was chosen since PWD's LTCP Update must be submitted by this date. A location adjustment factor of 15.2 percent was applied to the escalated construction cost, which is in agreement with the ENR 20-city Construction Cost Index (CCI).

Lastly, a market adjustment factor of 15 percent was applied to account for: busy contractors; contractors selectively bidding jobs; contractors selectively choosing which Owners they want to do jobs for; premium wages to keep skilled workers and management staff; availability of crafts/trades; immigration impacts and uncertainty; abnormal fuel impacts and uncertainty; and abnormal material impacts of the last two years.

EXHIBIT 4-7
Contractor Markups Assumed in Capital Cost Estimates

Contractor Markups	%	Applied to:
Overhead (OH)	10%	Subtotal of Construction Cost
Profit (P)	5%	Subtotal of Construction Cost + OH
Mobilization, Bonds, and Insurance (MOB)	5%	Subtotal of Construction Cost + OH&P
Contingency	25%	Subtotal of Construction Cost + OH&P + MOB

EXHIBIT 4-8
Escalation Factors for Various Construction Scenarios

Flow Capacity of Wet Weather Treatment Train (mgd)	Estimated Construction Duration (months)(1)	Escalation Factor(2)
220	27	21.2%
550, 600, 702	36	23.9%
980, 1000, 1200, 1740	48	28.2%

(1) Escalation factors are based on mid-point of construction with a construction start-date of 9/1/2009.

(2) Construction durations were estimated based on facilities of similar size, and need to be refined through each stage of design.

Non-Construction Costs

A factor of 30 percent was applied to the total construction costs to estimate non-construction costs related to the project. The breakdown of these factors is shown in Exhibit 4-9.

EXHIBIT 4-9
Non-Construction Cost Factors

Non-Construction Expenditure	Factor*
Permitting	2%
Engineering	10%
Services During Construction	10%
Commissioning and Startup	3%
Legal/Administration	5%

*Each factor was applied to the total construction cost of the project, including all markups and escalation.

4.3.2 O&M and Life Cycle Cost Analysis

Life cycle and O&M costs of each treatment train at each flow were also estimated using CH2M HILL's costing model and were based on financial and operational assumptions as listed in Exhibit 4-9. The O&M costs cover labor, power for equipment and buildings, chemicals, and repair, maintenance and replacement of structures and equipment. The average flows that were assumed for the O&M costs are shown in Exhibit 4-4, as described in Section 4.2.1.

The additional labor required for each treatment train is dependent on the flow capacity of the train, as shown in Exhibit 4-11. It was assumed that new maintenance workers and operators would be hired for the new wet weather facility, working full time throughout the year. For some flow scenarios, it was assumed that a portion of the labor requirements during wet weather events could be met by increasing the number of shifts for existing operators, who would work overtime at a rate of 1.5 times their normal wage. It was assumed that the operators on overtime would work one 8-hour shift per wet weather event.

A detailed break down of the O&M costs and the energy requirements for each train are presented in Attachment SW-2.1. It should be noted that all O&M costs presented for the treatment trains are annualized O&M costs that include escalation over the 30-year period.

Life cycle costs were calculated using the total capital cost, including construction and non-construction costs, and O&M costs. The present value of the life cycle costs are presented in the cost summary section of each train.

EXHIBIT 4-10
Assumed Factors for Life Cycle Cost Estimates

Factor	Value	
Financial		
Annual Discount Rate	4.875	%
Life-Cycle Calculation Period	30	Years
Inflation Rate	4	%[(1)]
Operation		
Days of operation of wet weather treatment train	48	days[(2)]
Duration of wet weather event	5	Hours[(2)]
Labor		
Hourly wage for plant operator	$50.44	including fringe benefits
Hourly wage for plant operator on overtime	$75.65	including fringe benefits
Hourly wage for maintenance worker	$52.35	including fringe benefits
Fringe benefits and overhead multiplier	2.7	applied on top of raw hourly rate
Number of working hours for full time operators at wet weather facility	2,080	hours per year per operator
Number of working hours for operators on overtime at wet weather facility	408	hours per year per operator (16 hours per event)
Number of working hours for maintenance workers at wet weather facility	2,080	hours per year per worker

EXHIBIT 4-10
Assumed Factors for Life Cycle Cost Estimates

Factor	Value	
Power for Buildings		
Building Electrical Cost Assumed	$0.10	$/kwh
Building Electrical Requirements	2	watts/sf of building area
Building Heating Requirements	1.2	BTU/hr/surface area of building
Natural gas cost assumed	$14	per MBTU
Power for Equipment(3)	$0.10	$/kwh
Chemicals(4)		
Ferric Chloride	$310	$/dry ton
Liquid Polymer	$3983	$/dry ton
Sodium Hypochlorite	$1450	$/dry ton
Sodium Bisulfite	$1000	$/dry ton
Repair, Maintenance, and Replacement		
	Percentage assumed for annual O&M cost	
Finishes	2%	of finishes cost during construction
Equipment	1%	of capital cost of equipment
Instrumentation and Controls	5%	of capital cost of I&C
Mechanical	0.1%	of capital cost of mechanical work (incl. valves)
Electrical	1%	of capital cost of electrical equipment
Disposal		
Grit and Screenings Disposal and Hauling Costs	$100	per cubic yard
Final Sludge Disposal Costs(5)	$75	per wet ton
Other		
Other O&M Costs (including vehicles, lab tests, office equipment and other miscellaneous costs)	$10,000	per additional full-time operator and maintenance worker
Contingency		
Contingency applied to O&M costs	20	%

(1) Based on CCI Index

(2) Based on hydraulic model simulations for the SW WPCP (CDM, 2008).

(3) Equipment power costs estimated by PWD.

(4) Based on existing costs at the plant (McKeon, 2008)

(5) Final sludge mass assumes 30% dewatered cake.

EXHIBIT 4-11
Additional Labor Requirements for each Flow Scenario

Treatment Train Flow Capacity	Number of Additional Full-Time Operators(1)	Number of Existing Operators on Overtime(2)	Number of Additional Maintenance Workers(1)
220	1	1	2
550, 600, 702	2	0	4
980, 1000, 1200	2	1	4
1740	2	3	4

(1) Full-time operators and maintenance workers are new hires who work 2080 hours per year. Maintenance workers include different trades required for the facility (e.g. electricians, instrument technicians, mechanics, etc..)

(2) Existing operators on overtime work 8 hours per wet weather event, or 408 hours per year.

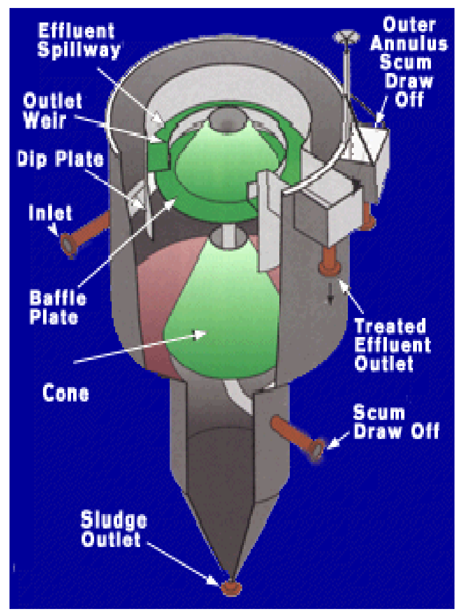
5.0 Treatment Train #1- Vortex/Swirl Concentrators

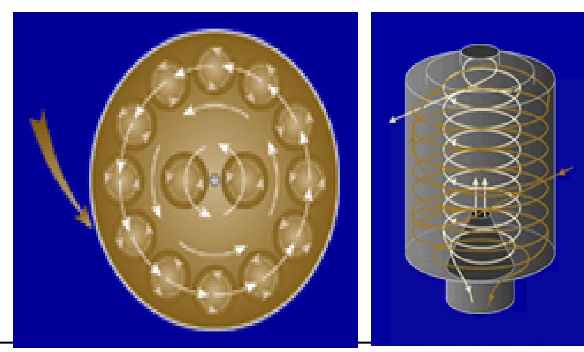
5.1 Process Flow Diagram

The first treatment train under evaluation utilizes the vortex separation technology as its main treatment process. After passing through bar screens and influent pumping at the PTB, the wet weather flow will enter the primary vortex/swirl concentrators. Vortex/swirl concentrators are flow-through structures with no moving parts. The wet weather flow enters the cylindrical structure tangentially, producing a swirling motion that concentrates the solids in the center (Exhibit 5-1). An underflow drain in the center of the unit continually draws the solid materials out of the flow.

The treated effluent flows out of the top of the vessel, continuing on to the chlorine contact chamber. The solids underflow, typically 10 percent of the influent, undergoes grit removal through a vortex grit unit before settling and thickening in gravity thickeners. The conceptual process flow diagram for this treatment train is shown in Exhibit 5-2.

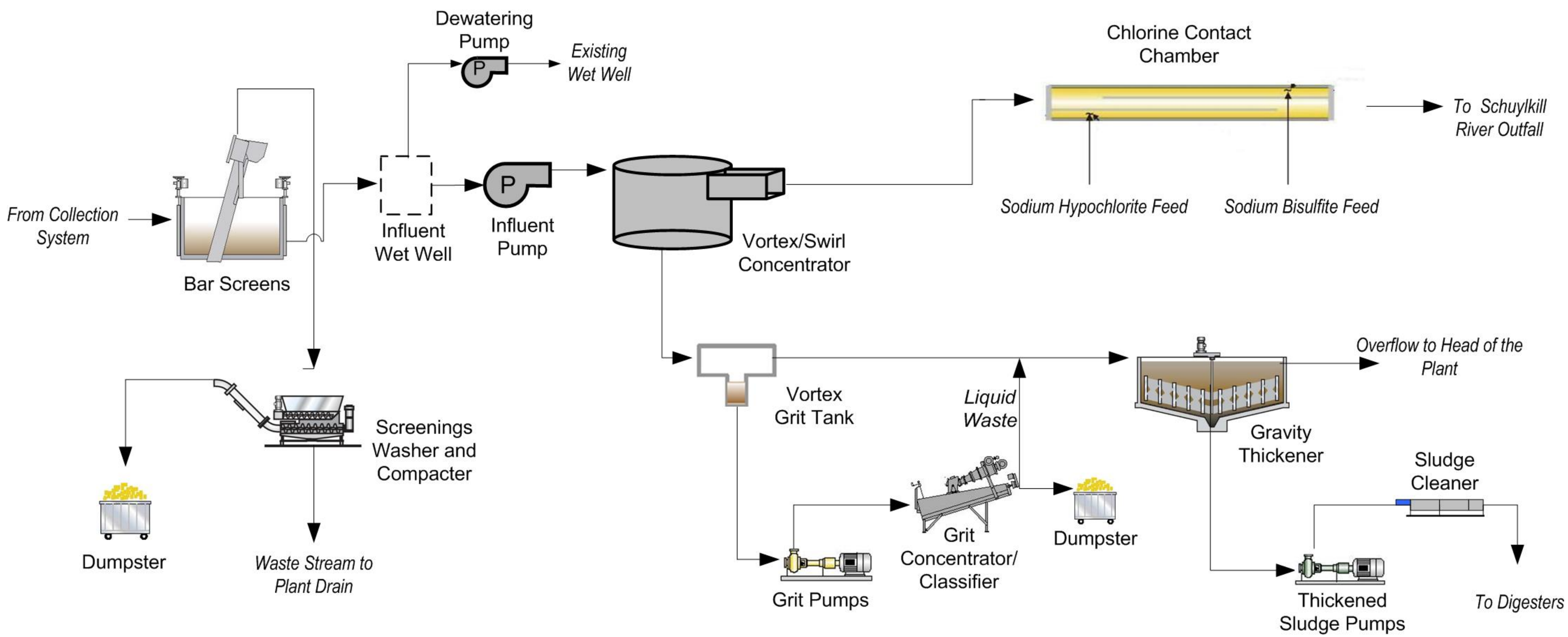
EXHIBIT 5-1
Diagrammatic Cutaway of Vortex/Swirl Device
(Storm King®, H.I.L. Technologies)





Flow Pattern Plan and Profile Views (H.I.L. Technologies)
The flow in vortex/swirl devices initially follows a path around the perimeter of the unit and is then directed into an inner swirl pattern with a lower velocity than the outer swirl. Solids separation is achieved by both centrifugal force and gravity because of the long flow path and inertial separation due to the circular flow pattern. 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.

EXHIBIT 5-2
Process Flow Diagram and Key Process Design Parameters for Treatment Train #1: Vortex/Swirl Concentrators



Flow (mgd)	Bar Screens	Influent Pumps	Vortex/Swirl Concentrators		Vortex Grit Tank		Screenings Washer/ Compactor	Grit Pumps		Grit Concentrator	Grit Classifier	Screenings and Grit Prod.	Sodium hypochlorite			Sodium Bisulfite			Gravity Thickeners & Sludge Cleaners	Primary Sludge Pumps		Thickened Sludge Pumps		Sludge Prod.	Digesters
	# units	# units	# primary units	Loading rate on primary unit (gpm/sf)	# units	Dia (ft)	# units	# duty	# standby	# units	# units	Compacted volume (cf/day)	Total storage vol (gal)	# duty pumps	# standby pumps	Total storage vol (gal)	# duty pumps	# standby pumps	# Units	# Duty	# Standby	# Duty	# Stand by	lb/day	# Units
220	3	3	5	24.3	1	12	3	1	1	1	1	1,265	109,537	1	1	6,347	1	1	5	10	3	5	2	124,339	0
702	7	10	15	25.9	1	20	7	1	1	1	1	2,605	235,006	1	1	13,616	1	1	16	30	8	16	4	260,108	1

EXHIBIT 5-3
Conceptual Layouts and Footprints for Treatment Train #1: Vortex/Swirl Concentrators
702 MGD Layout

FLOW (mgd)	PTB	GRIT UNITS	VORTEX SWIRLS	CHEMICAL BUILDING	CCC	GRAVITY THICKENERS*	DIGESTERS	TOTAL FOOTPRINT (acres)
220	54' x 49' & 59' x 39'	12' DIA (1 unit)	40' DIA (5 units)	137' x 47'	109' x 212' (5 passes)	80' DIA (5 units)	-	1.5
702	145' x 56' & 112' x 39'	20' DIA (1 unit)	40' DIA (15 units)	213' x 47'	172' x 268' (8 passes)	80' DIA (16 units)	115' DIA (1 unit)	3.2

5.2 Conceptual Design and Site Layouts

The main design parameters for each flow scenario of this treatment train are shown in Exhibit 5-2. A conceptual site layout for the maximum flow scenario of 702 mgd is shown in Exhibit 5-3. The conceptual design in this report is based on a loading rate on the vortex/swirls of approximately 25 gpm/sf, providing an estimated removal efficiency of 30 percent.

As Exhibit 5-3 shows, a 702-mgd facility does not fully occupy the Upper BRC area, and does not utilize the Lower BRC area at all. This provides the option of designing vortex swirls with lower loading rates in order to achieve high removals. According to a study performed in Columbus, Georgia, the vortex swirl can achieve removal efficiencies of up to 70 percent at a 5 gpm/sf loading rate (WERF, 2003). This option may be considered if regulating agencies require removal efficiencies equivalent to that of primary treatment for the new wet weather facility.

5.3 Operational and Technology-Specific Issues

The effectiveness of vortex/swirl concentrators greatly depends on the hydraulic loading rate on the unit and the characteristics of the solids entering the unit. The optimal loading rate must be determined through pilot or operational testing. In order to operate the vortex/swirl at its optimal operating rate or “sweet spot”, the vortex/swirl units can be brought online one by one as the influent flow increases. Alternatively, an equalization basin can be constructed to maintain a specific flow-rate into the units. An equalization basin was not included in the cost estimates, but conservative hydraulic loading rates were assumed for facility sizing.

5.3.1 Startup and Shutdown

The pretreatment processes (bar screens, influent pumps, and grit removal) can be brought online quickly at the start of a wet weather event. Vortex/ swirl concentrators would be empty at the start of a wet weather event. At small flows, the wet weather flow will exit through the underflow. As flows increase, the vessel will fill due to the increased hydraulic load and begin discharging treated effluent to the outfall.

During shutdown, the vortex/swirl and grit units will be emptied by pumping from the underflow sections to SW WPCP’s existing influent wet well. The influent wet well in the new PTB would also be pumped down to the plant’s existing wet well using dewatering pumps (Exhibit 5-2).

For long term shutdown, the chlorine contact chamber could be pumped down, with the flow recycled to the head of the main plant.

5.3.2 Interaction with Main Plant

The waste streams generated by the screenings washer/compactor and the grit classifiers are sent to the gravity thickeners of the wet weather treatment train and will not affect the main plant.

The overflow from the gravity thickeners is conveyed to the head of the entire plant. The estimated overflow range from wet weather thickeners only ranges from 21 to 69 mgd, depending on the size of the plant. To minimize the effect of this volume, the overflow is recycled back to both the main plant and the wet weather facility so that it can be distributed across all units in operation.

5.3.3 Impact on plant operations

Since the vortex/swirl unit has no moving parts, it is expected to have little operations and maintenance requirements. However, operators' attention may be necessary to monitor the hydraulic loading rates into the vortex/swirls to ensure that the "sweet spot" is maintained. The treatment train also includes grit pumps, concentrators, and classifiers, as well as sludge pumps and other equipment, all of which require maintenance. In addition, the new chemical building will include storage of sodium hypochlorite and bisulfite, which are fed to the new chorine contact chamber. Storage of hypochlorite will need to be monitored, since it degrades over time. In addition, the hypochlorite feed-lines should be flushed or degassed periodically.

5.4 Cost Analyses

The estimated capital, O&M, and lifecycle costs for each flow scenario are presented in Exhibit 5-4. Total capital costs and the capital costs per volume treated for all scenarios are shown in Exhibits 5-5. The estimated O&M costs by category are also presented in Exhibits 5-6. A more detailed breakdown of these costs is presented in Attachment SW-2.1.

EXHIBIT 5-4
Cost Summary for Vortex/Swirl Treatment Train #1

	Wet Weather Flow (mgd)	
Cost	**220**	**702**
Capital Cost ($M)	$170	$453
Annual Operations and Maintenance Cost ($M)	$2.1	$4.3
Present Value of the Cost ($M)	$202	$520

EXHIBIT 5-5
Capital Costs for Treatment Train #1: Vortex/Swirl
Includes cost of upgrading existing plant capacity to 540 mgd

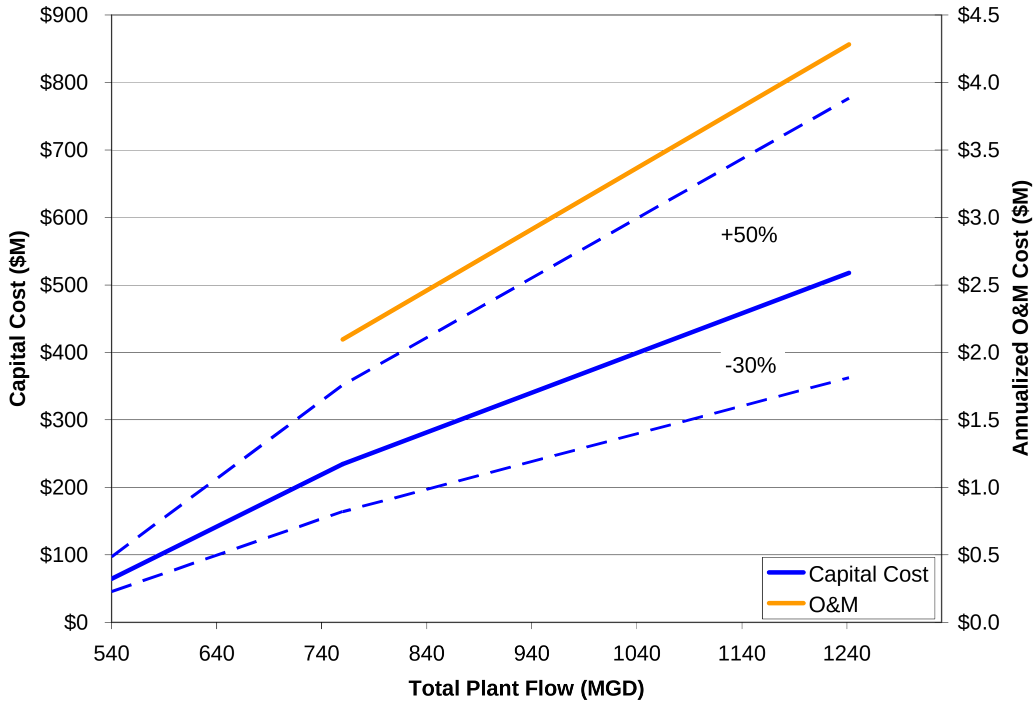


EXHIBIT 5-6
Capital Costs per Gallon Treated for Treatment Train #1: Vortex/Swirl

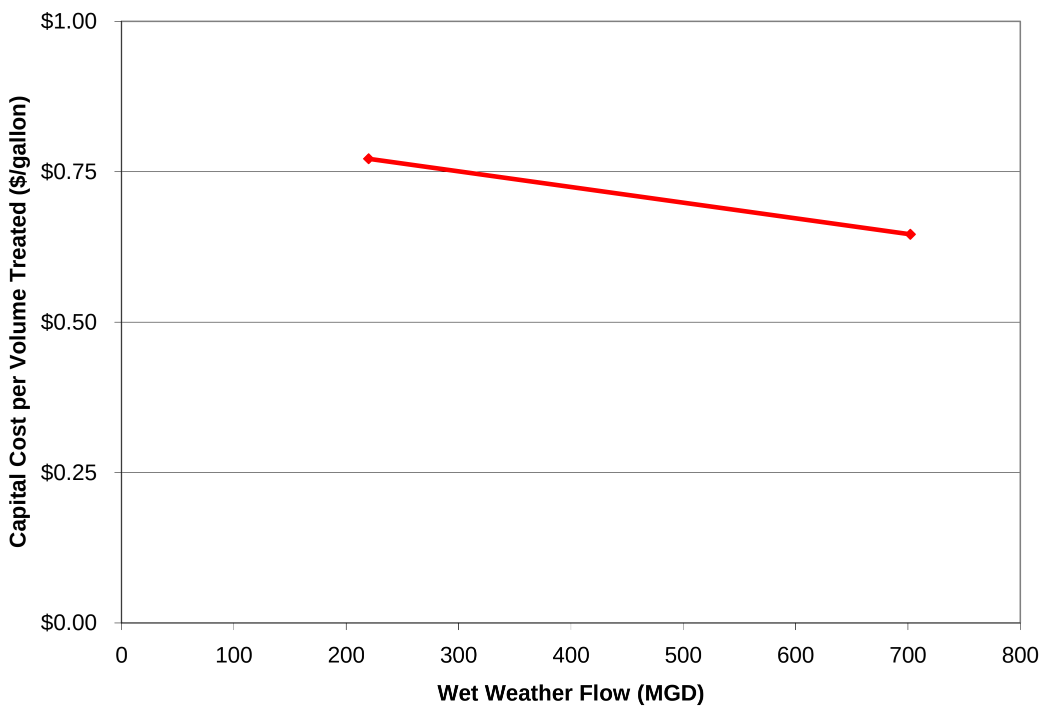
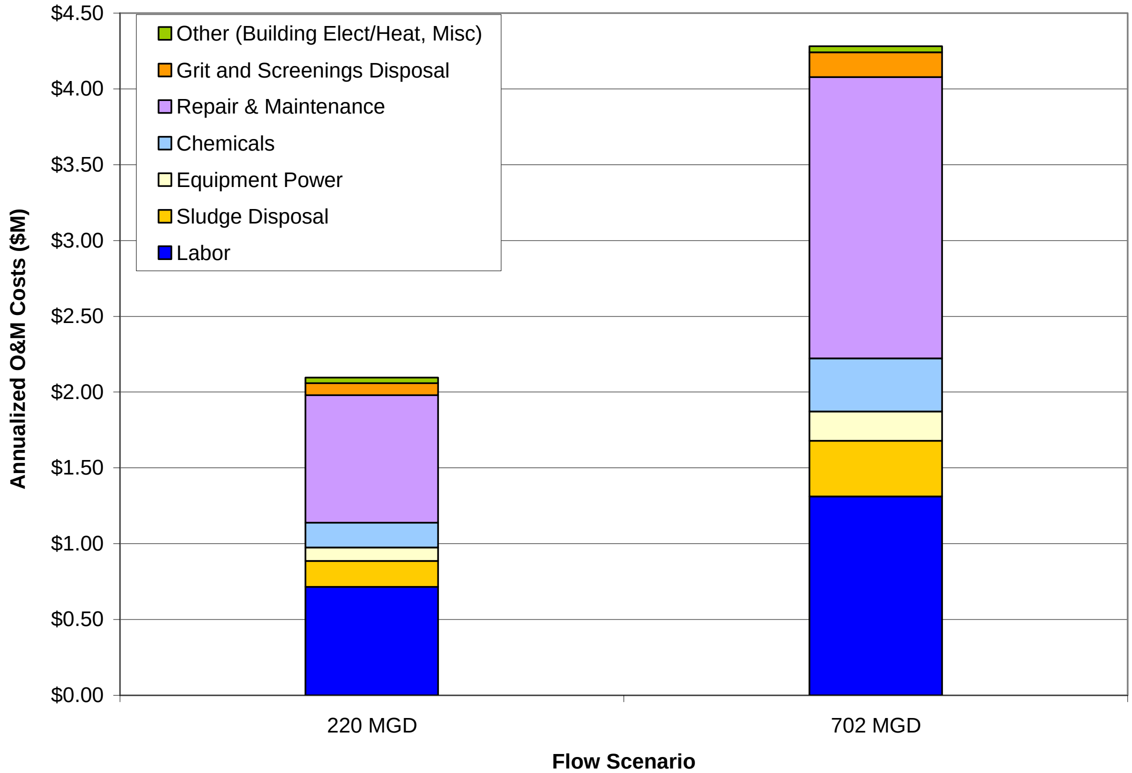


EXHIBIT 5-7
Operations and Maintenance by Category for Treatment Train #1: Vortex/Swirl



6.0 Treatment Train #2 - Conventional Clarifiers

6.1 Process Flow Diagram

Through treatment train #2, the wet weather flow undergoes essentially the same level of primary treatment as the flow through the existing SW WPCP. After preliminary treatment through the bar screens and grit removal, the wet weather flow passes through conventional primary clarifiers at a maximum loading rate of 2400 gpd/sf. This is the overflow rate achievable by the plant's existing primary clarifiers, as shown through stress testing (CH2M HILL, 2001). Primary sludge is collected by chain and flights in the clarifier tanks and is pumped to the gravity thickeners for thickening. The process flow diagram for this treatment train is shown in Exhibit 6-1.

6.2 Conceptual Design and Site Layouts

Conceptual designs were developed at three different flow scenarios for this train: 220, 600, and 1200 mgd. Key design parameters at these flows are shown in Exhibit 6-1. The conceptual layouts for the 600 and 1200 mgd scenarios are shown in Exhibit 6-2. The 600-mgd facility can fit on the Upper BRC area only, and the 1200-mgd facility utilizes the entire Upper and Lower BRC areas available.

6.3 Operational and Technology-Specific Issues

6.3.1 Startup and Shutdown

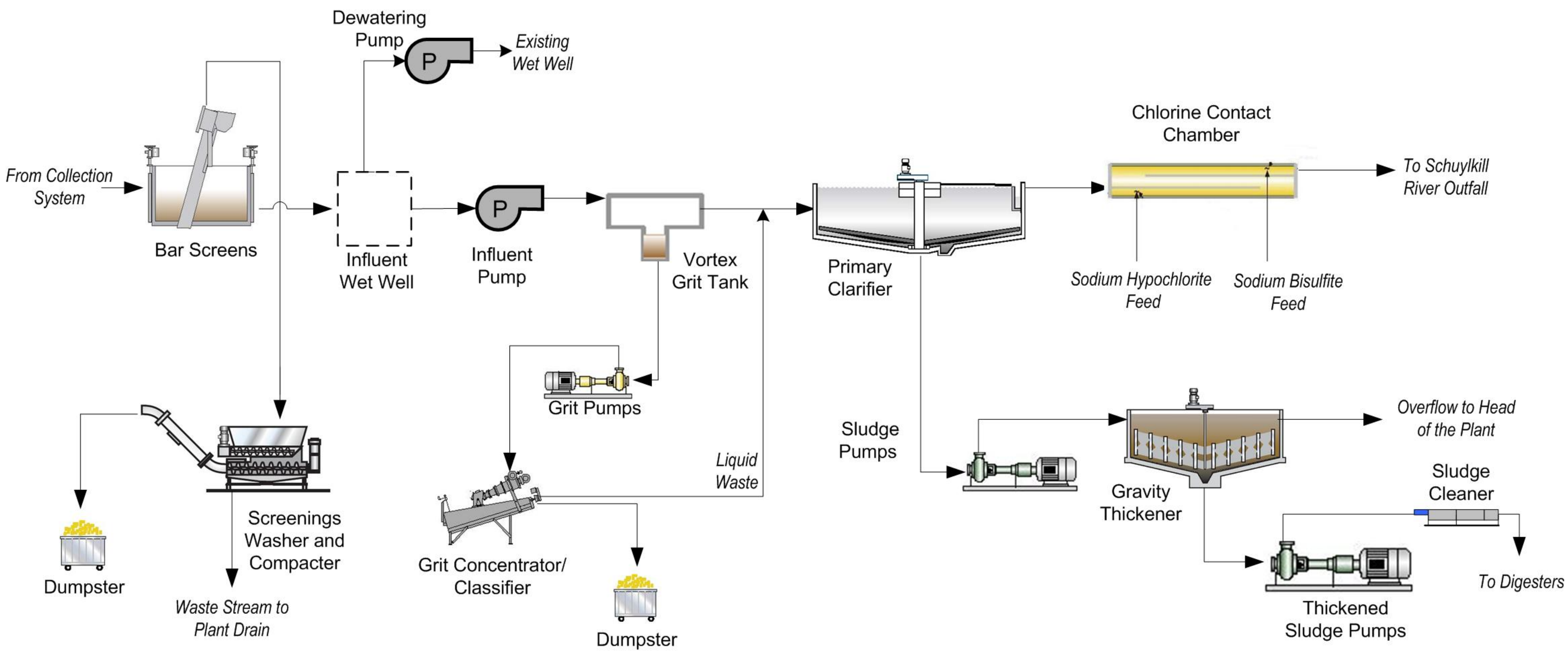
When the wet weather facility is initially put into service, it will take 2-3 hours before the conventional clarifiers begin to discharge treated wet weather flow. This is equivalent to the time needed to displace the existing wastewater in the tanks, or to fill the tanks if they are empty.

For shut down, the tanks may be filled with treated effluent, or drained down to the existing plant if freezing becomes an issue.

6.3.2 Interaction with Main Plant

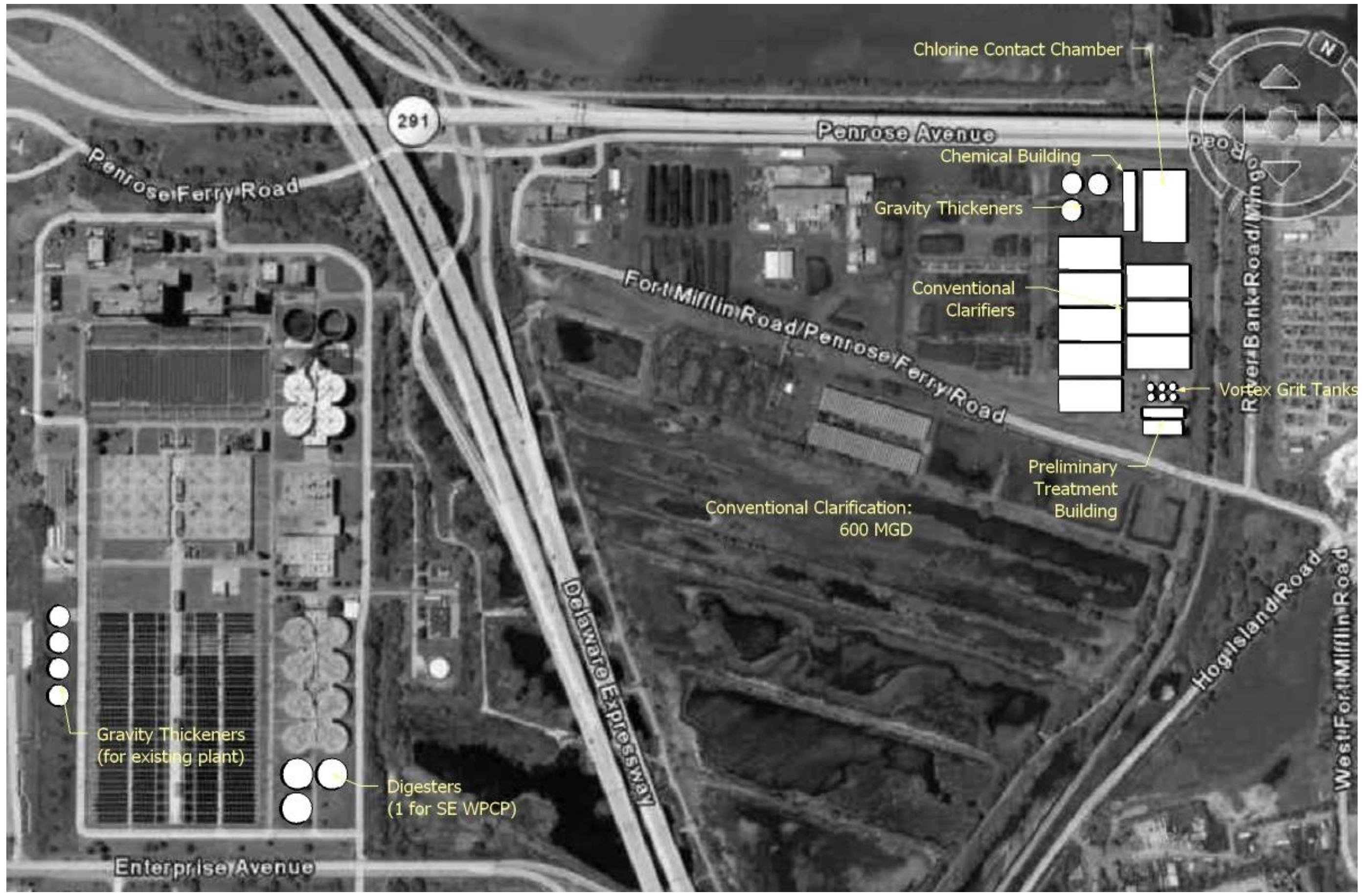
The waste streams generated by the screenings washer/compactor and the grit classifiers are sent to the primary clarifiers of the wet weather treatment train and will not affect the main plant. As with the other treatment trains, the overflow from the gravity thickeners will be conveyed to the head of the entire plant. The estimated overflow from wet weather thickeners only ranges from 4 to 25 mgd, depending on the size of the plant. To minimize the effect of this volume, the overflow is recycled back to the head of the entire plant so that it can be distributed across all units in operation.

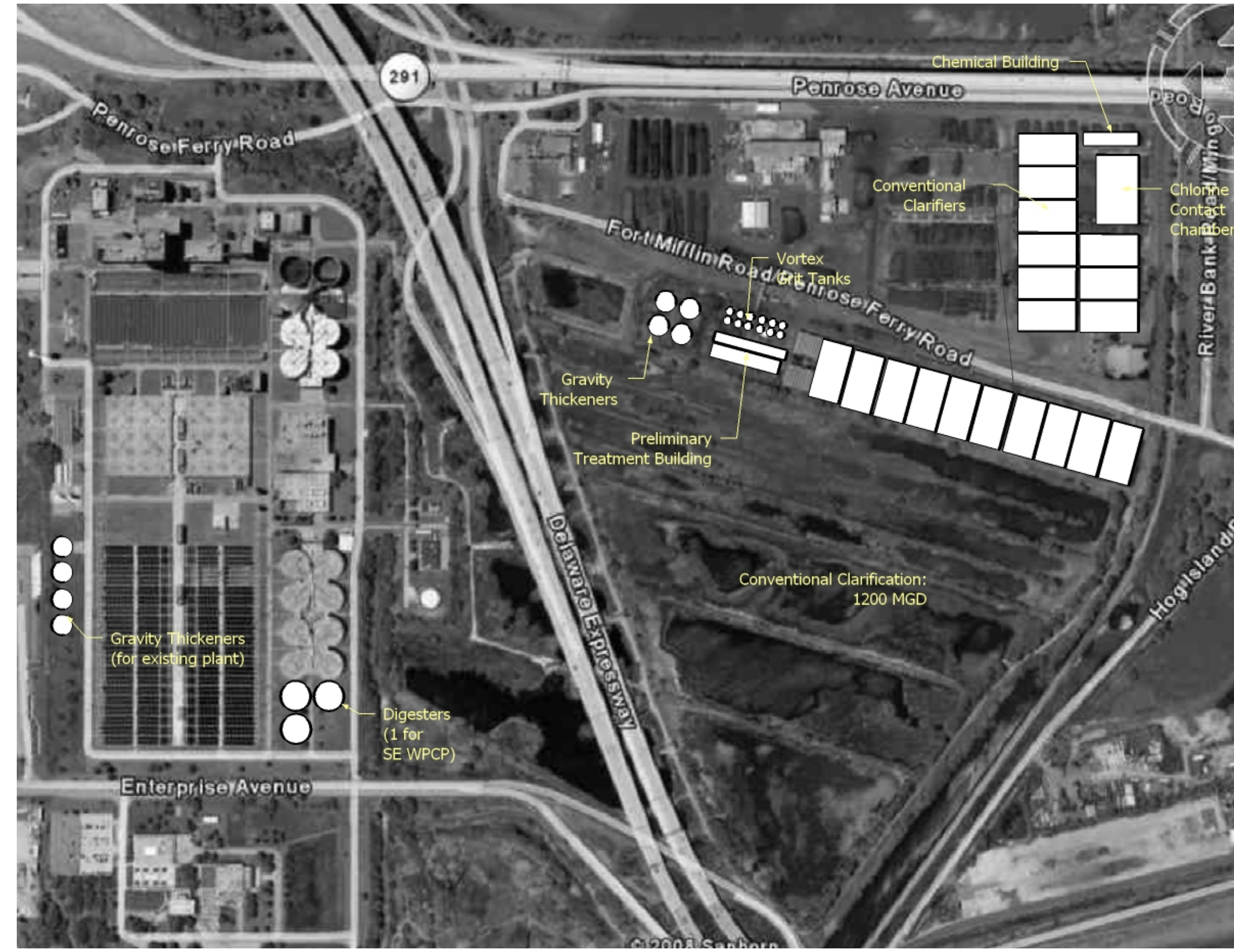
EXHIBIT 6-1
Process Flow Diagram and Key Process Design Parameters for Treatment Train #2: Conventional Clarifiers



	Bar Screens	Influent Pumps	Vortex Grit Tank		Screenings Washer/ Compactor	Grit Pumps		Grit Concentrator	Grit Classifier	Screenings and Grit Prod.	Sodium Hypochlorite			Sodium Bisulfite			Clarification	Gravity Thickeners & Sludge Cleaners	Primary Sludge Pumps		Thickened Sludge Pumps		Sludge Prod.	Digesters
Flow (mgd)	# Units	# Units	# Units	DIA (ft)	# Units	# Duty	# Standby	# Units	# Units	Compacted Volume (cf/day)	Total Storage Vol (gal)	# Duty Pumps	# Standby Pumps	Total Storage Vol (gal)	# Duty Pumps	# Standby Pumps	# Trains	# Units	# Duty	# Standby	# Duty	# Standby	lb/day	# Units
220	3	3	3	32	3	3	1	3	1	1,265	109,537	1	1	6,347	1	1	3	2	3	1	2	1	228066	1
600	6	9	6	32	6	6	3	6	3	1,984	180,238	1	1	10,443	1	1	9	3	9	3	3	1	357648	1
1200	12	17	12	32	12	12	3	12	4	2,645	235,006	1	1	13,616	1	1	19	4	19	6	4	1	476865	1

EXHIBIT 6-2
Conceptual Layouts and Footprints for Treatment Train #2: Conventional Clarifiers
600 MGD Layout (left) 1200 MGD Layout (right)





Flow (mgd)	PTB	Grit Units	Clarifier Tanks	Chemical Building	CCC	Gravity Thickeners	Digesters	TOTAL FOOTPRINT (acres)
220	54' x 49' & 73' x 39'	32' DIA (3 units)	124' x 259' (3 units)	119' x 47'	109' x 211' (5 passes)	80' DIA (2 units)	115' DIA (1 unit)	3.4
600	132' x 53' x 133' x 39'	32' DIA (6 units)	124' x 236' (9 units)	213' x 47'	172' x 268' (8 passes)	80' DIA (3 units)	115' DIA (1 unit)	8.5
1200	236' x 58' & 227' x 39'	32' DIA (12 units)	124' x 224' (19 units)	213' x 47'	172' x 268' (8 passes)	80' DIA (4 units)	115' DIA (1 unit)	15.8

6.3.3 Impact on Plant Operations

The operations and maintenance requirements for this treatment train should be similar to those needed for corresponding processes at the existing plant.

6.4 Cost Analyses

The estimated capital, O&M, and lifecycle costs for each flow scenario are shown in Exhibit 6-3. Total capital costs and the capital costs per volume treated are also shown in Exhibits 6-4 and 6-5. Estimated O&M costs by category are presented in Exhibit 6-6. A more detailed breakdown of these costs is presented in Attachment SW-2.1.

EXHIBIT 6-3
Cost Summary for Conventional Clarifiers: Treatment Train #2

	Wet Weather Flow (mgd)		
Cost	**220**	**600**	**1200**
Capital Cost ($M)	$236	$541	$1,027
Annual Operations and Maintenance Cost ($M)	$2.5	$4.4	$6.0
Present Value of the Cost ($M)	$275	$610	$1,121

EXHIBIT 6-4
Capital Costs for Treatment Train #2: Conventional Clarifiers
Includes cost of upgrading plant capacity to 540 MGD

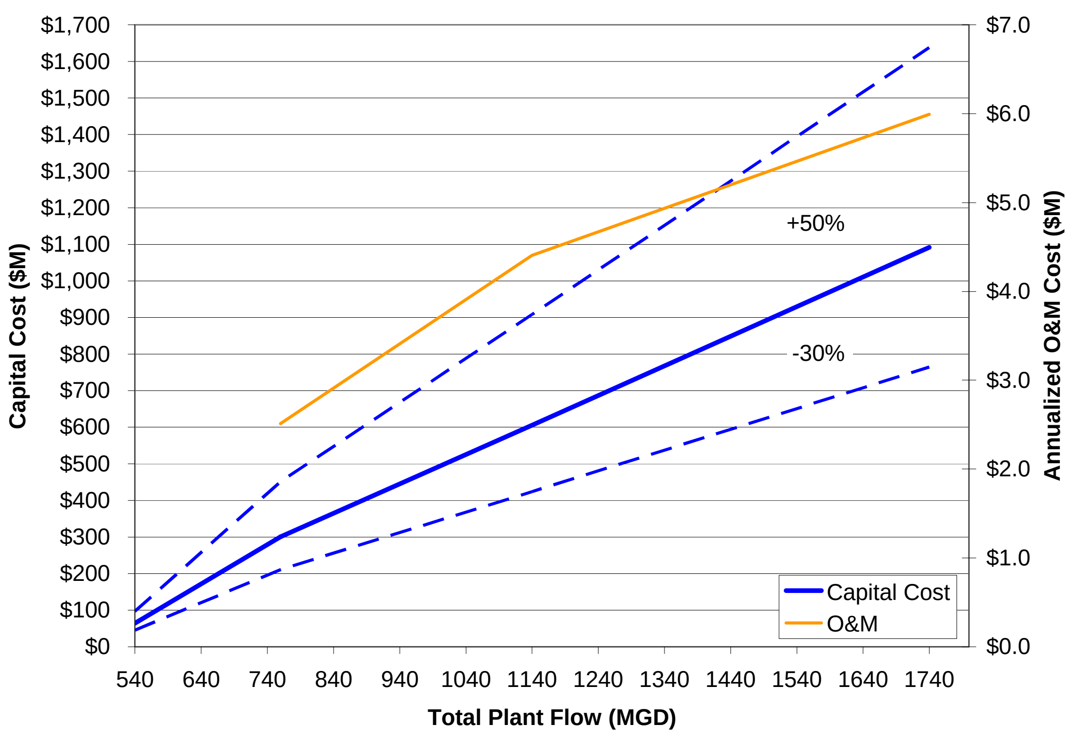


EXHIBIT 6-5
Capital Costs per Gallon Treated for Treatment Train #2: Conventional Clarifiers

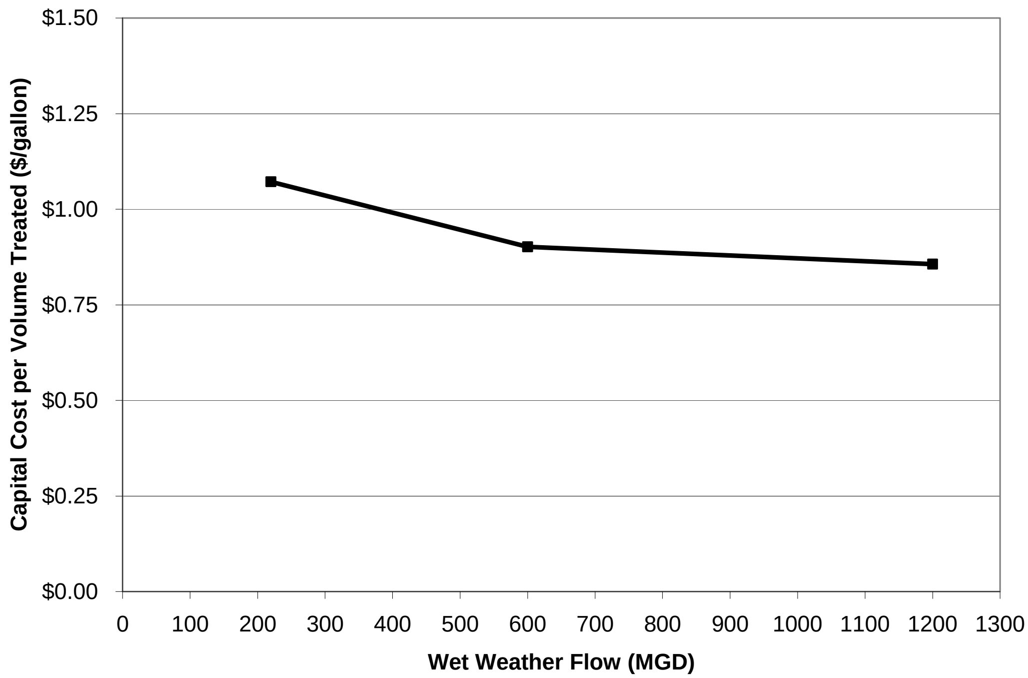
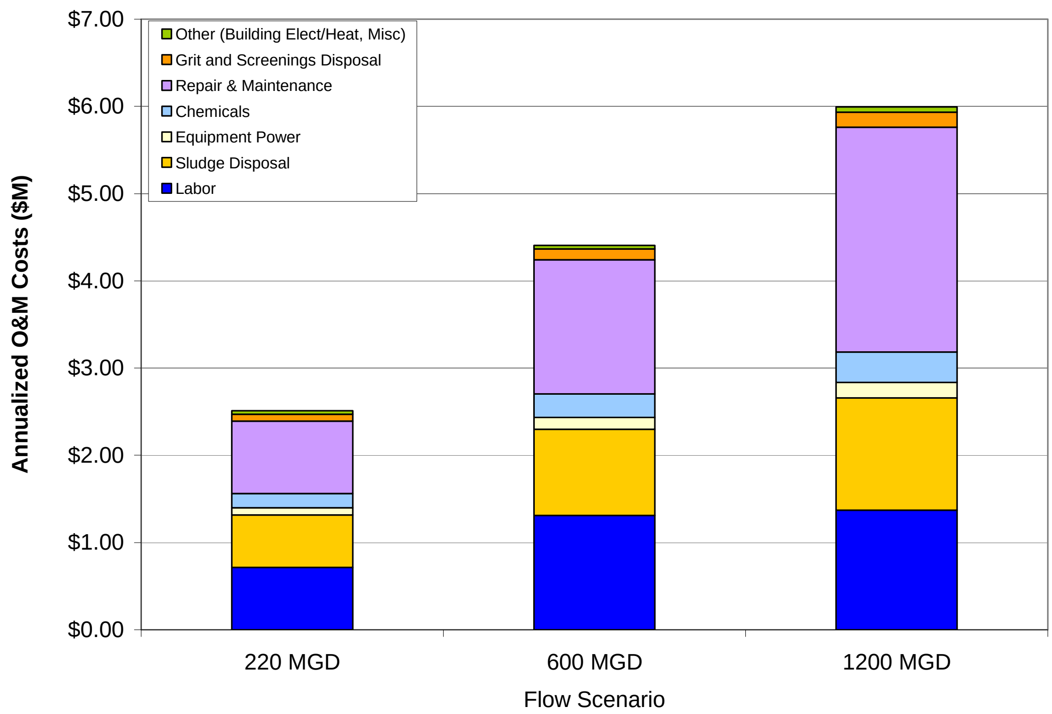


EXHIBIT 6-6
Operation and Maintenance Costs by Category for Treatment Train #2: Conventional Clarifiers



7.0 Treatment Train #3 - Chemically Enhanced Primary Treatment (CEPT)

7.1 Process Flow Diagram

Chemically enhanced primary treatment (CEPT) improves the removal efficiency of TSS and BOD through the addition of coagulants and flocculants to primary clarifiers. With chemical enhancement, the surface overflow rate of the primary clarifier is expected to increase from 2400 gpd/sf to 3000 gpd/sf, and the removal efficiency from 55 percent to 80 percent. As shown in the process flow diagram in Exhibit 7-1, the flow path is similar to Treatment Train #2. The only difference is the addition of rapid mixers and flocculation basins upstream of the primary clarifiers, along with their associated chemical feed and storage systems.

7.2 Conceptual Design and Site Layouts

Conceptual designs were developed at three different flow scenarios for this train: 220, 550, and 1000 mgd. Key design parameters at these flows are shown in Exhibit 7-1. The 550-mgd facility fits on the Upper BRC site alone, and the 1000-mgd facility utilizes both the Upper and Lower sites. As seen in Exhibit 7-2, the 1000-mgd requires more clarifiers per volume treated because the width of the Lower BRC tract limits the length of the clarifier tank to approximately 170-ft. Without this constraint, the length of the clarifiers in other flow scenarios can reach 250-ft.

The flow capacities in this train are lower than for Conventional Clarification due to the increased number of gravity thickeners required to treat the solids removed through CEPT.

7.3 Operational and Technology-Specific Issues

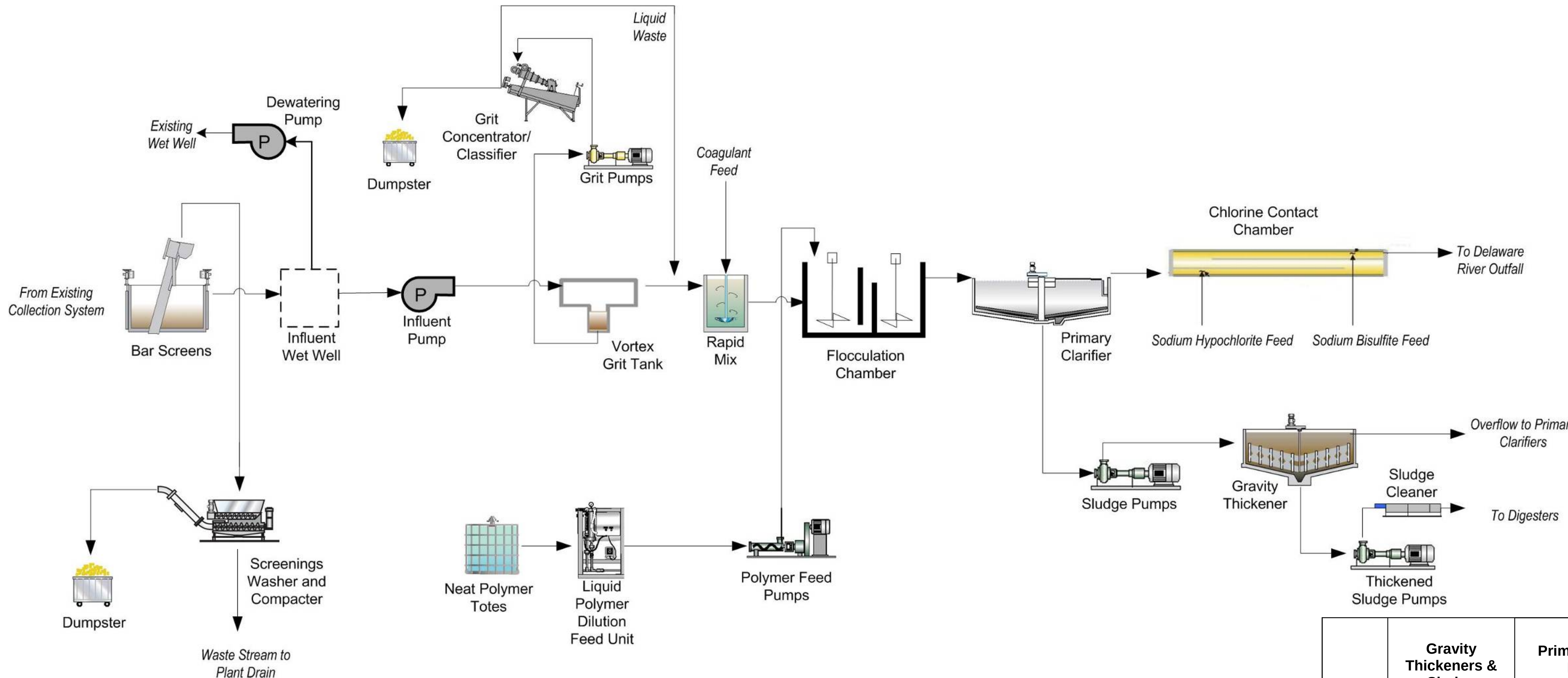
7.3.1 Startup and Shutdown

When the wet weather facility is initially put into service, it will take 2-3 hours before the clarifiers begin to discharge treated wet weather flow. This is equivalent to the time needed to displace the existing wastewater in the tanks, or to fill the tanks if they are empty.

For shut down, the tanks may be filled with treated effluent, or drained down to the existing plant if freezing becomes an issue.

The other processes in the system are physical or physical/chemical treatment systems that are easily and quickly brought online and will achieve normal levels of treatment efficiency quickly.

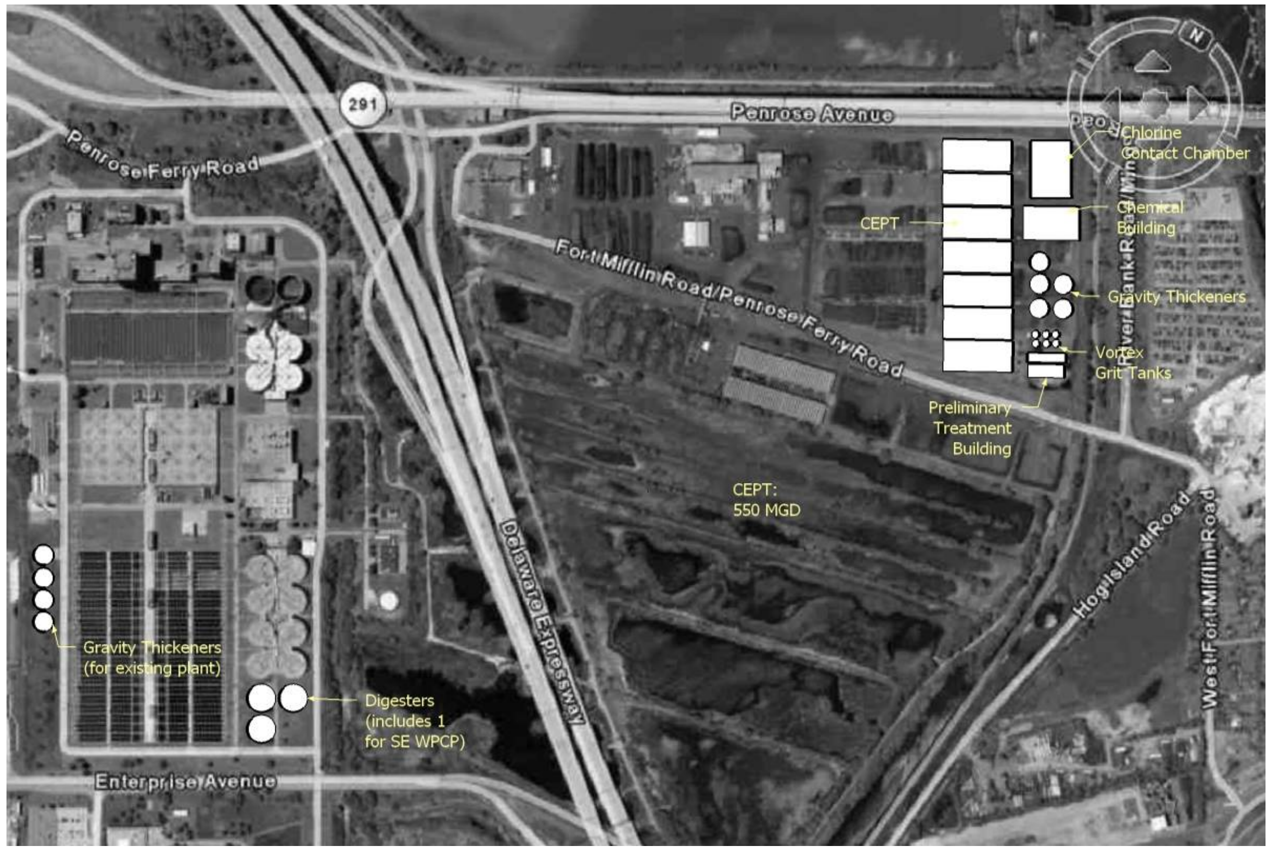
EXHIBIT 7-1
Process Flow Diagram and Key Process Design Parameters for Treatment Train #3: CEPT

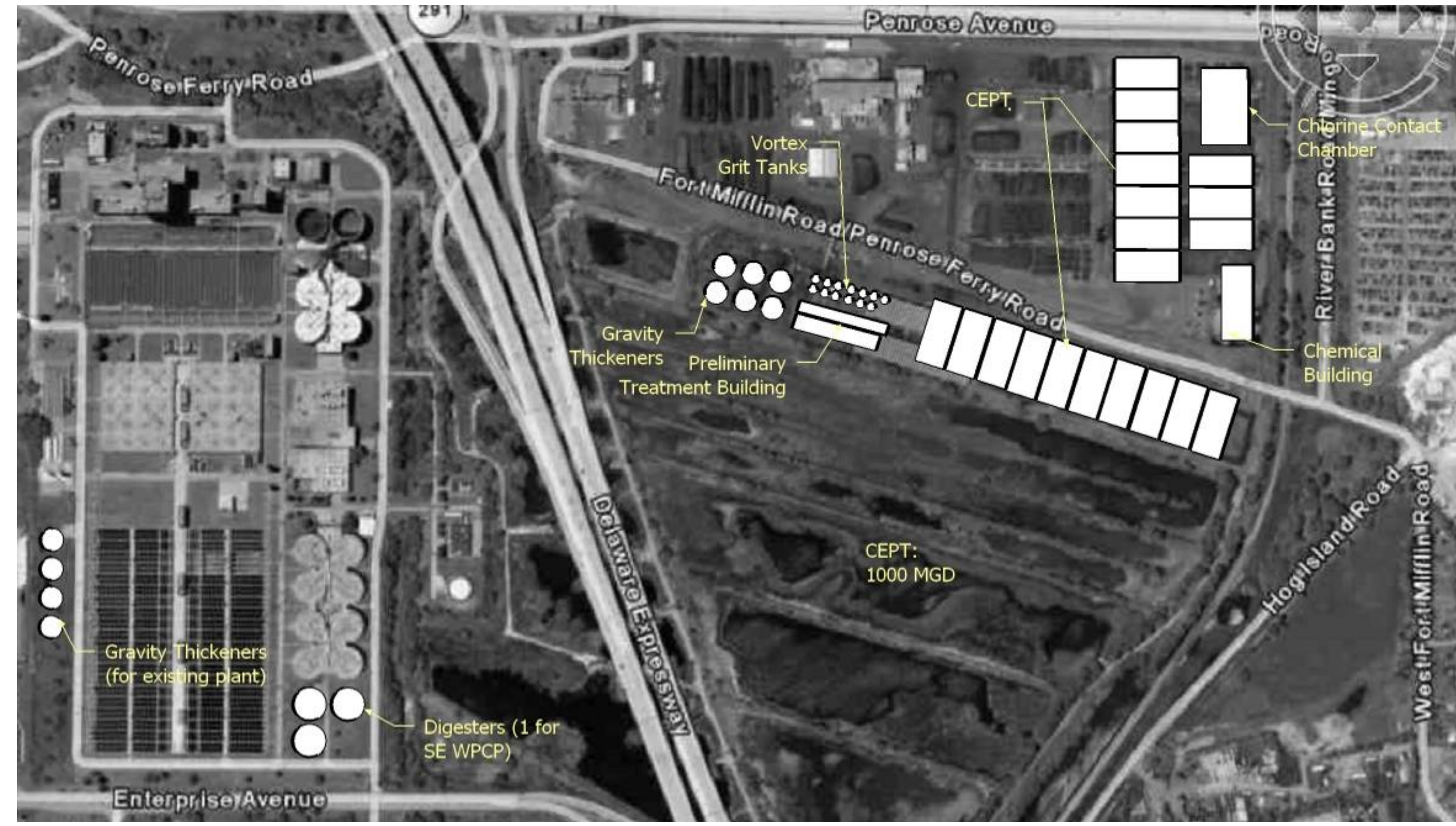


Flow (mgd)	Gravity Thickeners & Sludge Cleaners # Units	Primary Sludge Pumps # Duty	Primary Sludge Pumps # Standby	Thickened Sludge Pumps # Duty	Thickened Sludge Pumps # Standby	Sludge Prod. (lb/day)	Digesters # units
220	3	3	1	3	1	399492	1
550	5	7	2	5	2	626475	1
1000	6	20	6	6	2	835300	2

Flow (mgd)	Bar Screens # Units	Influent Pumps # Units	Vortex Grit Tank # Units	Vortex Grit Tank DIA (ft)	Screenings Washer/ Compactor # Units	Grit Pumps # Duty	Grit Pumps # Standby	Grit Concentrator # Units	Grit Classifier # Units	Screenings and Grit Prod. Compacted Volume (cf/day)	Ferric Chloride Total Storage Vol (gal)	Ferric Chloride # Duty Pumps	Ferric Chloride # Standby Pumps	Liquid Polymer Total Storage Vol (gal)	Liquid Polymer # Duty Pumps	Liquid Polymer # Standby Pumps	Sodium Hypochlorite Total Storage Vol (gal)	Sodium Hypochlorite # Duty Pumps	Sodium Hypochlorite # Standby Pumps	Sodium Bisulfite Total Storage Vol (gal)	Sodium Bisulfite # Duty Pumps	Sodium Bisulfite # Standby Pumps	Flocculation # Trains	Clarification # Trains
220	3	3	3	32	3	3	1	3	1	1,265	230,836	3	1	10,000	3	1	109,537	1	1	6,347	1	1	3	3
550	6	8	6	32	6	6	2	6	2	1,984	379,829	7	2	15,682	7	2	180,238	1	1	10,443	1	1	7	7
1000	10	14	10	32	10	10	3	10	5	2,645	495,247	20	5	20,909	20	5	235,006	1	1	13,616	1	1	20	20

EXHIBIT 7-2
Conceptual Layouts and Footprints for Treatment Train #3: CEPT
550 MGD Layout (left) 1000 MGD (right)





Flow (Mgd)	PTB	Grit Units	Flocculation Tanks	Clarifier Tanks	Chemical Building	CCC	Gravity Thickeners	DIGESTERS	TOTAL FOOTPRINT (acres)
220	54' x 49 & 73' x 39'	32' DIA (3 units)	127' x 55' (3 units)	127' x 208' (3 units)	119' x 100'	109' x 211' (5 passes)	80' DIA (3 unit)	115' DIA (1 unit)	3.6
550	119' x 54' & 133' x 39'	32' DIA (6 units)	127' x 56' (7 units)	127' x 223' (7 units)	209' x 100'	172' x 268' (8 passes)	80' DIA (5 units)	115' DIA (1 unit)	8.3
1000	197' x 58' & 195' x 39'	32' DIA(10 units)	107' x 51' (20 units)	107' x 171' (20 units)	229' x 100'	172' x 168' (8 passes)	80' DIA (6 units)	115' DIA (2 units)	14.6

7.3.2 Interaction with Main Plant

As described in the previous treatment trains, the overflow from the thickeners, ranging from 8 to 36 mgd depending on the flow scenario, is recycled back to the head of the plant for distribution across the main plant and the wet weather treatment train.

7.3.3 Impact on Plant Operations

CEPT requires the addition of chemicals, ferric chloride and polymer, that are not currently used at the SW WPCP. Storage of these new chemicals will need to be monitored to ensure that they are not degraded over time, especially during long periods of shutdown. The system effluent may need to be recycled to the head of the existing plant until the unit process is stabilized.

7.4 Cost Analyses

The estimated capital, O&M, and lifecycle costs for each flow scenario are shown in Exhibit 7-3. Total capital costs and the capital costs per volume treated are also shown in Exhibits 7-4 and 7-5. Estimated O&M costs by category are shown in Exhibit 7-6. A more detailed breakdown of these costs is presented in Attachment SW-2.1.

EXHIBIT 7-3
Cost Summary for CEPT Train #3

	Wet Weather Flow (mgd)		
Cost	**220**	**550**	**1000**
Capital Cost ($M)	$257	$545	$1,002
Annual Operations and Maintenance Cost ($M)	$2.7	$4.7	$6.3
Present Value of the Cost ($M)	$300	$618	$1,100

EXHIBIT 7-4
Capital Costs for Treatment Train #3: CEPT
Includes cost of upgrading plant capacity to 540 MGD

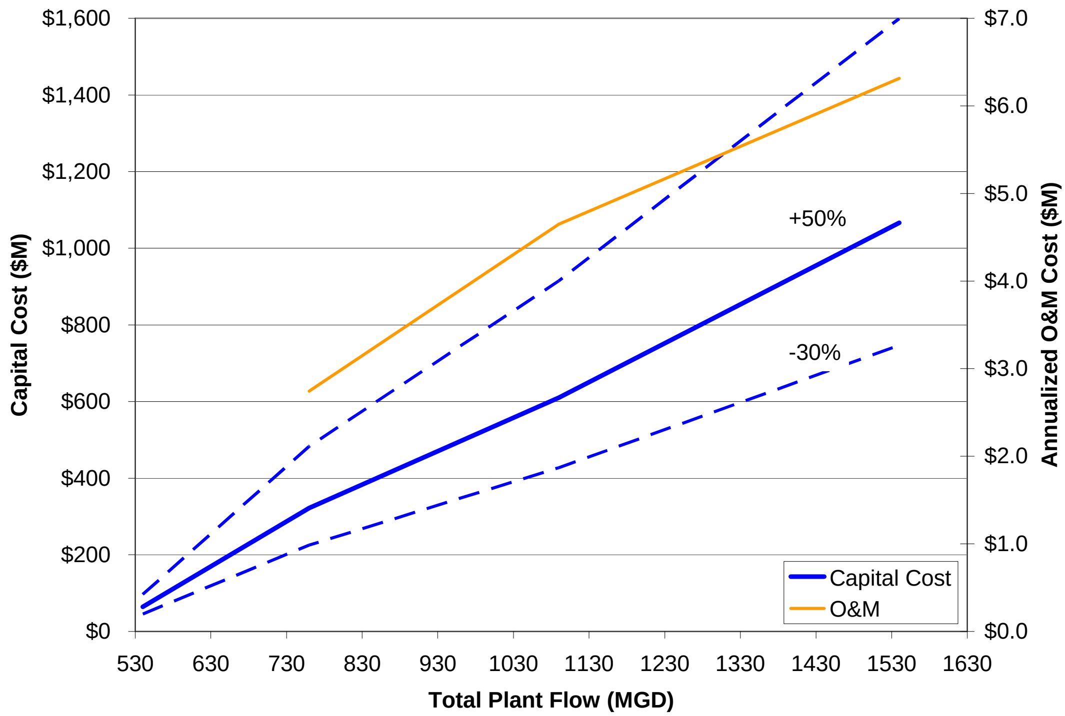


EXHIBIT 7-5
Capital Costs per Gallon Treated for Treatment Train #3: CEPT

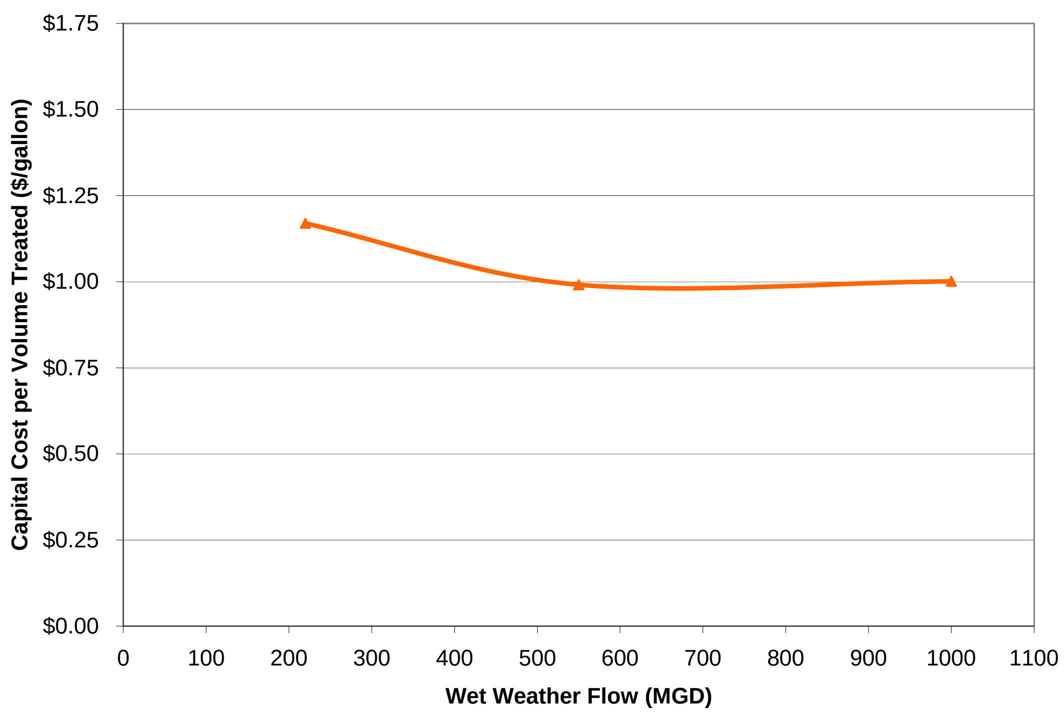
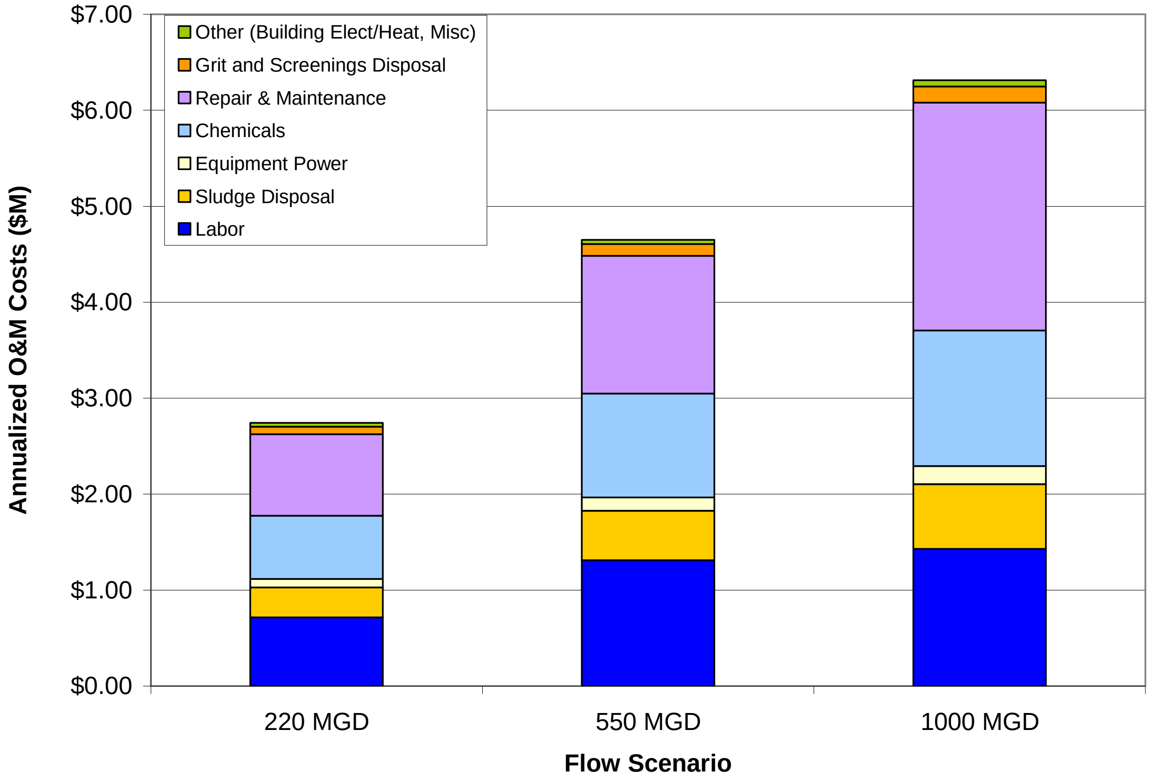


EXHIBIT 7-6
Operations and Maintenance Costs by Category for Treatment Train #3: CEPT



8.0 Treatment Train #4 - Ballasted Flocculation

The final treatment train uses ballasted flocculation to achieve removal efficiencies beyond that of CEPT. Ballasted flocculation, often referred to as "high rate treatment," creates extremely dense flocs with high settling velocities that can be removed efficiently even at very high surface overflow rates. Two proprietary systems that use ballasted flocculation are the DensaDeg and Actiflo systems. The DensaDeg system uses chemical sludge produced within it (recirculated from the clarifier underflow to the system influent) as a ballasting agent. The Actiflo system uses microsand as the ballasting agent. Both systems can achieve TSS removals in the range of 85 to 95 percent.

Actiflo requires separate gravity thickeners to process the sludge it generates, while Densadeg recirculates its sludge within its own process and therefore produces a thicker sludge not requiring thickening. The overall cost differential is not significant in most cases, however, since Densadeg has a lower overflow rate (40 gpm/sf compared with 60 gpm/sf) and larger footprint (CH2M HILL, 2007b).

Since the overall cost of the Actiflo and DensaDeg systems have been found to be similar, only one system was chosen for evaluation for this treatment train. The Actiflo system was selected in order to show the possibility of adding gravity thickeners to the plant layout. Pilot testing should be performed to determine the system best suited for the plant, while providing other benefits such as:

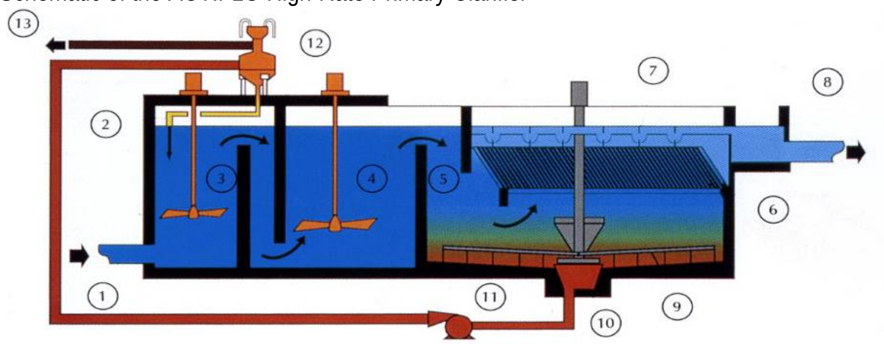
- Identification of influent wastewater constituents that may affect performance of either technology
- Determining suitable chemical dosages for the ballasted flocculation system
- Providing effluent quality information that can be used for design of downstream disinfection processes
- Assessing treatment performance at typical design overflow rates
- Providing better understanding of system operation through pilot testing.

8.1 Process Flow Diagram

In the ballasted flocculation treatment train, wet weather flow passes through bar screening, influent pumps, grit removal, and fine screening before entering the ballasted flocculation system (Exhibit 8-2). A schematic of the Actiflo system is shown in Exhibit 8-1.

Using the numbers in the Exhibit, the wastewater enters at point (1) along with the coagulant (ferric chloride) to the flash mixing zone (3) where microsand is also added (2). Addition of the coagulant enhances flocculation by destabilizing suspended solids in the wastewater. Compartment (4) is a gentle mixing zone where polymer is added to promote formation of strong flocs around the microsand. The flocculated solids flow to compartment (5), the clarification zone. Most of the solids settle at the bottom of this compartment, but this zone also has lamella settling modules (6) to enhance removal of suspended solids that may be present in the wastewater. The solids accumulated at the bottom of the clarification compartment (10) are recycled to a hydrocyclone (12), where the sludge is separated from the microsand. The microsand is recycled back to the flash mixing zone (3), and the sludge leaves the system by stream (13).

EXHIBIT 8-1
Schematic of the ACTIFLO High-Rate Primary Clarifier

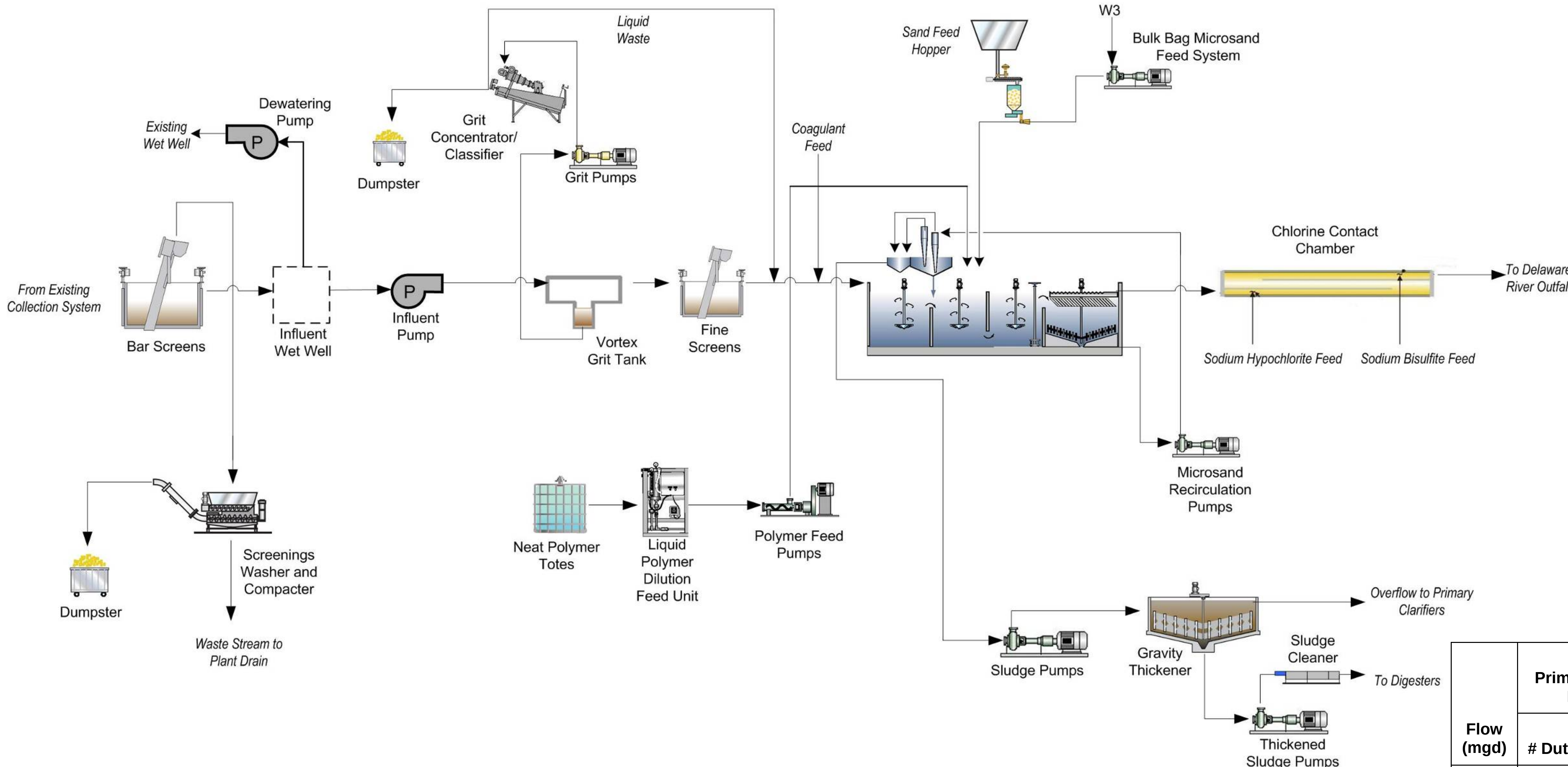


As shown in Exhibit 8-1, the sludge from the ballasted flocculation process is pumped to gravity thickeners to be thickened from 0.3 percent solids to 3-4 percent solids.

8.2 Conceptual Design and Site Layouts

Conceptual designs using the ballasted flocculation system were developed for flow capacities of 220, 980, and 1740 mgd. The key design parameters are presented in Exhibit 8-2. As seen in the conceptual layouts in Exhibit 8-3, the space requirements of this treatment train are minimal compared to the other alternatives. The 980-mgd facility fits on the Upper BRC site alone, utilizing the same area as a 550-mgd CEPT or 600-mgd Conventional Clarification plant. This is due to its extremely high surface overflow rate of 60 gpm/sf.

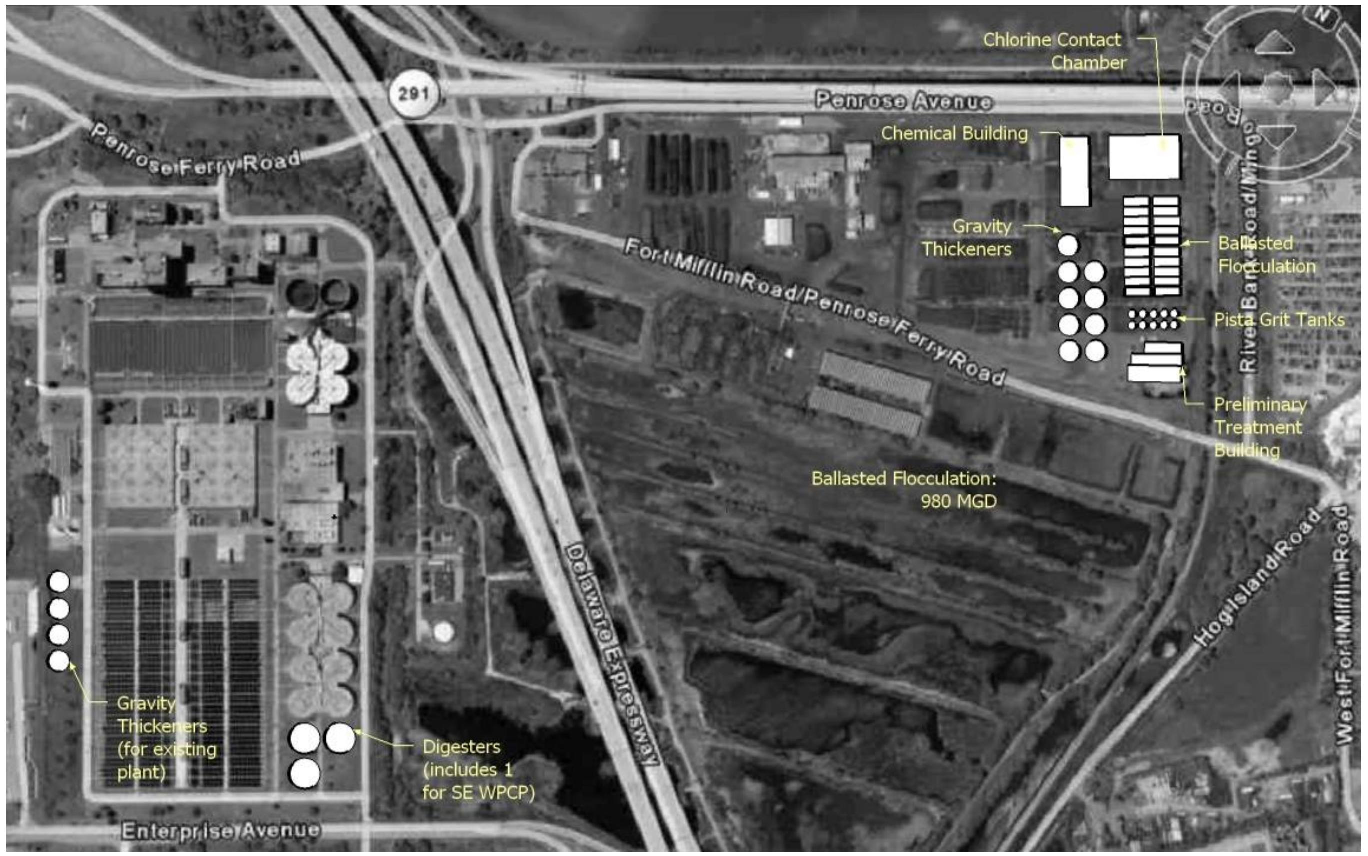
EXHIBIT 8-2
Process Flow Diagram and Key Process Design Parameters for Treatment Train #5: Ballasted Flocculation

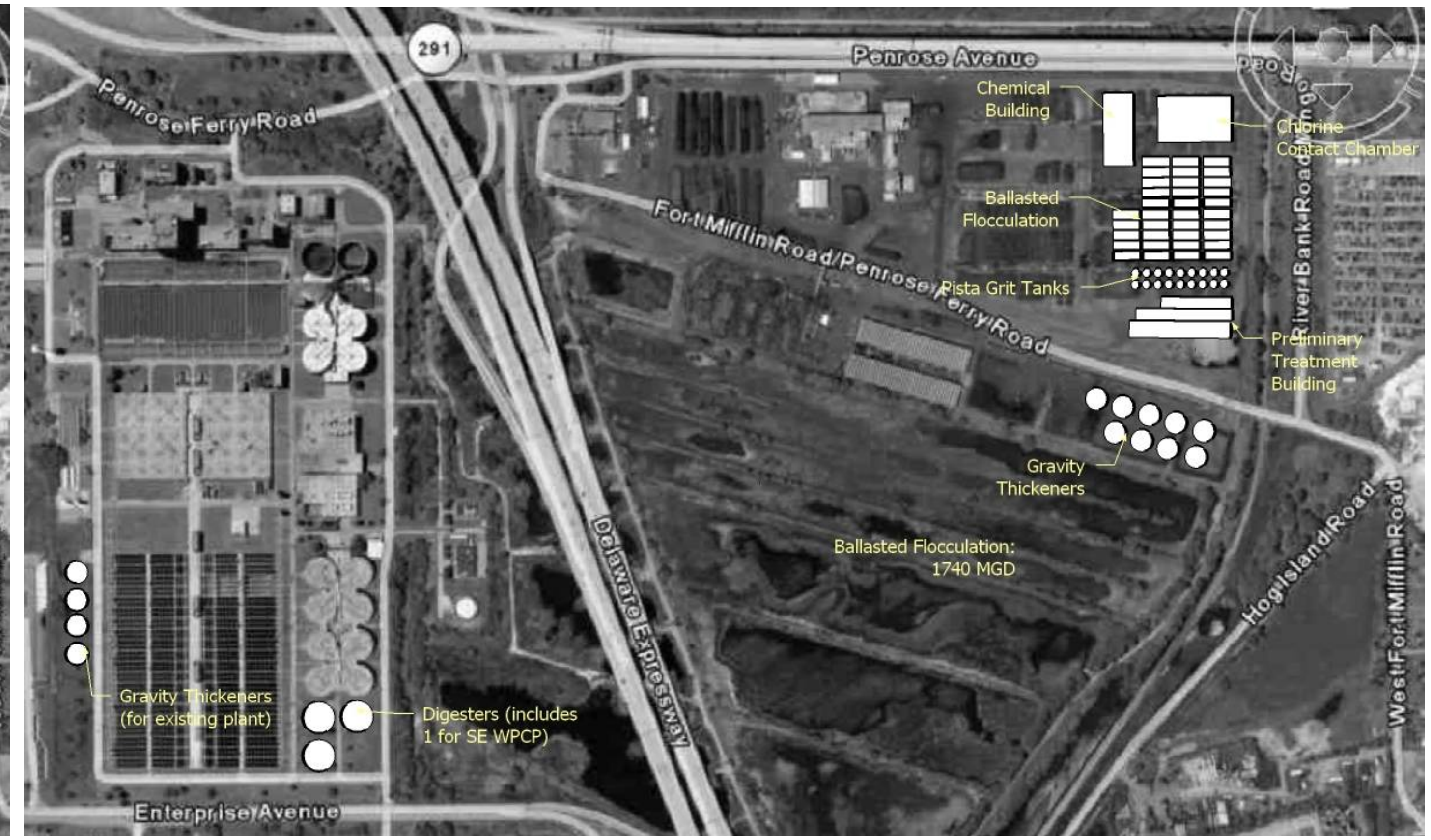


Flow (mgd)	Primary Sludge Pumps		Thickened Sludge Pumps		Sludge Prod. lb/day	Digesters (SW WPCP)
	# Duty	# Standby	# Duty	# Standby		# units
220	5	2	4	1	449428	1
980	20	6	9	3	939713	2
1740	35	11	9	3	939713	2

Flow (mgd)	Bar Screens # Units	Influent Pumps # Units	Vortex Grit Tank		Fine Screening # Units	Screenings Washer/ Compactor # Units (for bar/fine screening)	Grit Pumps		Grit Concentrator # Units	Grit Classifier # Units	Screenings and Grit Prod. Compacted Volume (Cf/Day)	Ferric Chloride			Liquid Polymer			Sodium Hypochlorite			Sodium Bisulfite			Actiflo	Gravity Thickeners & Sludge Cleaners
			# Units	Dia (Ft)			# Duty	# Standby				Total Storage Vol (Gal)	# Duty Pumps	# Standby Pumps	Total Storage Vol (Gal)	# Duty Pumps	# Standby Pumps	Total Storage Vol (Gal)	# Duty Pumps	# Standby Pumps	Total Storage Vol (Gal)	# Duty Pumps	# Standby Pumps	# Trains	# Units
220	3	3	3	32	3	6	3	1	3	1	1,515	230,836	5	2	10,000	5	2	109,537	1	1	6,226	1	1	5	4
980	10	14	10	32	10	20	10	3	10	3	3,168	495,247	20	5	21,455	20	5	235,006	1	1	13,616	1	1	20	9
1740	18	24	18	32	18	36	18	5	18	6	3,168	495,247	35	11	21,455	35	11	235,006	1	1	13,616	1	1	35	9

EXHIBIT 8-3
Conceptual Layouts and Footprints for Treatment Train #5: Ballasted Flocculation
980 MGD Layout (left), 1740 MGD (right)





Flow (Mgd)	PTB	Grit Units	Tanks	Chemical Building	CCC	Gravity Thickeners	Digesters	TOTAL FOOTPRINT (acres)
220	197' x 57' & 73' x 39'	32' (3 units)	25' x 85' (5 units)	119' x 100'	109' x 211' (5 passes)	80' DIA (4 units)	115' DIA (1 unit)	2.2
980	197' x 57' & 133' x 39'	32' (10 units)	20' x 86' (20 units)	231' x 100'	172' x 268' (8 passes)	80' DIA (9 units)	115' DIA (2 units)	4.7
1740	327' x 60' & 195' x 39'	32' (18 units)	35' x 86' (35 units)	231' x 100'	172' x 268' (8 passes)	80' DIA (9 units)	115' DIA (2 units)	7.4

8.3 Operational and Technology-Specific Issues

8.3.1 Startup and Shutdown

Ballasted flocculation systems stabilize quickly, with Actiflo taking less than 20 minutes and DensaDeg less than 45 minutes to start producing good quality effluent based on demonstration testing. Infilco Degremont indicated that the DensaDeg process will produce design effluent immediately if left filled with chlorinated plant effluent. However, based on piloting studies, a connection should be provided for discharging wet weather effluent to the head of the existing plant during startup until such time as the ballasted flocculation system performance stabilizes. To facilitate startup, the ballasted flocculation system should also be underloaded initially.

Shutdown can occur at the operator's convenience. Typically, equipment will simply need to be switched off. The hydrocyclones should be pumped down before being turned off. The tanks themselves can either be filled with treated effluent, or drained down. To prevent freezing during cold weather, any system that is not totally enclosed should have a constant flow of water, or be drained down. The cost estimate does not include a building for the ballasted flocculation units since they are able to be effectively operated in an outdoor environment, and the inclusion of a building would add unnecessary capital costs to this alternative.

The advantage of leaving the basins filled with water is that the startup time is substantially reduced and the basins reach their design effluent quality much more quickly. This reduces the volume of partially treated water that must be returned to the existing treatment plant. Running a small flow through the tanks also helps in maintaining equipment, such as the tank mixers. Actiflo's manufacturer recommends leaving the sand in the tanks only if the tanks are filled with effluent. With sand readily available in the tanks, treatment can begin sooner. If the system were fully drained, the sand within the Actiflo system would require removal and disposal to prevent freezing. Upon startup, sand would have to be reintroduced into the treatment flow using the bulk sand feed system. Infilco Degremont indicates that solids should be removed from the DensaDeg system within six hours to prevent septicity. The DensaDeg system can then be left filled with chlorinated plant effluent.

8.3.2 Interaction with Main Plant

During startup, effluent from the ballasted flocculation system will be discharged to the head of the main plant until system performance stabilizes.

Similar to the other treatment trains, recycle flows from the screenings washer/compactor and grit classifier will be conveyed to the ballasted flocculation system with the wet weather treatment train. The overflow stream from the gravity thickeners, however, must be sent to the head of the main plant for distribution across both the wet weather treatment train and the existing plant. Since this treatment train has the highest removal efficiency, it generates the highest sludge and overflow volumes. In addition, the solids content of the sludge is thinner compared to primary clarifier sludge as a result of the cyclones used to separate the ballast from the sludge. The estimated overflow volume is 16 to 128 mgd, depending on the flow capacity of the treatment train.

8.3.3 Impact on plant operations

To simplify routine operation, Actiflo and Densadeg typically have automated routine startup and shutdown sequences with PLC programming and adjustable timers (service interval, tank fill, equipment run, shutdown, and tank drain). However, operator attention will be necessary to monitor or optimize performance, and to confirm successful facility startup. The operators will have the following responsibilities:

- Start the process train
- Monitor coagulant and polymer dose and perform jar tests to optimize chemical dosing.
- Manage the loading of screenings and grit dumpsters.
- Observe equipment operation and contact maintenance if equipment malfunctions.

8.3.4 Other Issues

Foaming – Foaming may occur due to the addition of coagulants and polymer settling aids, and should be investigated in pilot studies. For example, during startup of the Actiflo unit at Lawrence WWTP in Lawrence, Kansas, the observed foaming resulted from the reaction of ferric chloride with biodegradable surfactants in the incoming wastewater. Foaming can be controlled using silica-based defoamers such as Tramfloc 110, Chemco DF, and Neo Solutions NS-8454 at low dosages.

Floc Carryover and Microsand Loss – Floc carryover is an issue for the DensaDeg system that should be investigated through pilot tests. As flows approach the design SOR, sludge densities may decrease, sending large flocs of sludge out in the effluent. These large flocs not only affect effluent quality in terms of TSS and BOD levels, but may also decrease effectiveness of the disinfection process downstream.

Regarding the Actiflo system, a certain degree of microsand loss is expected from normal operation of the system. The manufacturer indicates that about 8 pounds of microsand are lost for each million gallons of wastewater treated. The sand must be replaced for optimal operation of the system. According to information gathered during the team’s site visit to the Cincinnati Metropolitan Sewer District, the SSO 700 Facility loses 350 lbs of sand per 15 mg wet weather event. In the conceptual design of this treatment train, adequate storage space was provided in the chemical buildings for 10 day storage of sand. Additionally, the microsand needs to be maintained in the system in case rapid startup is required, and the sand must be prevented from freezing during the winter so that the unit can start up quickly if needed during the cold season. The DensaDeg unit is totally drained when the system is shut down, and no chemical sludge is maintained in the system when it is not in use.

Sludge Concentration - One important difference between Actiflo and Densadeg is the sludge concentration that they produce. Sludge from the DensaDeg system can be four to five times more concentrated than sludge from the Actiflo system. Since the two systems are expected to produce the same mass of sludge, because they operate with similar coagulant dosages, it is expected that the volume of sludge produced in the ACTIFLO system will be four to five times greater than that in the DensaDeg unit. Gravity thickeners have been included in the conceptual design for the Actiflo treatment train to thicken the sludge to 3-4 percent solids. These thickeners may not be necessary if the Densadeg system is chosen.

8.4 Cost Analyses

The estimated capital, O&M, and lifecycle costs for each flow scenario are shown in Exhibit 8-4. Total capital costs and the capital costs per volume treated are also shown in Exhibits 8-5 and 8-6. Estimated O&M costs by category are presented in Exhibit 8-7. A more detailed breakdown of these costs is presented in Attachment SW-2.1.

EXHIBIT 8-4
Cost Summary for Ballasted Flocculation: Treatment Train #4

	Wet Weather Flow (mgd)		
Cost	**220**	**980**	**1740**
Capital Cost ($M)	$253	$851	$1,357
Annual Operations and Maintenance Cost ($M)	$3.4	$7.9	$10.0
Present Value of the Cost ($M)	$306	$974	$1,514

EXHIBIT 8-5
Capital Costs for Treatment Train #5: Ballasted Flocculation
Includes cost of upgrading plant capacity to 540 MGD

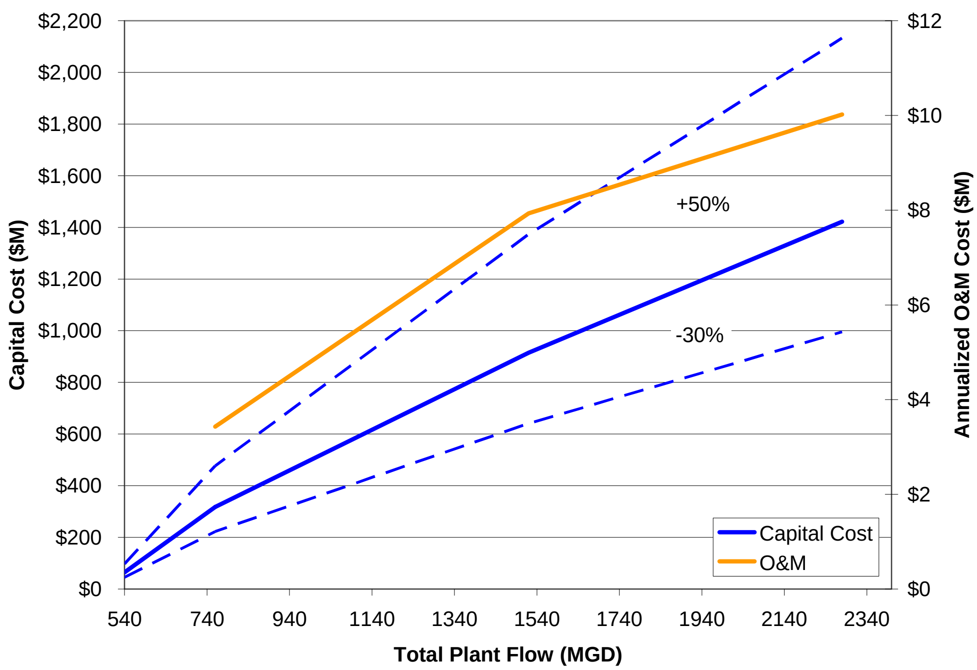


EXHIBIT 8-6
Capital Costs per Gallon Treated for Treatment Train #5: Ballasted Flocculation

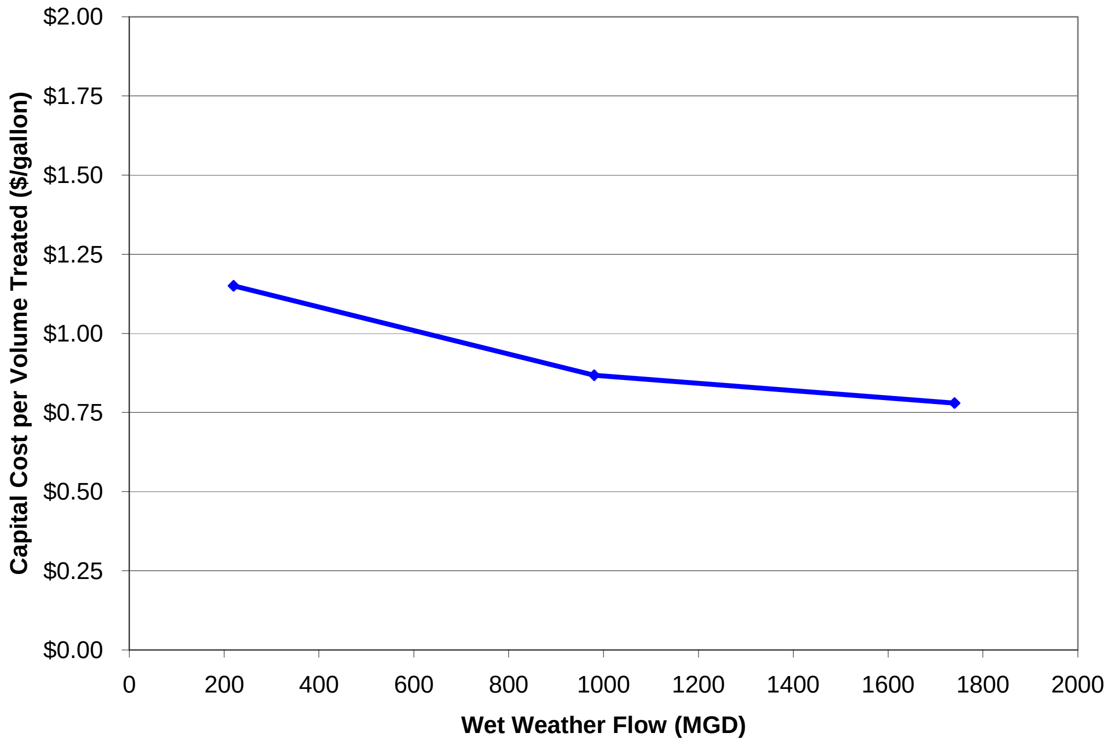
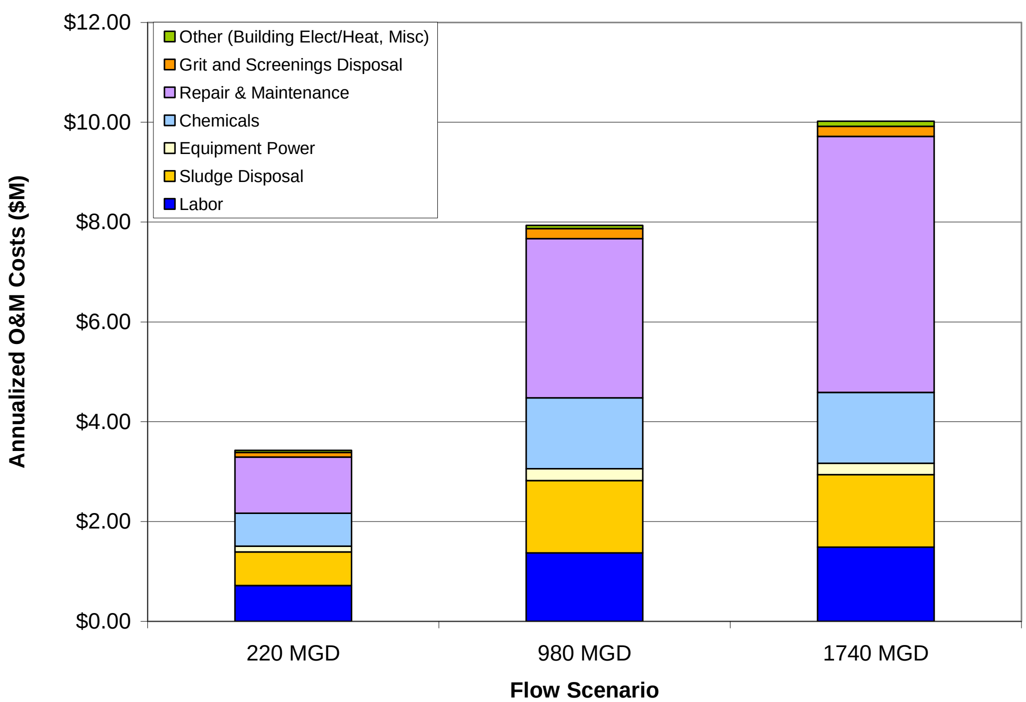


EXHIBIT 8-7
Operations and Maintenance Costs by Category for Treatment Train #5: Ballasted Flocculation



9.0 Alternatives for Optimizing Capital Costs

9.1 Ballasted Flocculation

As mentioned in Section 8, the costs presented for Treatment Train #5, Ballasted Flocculation, are based on the Actiflo system, which similar in cost to Densadeg, the other proprietary high rate treatment technology. If the ballasted flocculation treatment train is selected, a cost estimate for the Densadeg system should be developed to examine the cost differential. The main contributions to the cost differential will include:

- **Reduction in number of thickeners** - Densadeg maintains a 3-4 percent sludge thickness for its ballast, compared to the 0.3 percent sludge thickness in the Actiflo system.
- **Increase in footprint** – Densadeg has a 40 gpm/sf loading rate, compared to Actiflo's 60 gpm/sf loading rate.
- **Elimination of fine screening** – Actiflo requires fine screening to protect the hydrocyclones in the system, which separate sand from sludge. Since Densadeg uses sludge only as its ballast, it does not require fine screening upstream.

Implications to operations and maintenance should also be examined between the two systems. For example, Actiflo requires sand as the ballasting agent, which requires storage and maintenance.

9.2 Refined Design Assumptions via Influent Sampling

Influent sampling at the plant during wet weather events will shed light on the wastewater characteristics of the wet weather flow, as well as the flow regime during events. More concrete numbers for influent TSS, BOD, and flow can be used to refine process design parameters, which may lead to a reduction in the size and cost of the treatment trains.

10.0 Comparison of Treatment Alternatives

10.1 Effluent Water Quality

As discussed in Section 3, effluent from the wet weather treatment facility will discharge to a new outfall at the Schuylkill River and will not commingle with the effluent from the main plant, which currently discharges into the Delaware River. It is likely that a new NPDES permit will need to be negotiated for this new discharge. If treated as a separate wet weather facility, it is clear that the effluent water quality in order from best to worst will come from: Ballasted Flocculation, CEPT, Conventional Clarification, and finally the Vortex/Swirl train (Exhibits 10-1 and 10-2).

10.1.1 Effluent Water Quality – Assuming Blending

An alternative way of analyzing water quality is to consider the new wet weather facility and the main SW WPCP as one system with a single discharge permit. In this system, the effluent from the two plants is "blended" before discharge into the water body, and this "blended" effluent must meet permit limits. This is similar to the water quality analyses performed for the Southeast and Northeast WPCPs.

The TSS and cBOD concentrations of the "blended" effluent for each treatment train and flow scenario is presented in Exhibit 10-1 and 10-2, respectively.

EXHIBIT 10-1
Blended Effluent TSS Concentrations

Treatment Train	Wet Weather Treatment Train Effluent Conc. (mg/L)	Blended Effluent TSS Concentration (mg/L)							
		Wet Weather Treatment Train Flow (mgd)							
		220	***550***	***600***	***702***	***980***	***1000***	***1200***	***1740***
#1) Vortex/Swirl Concentrators	158	61			99				
#2) Conventional Clarifiers	102	45		64				77	
#3) CEPT w/ Conventional Clarifiers	45	29	34				37		
#4) Ballasted Flocculation	21	22				21			21

Notes: Based on the 95th percentile wet weather TSS concentration of 22 mg/L and a maximum of 540 MGD through the existing plant. Allowable daily blended effluent TSS concentration on wet weather days is 112 mg/L, to meet monthly TSS permit limits.

EXHIBIT 10-2
Blended Effluent cBOD Concentrations

Treatment Train	Wet Weather Treatment Train Effluent Conc. (mg/L)	Blended Effluent cBOD Concentration (mg/L) *Wet Weather Treatment Train Flow (mgd)*							
		220	***550***	***600***	***702***	***980***	***1000***	***1200***	***1740***
#1) Vortex/Swirl Concentrators	75	27			46				
#2) Conventional Clarifiers	64	24		37				47	
#3) CEPT w/ Conventional Clarifiers	54	21	31				38		
#4) Ballasted Flocculation	49	20				34			39

Notes: Based on the 95th percentile wet weather cBOD concentration of 8 mg/L and a maximum of 540 MGD through the existing plant.

As described in Section 4.1, the maximum flow through all the treatment trains, with the exception of the vortex swirl, is unlimited if the number of wet weather days is less than 7 days per month. To illustrate the risk of exceeding permit limits at these design flows, Exhibit 10-3 presents the maximum number of days that the wet weather treatment train can operate at its maximum capacity without the system exceeding monthly TSS permit limits. The ballasted flocculation train is unlimited in frequency of operation since its effluent quality (30 mg/L TSS) surpasses permit limits without blending.

EXHIBIT 10-3
Allowable Number of Operating Days of Wet Weather Treatment Train

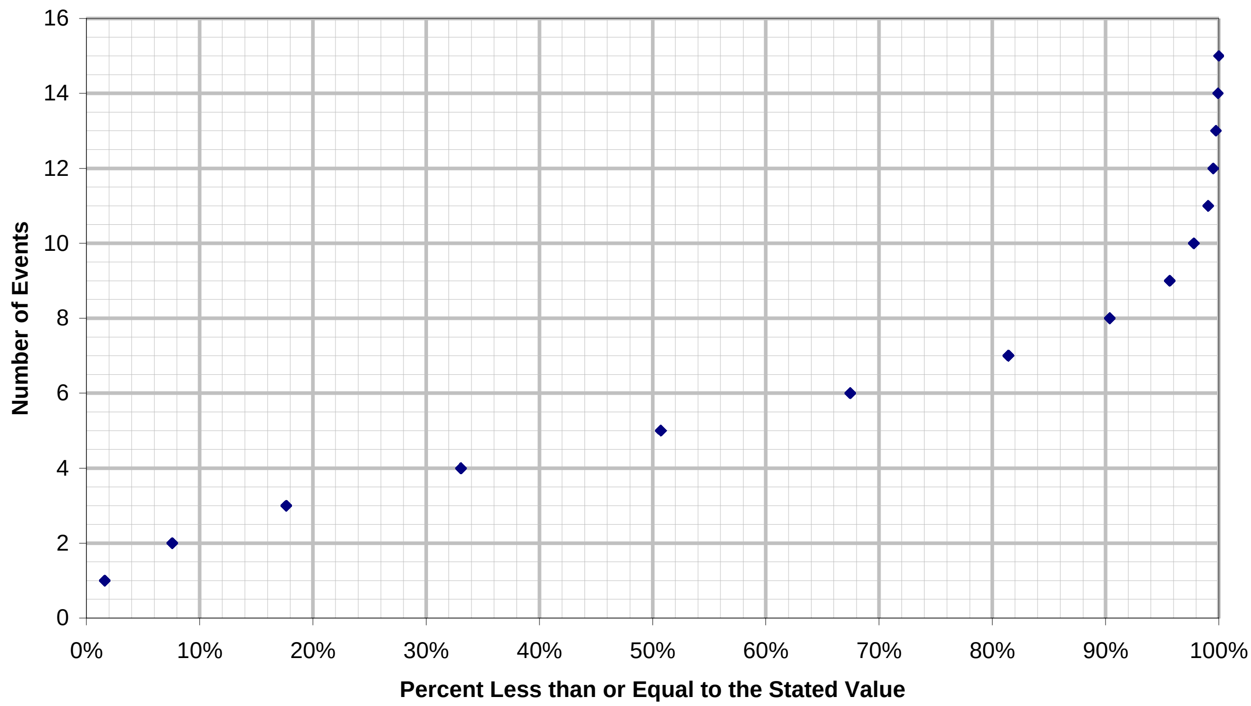
Treatment Train	Maximum Allowable Number of Operating Days per Month(1) *Wet Weather Treatment Train Flow (mgd)*							
	220	***550***	***600***	***702***	***980***	***1000***	***1200***	***1740***
#1) Vortex/Swirl Concentrators	12			7				
#2) Conventional Clarifiers	17		11				9	
#3) CEPT w/ Conventional Clarifiers	UNLIMI-TED	25				22		
#4) Ballasted Flocculation	UNLIMITED							

Notes:
(1) Allowable number of operating days without exceeding permit limits for monthly TSS concentrations. Assumes entire plant operates at maximum capacity during every wet weather event.

A frequency plot of the number of wet weather events per month and the duration of each event is shown in Exhibits 10-4 and 10-5 for comparison purposes (Myers, 2008b). As shown, wet weather events have occurred at a historical maximum of 15 per month. This suggests that CEPT, and Ballasted Flocculation have a very low probability of exceeding permit limits. It should be noted that the wet weather event referred to in this plot occurs whenever rainfall exceeds 0.1 inch, and does not necessarily correspond to operation of the new wet weather treatment train. If the flow does not exceed the capacity of the conventional plant, the wet weather treatment train will not come online. Thus, the new wet weather treatment train is expected to operate less than 15 times per month.

It should be noted that a continuous simulation-based approach would give a more accurate estimate of risk, and more detailed analyses should be performed during the facility planning and design phases.

EXHIBIT 10-4
Cumulative Frequency Plot of the Number of Wet Weather Events per Month



Notes: Based on Philadelphia International Airport NOAA Rain Gauge Hourly Data from1902-2000. Minimum Interevent Time = 4 hrs, Minimum Storm = 0.1 Inches (provided by CDM)

10.1.2 Capital, O&M and Life-Cycle Costs

The capital cost estimates for the four treatment trains are shown in Exhibit 10-5. Train #3, CEPT, is the most expensive, followed by Trains #2 and #4, Conventional Clarification and Ballasted Flocculation, which appear similar in cost. The cost of Train #1, Vortex/Swirl, is significantly less expensive than the other three trains. Translated into a cost per volume treated, all trains appear to become more cost effective as flow capacity increases (Exhibit 10-6).

The reason that CEPT is more expensive than Ballasted Flocculation for the SW WPCP wet weather facility is likely due to the limited length and increased number of its clarifiers, as described in Section 7.2, as well as the increased cost for piles.

The comparison of O&M costs for each treatment train is shown in Exhibit 10-7. As expected, the O&M costs for vortex swirls and conventional clarifiers, which do not require chemical settling aids, are the lowest. Ballasted Flocculation has the highest O&M costs due to its chemical usage and the complexity of its system.

Taking construction, non-construction, and O&M costs into consideration, Exhibit 10-8 shows the present value of the total cost of each wet weather treatment train. Again, CEPT and Ballasted Flocculation remain most costly due to their high capital and O&M costs. Train #1, vortex/swirl concentrators, is significantly less expensive compared with other technologies from the life-cycle cost perspective. This is due to its low chemical usage and minimal operations and maintenance needs.

EXHIBIT 10-5
Comparison of Capital Costs for All Treatment Trains

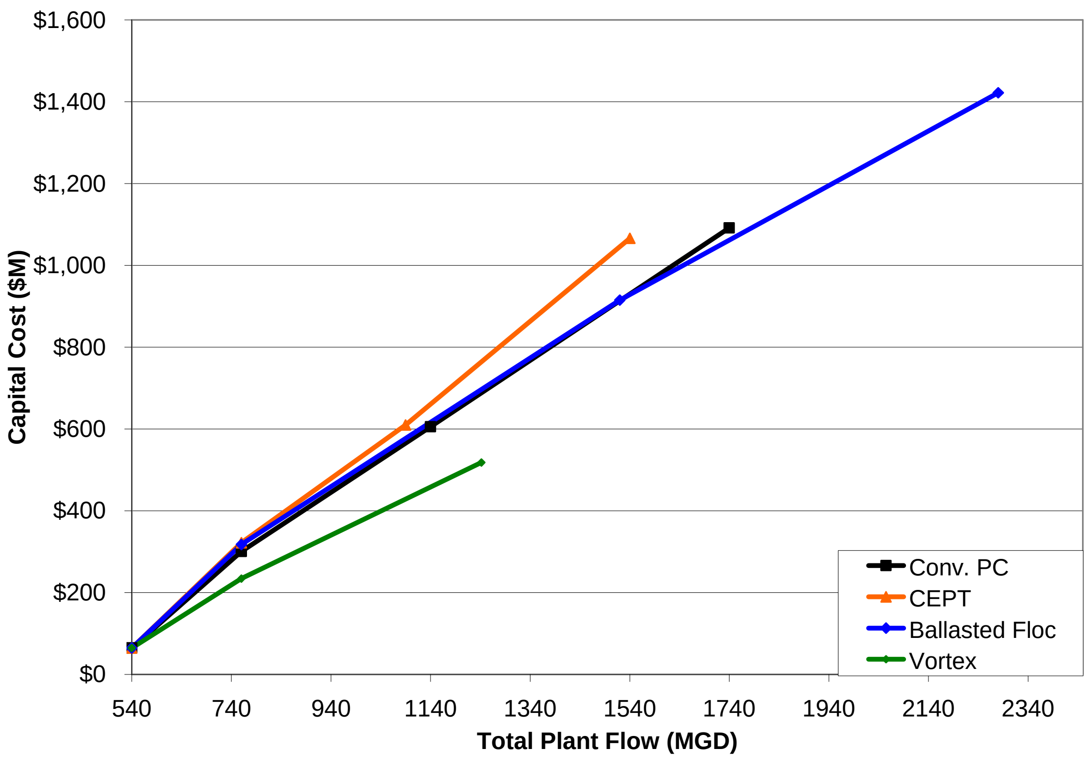


EXHIBIT 10-6
Comparison of Cost Effectiveness for all Treatment Trains

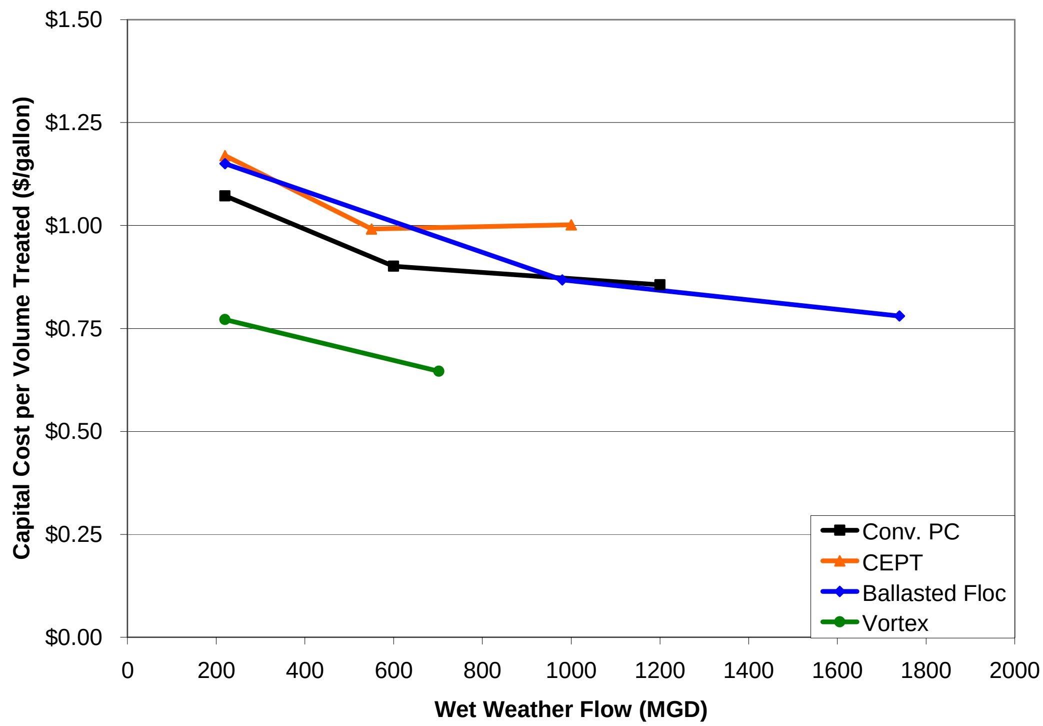


EXHIBIT 10-7
Comparison of Operations and Maintenance Costs for all Treatment Trains

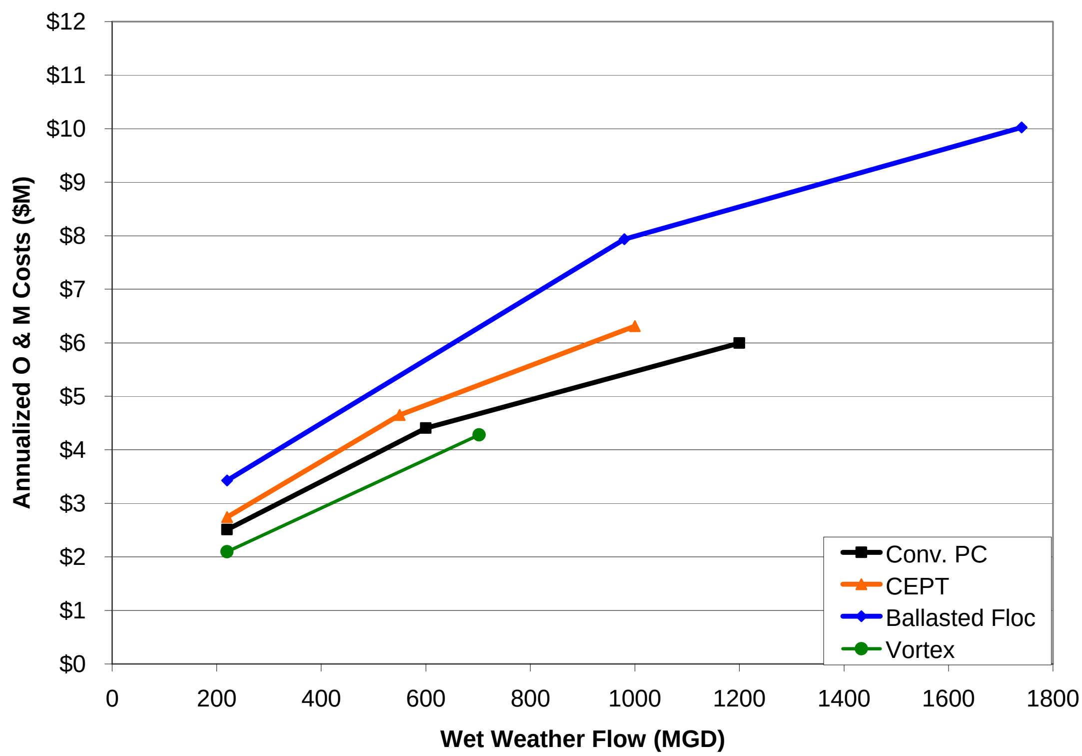
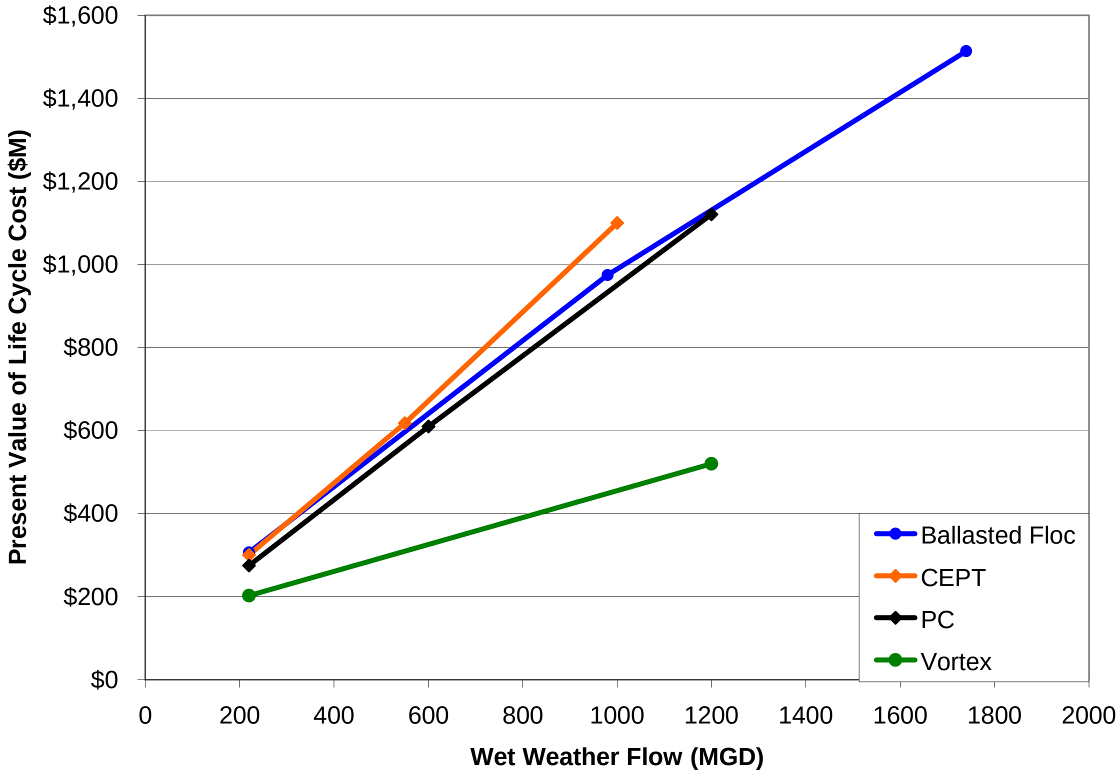


EXHIBIT 10-8
Comparison of Life-Cycle Costs for all Treatment Trains



10.2 Overall Comparison

Aside from capital, O&M, and lifecycle costs, there are numerous other criteria by which the treatment trains should be evaluated, including:

- Reliability of the system
- Community and environmental impacts or perception
- Ability to handle large variations in flow
- Land requirements
- Constructability
- Requirements for maintenance and operator attention
- Sustainability

These evaluation criteria were discussed in Workshop No. 2B, and are presented in TM-SE2 for various wet weather treatment technologies (CH2M HILL, 2008a). Several key advantages and disadvantages of Treatment Trains #1 - #4, as evaluated in this report, are described in Exhibit 10-9.

EXHIBIT 10-9
Summary of Pros and Cons for Each Wet Weather Treatment Train

Treatment Train	Pros	Cons
Train #1: Vortex/Swirl Concentrators	• Simple operation • Low maintenance requirements – no moving parts	• Maximum design flow may decrease if the assumed number of operating days per month is greater than 7. • Unless operated at lower loading rates, removal efficiency may not be high enough to operate alone without blending effluent with main plant effluent.
Train #2: Conventional Clarifiers	• Simple operation • Same technology as existing plant – operators familiar with equipment	• Space limited • Maximum design flow may decrease if the assumed number of operating days is greater than 9.
Train #3: CEPT	• Lower chlorine dose possible due to high TSS removal efficiencies • May be operated as Conventional Clarifiers if chemicals found to be unnecessary	• Operators unfamiliar with technology • Space limited • Can treat less flow on land available than conventional clarifiers
Train #4: Ballasted Flocculation	• Can treat up to 1740 mgd with available land on site • Highest removal efficiencies • Unlimited number of operating days per month • Lower chlorine dose possible due to high TSS removal efficiencies	• Operators unfamiliar with technology • Most labor intensive and complex system • Uses two additional chemical systems for coagulation and flocculation

The costs for wet weather treatment at the SW WPCP should be analyzed with the costs of other wet weather treatment alternatives, such as improvements in the collection system, to determine which treatment train alternatives and flow regimes should be evaluated further. Treatment trains that are selected for further evaluation should undergo more detailed design and costing methods, water quality sampling, and bench and pilot scale testing, so that removal efficiencies, land requirements, capital costs, and O&M costs can be further refined.

11.0 References

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Attachment SW-2.1

Breakdown of Capital and O&M Costs

SW WPCP Wet Weather Treatment Train Alternatives: Capital Cost Estimates

Train	Train #1: Vortex/Swirl		Train #2: Conventional Clarifiers			Train #3: CEPT			Train #4: Ballasted Flocculation		
Flow (mgd)	220	702	220	600	1200	220	550	1000	220	980	1740
Influent Pump Station	$6,211,840	$19,204,881	$6,211,840	$17,216,238	$32,224,067	$6,211,840	$15,440,402	$26,699,344	$6,211,840	$26,620,062	$45,396,179
Bar Screens, Grit Removal, and Fine Screens	$4,749,552	$9,819,610	$6,281,013	$12,522,818	$26,565,308	$6,281,013	$12,522,818	$20,881,889	$9,785,312	$32,776,926	$58,738,547
Vortex Swirl	$11,399,923	$32,130,118	$0	$0	$0	$0	$0	$0	$0	$0	$0
Flocculation Tanks	$0	$0	$0	$0	$0	$3,730,191	$8,596,429	$19,257,646	$0	$0	$0
Primary Clarifiers	$0	$0	$11,475,907	$31,479,253	$63,398,121	$9,347,391	$22,244,693	$44,722,607	$0	$0	$0
Actiflo System	$0	$0	$0	$0	$0	$0	$0	$0	$16,392,721	$68,027,829	$119,182,929
Chemical Feed	$1,658,414	$2,709,339	$1,509,522	$2,395,083	$2,711,950	$3,951,403	$6,745,873	$8,564,594	$4,170,695	$8,784,387	$10,114,942
Chlorine Contact Chamber (1)	$3,265,976	$6,247,533	$3,263,919	$6,247,533	$6,247,533	$3,263,919	$6,247,533	$6,247,533	$3,263,919	$6,247,533	$6,247,533
Gravity Thickeners	$4,094,524	$9,990,886	$2,109,922	$2,839,337	$3,900,703	$2,995,095	$4,870,987	$5,761,509	$3,907,373	$7,421,255	$8,141,207
Yard Piping (large)	$1,009,868	$2,981,295	$1,635,436	$5,811,516	$16,320,993	$1,399,466	$4,368,383	$12,451,821	$1,639,449	$9,442,449	$15,200,742
Digesters	$0	$6,259,941	$6,379,355	$6,295,765	$6,337,560	$6,325,676	$6,409,265	$14,728,460	$6,325,619	$11,678,693	$11,421,953
Subtotal Project Cost	$32,390,097	$89,343,603	$38,866,914	$84,807,543	$157,706,235	$43,505,994	$87,446,383	$159,315,403	$51,696,928	$170,999,134	$274,444,032
Additional Project Costs:											
General Demolition	$323,901	$893,436	$388,669	$848,075	$1,577,062	$435,060	$874,464	$1,593,154	$516,969	$1,709,991	$2,744,440
Overall Sitework	$2,591,208	$7,147,488	$3,109,353	$6,784,603	$12,616,499	$3,480,480	$6,995,711	$12,745,232	$4,135,754	$13,679,931	$21,955,523
Plant Computer System	$2,753,158	$7,594,206	$3,303,688	$7,208,641	$13,405,030	$3,698,009	$7,432,943	$13,541,809	$4,394,239	$14,534,926	$23,327,743
Yard Electrical	$2,591,208	$7,147,488	$3,109,353	$6,784,603	$12,616,499	$3,480,480	$6,995,711	$12,745,232	$4,135,754	$13,679,931	$21,955,523
Yard Piping	$1,943,406	$5,360,616	$2,332,015	$5,088,453	$9,462,374	$2,610,360	$5,246,783	$9,558,924	$3,101,816	$10,259,948	$16,466,642
Subtotal with Additional Project Costs	$42,592,978	$117,486,838	$51,109,992	$111,521,919	$207,383,699	$57,210,382	$114,991,994	$209,499,755	$67,981,460	$224,863,861	$360,893,902
Subtotal with Contractor Markups (1)	$64,568,292	$178,102,703	$77,479,553	$169,060,259	$314,380,726	$86,727,364	$174,320,675	$317,588,535	$103,055,645	$340,879,560	$547,092,600
Subtotal with Escalation (2)	$78,256,770	$220,669,250	$93,905,219	$209,465,661	$403,036,091	$105,113,565	$215,983,317	$407,148,502	$124,903,442	$437,007,595	$701,372,713
Subtotal with Local Adjustment Factor (3)	$90,151,799	$254,210,975	$108,178,812	$241,304,442	$464,297,577	$121,090,827	$248,812,781	$469,035,074	$143,888,765	$503,432,750	$807,981,365
Dewatering	$485,851	$1,340,154	$583,004	$1,272,113	$2,365,594	$652,590	$1,311,696	$2,389,731	$775,454	$2,564,987	$4,116,660
Structural Piles	$22,920,782	$47,676,536	$48,987,733	$119,161,825	$220,484,354	$50,393,334	$114,594,478	$198,490,902	$24,556,943	$63,013,829	$95,826,465
Subtotal - Construction Cost, including Market Adjustment Factor (4)	**$130,592,197**	**$348,711,815**	**$181,411,981**	**$415,999,137**	**$790,219,653**	**$197,957,263**	**$419,426,798**	**$770,403,063**	**$194,604,336**	**$654,363,301**	**$1,044,113,164**
Total Capital Cost (with non construction costs)	**$169,769,856**	**$453,325,359**	**$235,835,575**	**$540,798,878**	**$1,027,285,548**	**$257,344,441**	**$545,254,838**	**$1,001,523,981**	**$252,985,637**	**$850,672,291**	**$1,357,347,114**
Total Capital Cost ($M)	$170	$453	$236	$541	$1,027	$257	$545	$1,002	$253	$851	$1,357
.+50% Capital Cost ($M)	$255	$680	$354	$811	$1,541	$386	$818	$1,502	$379	$1,276	$2,036
.-30% Capital Cost ($M)	$119	$317	$165	$379	$719	$180	$382	$701	$177	$595	$950
Cost Efficiency ($/gallon)	**$0.77**	**$0.65**	**$1.07**	**$0.90**	**$0.86**	**$1.17**	**$0.99**	**$1.00**	**$1.15**	**$0.87**	**$0.78**

Notes:
1. Contractor markups - use 1.516 multiplier (see TM-SW2 Section 4.3)
2. Escalation - multiplier depends on duration of construction (see Exhibit 4-7 in TM-SW2 Section 4.3)
3. Local Adjustment Factor - use 1.152 multiplier (see TM-SW2 Section 4.3)
4. Market Adjustment Factor - use 1.15 multiplier (see TM-SW2 Section 4.3)
5. Non-construction costs - use 1.3 multiplier (see TM-SW2 Section 4.3)

SW WPCP Wet Weather Treatment Train Alternatives: Operations and Maintenance Cost Estimates [1]

	Flow (mgd)	Labor	Sludge Disposal	Building Electrical & Heating	Chemicals	Other [3]	Grit and Screenings Disposal	Equipment Power [2]	Repair & Maintenance	Total	Horsepower requirements (HP)
Train #1: Vortex/Swirls	220	$715,021	$171,218	$3,270	$163,176	$33,880	$79,366	$89,447	$840,477	$2,095,855	2,950
	702	$1,311,933	$367,341	$7,203	$350,086	$33,880	$163,438	$192,999	$1,855,270	$4,282,149	9,468
Train #2: Conventional Clarifiers	220	$715,021	$600,061	$4,200	$163,176	$33,880	$79,366	$84,411	$829,620	$2,509,734	2,784
	600	$1,311,933	$987,373	$6,682	$268,498	$33,880	$124,460	$135,428	$1,538,264	$4,406,518	7,769
	1200	$1,370,988	$1,287,403	$10,038	$350,086	$50,819	$170,276	$176,235	$2,577,338	$5,993,185	14,779
Train #3: CEPT	220	$715,021	$313,900	$5,865	$658,596	$33,880	$79,366	$86,403	$849,710	$2,742,741	2,850
	550	$1,311,933	$516,508	$10,147	$1,083,690	$33,880	$124,460	$136,717	$1,433,439	$4,650,775	7,189
	1000	$1,430,042	$673,458	$12,886	$1,412,989	$50,819	$170,276	$189,274	$2,373,861	$6,313,606	13,227
Train #5: Ballasted Flocculation	220	$715,021	$675,069	$9,773	$658,308	$33,880	$95,065	$116,004	$1,125,026	$3,428,146	3,826
	980	$1,370,988	$1,448,329	$14,605	$1,417,827	$50,819	$203,958	$239,699	$3,187,738	$7,933,962	16,416
	1740	$1,489,097	$1,448,329	$19,109	$1,417,827	$84,699	$203,958	$230,810	$5,127,044	$10,020,872	28,066

Notes:

1. All O&M costs are annualized costs based on escalation through a 30-year period. See TM-SW2 Section 4.2.1 for description of average flows
2. Power costs are estimated based on the total horsepower requirements and the average-to-max flow ratio.
3. "Other" costs cover miscellaneous costs for vehicles, lab tests, office equipment, etc.

Percentage of Costs by Category

	Flow (mgd)	Labor	Sludge Disposal	Building Electrical & Heating	Chemicals	Other	Grit and Screenings Disposal	Equipment Power	Repair & Maintenance
Train #1: Vortex/Swirls	220	34.1%	8.2%	0.2%	7.8%	1.6%	3.8%	4.3%	40.1%
	702	30.6%	8.6%	0.2%	8.2%	0.8%	3.8%	4.5%	43.3%
Train #2: Conventional Clarifiers	220	28.5%	23.9%	0.2%	6.5%	1.3%	3.2%	3.4%	33.1%
	600	29.8%	22.4%	0.2%	6.1%	0.8%	2.8%	3.1%	34.9%
	1200	22.9%	21.5%	0.2%	5.8%	0.8%	2.8%	2.9%	43.0%
Train #3: CEPT	220	26.1%	11.4%	0.2%	24.0%	1.2%	2.9%	3.2%	31.0%
	550	28.2%	11.1%	0.2%	23.3%	0.7%	2.7%	2.9%	30.8%
	1000	22.7%	10.7%	0.2%	22.4%	0.8%	2.7%	3.0%	37.6%
Train #5: Ballasted Flocculation	220	20.9%	19.7%	0.3%	19.2%	1.0%	2.8%	3.4%	32.8%
	980	17.3%	18.3%	0.2%	17.9%	0.6%	2.6%	3.0%	40.2%
	1740	14.9%	14.5%	0.2%	14.1%	0.8%	2.0%	2.3%	51.2%