Supplemental Documentation Volume 10

Analysis of Wet Weather Treatment Alternatives for Southeast WPCP

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Final Tech Memo

Wet Weather Treatment Alternatives at Northeast, Southeast and Southwest WPCPs

SE3: Analysis of Wet Weather Treatment Alternatives for Southeast 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 five wet weather treatment alternatives for the Southeast Water Pollution Control Plant (SE WPCP). The wet weather treatment technologies for the SE WPCP evaluated in this report are as follows:

1. Vortex Swirl Concentrators (at low and high loading rates)
2. Conventional Clarifiers
3. Chemically Enhanced Primary Treatment (CEPT) with Conventional Clarifiers
4. CEPT with Plate Settlers (includes fine screening)
5. Ballasted Flocculation (includes fine screening)

Conceptual treatment trains were developed for each treatment technology at various wet weather flows ranging from 80 million gallons per day (mgd) to 1200 mgd and cost curves for capital, operations and maintenance (O&M), and lifecycle costs were generated for each treatment train alternative.

In order to increase the flow capacity of the SE WPCP for wet weather conditions, the potential of maximizing flow through the existing plant was evaluated. According to stress testing results, the SE WPCP currently has a firm capacity of 240 mgd (CH2M HILL, 2001). With several process and hydraulic modifications, the SE WPCP's firm capacity can potentially reach 330 mgd. The necessary improvements to achieve this flow were identified in the 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 SE WPCP plant staff.

In sizing the wet weather treatment trains, it was assumed that the upgrades proposed in the Stress Testing Report and discussed in this report will have been completed, increasing the plant's capacity to a minimum of 330 mgd. Thus, the baseline cost that is used in the wet weather treatment train cost estimates is $48.1, which is reflected in the cost curves for each treatment train.

To expand the flow capacity of SE WPCP beyond 330 mgd for the treatment of wet weather flows, a separate wet weather treatment train will be required. Wet weather flows in excess of 330 mgd will be diverted to one of the new treatment trains, listed above, eventually blending with effluent from the existing plant. Conceptual designs and cost estimates were performed for each treatment train at various design flows.

Design Flows

The maximum allowable flow through each wet weather treatment train is a function of its removal efficiency, the achievable effluent concentration after blending, and the plant's continued ability to meet NPDES permit limits for weekly and monthly TSS and BOD concentrations. With the exception of the vortex/swirl train at high loading rates, 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. Other design flow points were selected based on the existing collection system capacity, the existing outfall conduit capacity, and limits of available land on site and are indicated in the Exhibit ES-1.

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

Treatment Train	Design Flows Evaluated (mgd)
#1) Vortex/Swirl Concentrators	
High Loading Rate:	80, 200, 380
Low Loading Rate:	80, 200, 900
#2) Conventional Clarifiers	80, 200, 540, 900
#3) CEPT w/ Conventional Clarifiers	80, 200, 470, 900
#4) CEPT w/ Plate Settlers	80, 200, 900
#5) Ballasted Flocculation	80, 200, 900, 1200

Comparison of Treatment Alternatives

Effluent Water Quality

While each flow scenario for each treatment train evaluated is sized to produce blended effluent concentrations compliant with permit limits, the resulting water quality differs widely between different scenarios. The TSS and BOD concentrations of the blended effluent for each treatment train and flow scenario is presented under Section 10 in Exhibits 10-1 and 10-2, respectively. In general, ballasted flocculation achieves the lowest TSS and BOD concentrations after treatment and can operate an unlimited number of times during the month and continue to meet permit limits.

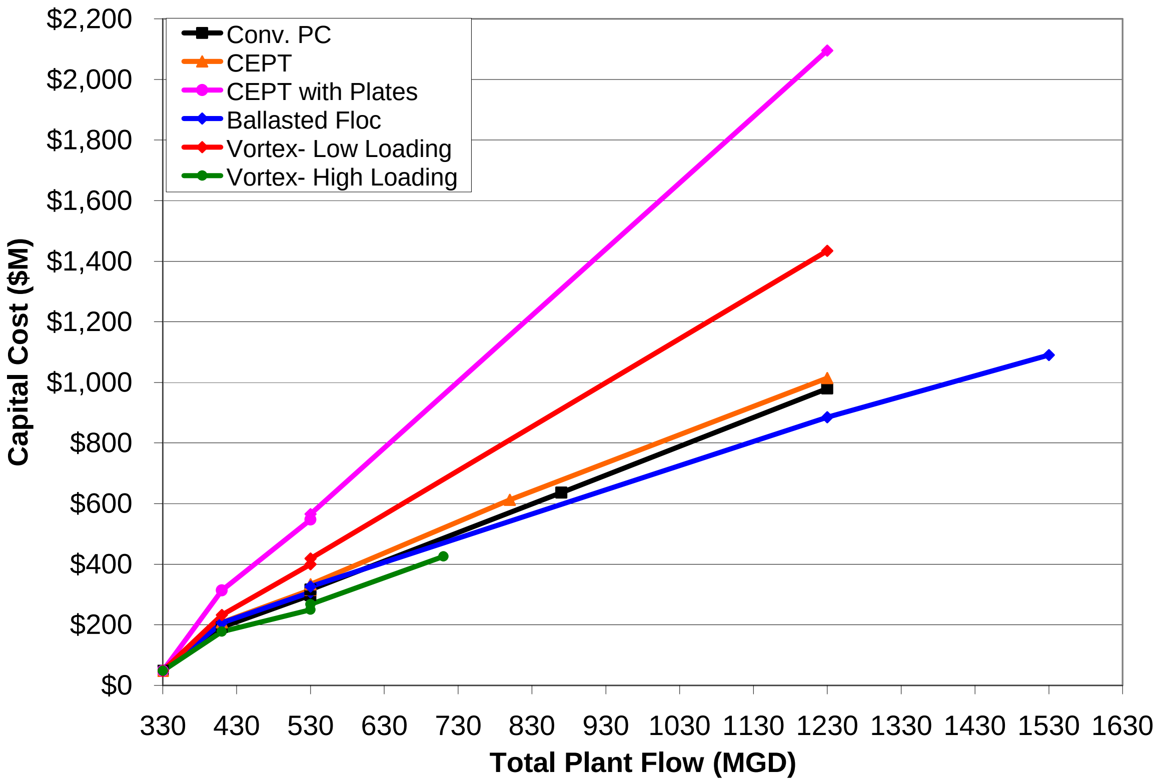
Capital and O&M Costs

The capital cost estimates for the five treatment trains are shown in Exhibit ES-2. Train #4, CEPT with Plates, is the most expensive, followed by Train #1, vortex/swirl at low loading rates. Trains #2, 3, and 5 appear to have similar costs throughout the entire flow range, with Train 5 being slightly less costly. Translated into a capital cost per volume treated, all trains appear to become more cost effective as flow capacity increases (Exhibit ES-3).

The comparison of O&M costs for each treatment train is shown in Exhibit ES-4. As expected, the O&M costs are lowest for vortex swirls at high loading and conventional clarifiers, which do not require chemical settling aids. Vortex swirls at low loading rates has the highest O&M costs for repair and maintenance of the large number of vortex units and gravity thickeners required.

Taking construction, non-construction, and O&M costs into consideration, Exhibit ES-5 shows the present value of the total cost of each wet weather treatment train. Train #4, CEPT with Plates, remains most costly since it requires the highest capital and O&M costs. Train #1, vortex/swirl concentrators, appears to be least costly from the life-cycle cost perspective, especially at lower flows. 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 ($48.1M). 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

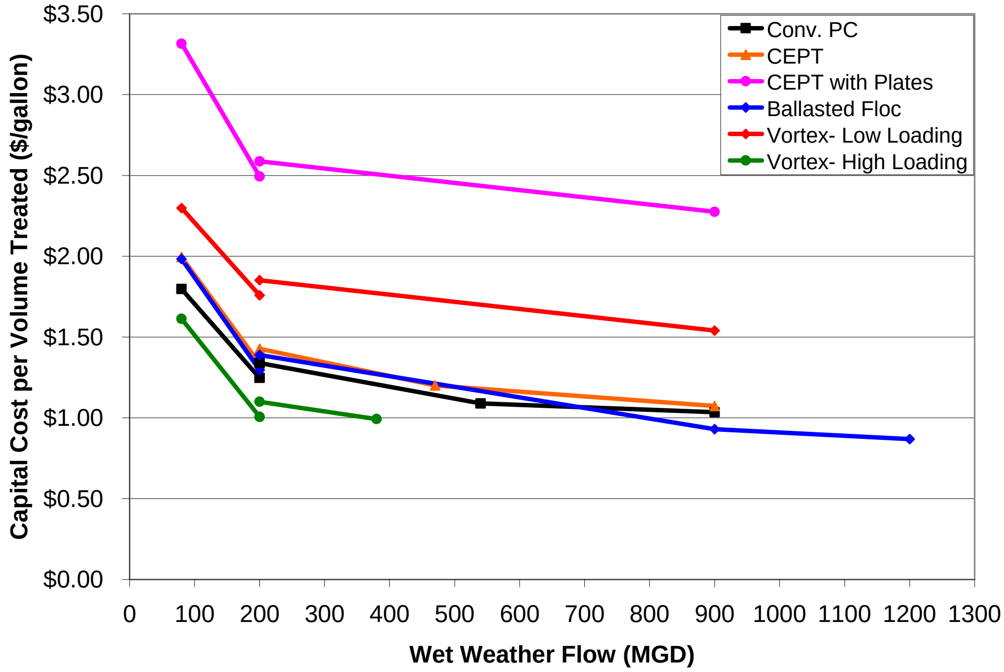


EXHIBIT ES-4
Comparison of Operations and Maintenance Costs for all Treatment Trains

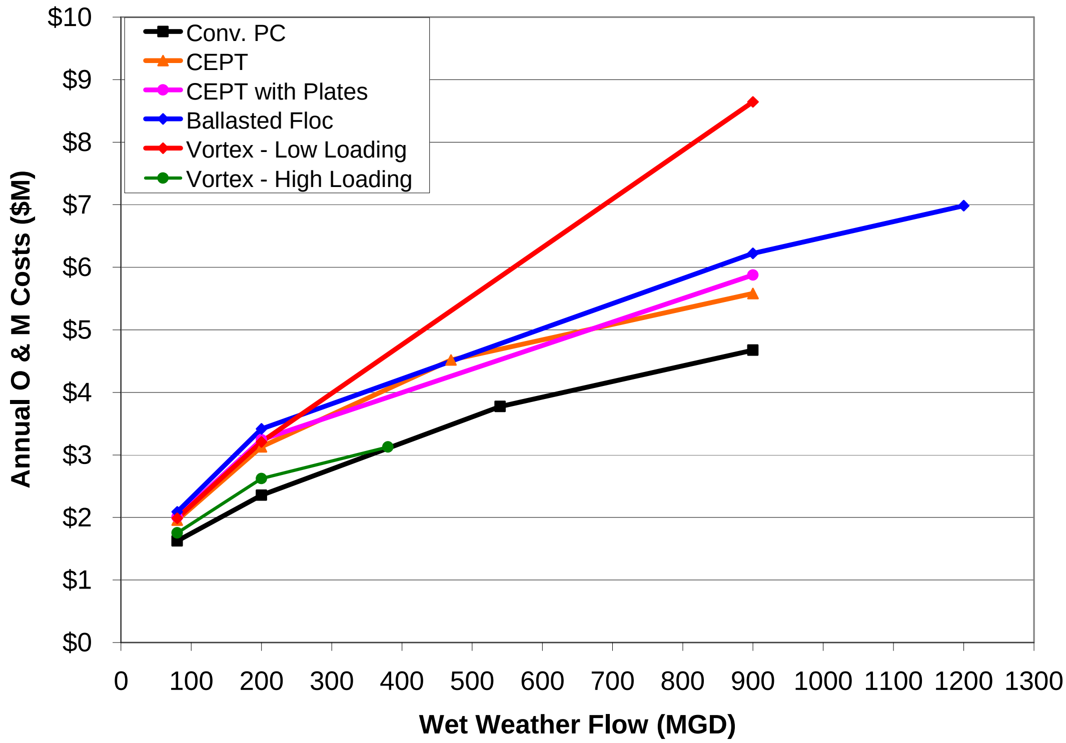
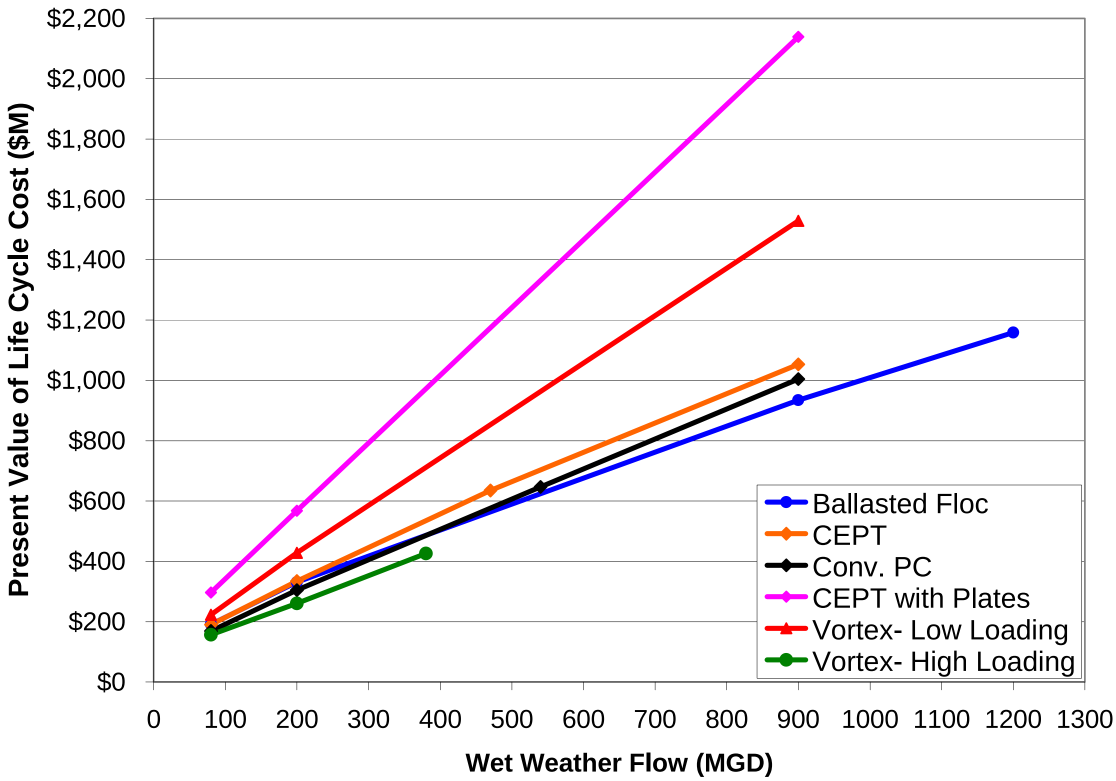


EXHIBIT ES-5

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:

- 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, 2008). The main advantages and disadvantages for Treatment Trains #1 - #5, 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	• Only cost competitive at high loading rates and low removal efficiencies. • Maximum design flow may decrease if the assumed number of operating days is greater than 7.
Train #2: Conventional Clarifiers	• Simple operation • Same technology as existing plant –operators familiar with equipment	• Space limited • May exceed instantaneous blended effluent BOD concentration at high flows • Maximum design flow may decrease if the assumed number of operating days is greater than 7.
Train #3: CEPT	• Lower chlorine dose possible due to high TSS removal efficiencies	• Operators unfamiliar with technology • Space limited • Uses chemicals • Can treat less flow on existing site than conventional clarifiers • Operators unfamiliar with technology
Train #4: CEPT with Plates	• Can treat 900 mgd with available land on site • Lower chlorine dose possible due to high TSS removal efficiencies • Unlimited number of operating days per month	• High capital and O&M costs • Operators unfamiliar with technology • Labor intensive to clean plates • Uses chemicals
Train #5: Ballasted Flocculation	• Can treat up to 1200 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 • Second most labor intensive • Uses chemicals

The costs for wet weather treatment at the SE 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

Attachment

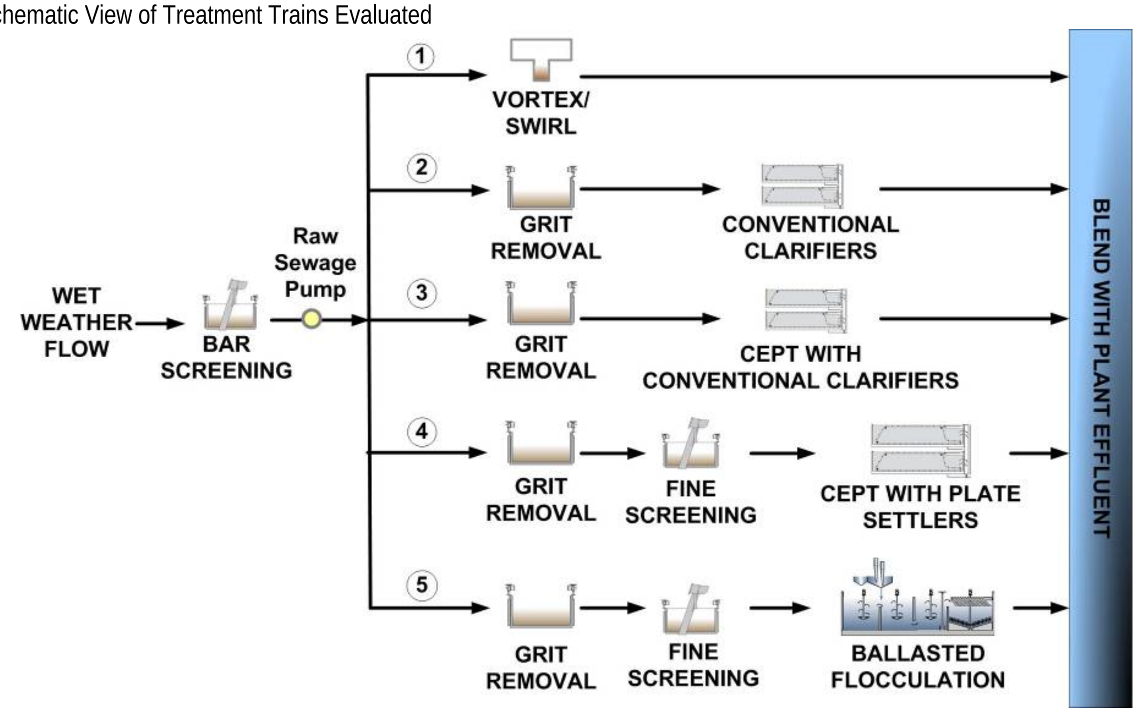
1.0 Introduction

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 five wet weather treatment alternatives for the Southeast Water Pollution Control Plant (SE 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 SE WPCP; survey of various potential wet weather treatment technologies; and site visits to three existing wet weather treatment facilities in Ohio (CH2M HILL, 2007a; CH2M HILL, 2008). The wet weather treatment technologies for the SE WPCP evaluated in this report are as follows:

1. Vortex Swirl Concentrators (at low and high loading rates)
2. Conventional Clarifiers
3. Chemically Enhanced Primary Treatment (CEPT) with Conventional Clarifiers
4. CEPT with Plate Settlers (includes fine screening)
5. Ballasted Flocculation (includes fine screening)

Conceptual treatment trains were developed for each treatment technology at various wet weather flows ranging from 80 million gallons per day (mgd) to 900 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 SE WPCP for wet weather conditions, the potential of maximizing flow through the existing plant was evaluated. According to stress testing results, the SE WPCP currently has a firm capacity of 240 mgd (CH2M HILL, 2001). Firm capacity is defined as the treatment capacity when the largest unit process is out of service. With several process and hydraulic modifications, the SE WPCP's firm capacity can potentially reach 330 mgd (Exhibit 2-1). The necessary improvements to achieve this flow were identified in the 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 SE WPCP plant staff.

In sizing the wet weather treatment trains, it was assumed that the upgrades proposed in the Stress Testing Report and identified in Exhibit 2-1 will have been completed, increasing the plant's capacity to a minimum of 330 mgd. Thus, the baseline cost that is used in the wet weather treatment train cost estimates is $48.1 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 SEWPCP

	Improvement Description	Cost[1]
1	Provide facilities for phosphorous addition to wastewater	Completed
2, 3	Resolve capacity limitations associated with having one coarse bar rack out of service and hydraulic bottleneck at existing influent pump station	$23,780,982
4	Replace existing primary clarifier effluent launders with new launders running parallel to flow to increase hydraulic capacity	$2,591,292
5	Provide two gravity thickeners to perform offline sludge thickening and improve performance of the primary clarifiers	$13,499,572
6	Provide an additional 71-MGD effluent pump at the effluent pumping station	$783,037
8	Resolve hydraulic limitation between primary clarifiers and the aeration basins by adding pumps to pass greater flow and increase available head.	$7,441,414
	TOTAL	**$48,096,297**

(1) See Section 3.3 for markups applied. Assume escalation factor of 19.8% - based on 9/1/2009 start date and 2-year construction duration.

Since Improvements # 2, 3, and 5 involve the addition of new structures on site, these improvements were examined more closely to see how they would interface with the new wet weather treatment trains.

2.1 Improvements #2 and #3

The current configuration of the influent wet wells limits the plant flow to 200 mgd when one coarse screen is out of service. To provide redundancy, Improvements #2 and 3 include the addition of two new bar screens and influent pumps with a capacity of 130 mgd. Due to the configuration and space limitations of the existing influent pump station, a new pump station will be needed for this new equipment. Since any new wet weather treatment facility will also require influent screening and pumping, a single building can be constructed to house all the new equipment. This new preliminary treatment building (PTB) will include the two new bar screens and influent pumps for the existing plant, as well as the additional units needed for the wet weather treatment train alternatives. A new conduit will be constructed from the new PTB to the head of the existing grit channels, carrying up to 130 mgd to the existing plant for treatment during either dry or wet weather conditions. The cost shown in Exhibit 2-1 for this improvement includes only the cost for a new PTB with the two bar screens and influent pumps for the existing plant. The additional cost of equipment for wet weather flows is included in the cost estimates for the separate wet weather treatment trains. The footprint of the entire PTB for dry and wet weather flows is shown in the conceptual layouts for each wet weather treatment train.

2.2 Improvement #5

To increase the capacity of the existing primary clarifiers, Improvement #5 provides for the addition of offline sludge thickening. Currently, primary sludge is thickened in the clarifiers. The thickened sludge is pumped from the clarifiers to sludge storage tanks, which store the sludge until it is pumped to the Southwest WPCP for further treatment. The addition of separate gravity thickeners on site will eliminate the need to carry a sludge blanket in the primary clarifiers. This will eliminate scour of the solids from the sludge blanket during high surface overflow rates, allowing the clarifiers to maintain removal efficiencies during peak flows.

The cost estimate for this improvement, shown in Exhibit 2-1, is based on the addition of two gravity thickeners, which would thicken the dilute sludge before it is pumped to the existing sludge storage tanks. The sizing of these gravity thickeners is based on a 55 percent removal efficiency in the existing clarifiers, a 0.5 percent solids concentration, and a solids loading rate of 30.7 lb/sf/day for the thickeners. These assumptions are consistent with those for the wet weather treatment trains (see Section 3.2). Cost estimates also include thickened sludge pumps and Strainpress sludge cleaners for pumping to the digesters. Since the majority of the proposed wet weather treatment trains require gravity thickening also, all gravity thickeners for both the existing plant and the wet weather treatment facility will be located in the same area on site.

3.0 Wet Weather Treatment Alternatives: Evaluation Methodology

To expand the flow capacity of SE WPCP beyond 330 mgd for the treatment of wet weather flows, a separate wet weather treatment train will be required. Wet weather flows in excess of 330 mgd will be diverted to this new treatment train, eventually blending with effluent from the existing plant. As depicted in Exhibit 1-1, the five wet weather treatment trains under evaluation are:

1. Vortex Swirl Concentrators (at low and high loading rates)
2. Conventional Clarifiers
3. Chemically Enhanced Primary Treatment (CEPT) with Conventional Clarifiers
4. CEPT with Plate Settlers (includes fine screening)
5. 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.

3.1 Design Flows

The maximum allowable flow through each wet weather treatment train is a function of its removal efficiency, the achievable effluent concentration after blending, and the plant's continued ability to meet NPDES permit limits for weekly and monthly TSS and BOD concentrations. The data analysis performed for SE WPCP determined that the monthly TSS limit was the most stringent, and were thus used to determine the maximum allowable flow through each train, as shown in Exhibit 3-1 (CH2M HILL, 2008).

EXHIBIT 3-1
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			
High Loading Rate:	30%	154	378
Low Loading Rate:	65%(4)	77	Unlimited*
#2) Conventional Clarifiers	55%	99	Unlimited*
#3) CEPT w/ Conventional Clarifiers	80%	44	Unlimited*
#4) Fine Screening -> CEPT w/ Plate Settlers	81%	42	Unlimited*
#5) 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, 2008).

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

(2) Achievable effluent concentrations based on 95th percentile influent wet weather TSS concentration (220 mg/L)

(3) Maximum flow determined by NPDES Monthly TSS Limit. The allowable daily blended effluent TSS concentration during wet weather was calculated to be 99 mg/L (CH2M HILL, 2008).

(4) Based on results of Wet Weather Demonstration Project in Columbus, Georgia (WERF, 2003)

With the exception of the vortex/swirl train at high loading rates, 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. For these "unlimited" trains, the maximum design flow was based on CDM's assumptions on the capacity of the upgraded collection system. Other design flow points were selected based on the existing collection system capacity, the existing outfall conduit capacity, and limits of available land on site. The design flows that were selected for evaluation for each treatment train are shown in Exhibit 3-2 and are described below in further detail.

EXHIBIT 3-2
Design Flows Evaluated for each Wet Weather Treatment Train

Treatment Train	Design Flows Evaluated (mgd)
#1) Vortex/Swirl Concentrators	
High Loading Rate:	80, 200, 380
Low Loading Rate:	80, 200, 900
#2) Conventional Clarifiers	80, 200, 540, 900
#3) CEPT w/ Conventional Clarifiers	80, 200, 470, 900
#4) CEPT w/ Plate Settlers	80, 200, 900
#5) Ballasted Flocculation	80, 200, 900, 1200

3.1.1 Minimum Design Flow: 80 MGD

The 80 mgd flow point reflects the capacity of the wet weather treatment train required to bring the treatment capacity of SE 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 410 mgd to the SE WPCP assuming all process and hydraulic limitations in the plant are removed (Myers, 2007). With the assumption that 330 mgd can be treated by upgrading the existing plant, the new wet weather treatment train will need a minimum capacity of 80 mgd.

3.1.2 Maximum Design Flow: 380 or 900 MGD

The 900 mgd flow point is based on the maximum flow expected to be delivered to SE WPCP after improvements have been made to the collection system. In a technical memorandum provided by CDM, it was noted that collection system improvements could allow a flow of up to 1,230 mgd to the SE WPCP (Myers, 2007). Again, assuming a flow capacity of 330 mgd for the upgraded existing plant, the new wet weather treatment train will need to treat a maximum of 900 mgd. This excludes Train #1, Vortex /Swirl, which is capped at 380 mgd by permit limits.

3.1.3 200 MGD Design Flow

The 200 mgd flow point is the maximum flow that the new wet weather treatment train can discharge through the plant's existing outfall conduits. The estimated capacity of the existing 7 feet by 9 feet twin outfall conduits is 530 mgd. This hydraulic capacity assumes gravity flow from the new chlorine contact chamber (CCC) of the wet weather treatment train (water surface level of 109.88 feet) to the Delaware River (assume maximum river level of 102 feet; see Section 3.2.3 on hydraulics). Under these assumptions, the 330 mgd from the main plant will be pumped from the existing effluent pump station to the head of the new CCC, blending with up to 200 mgd of the wet weather flow before chlorination. This will ensure that adequate chlorination contact time is maintained. (Currently, flow from the existing plant achieves chlorination contact through the outfall conduits alone. At 330 mgd, the contact time is 20 minutes.)

Wet weather flow in excess of 200 mgd (or 530 mgd for total plant flow) will require the construction of a new double barrel outfall conduit from the plant to the Delaware River. In this case, flow from the main plant will not be affected and will only blend with the wet weather flow at the river outfall.

3.1.4 Design Flows by Available Land

For Trains #2 and #3, Conventional Clarifiers and CEPT, design flows may be limited by the available land within the property boundaries of the SE WPCP. With the footprint of the wet weather treatment facility limited to the existing site, the maximum flow capacities of Trains #2 and #3 are 540 mgd and 470 mgd, respectively. Flow capacities exceeding these values will require acquisition of neighboring properties.

For Train #4, CEPT with Plates, a 900 mgd facility will require all the available land on site. Train #5, Ballasted Flocculation, occupies the smallest footprint and will be able to treat flows of up to 1200 mgd using the available land on site.

3.2 Key Design Assumptions

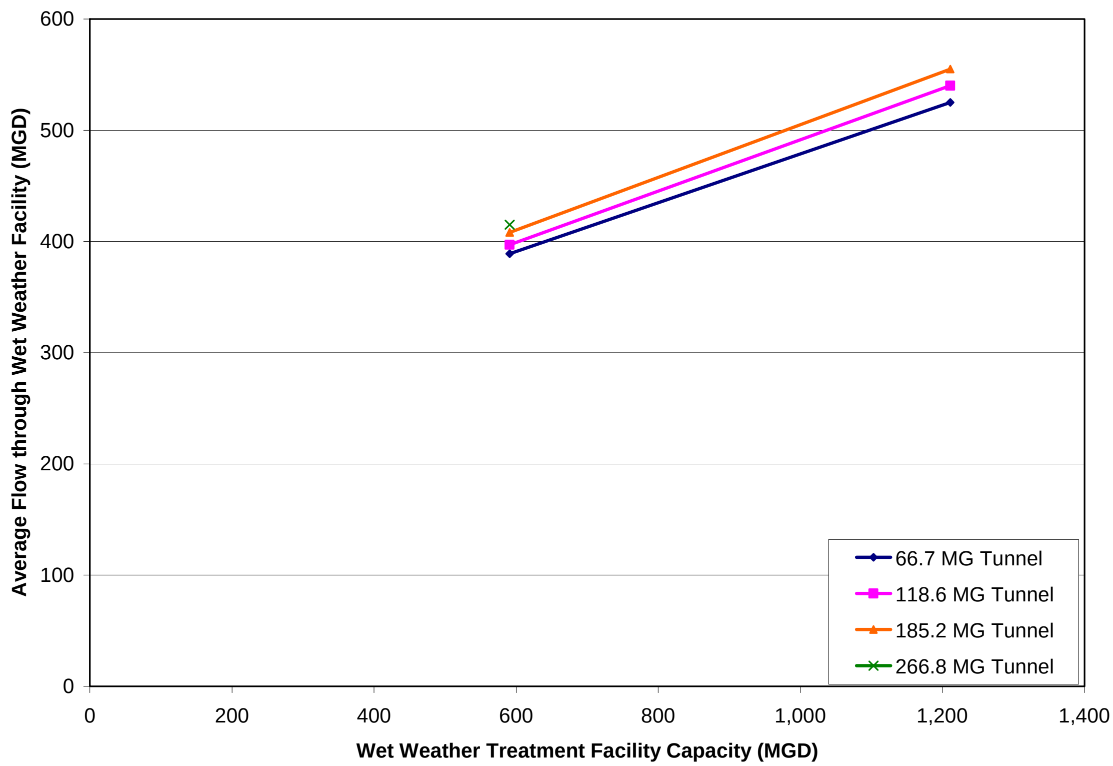
3.2.1 Average Design Flow

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 Southeast Drainage district (SEDD) 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 3-3).

Model runs for a 490-mgd and a 900-mgd wet weather facility generated an average flow of 204-mgd and 229-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 229-mgd. The average flows assumed for each of the treatment train scenarios is presented in Exhibit 3-4.

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



*This plots the average wet weather treatment rates using data from the high flow scenario hydrologic model (CDM, 2008).

EXHIBIT 3-4
Average Design Flows

Maximum Design Flow (mgd)	Average Design Flow (mgd)
80	80
200	200
380, 470, 540	204 (1)
900, 1200	229 (2)

(1) Model runs with a 490-mgd facility generated an average flow of 204-mgd.

(2) Model runs with a 900-mgd facility generated an average flow of 229-mgd.

3.2.2 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 was used for sizing the chlorine contact chamber, chemical storage facilities, screenings and grit storage, 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 330 mgd. For each case, the main treatment train is located on the strip of vacant land to the east of the existing structures. A new influent conduit will divert excess wet weather flow to the new preliminary treatment building (PTB) of the wet weather treatment facility, to be located at the northeast corner of the plant. 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 4 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, which provides a minimum of 20 minutes detention time at average flow. At higher flows, 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.

For wet weather design flows of less than 200 mgd, the new CCC and the existing outfall conduits will be shared by the wet weather flow and the flow from the main plant. Under these scenarios, the CCC is sized for both the average design flow of the wet weather treatment facility and the maximum flow of 330 mgd from the plant.

Chemical Feed

For Treatment Trains #3, #4 and #5, which provide chemically-enhanced clarification, a coagulant and flocculant are added as settling aids. For Trains #3 and #4 that use CEPT, these chemicals are added to a rapid mixer and flocculation basin upstream of the sedimentation tank. In the ballasted flocculation train (#5), 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.

Polymer is used as the flocculant, and is stored in both liquid and dry form. Since preparation of dry polymer usually takes approximately 2 hours, a liquid polymer system is provided to allow immediate startup of the wet weather treatment system. With the exception of liquid polymer, a 10-day storage at average flow was assumed for all chemicals. The option of using liquid polymer only is discussed in Section 9.1.

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 3-4) with a 95 percentile influent solids concentration (220 mg/L) for a continuous period of 24 hours.

The thickened sludge will be pumped to the plant’s existing sludge storage tanks, from which it will be pumped to anaerobic digesters at the Southwest (SW) WPCP. The sludge will be screened through StrainPress® sludge cleaners to remove inert solids before entering the digesters. Since the maximum inlet pressure of the sludge cleaners is 14 psi, they will be located at the SW WPCP at the tail end of the sludge pump discharge.

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 (as presented in Exhibit 3-4), a 95 percentile influent solids concentration (220 mg/L), an average wet weather event duration of seven hours, and five events in 20 days. The cost of an additional sludge pump and 8” force main to the SW WPCP ($7.7 M, including markups) was also added as a line-item to the overall cost of each scenario.

The design parameters that were assumed for all the treatment train processes are summarized in Exhibit 3-5. The process flows are described in further detail in each of the treatment train sections.

EXHIBIT 3-5
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)	45	ft (match existing 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	High: 36,000 (25 gpm/sf)
	Low: 7,200 (5 gpm/sf)
Conventional Clarifiers	2,400 (3)
CEPT	3,000
CEPT with Plates	7,000
Ballasted Flocculation	84,600 (60 gpm/sf)

Chlorine Contact			
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	20 hours(4)
Dry Polymer	Flocculation	2 mg/L	10 days
Sodium Hypochlorite	Chlorination	5 mg/L	10 days
Sodium Bisulfite	De-chlorination	1.5 mg/L(5)	10 days

EXHIBIT 3-5
Key Process Design Assumptions for Wet Weather Treatment Trains(1)

Primary Sludge Generation(6)

Train	% TSS Removal	% Solids in Sludge
#1: Vortex/Swirl	High Loading Rate: 30%	0.07%(7)
	Low Loading Rate: 65%	0.14% (7)
#2: Conventional Clarifiers	55%	0.5%
#3: CEPT	80%	0.5%
#4: CEPT with Plates	80%	0.5%
#5: 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 (SW WPCP)

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.

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

(4) Liquid polymer required for startup only

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

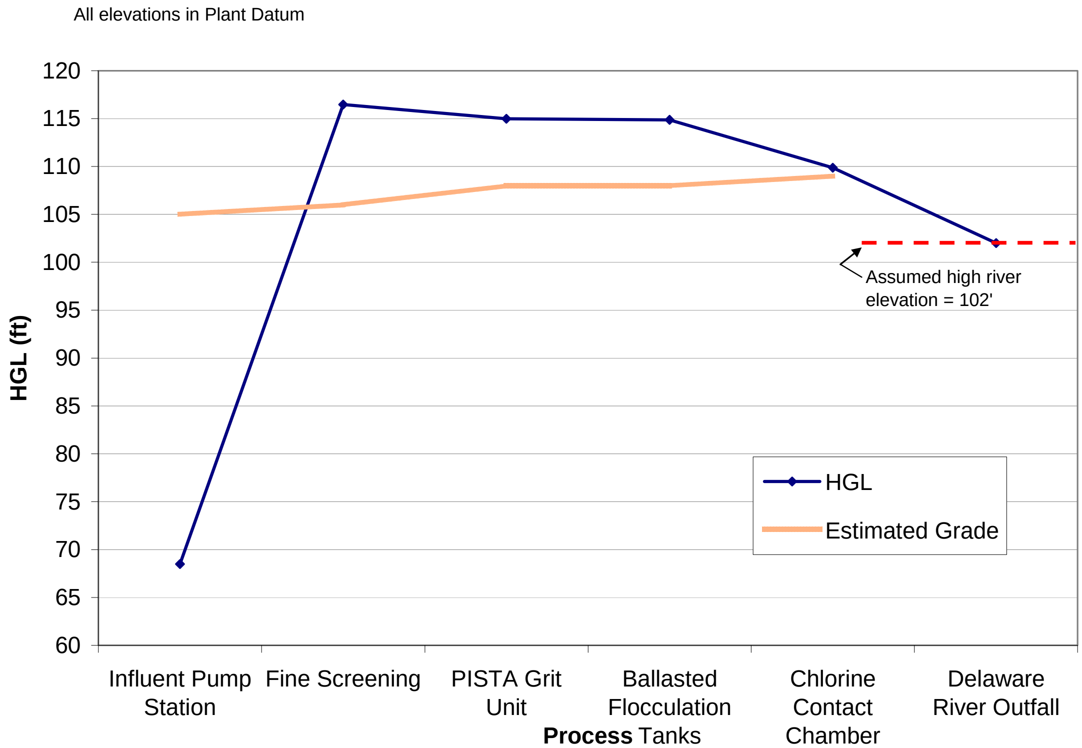
(6) Assumes 95 percentile influent TSS concentration of 220 mg/L, and volatile solids percentage of 70%

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

3.2.3 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 Delaware River outfall. A preliminary hydraulic profile for the ballasted flocculation train at 900 mgd is shown in Exhibit 3-6 as an example of a maximum head loss scenario.

EXHIBIT 3-6
Preliminary Hydraulic Gradeline for the Ballasted Flocculation Treatment Train at 900 MGD



As an initial condition, the high river elevation was assumed to be 102 feet. The mean high tide level shown in SE WPCP plant drawings of the outlet structure is 97.75 feet. According to historic data, the peak river level in 2005 was 101.49 feet. Head loss through the outfall conduits at 900 mgd was estimated to be 7.88 feet using Manning's equation (assume new twin outfall conduits, 13.5 feet by 10 feet each; K factor of 3 for minor losses). As shown in the hydraulic profile, this sets the water surface level of the new chlorine contact chamber at 109.88 feet. This is only 0.7 feet lower than the high discharge level of the existing effluent pumps at the plant (110.58 feet), so is assumed to be a reasonable elevation.

The elevation of the chlorine contact chamber sets the elevations of the upstream unit processes. As shown in Exhibit 3-6, the tank walls may rise above grade by several feet. To be conservative, however, the capital cost estimates assume complete burial of all tanks.

3.2.4 Existing Site

In developing conceptual layouts of the wet weather treatment trains, it was assumed that the parking lot to the east of the existing Equipment Building (northeast corner of the plant) can be reduced in size if necessary to accommodate the new Preliminary Treatment Building.

3.2.5 Site Conditions

The site and soil conditions on the vacant land surrounding the plant were assumed to be similar to the SE WPCP. Two main assumptions were made based on existing plant drawings:

- Piles will be needed for foundations of all structures. A pile density and depth of 0.056 piles/sf and 30 feet were used for all structures on site. A pile density and depth of 0.062 piles/sf and 50 feet were used for the outfall conduits going out to the Delaware River. These numbers were based on existing pile plans for the SE WPCP.
- Dewatering will be required for all buried structures. According to plant drawings, the groundwater elevation is approximately 5-ft below grade at the SE WPCP.

3.3 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.

3.3.1 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 3-7. 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 3-8). 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; abnormal material impacts of the last two years; and Katrina impacts.

EXHIBIT 3-7
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 3-8
Escalation Factors for Various Construction Scenarios

Flow Capacity of Wet Weather Treatment Train (mgd)	Estimated Construction Duration (months)(1)	Escalation Factor(2)
80	24	19.8%
200	27	21.2%
380	30	21.8%
470	36	23.9%
540	36	23.9%
900	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 3-9.

EXHIBIT 3-9
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.

Land Acquisition

For Trains #2 and 3, Conventional Clarifiers and CEPT, neighboring properties must be purchased in order to reach flow capacities beyond 540 mgd and 470 mgd, respectively. The cost of this land was estimated to be $784,000 per acre, based on cost information found in the Philadelphia parcelBase, relating to the 2007 purchase of a block directly east of the plant (Parcel block 88-4-3514-60).

For both cases, the estimated parcel of land that would need to be acquired is 11 acres (See Exhibits 5-2 and 6-2). The estimated cost of acquiring this block of land is $9.23M in 2009 dollars, which includes a 7 percent markup for permitting, legal and administration fees.

3.3.2 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 3-10. The O&M costs cover labor, power for equipment and buildings, chemicals, and repair, maintenance and replacement of structures and equipment. O&M costs are based on average flows through the plant, as described in Section 3.2.1 and shown in Exhibit 3-4.

The additional labor required for each treatment train is dependent on the flow capacity of the train, as shown in Exhibit 3-11. 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 SE-3.1. 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 3-10
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	35	days(2)
Duration of wet weather event	7	Hours
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

EXHIBIT 3-10
Assumed Factors for Life Cycle Cost Estimates

Factor	Value	
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	280	hours per year per operator (8 hours per event)
Number of working hours for maintenance workers at wet weather facility	2,080	hours per year per worker
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
Dry Polymer	$3400	$/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[(5)]
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[(6)]	$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		

EXHIBIT 3-10
Assumed Factors for Life Cycle Cost Estimates

Factor	Value	
Contingency applied to O&M costs	20	%

(1) Based on CCI Index

(2) The maximum average annual number of wet weather events with flows higher than 330 MGD is 35 under scenarios modeled by CDM. Similarly, the maximum average annual wet weather duration is 222 hours (CDM, 2008). The duration of each event is then assumed to be 7 hours.

(3) Equipment power estimated by PWD.

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

(5) For Train #4, CEPT with Plates, the equipment cost does not include that of the stainless steel plates.

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

EXHIBIT 3-11
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)
80, 200, 380	1	1	2
470, 540	2	0	4
900, 1200	2	1	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 280 hours per year.

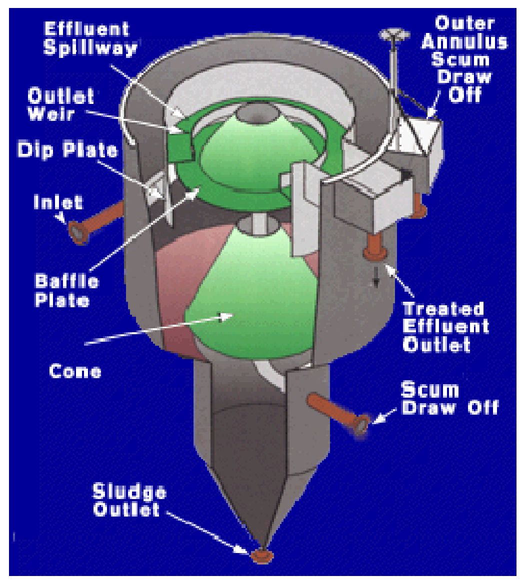
4.0 Treatment Train #1- Vortex/Swirl Concentrators

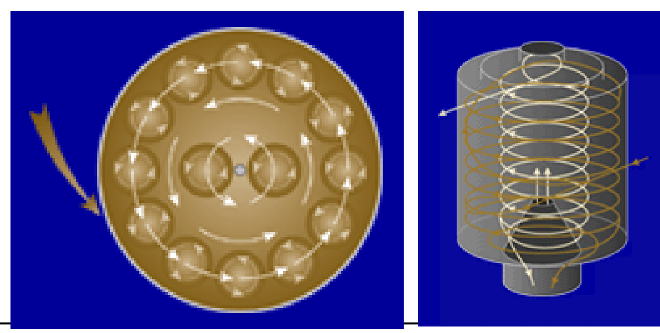
4.1 Process Flow Diagram

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 4-1). 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 4-2.

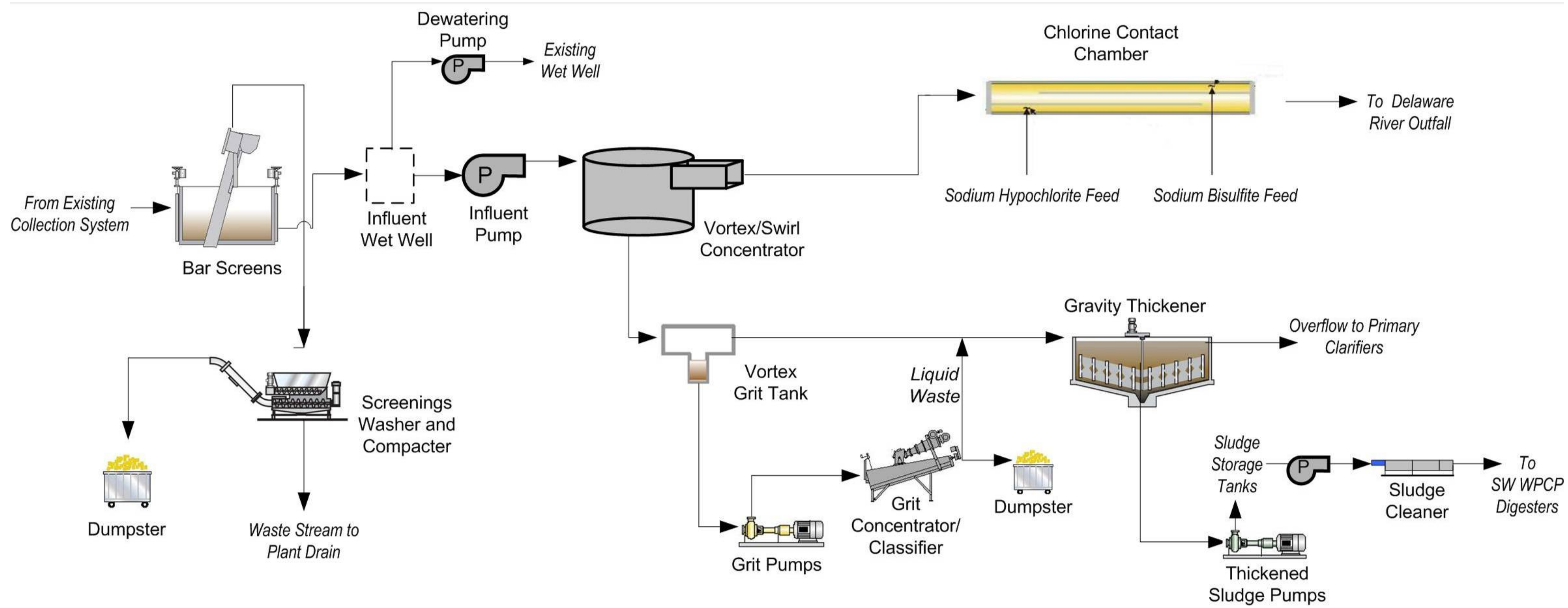
EXHIBIT 4-1
Diagrammatic Cutaway of Vortex/Swirl Device (Storm King®, H.I.L. Technologies)





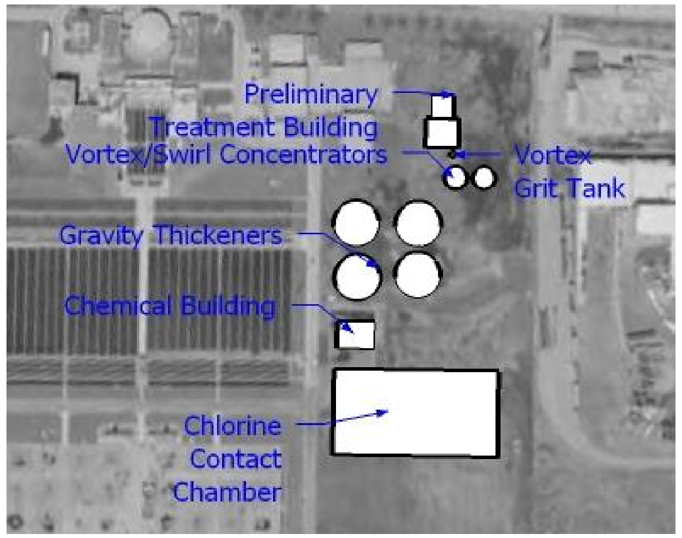
Flow Pattern Plan and Profile Views (H.I.L. Technologies)
The flow in vortex/swirl devices initially follows a path around the perimeter of the unit and is then directed into an inner swirl pattern with a lower velocity than the outer swirl. Solids separation is achieved by both centrifugal force and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

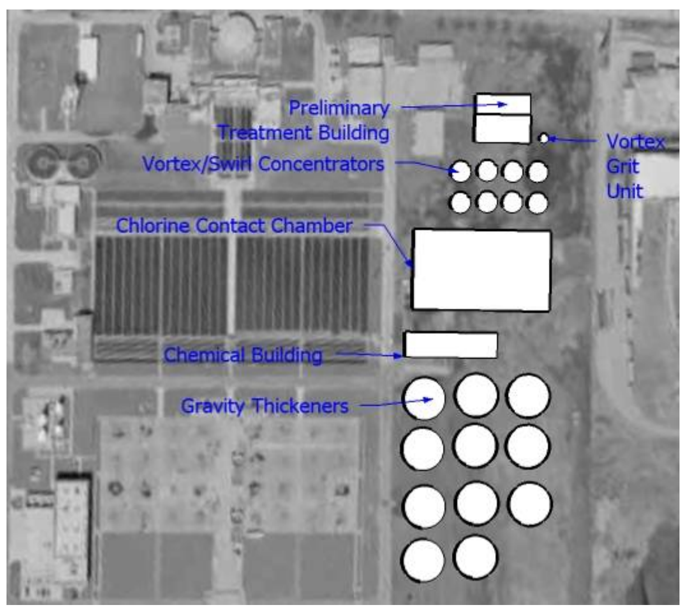
EXHIBIT 4-2
Process Flow Diagram and Key Process Design Parameters for Treatment Train #1: Vortex/Swirl Concentrators

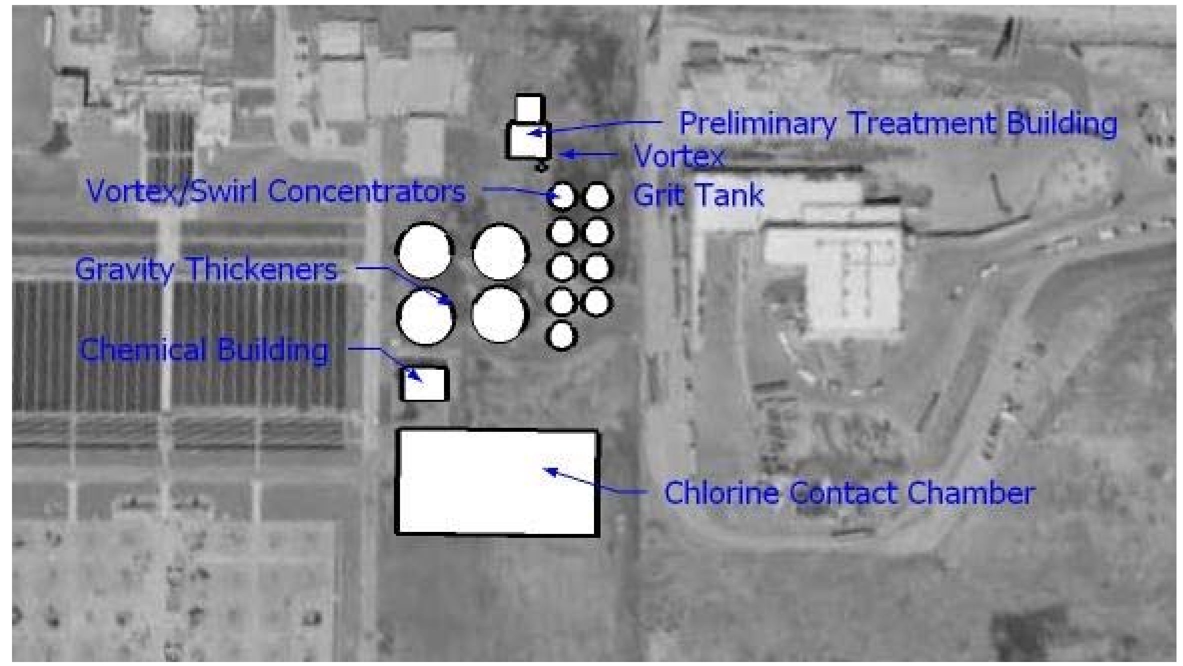


	Bar Screens	Influent Pumps	Vortex/Swirl Concentrators		Vortex Grit Tank		Screenings Washer/ Compactor	Grit Pumps		Grit Concentrator	Grit Classifier	Screenings and Grit Prod.	Sodium hypochlorite			Sodium Bisulfite			Gravity Thickeners & Sludge Cleaners	Primary Sludge Pumps		Thickened Sludge Pumps		Sludge Prod.	Digesters (at SW WPCP)
Flow (mgd)	# 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
HIGH LOADING:																									
80	1	1	2	22.1	1	12	1	1	1	1	1	460	39,831	1	1	6,226	1	1	2	4	1	2	1	44,035	1
200	2	3	4	27.6	1	18	2	1	1	1	1	1,150	99,579	1	1	6,226	1	1	5	8	2	5	2	110,088	1
380	4	5	8	26.2	1	18	4	1	1	1	1	1,173	101,570	1	1	6,226	1	1	9	16	5	9	3	112,290	1
LOW LOADING:																									
80	1	1	9	4.9	1	12	1	1	1	1	1	460	39,831	1	1	6,226	1	1	2	9	1	2	1	44,035	1
200	2	3	22	5.0	1	18	2	1	1	1	1	1,150	99,579	1	1	6,226	1	1	5	22	6	5	2	110,088	1
900	9	12	100	5.0	1	32	9	1	1	1	1	1,317	114,018	1	1	6,606	1	1	20	100	25	20	5	273,110	1

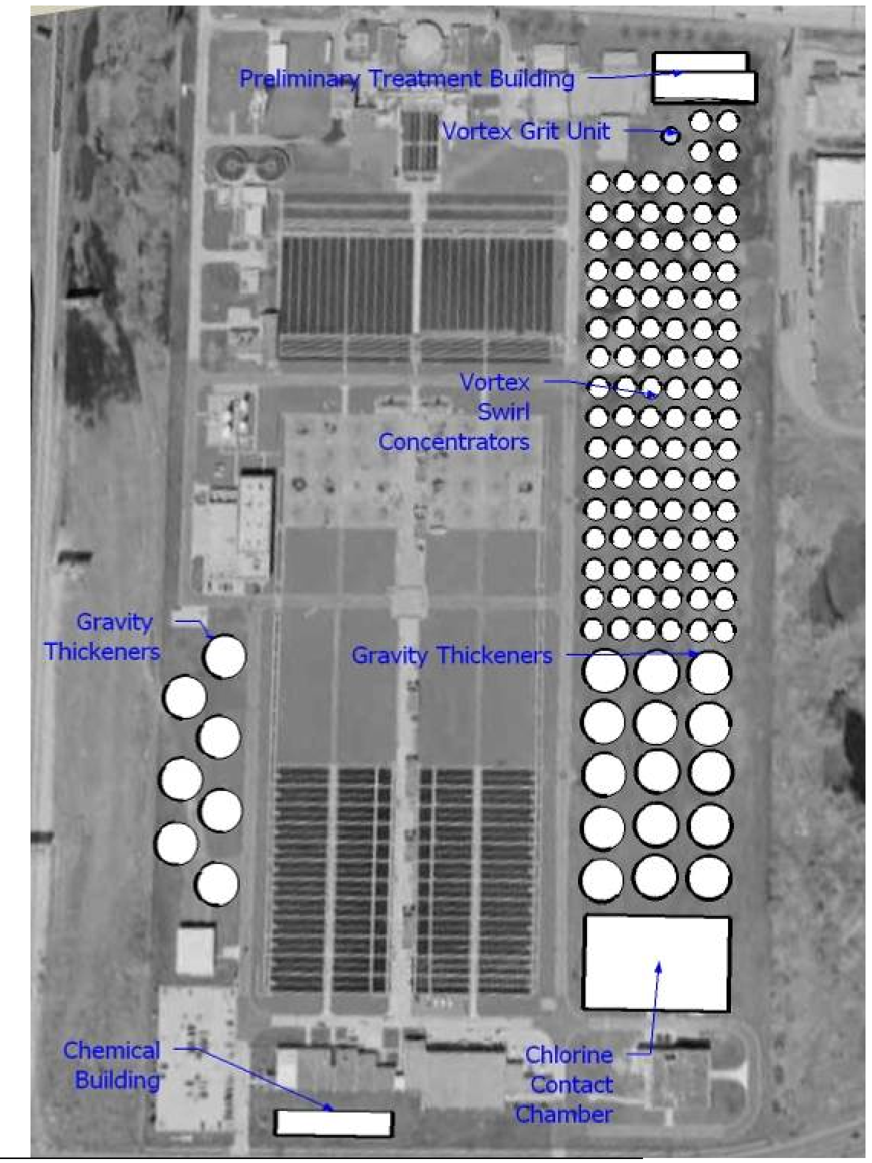
EXHIBIT 4-3
Conceptual Layouts and Footprints for Treatment Train #1: Vortex/Swirl Concentrators
High Loading: 80 MGD Layout (top left) and 380 MGD Layout (bottom left), Low Loading: 80 MGD Layout (center) and 900 MGD Layout (right)







*Layouts show 2 extra thickeners for existing primary clarifiers



FLOW (mgd)	PTB	GRIT UNITS	VORTEX SWIRLS	CHEMICAL BUILDING	CCC	GRAVITY THICKENERS*	TOTAL FOOTPRINT (acres)
80	54' x 47' & 39' x 39'	12' (1 unit)	40' (high loading: 2 units low loading: 9 units)	65' x 47'	147' x 287' (7 passes)	80' (2 units)	1.4
200	80' x 49' x 63' x 39'	18' (1 unit)	40' (high loading: 4 units low loading: 22 units)	101' x 47'	109' x 193' (5 passes) or 176' x 310' (9 passes)	80' (5 units)	1.4
380 (high loading)	106' x 56' & 101' x 39'	18' (1 unit)	40' (8 units)	111' x 45'	151' x 259' (7 passes)	80' (9 units)	2.7
900 (low loading)	197' x 60' & 180' x 39'	32' (1 unit)	40' (100 units)	143' x 45'	172' x 268' (8 passes)	80' (20 units)	8.1

4.2 Conceptual Design and Site Layouts

Two different loading rates were assumed for this treatment train, as presented in Exhibit 4-4.

EXHIBIT 4-4
Design Assumptions for Treatment Train #1: Vortex/Swirl Concentrators

Loading Rate (gpm/sf)	Removal Efficiency (%)	Flows Evaluated (mgd)
25	30	80, 200, 380
5	65	80, 200, 900

As with clarification units, the performance of the vortex swirl concentrators varies widely depending on the loading rate. In typical installations where vortex swirls are used to treat combined sewer overflows in the collection system, the units are designed for a loading rate of approximately 25 gpm/sf. At this loading rate, manufacturers estimate that a TSS removal rate of 30 percent can be achieved.

According to a study performed in Columbus, Georgia, the vortex performs similarly to a primary clarifier at loading rates of 5 gpm/sf or less (7,200 gpd/sf). The study showed that removal efficiencies of up to 70 percent were achieved at a 5 gpm/sf loading rate (WERF, 2003). To be conservative, a 65 percent removal efficiency was assumed in this report. Actual performance of the units will need to be verified in pilot studies.

The main design parameters for each flow scenario of this treatment train are shown in Exhibit 4-2. The conceptual site layouts for the minimum and maximum flow scenarios are shown in Exhibits 4-3.

4.3 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.

4.3.1 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 the main plant's 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 4-2).

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

4.3.2 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. However, there are two streams from the gravity thickeners that will interact with the main plant.

Thickened sludge from the gravity thickeners is pumped to the existing sludge storage tanks at a rate of 0.2 to 4.3 mgd, depending on the flow capacity of the treatment train. This does not include the two gravity thickeners needed for the existing plant. Since the thickened sludge can be pumped at any time, the thickeners themselves can serve as storage tanks for the sludge before it is pumped to the existing storage tanks.

The overflow from the gravity thickeners is conveyed to the head of the entire plant. The estimated overflow range from wet weather thickeners only is 8 to 86 mgd, depending on the treatment train capacity. 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.

4.3.3 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.

4.4 Cost Analyses

The estimated capital, O&M, and lifecycle costs for each flow scenario at low and high loading rates are shown in Exhibit 4-5 and 4-6, respectively. Total capital costs and the capital costs per volume treated for all scenarios are shown in Exhibits 4-7 and 4-8. The estimated O&M costs by category are also presented in Exhibits 4-9 and 4-10. A more detailed breakdown of these costs is presented in Attachment SE-3.1. As expected, the cost of this technology at low loading rates is significantly greater than the cost for high loading rates due to the greater number of units required for operation at lower loading rates.

EXHIBIT 4-5
Cost Summary for Vortex/Swirl Treatment Train #1 with Low Loading Rates

	Wet Weather Flow (mgd)		
Cost	**80**	**200**	**900**
Capital Cost ($M)	$192	$378	$1,394
Annual Operations and Maintenance Cost ($M)	$2.0	$3.2	$8.6
Present Value of the Cost ($M)	$223	$428	$1,529

EXHIBIT 4-6
Cost Summary for Vortex/Swirl Treatment Train #1 with High Loading Rates

	Wet Weather Flow (mgd)		
Cost	**80**	**200**	**380**
Capital Cost ($M)	$129	$220	$377
Annual Operations and Maintenance Cost ($M)	$1.8	$2.6	$3.1
Present Value of the Cost ($M)	$156	$261	$426

EXHIBIT 4-7
Capital Costs for Treatment Train #1: Vortex/Swirl

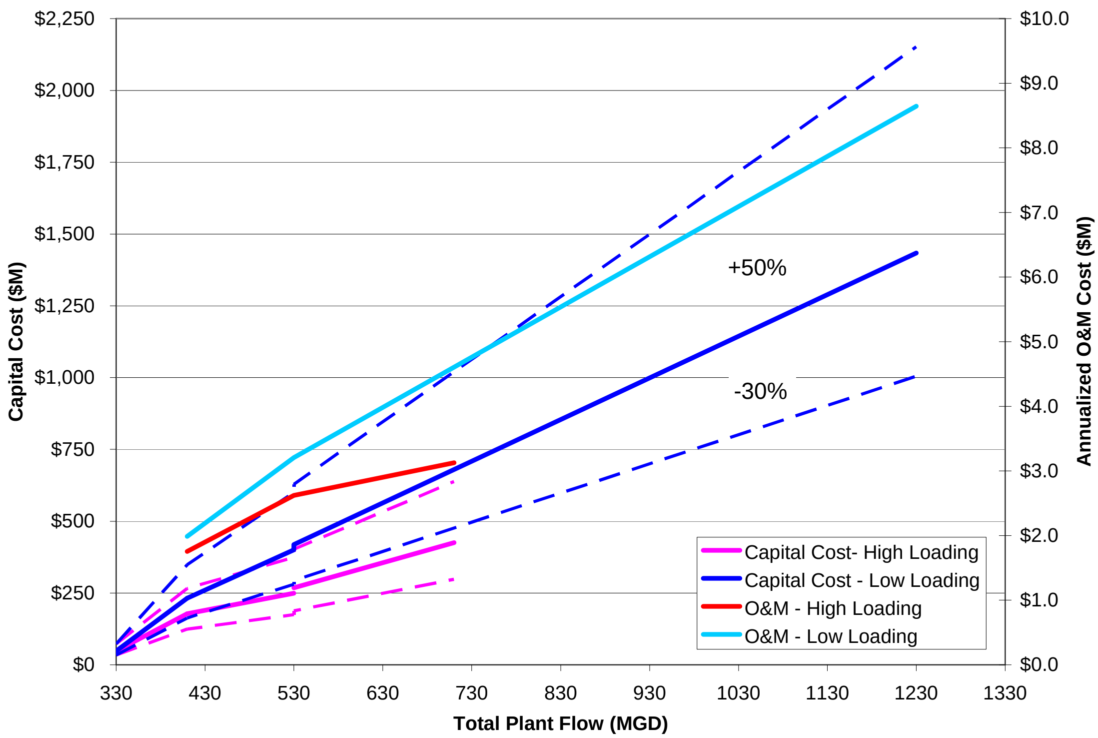


EXHIBIT 4-8
Capital Costs per Gallon Treated for Treatment Train #1: Vortex/Swirl

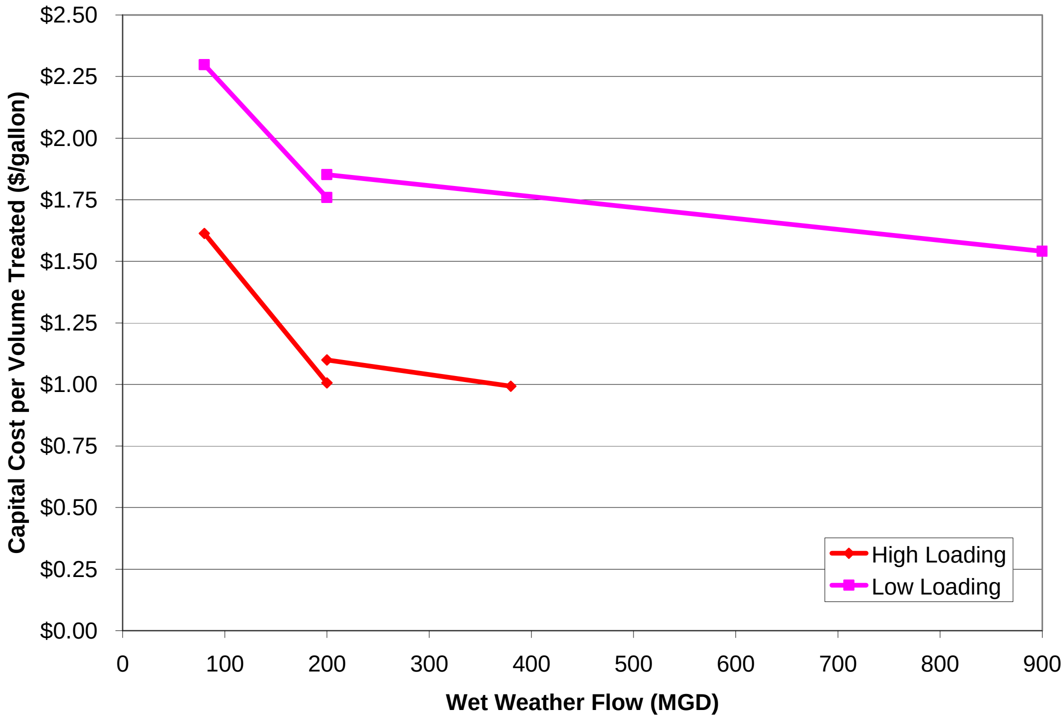


EXHIBIT 4-9
Operations and Maintenance by Category for Treatment Train #1: Vortex/Swirl at Low Loading Rates

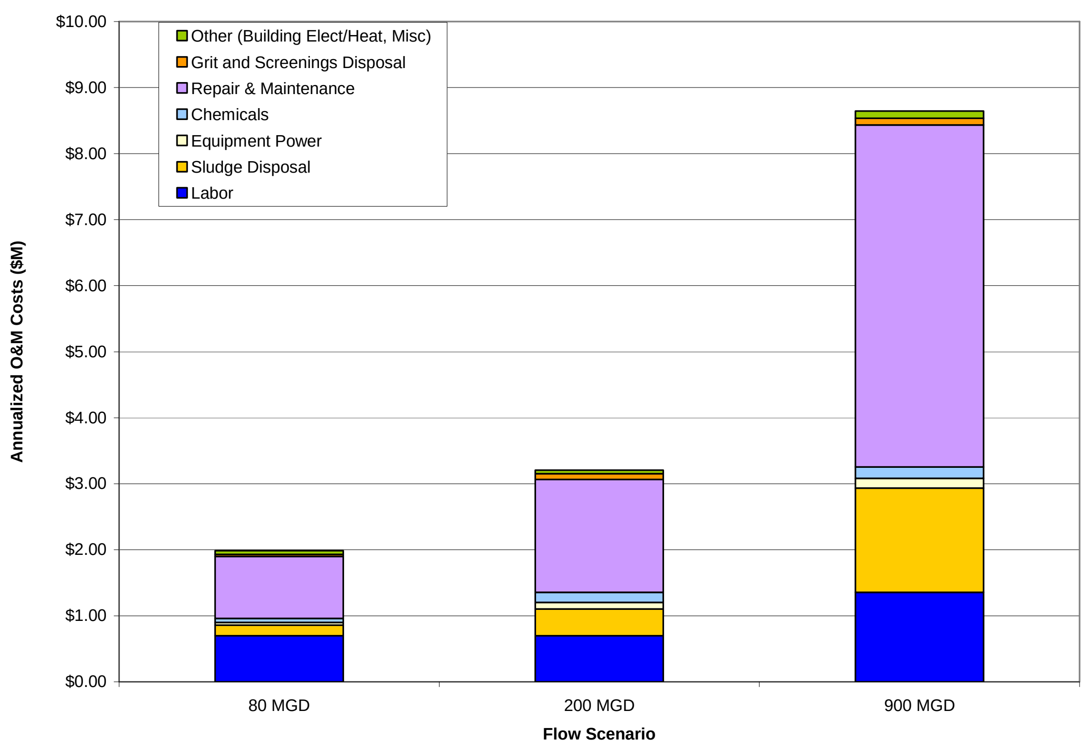
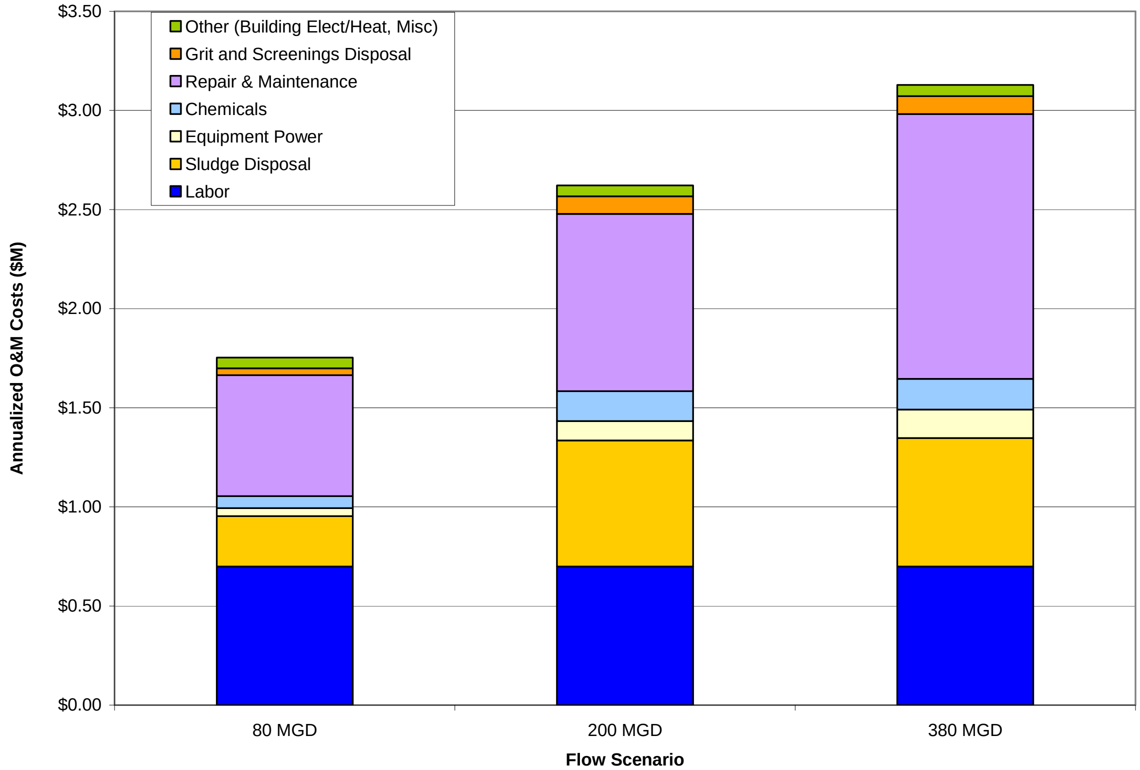


EXHIBIT 4-10
Operations and Maintenance by Category for Treatment Train #1: Vortex/Swirl at High Loading Rates



5.0 Treatment Train #2 - Conventional Clarifiers

5.1 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 SE 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 5-1.

5.2 Conceptual Design and Site Layouts

Conceptual designs were developed at four different flow scenarios for this train: 80, 200, 540, and 900 mgd. Key design parameters at these flows are shown in Exhibit 5-1. The conceptual layouts for the 80, 540, and 900 mgd scenarios are shown in Exhibit 5-2. At a flow of 900 mgd, 11 acres of land will need to be acquired to the east of the plant. The 540 mgd scenario can fit on the existing site.

5.3 Operational and Technology-Specific Issues

5.3.1 Startup and Shutdown

The startup time required for conventional clarifiers will be 2-3 hours, the duration needed to displace the wastewater in the existing tank. For shut down, the tank may be filled with treated effluent, or pumped down to the existing plant if freezing becomes an issue.

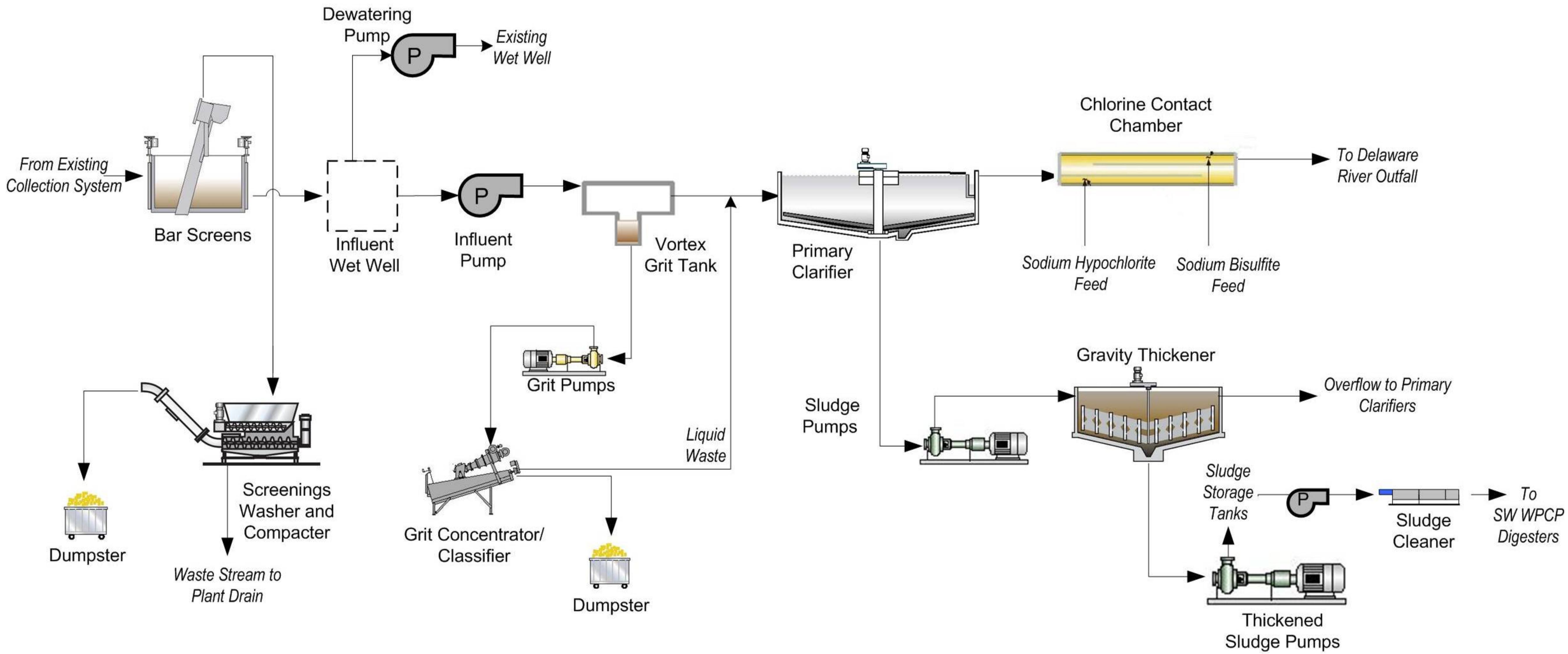
5.3.2 Interaction with Main Plant

Since the existing plant uses primary clarifiers, the new primary clarifiers for wet weather treatment can provide redundancy on primary treatment for the entire plant. If connected to the influent of the existing aeration basins, the new clarifiers could be used for treatment of dry weather flows.

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, there are two streams from the gravity thickeners that will interact with the main plant.

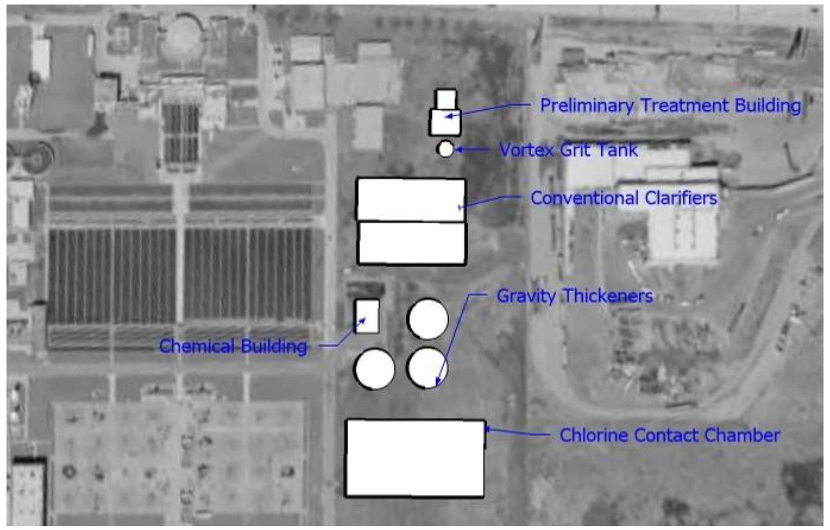
Thickened sludge from the gravity thickeners is pumped to the existing sludge storage tanks at an estimated rate of 0.3 to 3.6 mgd, depending on the flow capacity of the treatment train. This does not include the two gravity thickeners needed for the existing plant. Since

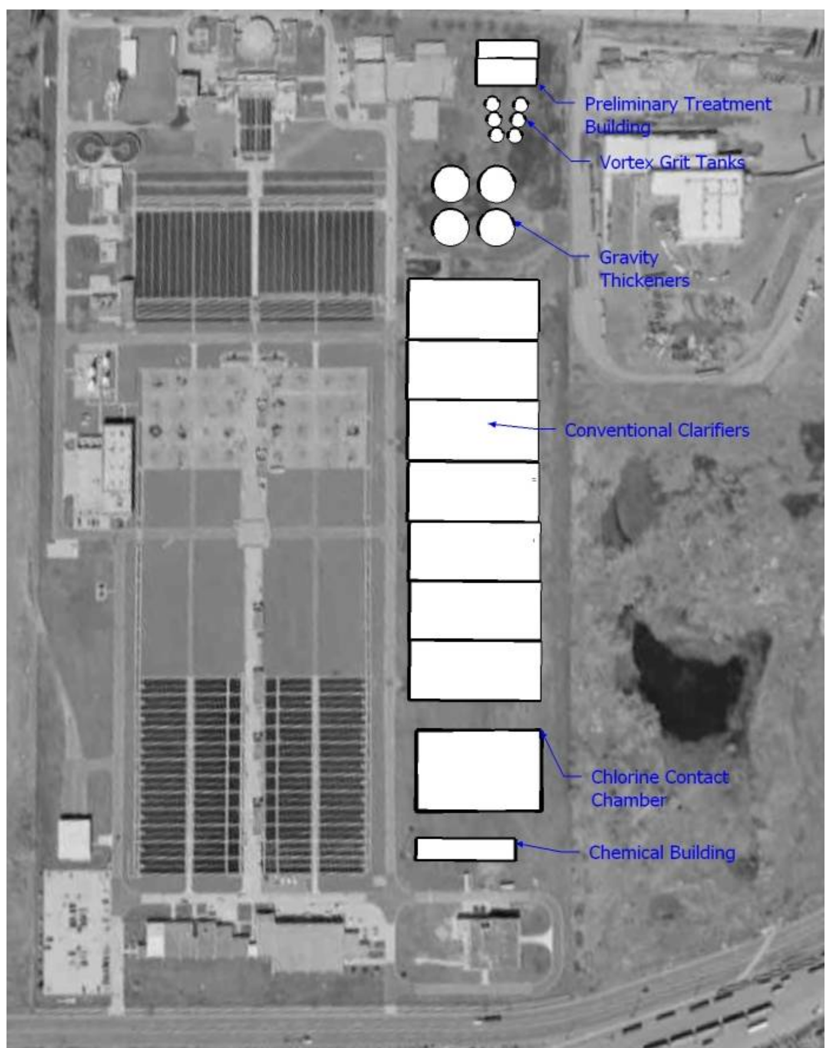
EXHIBIT 5-1
Process Flow Diagram and Key Process Design Parameters for Treatment Train #2: Conventional Clarifiers

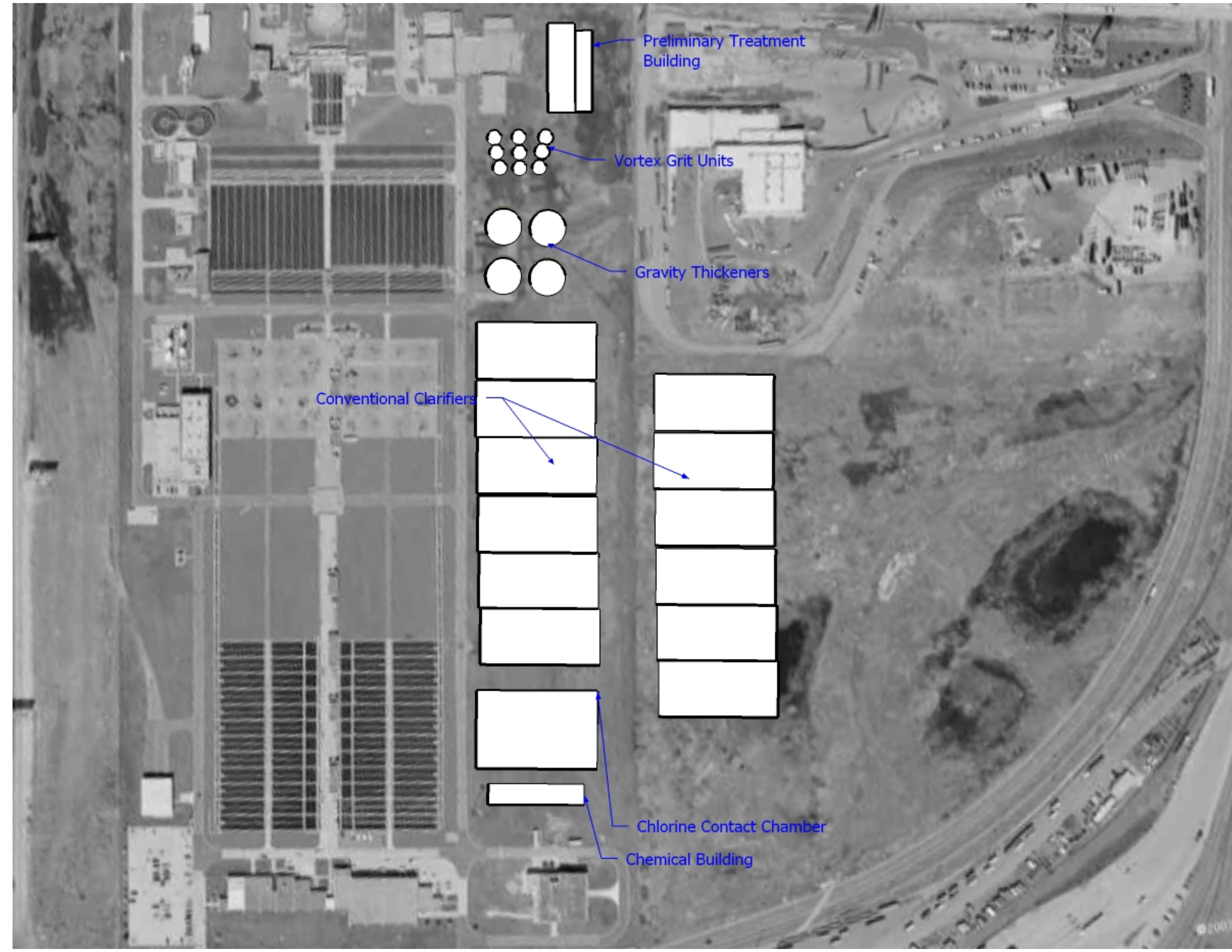


	Bar Screens	Influent Pumps	Vortex Grit Tank		Screenings Washer/ Compactor	Grit Pumps		Grit Concentrator	Grit Classifier	Screenings and Grit Prod.	Sodium Hypochlorite			Sodium Bisulfite			Clarification	Gravity Thickeners & Sludge Cleaners	Primary Sludge Pumps		Thickened Sludge Pumps		Sludge Prod.	Digesters (at SW WPCP)
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
80	1	1	1	32	1	1	1	1	1	460	39,831	1	1	6,226	1	1	2	1	2	1	1	1	80731	1
200	2	3	2	32	2	2	1	2	1	1,150	99,579	1	1	6,226	1	1	3	2	3	1	2	1	201828	1
540	6	7	6	32	6	6	2	6	3	1,173	101,570	1	1	6,226	1	1	7	2	7	2	2	1	205865	1
900	9	12	9	32	9	9	3	9	5	1,317	114,018	1	1	6,606	1	1	12	2	12	4	2	1	231093	1

EXHIBIT 5-2
Conceptual Layouts and Footprints for Treatment Train #2: Conventional Clarifiers
80 MGD Layout (top left), 540 MGD Layout (bottom left), 900 MGD (right)







*Layouts show 2 extra thickeners for existing primary clarifiers

Flow (mgd)	PTB	Grit Units	Clarifier Tanks	Chemical Building	CCC	Gravity Thickeners*	Land Acquired	TOTAL FOOTPRINT (acres)
80	54' x 47' & 39' x 39'	32' (1 unit)	84' x 212' (2 units)	65' x 47'	147' x 287' (7 passes)	70' (1 unit)	NONE	2.1
200	80' x 49' x 63' x 39'	32' (2 units)	129' x 245' (3 units)	101' x 47'	109' x 193' (5 passes) or 176' x 310' (9 passes)	80' (2 units)	NONE	3.3
540	132' x 58' & 133' x 39'	32' (6 units)	129' x 283' (7 units)	127' x 45'	172' x 268' (8 passes)	80' (2 units)	NONE	8.4
900	197' x 60' & 180' x 39'	32' (9 units)	124' x 265' (12 units)	143' x 45'	172' x 268' (8 passes)	80' (2 units)	11 acres	12.6

the thickened sludge can be pumped at any time, the thickeners themselves can serve as storage tanks for the sludge before it is pumped to the existing storage tanks.

The overflow from the gravity thickeners is conveyed to the head of the entire plant. The estimated overflow range from wet weather thickeners only is 2 to 18 mgd, depending on the treatment train capacity. 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.

5.3.3 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.

5.4 Cost Analyses

The estimated capital, O&M, and lifecycle costs for each flow scenario are shown in Exhibit 5-3. Total capital costs and the capital costs per volume treated are also shown in Exhibits 5-4 and 5-5. Estimated O&M costs by category are presented in Exhibit 5-6. A more detailed breakdown of these costs is presented in Attachment SE-3.1.

EXHIBIT 5-3
Cost Summary for Conventional Clarifiers: Treatment Train #2

	Wet Weather Flow (mgd)			
Cost	**80**	**200**	**540**	**900**
Capital Cost ($M)	$144	$268	$588	$931
Annual Operations and Maintenance Cost ($M)	$1.6	$2.4	$3.8	$4.7
Present Value of the Cost ($M)	$169	$305	$647	$1,004

EXHIBIT 5-4
Capital Costs for Treatment Train #2: Conventional Clarifiers

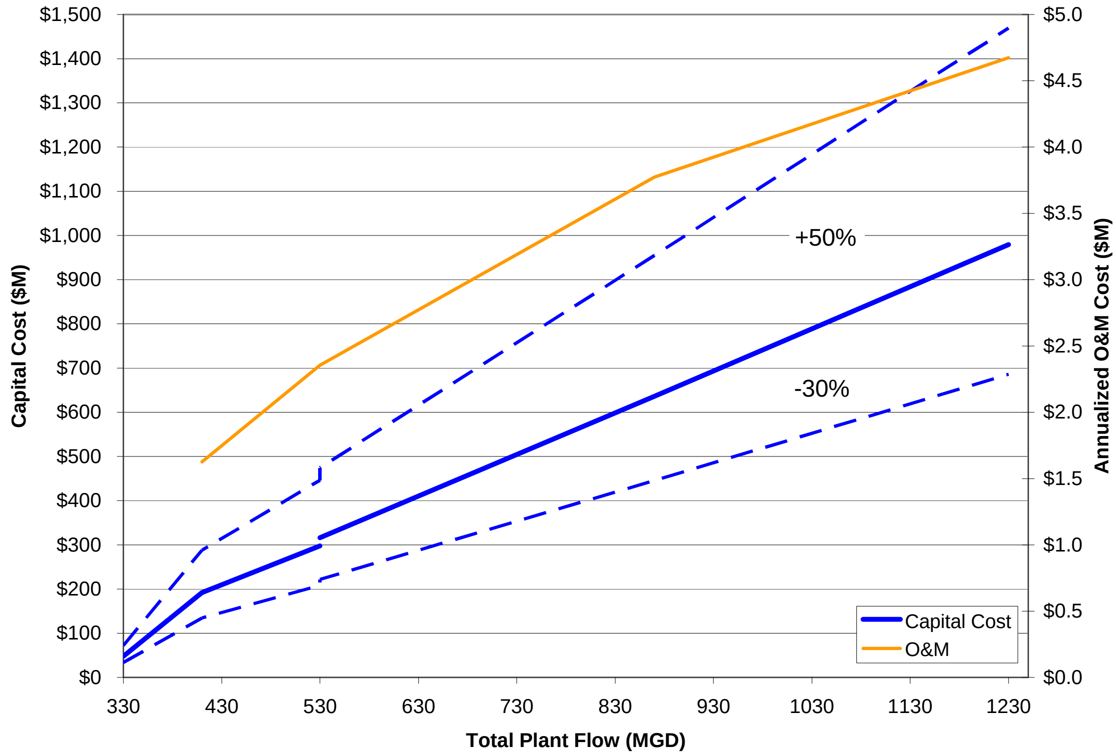


EXHIBIT 5-5
Capital Costs per Gallon Treated for Treatment Train #2: Conventional Clarifiers

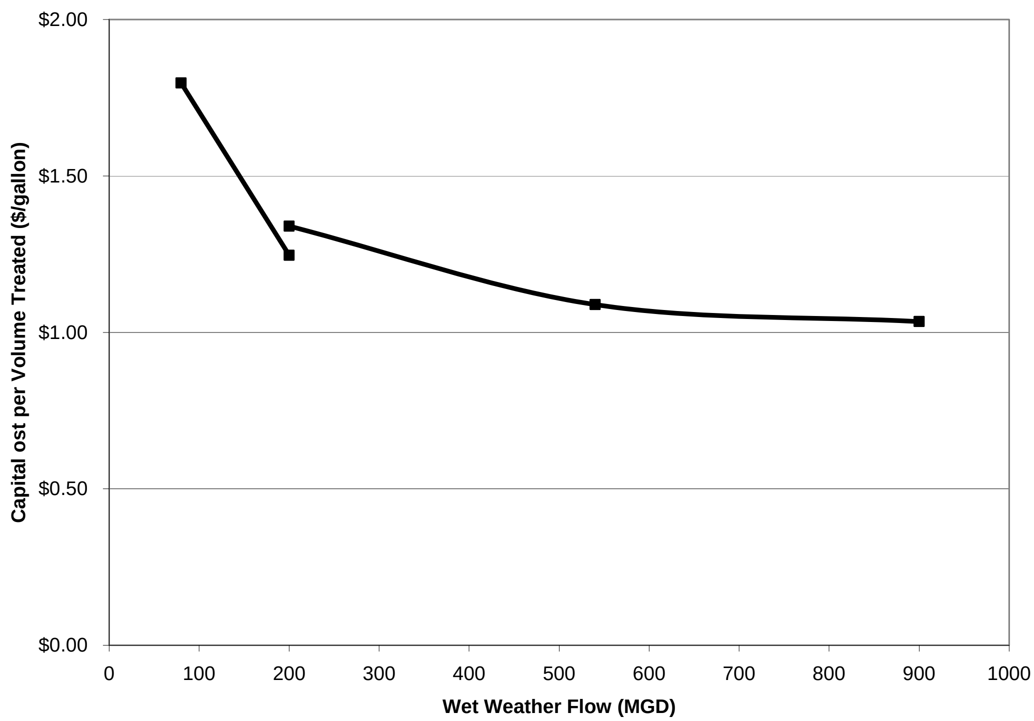
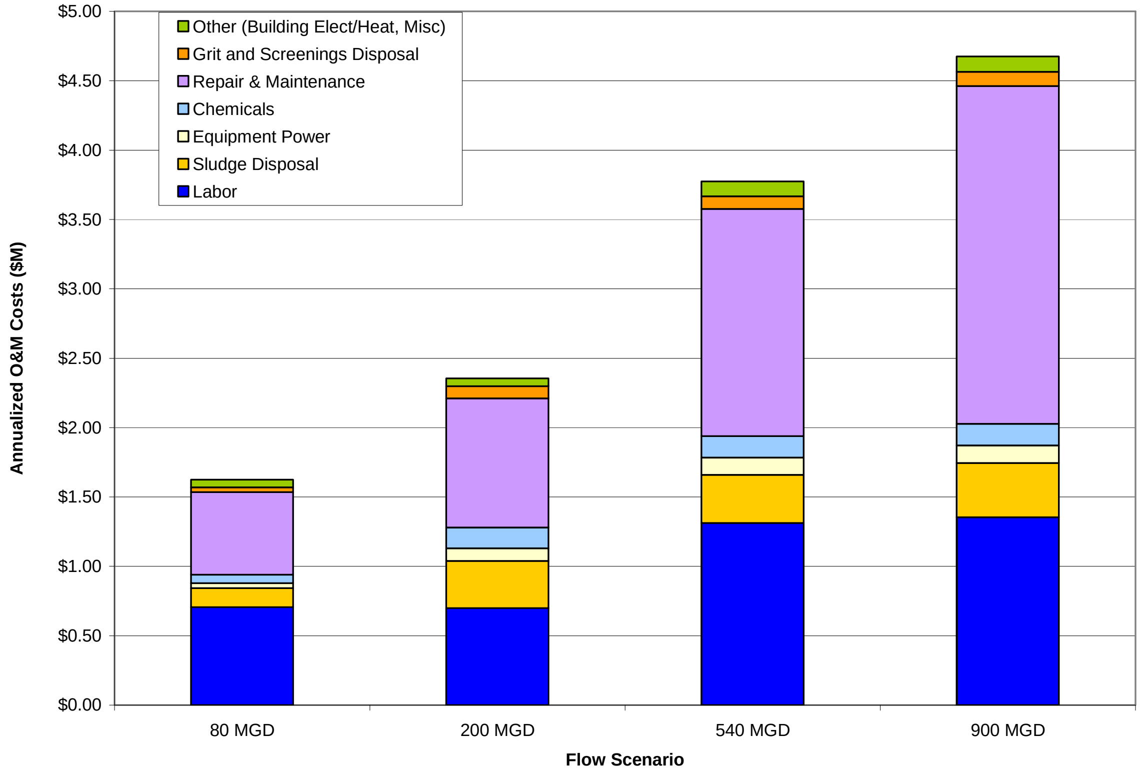


EXHIBIT 5-6
Operation and Maintenance Costs by Category for Treatment Train #2: Conventional Clarifiers



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

6.1 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 6-1, 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.

6.2 Conceptual Design and Site Layouts

Conceptual designs were developed at four different flow scenarios for this train: 80, 200, 470, and 900 mgd. Key design parameters at these flows are shown in Exhibit 6-1. As with Treatment Train #2, the 900 mgd flow scenario requires acquisition of neighboring property. As shown in Exhibit 6-2, there is adequate space on the existing site to treat up to 470 mgd of wet weather flow. Compared to Treatment Train #2, the CEPT primary clarifiers have a smaller footprint due to its slightly higher surface overflow rate, but the number of gravity thickeners required increases due to the higher removal efficiency of CEPT.

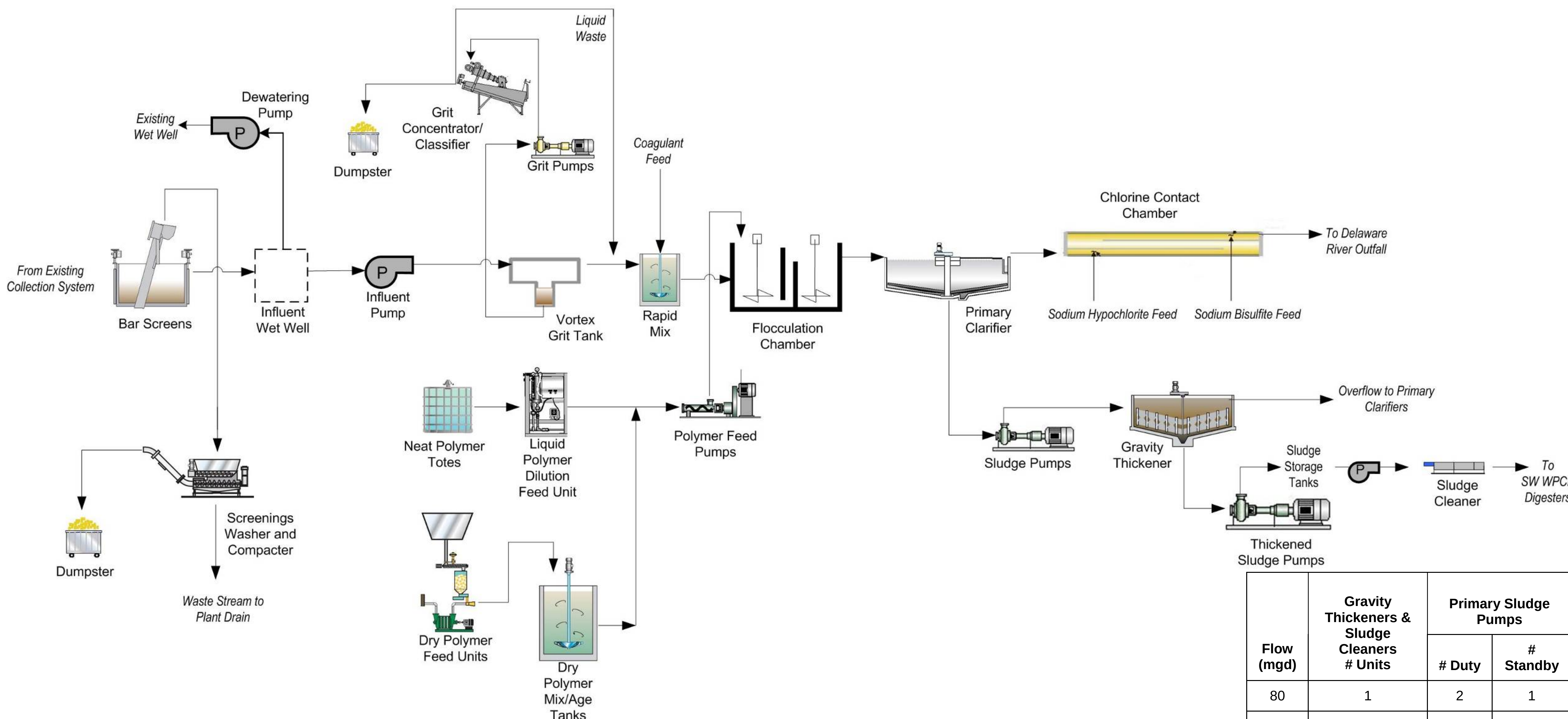
6.3 Operational and Technology-Specific Issues

6.3.1 Startup and Shutdown

The startup time of the CEPT treatment train is approximately 2 to 3 hours, which is the time it takes to either fill up an empty clarifier tank, or to displace existing wastewater in a tank. As with the conventional primary clarifiers, the CEPT tanks can be filled with treated effluent or pumped down when taken out of service.

A liquid polymer system is provided to allow immediate start up of this wet weather treatment train, since dry polymer preparation and aging takes approximately 2 hours. Once the dry polymer has aged, it can be substituted for liquid polymer. Dry polymer has the benefit of taking up less space and having a somewhat longer shelf life than emulsion polymer. A well-designed neat polymer storage tank system provides a shelf life of about six months, while dry polymer generally has a shelf life of 12 months when properly stored in a clean, dry environment. A small liquid polymer system for startup and a dry polymer system following startup are both included in the cost and footprint estimates. For a cost estimate of using liquid polymer only, see Section 9-1.

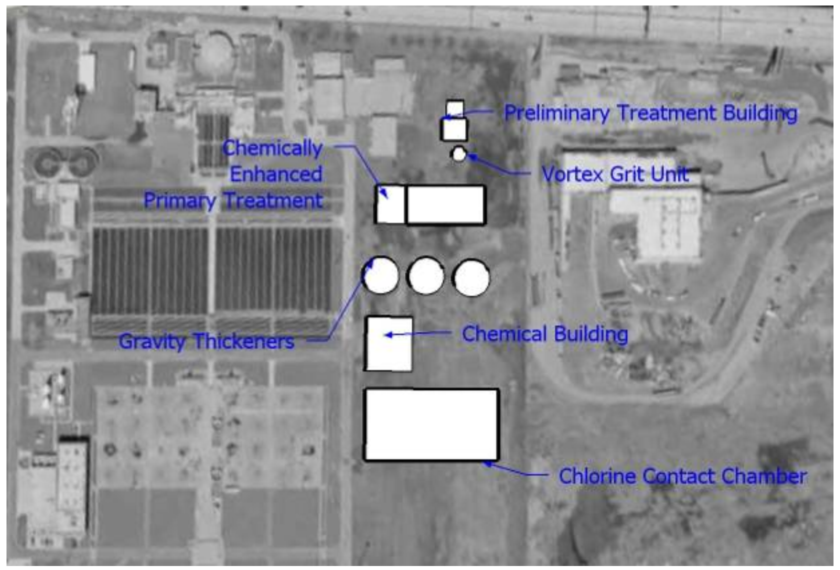
EXHIBIT 6-1
Process Flow Diagram and Key Process Design Parameters for Treatment Train #3: CEPT

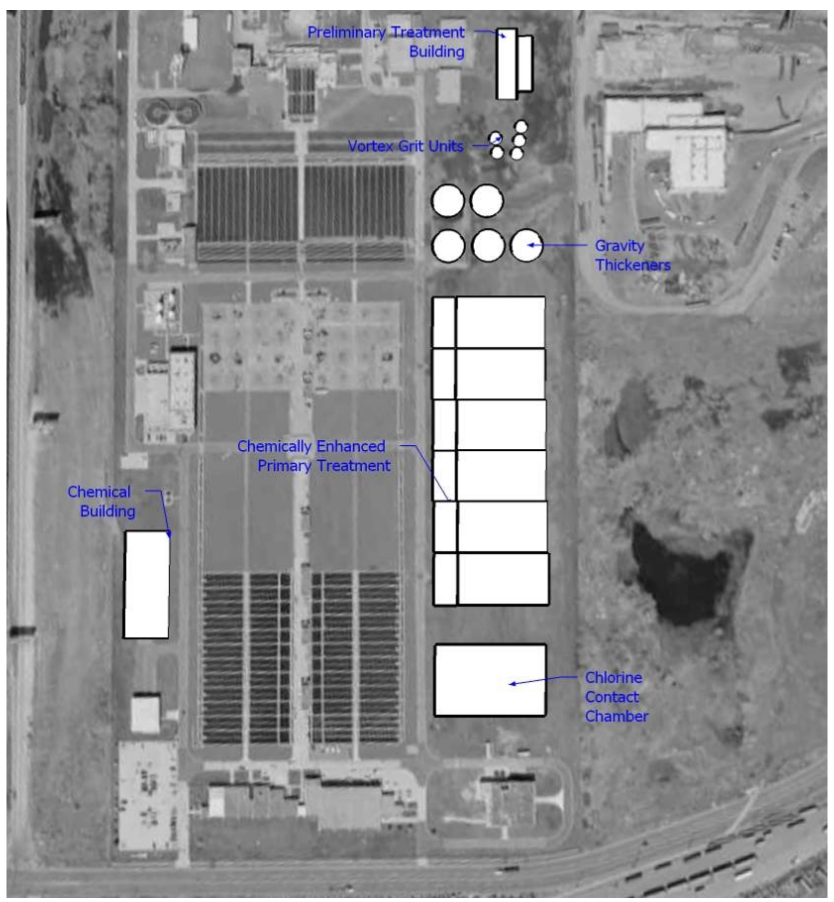


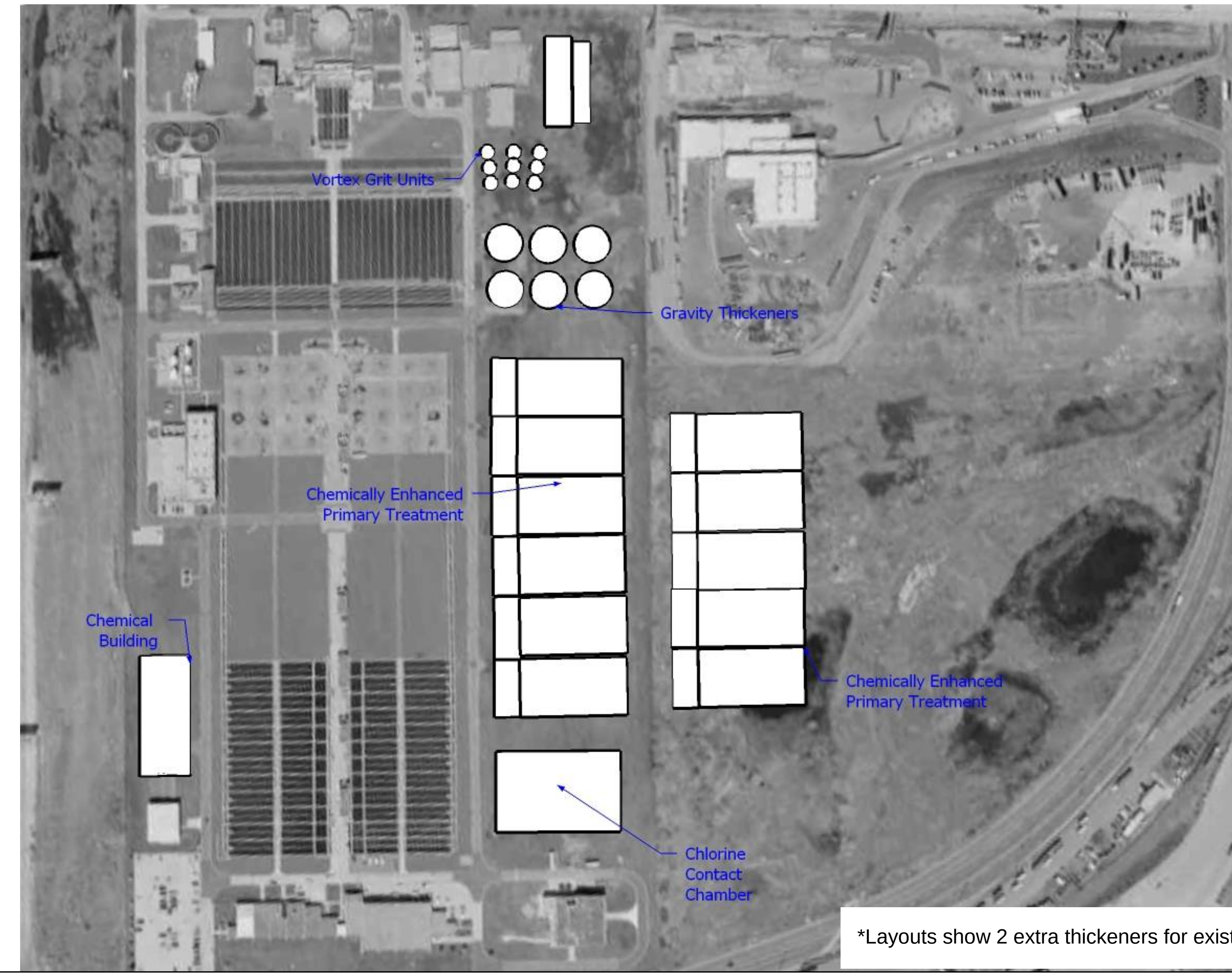
Flow (mgd)	Gravity Thickeners & Sludge Cleaners # Units	Primary Sludge Pumps		Thickened Sludge Pumps		Sludge Prod. lb/day	Digesters (SW WPCP)
		# Duty	# Standby	# Duty	# Standby		# units
80	1	2	1	1	1	142067	1
200	3	3	1	3	1	355168	1
470	3	6	2	3	1	362271	1
900	4	11	3	4	1	406667	1

Flow (mgd)	Bar Screens # Units	Influent Pumps # Units	Vortex Grit Tank		Screenings Washer/ Compactor # Units	Grit Pumps		Grit Concentrator # Units	Grit Classifier # Units	Screenings and Grit Prod. Compacted Volume (cf/day)	Ferric Chloride			Liquid Polymer Total Storage Vol (gal)	Dry Polymer			Sodium Hypochlorite			Sodium Bisulfite			Flocculation # Trains	Clarification # Trains
			# Units	DIA (ft)		# Duty	# Standby				Total Storage Vol (gal)	# Duty Pumps	# Standby Pumps		Total Storage Vol (ton)	# Duty Pumps	# Standby Pumps	Total Storage Vol (gal)	# Duty Pumps	# Standby Pumps	Total Storage Vol (gal)	# Duty Pumps	# Standby Pumps		
80	1	1	1	32	1	1	1	1	1	460	83,940	2	1	300	7	2	1	39,831	1	1	6,226	1	1	2	2
200	2	3	2	32	2	2	1	2	1	1150	209,851	3	1	900	17	3	1	99,579	1	1	6,226	1	1	3	3
470	5	7	5	32	5	5	1	5	3	1173	214,048	6	2	900	17	6	2	101,570	1	1	6,226	1	1	6	6
900	9	12	9	32	9	9	1	9	5	1317	240,279	11	4	1200	19	11	4	114,018	1	1	6,606	1	1	11	11

EXHIBIT 6-2
Conceptual Layouts and Footprints for Treatment Train #3: CEPT
80 MGD Layout (top left), 470 MGD Layout (bottom left), 900 MGD (right)







*Layouts show 2 extra thickeners for existing primary clarifiers

Flow (Mgd)	PTB	Grit Units	Flocculation Tanks	Clarifier Tanks	Chemical Building	CCC	Gravity Thickeners*	Land Acquired	TOTAL FOOTPRINT (acres)
80	54' x 47' & 39' x 39'	32' (1 unit)	84' x 51' (3 units)	84' x 171' (2 units)	116' x 106'	147' x 287' (7 passes)	80' (1 unit)	NONE	2.3
200	80' x 49' x 63' x 39'	32' (2 units)	84' x 62' (3 units)	104' x 226' (3 units)	165' x 106'	109' x 193' (5 passes) or 176' x 310' (9 passes)	80' (3 units)	NONE	3.4
470	132' x 53' & 140' x 39'	32' (5 units)	125' x 56' (6 units)	125' x 221' (6 units)	189' x 100'	172' x 168' (8 passes)	80' (3 units)	NONE	7.5
900	197' x 60' & 180' x 39'	32' (9 units)	125' x 57' (11 units)	124' x 231' (11 units)	205' x 100'	172' x 268' (8 passes)	80' (4 units)	11 acres	12.9

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.

6.3.2 Interaction with Main Plant

As described in the previous treatment trains, two waste streams from the gravity thickeners will interact with the existing plant. Thickened sludge will be pumped to the existing storage tanks at an estimated rate of 0.6 to 6.4 mgd, depending on the flow capacity of the treatment train. The overflow from the thickeners, ranging from 3 to 32 mgd, is recycled back to the head of the plant for distribution across the main plant and the wet weather treatment train.

6.3.3 Impact on Plant Operations

CEPT requires the addition of chemicals, ferric chloride and polymer, that are not currently used at the SE 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.

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 shown in Exhibit 6-6. A more detailed breakdown of these costs is presented in Attachment SE-3.1.

EXHIBIT 6-3
Cost Summary for CEPT Train #3

	Wet Weather Flow (mgd)			
Cost	**80**	**200**	**470**	**900**
Capital Cost ($M)	$160	$286	$564	$966
Annual Operations and Maintenance Cost ($M)	$2.0	$3.1	$4.5	$5.6
Present Value of the Cost ($M)	$190	$334	$635	$1,053

EXHIBIT 6-4
Capital Costs for Treatment Train #3: CEPT

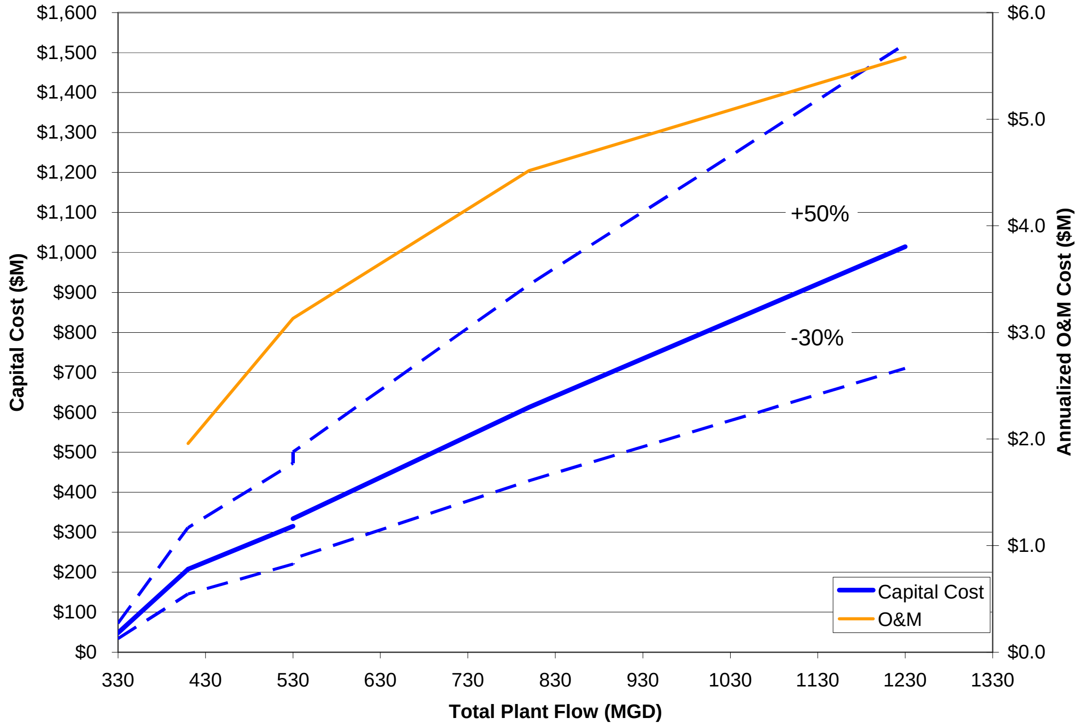


EXHIBIT 6-5
Capital Costs per Gallon Treated for Treatment Train #3: CEPT

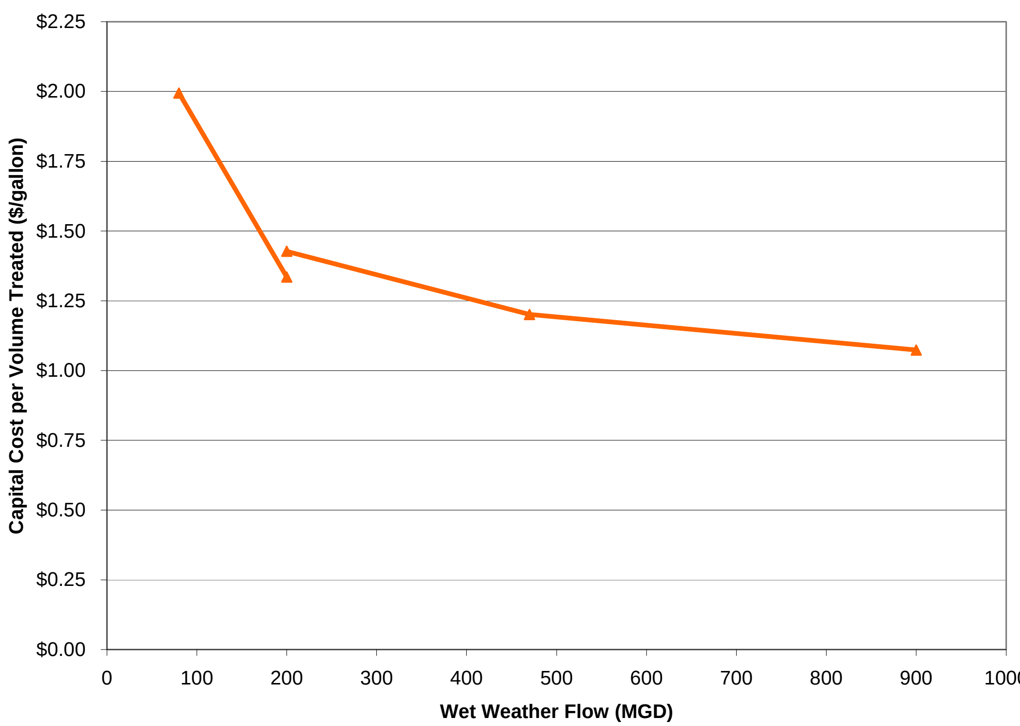
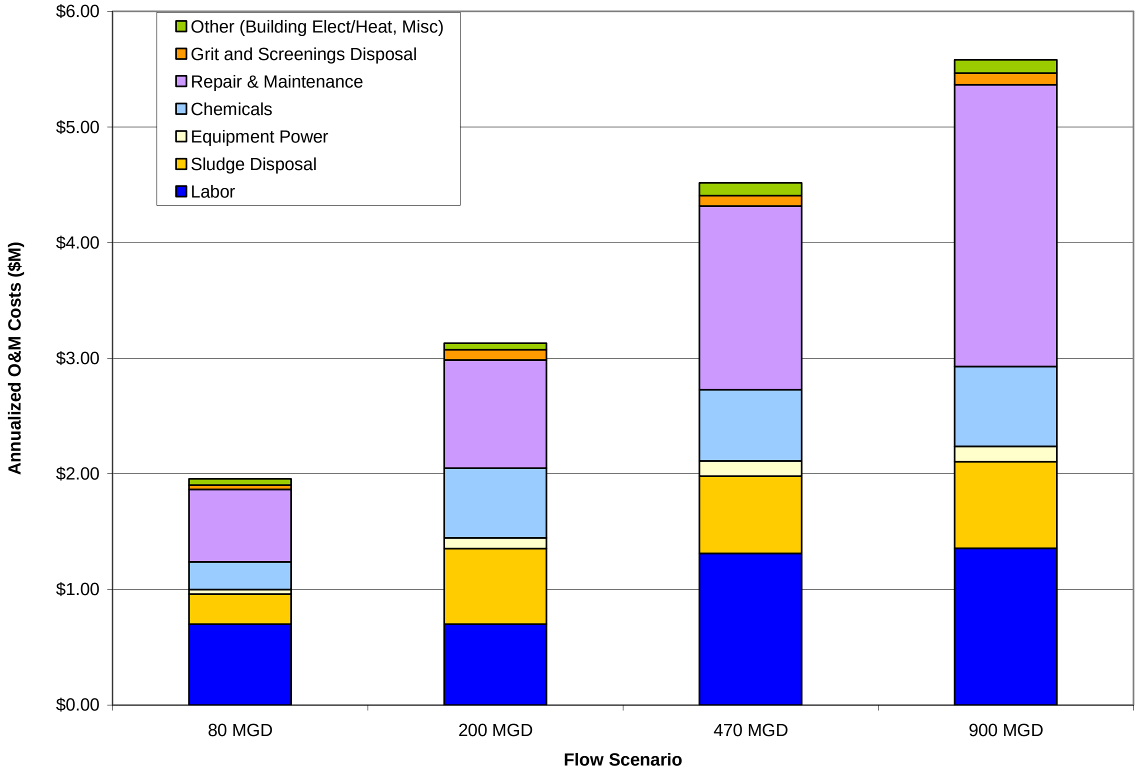


EXHIBIT 6-6
Operations and Maintenance Costs by Category for Treatment Train #3: CEPT



7.0 Treatment Train #4 - CEPT with Plate Settlers

7.1 Process Flow Diagram

Building upon Treatment Train #3, this train utilizes the addition of plate settlers in the primary clarifiers to increase the effective settling area of the tank. With chemical addition and the increased settling area, the surface overflow rate is estimated to increase from 3000 gpd/sf for CEPT only, to 7000 gpd/sf with the addition of plates. To prevent the plate settlers from clogging, fine screening is included as an additional process in this train (Exhibit 7-1).

7.2 Conceptual Design and Site Layouts

Conceptual designs were developed at three different flow scenarios for this train: 80, 200, and 900 mgd. Key design parameters at these flows are shown in Exhibit 7-1. Due to the higher surface loading rate of these tanks, a 900 mgd facility will be able to fit on the existing site (Exhibit 7-2).

7.3 Operational and Technology-Specific Issues

7.3.1 Startup and Shutdown

The requirements for startup and shutdown are similar to those for the CEPT treatment train.

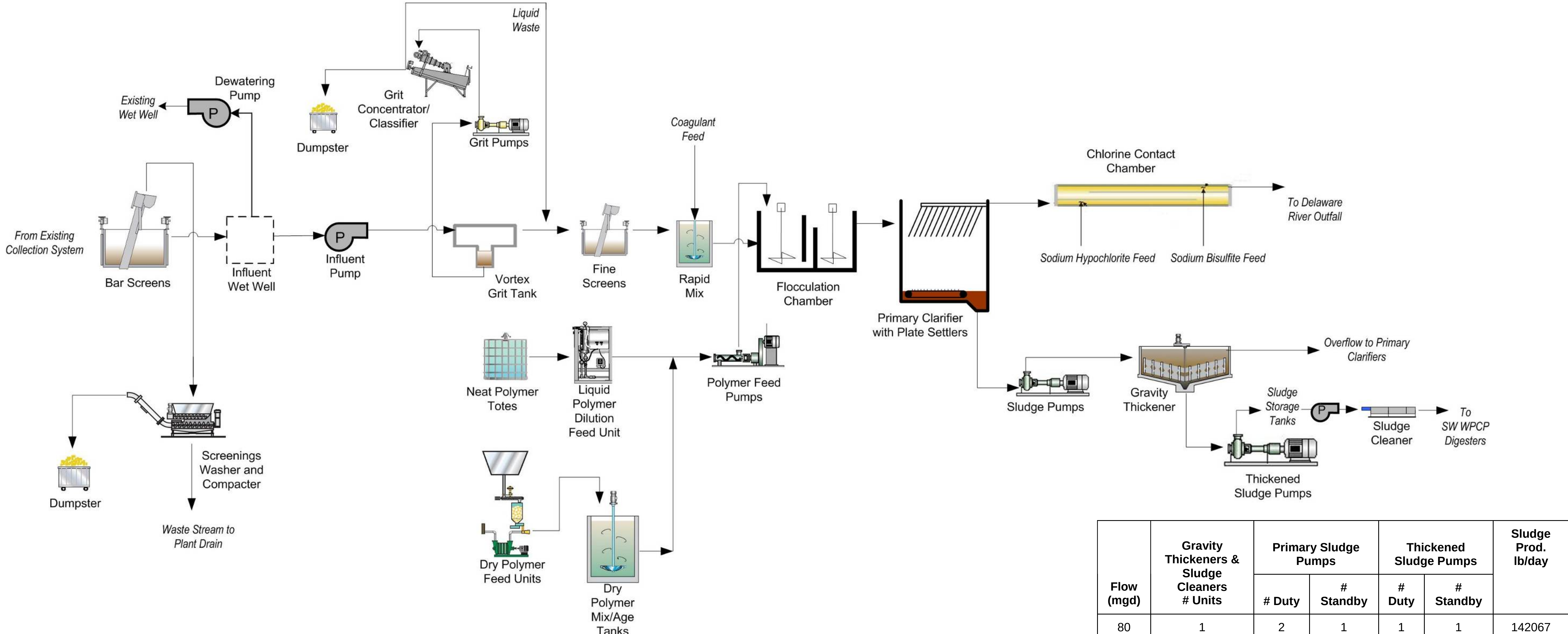
7.3.2 Interactions with Main Plant

The waste streams from the gravity thickeners will be similar in flow to the CEPT treatment train. An estimated thickened sludge flow of 0.6 to 6.4 mgd, depending on the flow capacity of the treatment train, will be pumped to the existing sludge storage tanks. The overflow from the thickeners, ranging from 3 to 32 mgd depending on the flow capacity of the treatment train, will be recycled back to the head of the entire plant.

7.3.3 Impact on plant operations

In addition to the same impacts on plant operations associated with CEPT, plate settlers require regular cleaning to maintain performance, especially due to the sticky nature of the solids that are typically present in wastewater. There will also be additional maintenance associated with the set of fine screens as well.

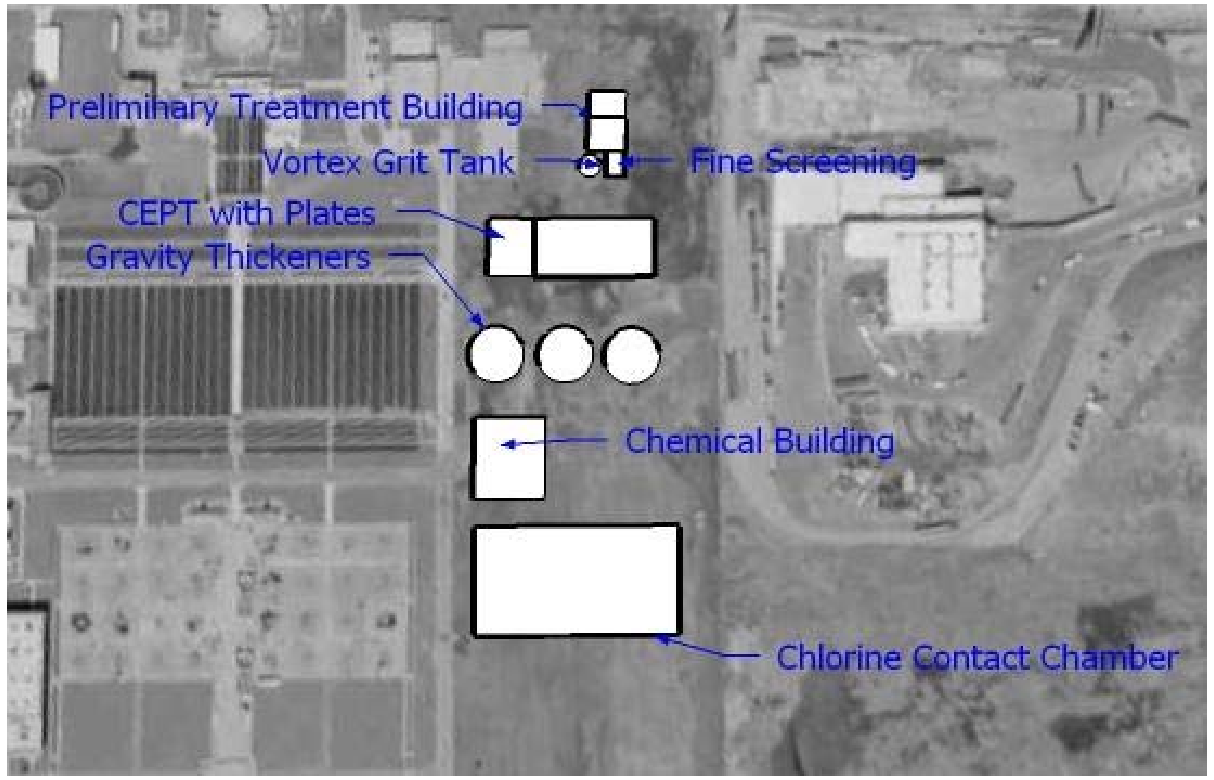
EXHIBIT 7-1
Process Flow Diagram and Key Process Design Parameters for Treatment Train #4: CEPT with Plates

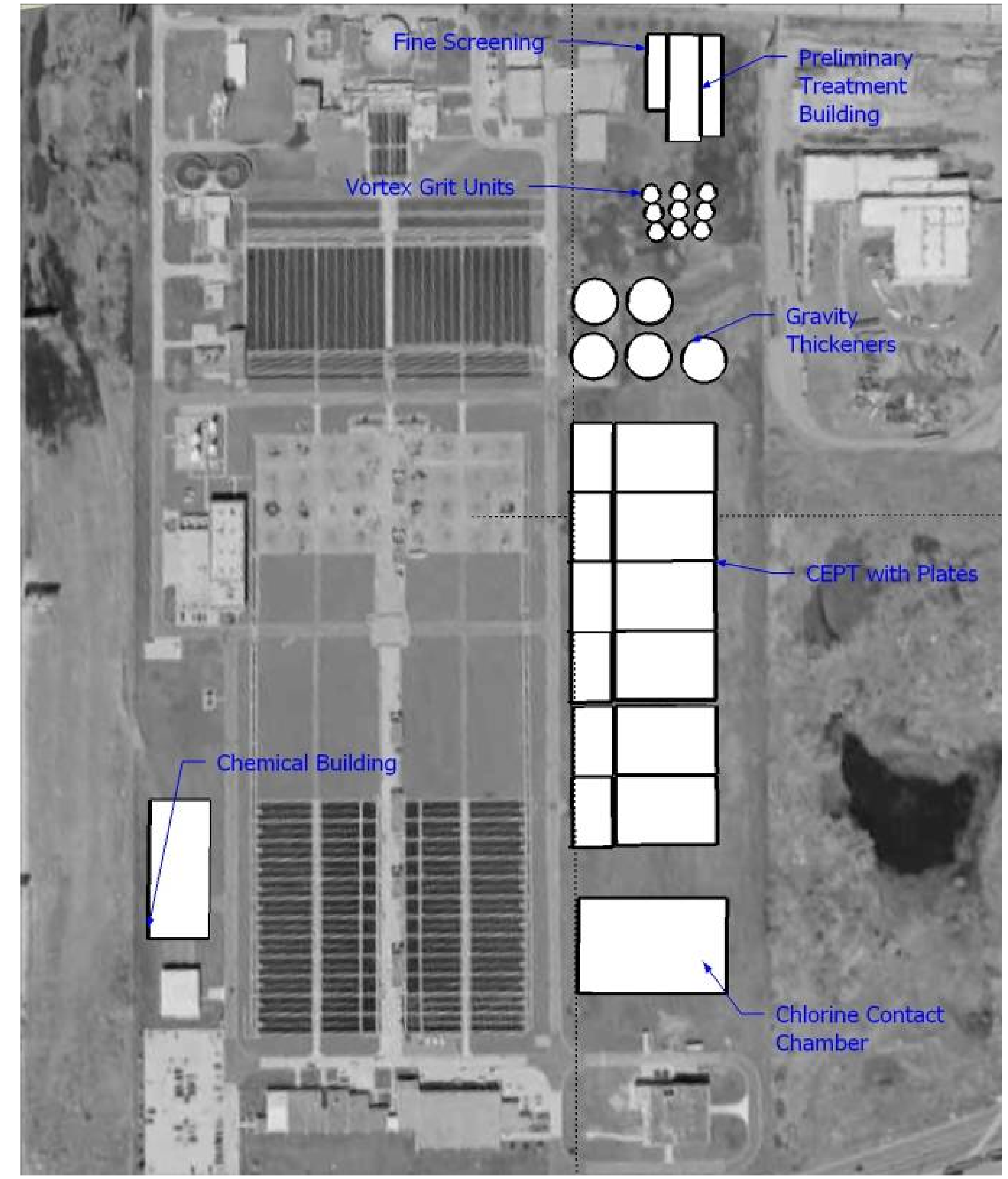


Flow (mgd)	Gravity Thickeners & Sludge Cleaners # Units	Primary Sludge Pumps		Thickened Sludge Pumps		Sludge Prod. lb/day	Digesters (SW WPCP)
		# Duty	# Standby	# Duty	# Standby		# units
80	1	2	1	1	1	142067	1
200	3	3	1	3	1	355168	1
900	3	12	4	3	1	406667	1

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 Total Storage Vol (Gal)	Dry Polymer			Sodium Hypochlorite			Sodium Bisulfite			Flocculation	Clarification
			# Units	Dia (Ft)			# Duty	# Standby				Total Storage Vol (Gal)	# Duty Pumps	# Standby Pumps		Total Storage Vol (Ton)	# Duty Pumps	# Standby Pumps	Total Storage Vol (Gal)	# Duty Pumps	# Standby Pumps	Total Storage Vol (Gal)	# Duty Pumps	# Standby Pumps	# Trains	# Trains
80	1	1	1	32	1	2	1	1	1	1	551	83,940	1	1	300	7	1	1	39,831	1	1	6,226	1	1	1	1
200	2	3	2	32	2	4	2	1	2	1	1377	209,851	2	1	900	17	2	1	99,579	1	1	6,226	1	1	2	2
900	9	12	9	32	9	18	9	1	9	5	1577	240,279	6	2	1200	19	6	2	114,018	1	1	6,609	1	1	6	6

EXHIBIT 7-2
Conceptual Layouts and Footprints for Treatment Train #4: CEPT with Plates
80 MGD Layout (left), 900 MGD (right)





*Layouts show 2 extra thickeners for existing primary clarifiers

Flow (mgd)	PTB	Grit Units	Fine Screening	Flocculation Tanks	Clarifier Tanks	Chemical Building	CCC	Gravity Thickeners*	TOTAL FOOTPRINT (acres)
80	54' x 47' & 46' x 39'	32' (1 unit)	27' x 38'	84' x 66' (1 unit)	84' x 147' (1 unit)	116' x 106'	147' x 287' (7 passes)	80' (1 unit)	1.9
200	80' x 49' x 63' x 39'	32' (2 units)	37' x 38'	84' x 72' (2 units)	84' x 183' (2 units)	165' x 106'	109' x 193' (5 passes) or 176' x 310' (9 passes)	80' (3 units)	2.4
900	197' x 60' & 187' x 39'	32' (9 units)	140' x 38'	124' x 73' (6 units)	124' x 183' (6 units)	259' x 104'	172' x 268' (8 passes)	80' (3 units)	7.8

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 presented in Exhibit 7-6. A more detailed breakdown of these costs is presented in Attachment SE-3.1.

EXHIBIT 7-3
Cost Summary for CEPT with Plates: Treatment Train #4

	Wet Weather Flow (mgd)		
Cost	**80**	**200**	**900**
Capital Cost ($M)	$265	$517	$2,047
Annual Operations and Maintenance Cost ($M)	$2.0	$3.2	$5.9
Present Value of the Cost ($M)	$296	$568	$2,139

EXHIBIT 7-4
Capital Costs for Treatment Train #4: CEPT with Plates

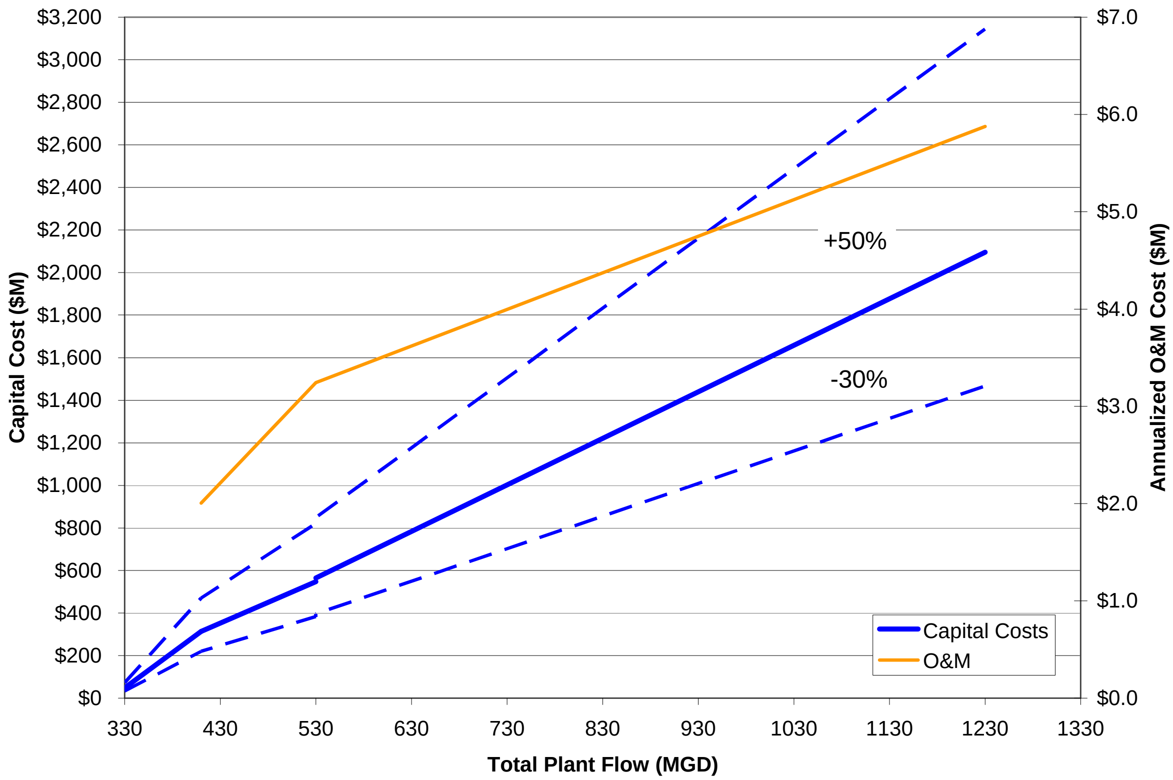


EXHIBIT 7-5
Capital Costs per Gallon Treated for Treatment Train #4: CEPT with Plates

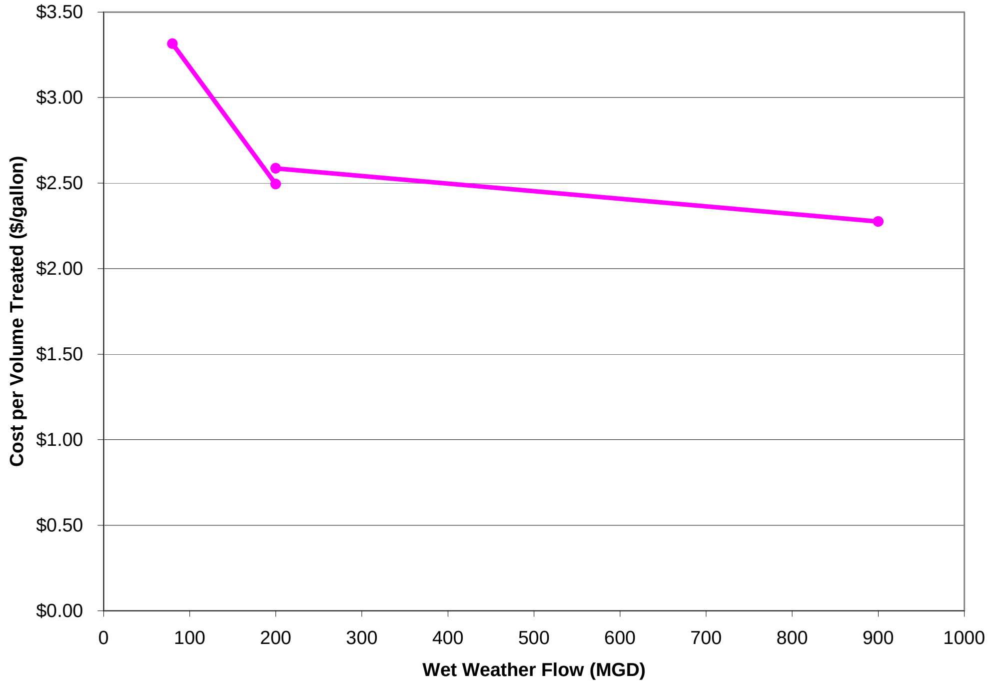
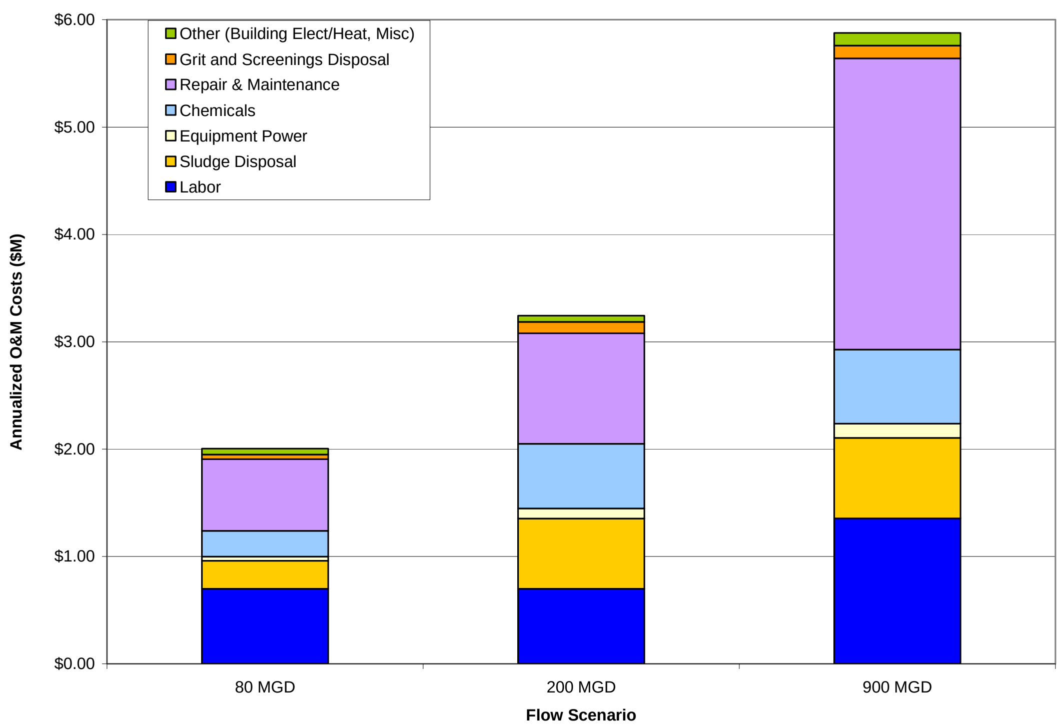


EXHIBIT 7-6
Operation and Maintenance Costs by Category for Train #4: CEPT with Plates



8.0 Treatment Train #5 - 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.

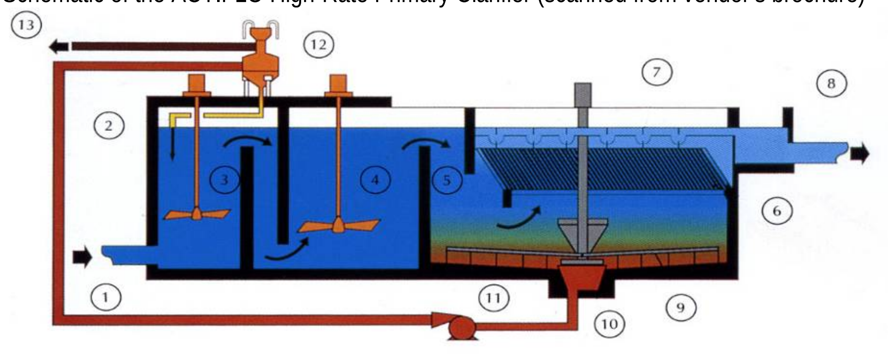
8.1 Process Flow Diagram

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).

As shown in Exhibit 8-2, 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.

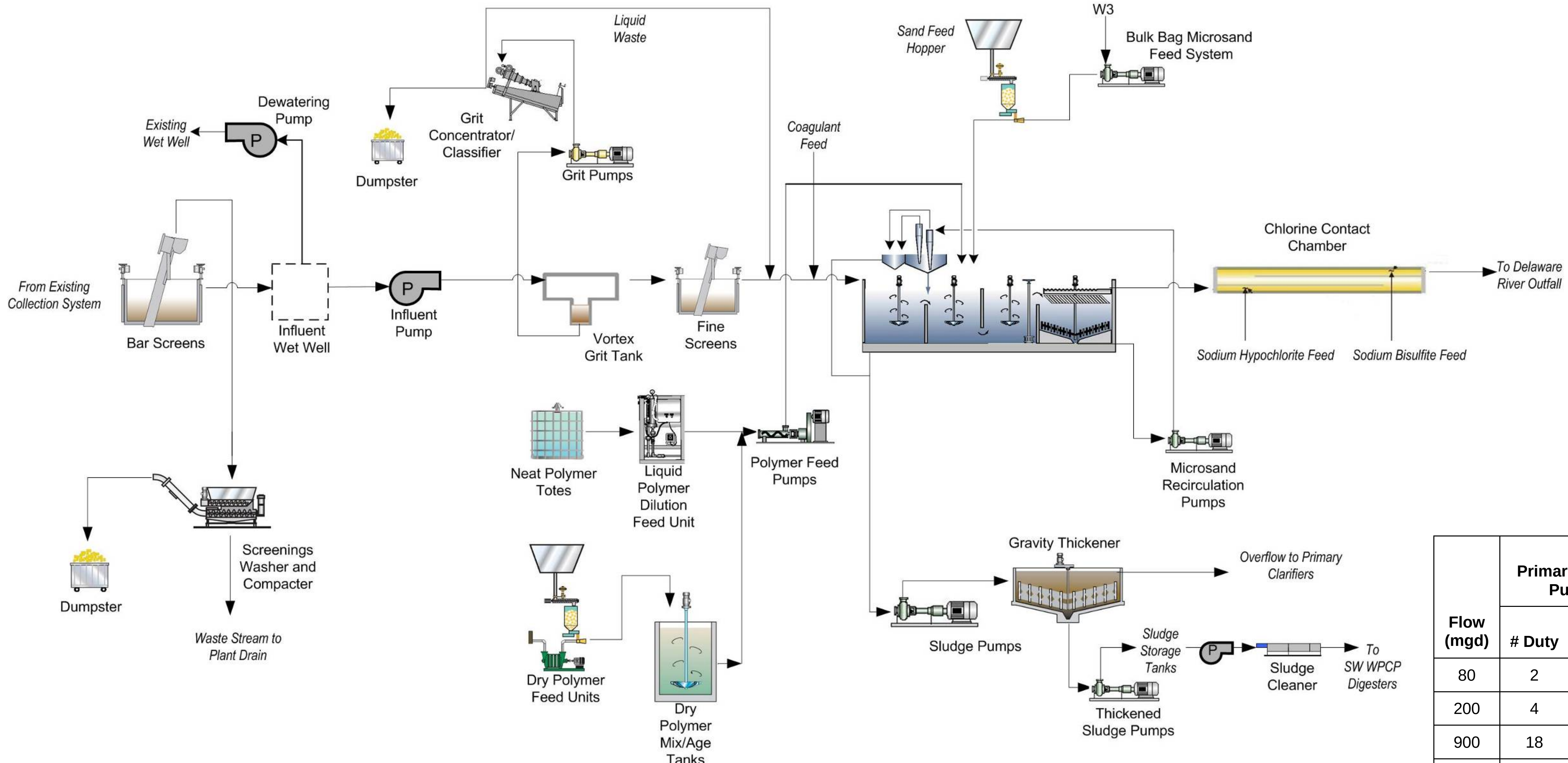
EXHIBIT 8-1
Schematic of the ACTIFLO High-Rate Primary Clarifier (scanned from vendor's brochure)



8.2 Conceptual Design and Site Layouts

Conceptual designs using the ballasted flocculation system were developed for flow capacities of 80, 200, 900, and 1,200 mgd. The 1,200 mgd scenario was developed to show the maximum flow that can be treated using the available land onsite. 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. This is due to its extremely high surface overflow rate of 60 gpm/sf.

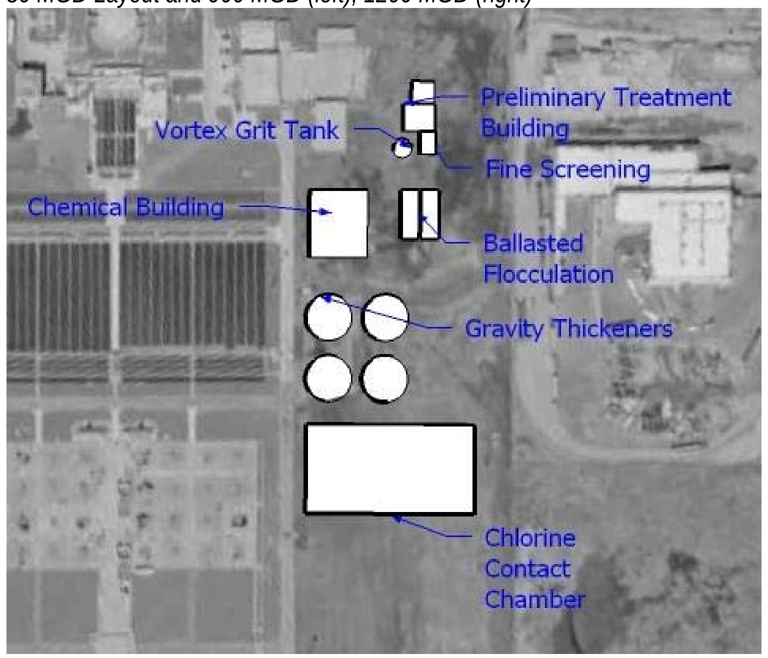
EXHIBIT 8-2
Process Flow Diagram and Key Process Design Parameters for Treatment Train #5: Ballasted Flocculation

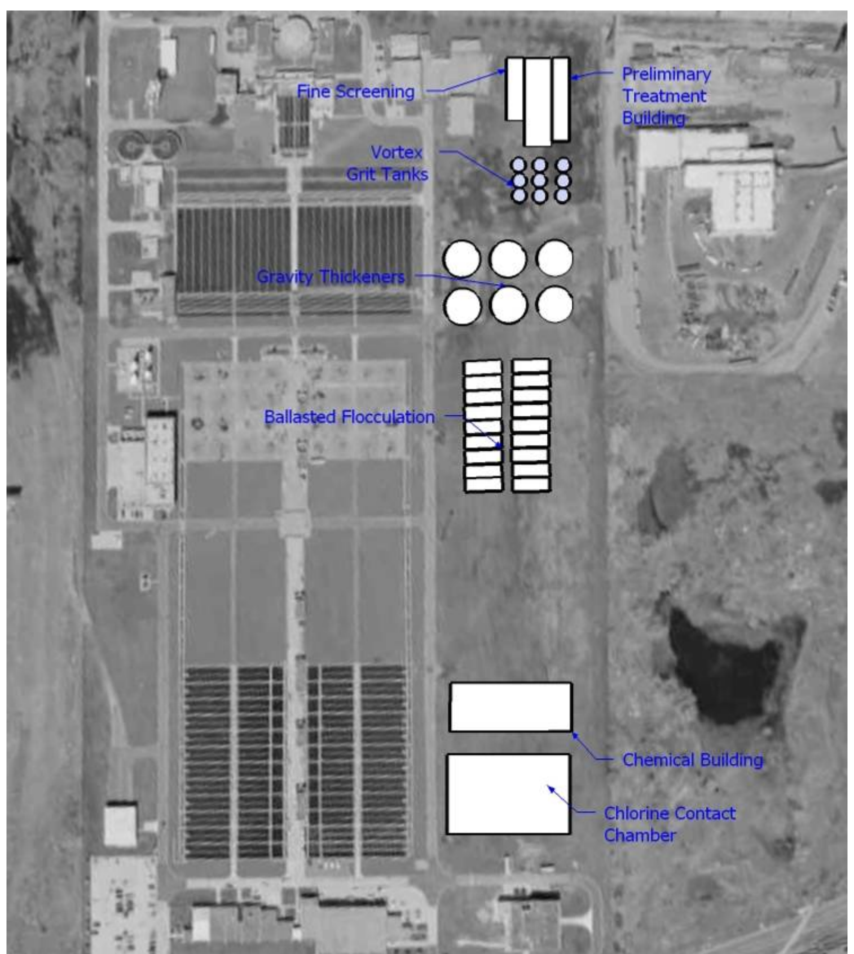


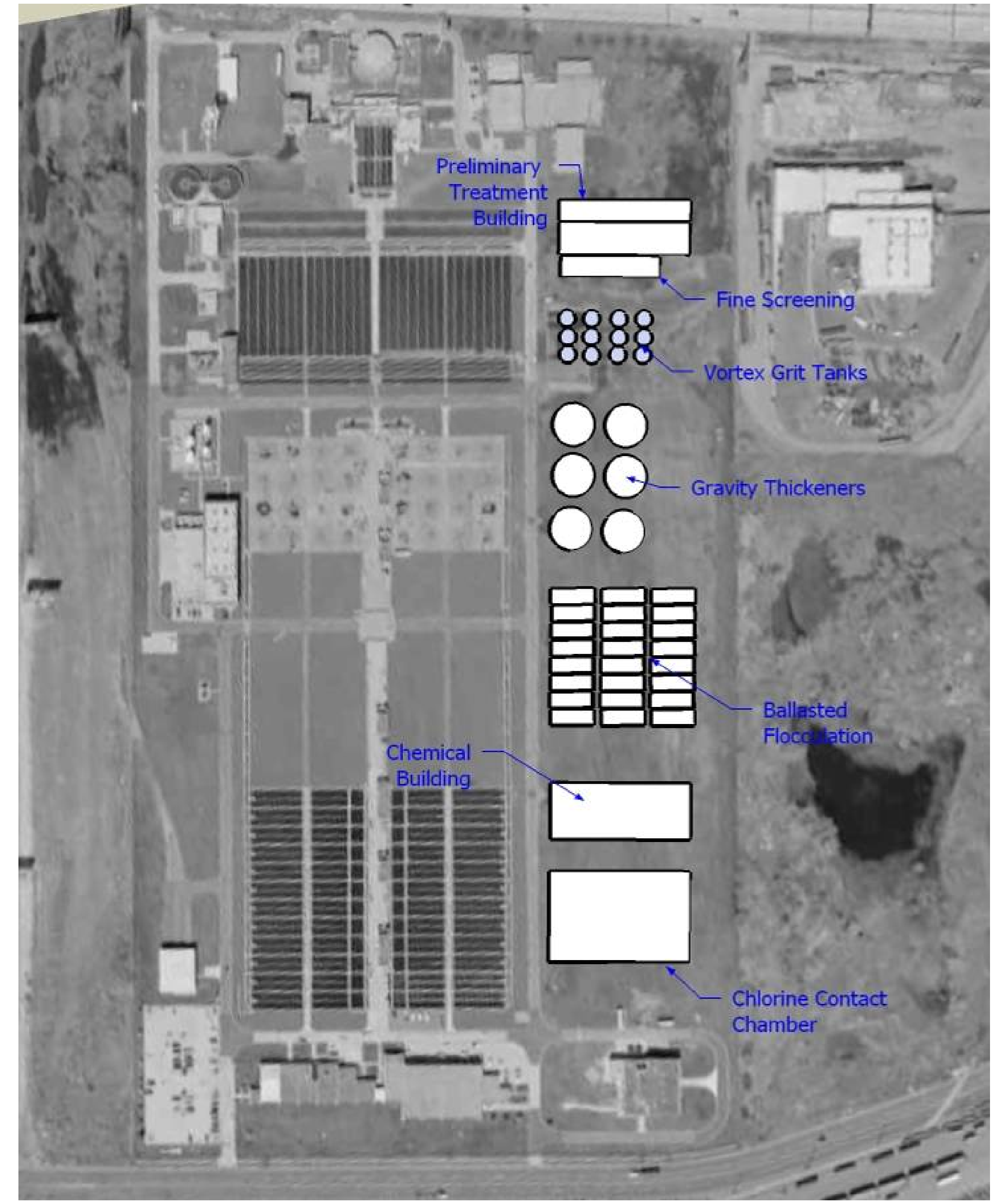
Flow (mgd)	Primary Sludge Pumps		Thickened Sludge Pumps		Sludge Prod. lb/day	Digesters (SW WPCP)
	# Duty	# Standby	# Duty	# Standby		# units
80	2	1	2	1	159,825	1
200	4	1	4	1	399,564	1
900	18	6	4	1	457,500	1
1200	24	8	4	1	457,500	1

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 Total Storage Vol (Gal)	Dry 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 (Ton)	# Duty Pumps	# Standby Pumps	Total Storage Vol (Gal)	# Duty Pumps	# Standby Pumps	Total Storage Vol (Gal)	# Duty Pumps	# Standby Pumps	# Trains	# Units
80	1	1	1	32	1	2	1	1	1	1	551	83,940	2	1	600	7	2	1	39,831	1	1	6,226	1	1	2	2
200	2	3	2	32	2	4	2	1	2	1	1377	209,851	4	1	900	17	4	1	99,579	1	1	6,226	1	1	4	4
900	9	12	9	32	9	18	9	3	9	5	1577	240,279	18	5	1200	19	18	5	114,018	1	1	6,606	1	1	18	4
1200	12	16	12	32	12	24	12	4	12	7	1577	240,279	24	6	1200	19	24	6	114,018	1	1	6,606	1	1	24	4

EXHIBIT 8-3
Conceptual Layouts and Footprints for Treatment Train #5: Ballasted Flocculation
80 MGD Layout and 900 MGD (left), 1200 MGD (right)







*Layouts show 2 extra thickeners for existing primary clarifiers

Flow (mgd)	PTB	Grit Units	Fine Screening	Actiflo Units	Chemical Building	CCC	Gravity Thickeners*	TOTAL FOOTPRINT (acres)
80	54' x 47' & 39' x 39'	32' (1 unit)	27' x 38'	32' x 86' (2 unit)	116' x 106'	147' x 287' (7 passes)	80' (2 unit)	1.6
200	80' x 49' x 63' x 39'	32' (2 units)	37' x 38'	32' x 86' (4 units)	165' x 106'	109' x 193' (5 passes) or 176' x 310' (9 passes)	80' (4 units)	1.8
900	197' x 60' & 187' x 39'	32' (9 units)	140' x 38'	32' x 86' (18 units)	187' x 106'	172' x 268' (8 passes)	80' (4 units)	4.0
1200	249' x 61' & 248' x 39'	32' (12 units)	187' x 38'	32' x 86' (24 units)	205' x 106'	172' x 268' (8 passes)	80' (4 units)	4.5

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 or until 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 streams 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 6 to 86 mgd, depending on the flow capacity of the treatment train. Thickened sludge will be pumped to the existing sludge storage tanks at a rate of 0.6 to 9.6 mgd.

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 SE-3.1.

EXHIBIT 8-4
Cost Summary for Ballasted Flocculation: Treatment Train #5

	Wet Weather Flow (mgd)			
Cost	**80**	**200**	**900**	**1200**
Capital Cost ($M)	$159	$278	$837	$1,050
Annual Operations and Maintenance Cost ($M)	$2.1	$3.4	$6.2	$7.0
Present Value of the Cost ($M)	$191	$331	$934	$1,159

EXHIBIT 8-5
Capital Costs for Treatment Train #5: Ballasted Flocculation

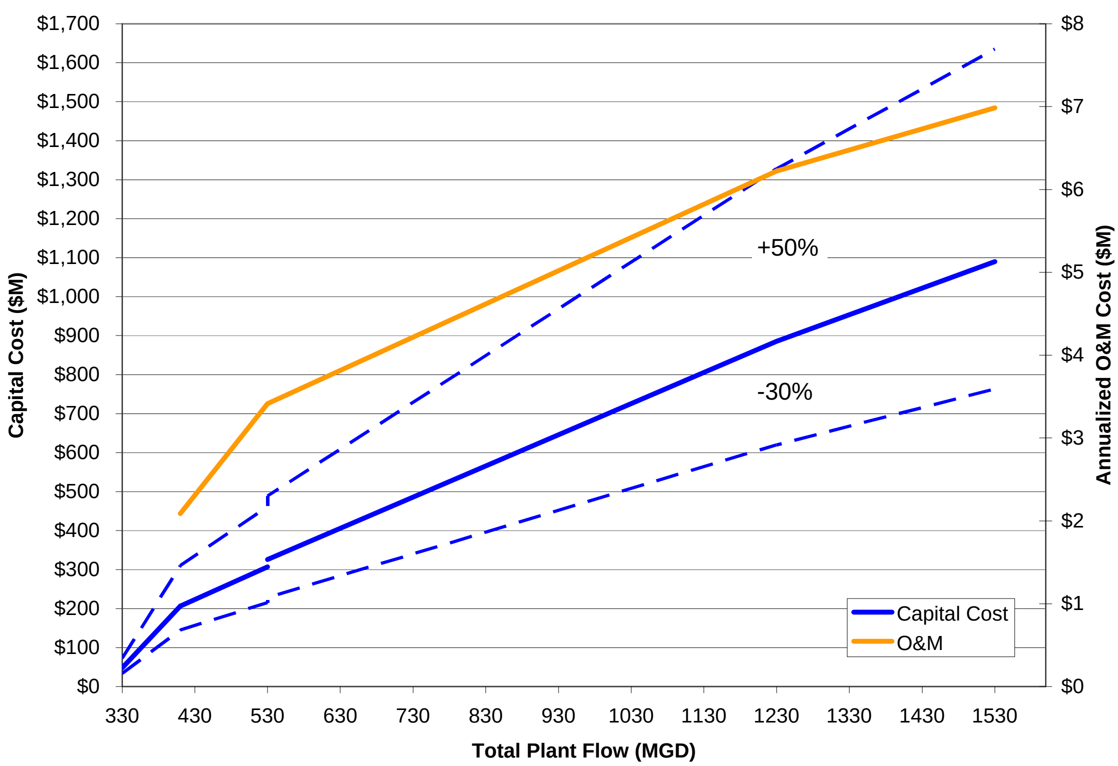


EXHIBIT 8-6
Capital Costs per Gallon Treated for Treatment Train #5: Ballasted Flocculation

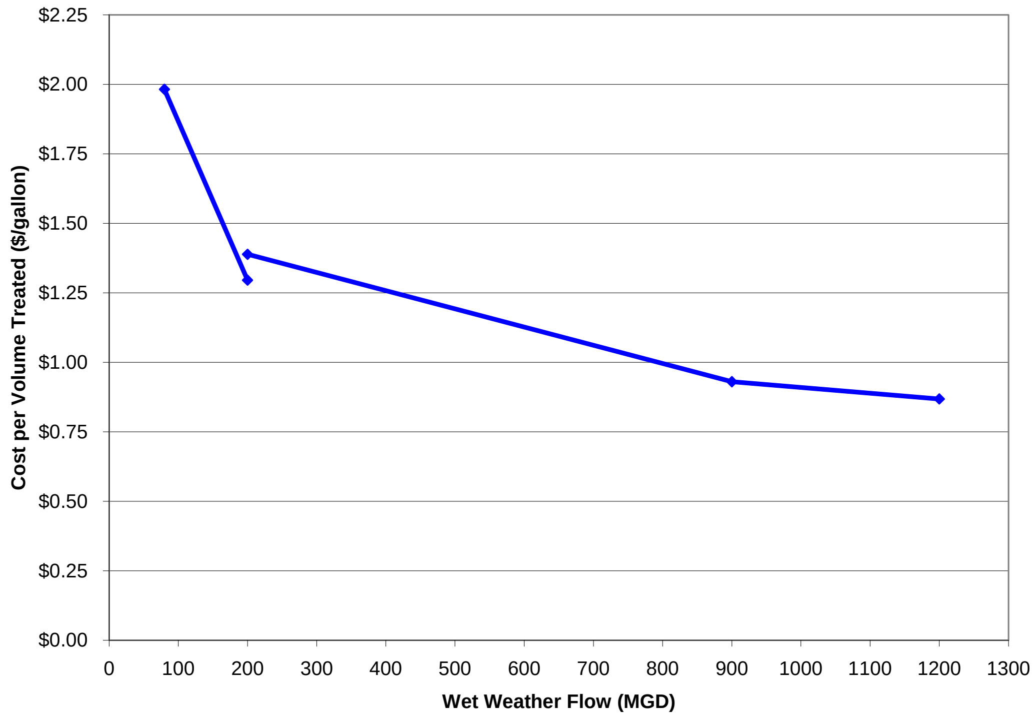
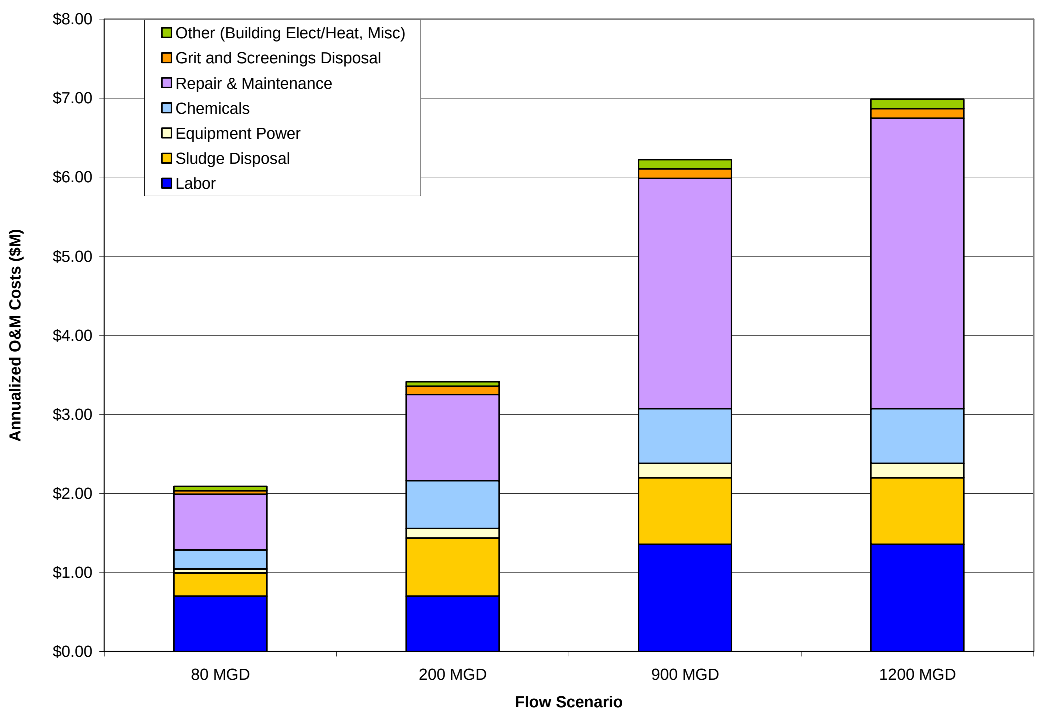


EXHIBIT 8-7
Operations and Maintenance Costs by Category for Treatment Train #5: Ballasted Flocculation



9.0 Alternatives for Optimizing Capital Costs

9.1 Polymer Usage

For Trains #3-#5, polymer is added as a flocculant to the wet weather flow. The capital costs presented for these trains include the cost for both a liquid polymer system and a dry polymer feed system. The liquid polymer system is sized for a 20-hour storage of 40 percent emulsion polymer, and would be used during the first two hours of start up of the wet weather treatment facility. This allows time for the dry polymer to be mixed and aged. The dry polymer system would include a hopper and solution tank(s) for mixing and aging. Ten day storage of dry polymer supersacks would be maintained on site.

An alternative to using dry polymer would be to maintain a 10-day storage of the liquid polymer in bulk storage tanks. The capital cost savings from using liquid polymer only for various flow scenarios is presented in Exhibit 9-1.

EXHIBIT 9-1
Capital Cost of Using Liquid Polymer Only

	Total Capital Cost ($)		
Flow (mgd)	**Liquid and Dry Polymer**	**Liquid Polymer Only**	**Cost Differential**
80	$2,142,080	$1,088,080	$1,054,000
200	$3,538,778	$1,424,771	$2,114,007
470	$5,085,895	$2,574,029	$2,511,866
900	$7,016,125	$3,355,787	$3,660,338

Note: 40% active liquid emulsion polymer assumed.

The capital cost savings are mostly due to the high cost of the dry polymer feed equipment. The main advantage of dry polymer systems is the reduction in chemical costs, which contribute significantly to the operations and maintenance costs of the plant. Dry polymer is $3400 per dry ton, which is approximately 15% cheaper than liquid polymer ($3983 per dry ton for 40 percent active emulsion). Dry polymer also has a 12-month shelf life, which is double that for liquid polymer. This is useful for systems where wet weather events occur less frequently or predictably.

Since the chemical cost of dry polymer is lower than liquid polymer, but the capital costs are higher for the dry polymer system, there is not a significant difference in the life cycle cost of the two alternatives. Thus, selection of the polymer system often depends on operational preferences. Liquid polymer systems are easier to maintain than dry polymer systems, which have the risk of clogging in the hopper and feed-lines. Having only one system to operate also reduces the complexity of the chemical feed system.

9.2 Digesters at the SW WPCP

The capital cost of one digester was included for each of the treatment trains and flow scenarios described in previous sections. Since sludge from the SE WPCP is currently transferred to the SW WPCP for treatment, the new digester is assumed to be located in the SW WPCP also.

According to PWD, as discussed in Workshop No. 3, the existing digesters at the SW WPCP may have adequate capacity to treat the wet weather flow. Since there will be gravity thickeners in the new wet weather treatment facility, the thickness and pumping rate of the sludge transferred to the SW WPCP can be controlled. Sludge can also be stored in the gravity thickeners and metered to the SW WPCP at the desired flow-rate.

The need to expand the digestion capacity of the SW WPCP for treatment of primary sludge from the SE WPCP will be determined after further analysis of the digesters and the wet weather treatment trains in SW WPCP. The costs of the digester (without markups) are included as separate line items in the detailed cost tables in Attachment SE-3.1 and can be subtracted from the total if necessary.

9.3 Ballasted Flocculation

As mentioned in Section 8, the costs presented for Treatment Train #5, Ballasted Flocculation, are based on the Actiflo system, which is 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.

9.4 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

While each flow scenario for each treatment train evaluated above is capable of producing blended effluent concentrations that meet permit limits, the resulting water quality differs widely between different scenarios. The TSS and BOD 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)*						
		80	***200***	***380***	***470***	***540***	***900***	***1200***
#1) Vortex/Swirl Concentrators								
High Loading Rate:	154	59	81	99				
Low Loading Rate:	77	44	51				66	
#2) Conventional Clarifiers	99	48	60			75	82	
#3) CEPT w/ Conventional Clarifiers	44	38	39		41		42	
#4) CEPT w/ Plate Settlers	42	37	38				40	
#5) Ballasted Flocculation	21	33	30				25	24

Notes: Based on the 95th percentile wet weather TSS concentration of 36 mg/L and a maximum of 330 MGD through the existing plant. Allowable daily blended effluent TSS concentration on wet weather days is 99 mg/L, based on permit limits.

EXHIBIT 10-2
Blended Effluent BOD Concentrations

Treatment Train	Wet Weather Treatment Train Effluent Conc. (mg/L)	Blended Effluent BOD Concentration (mg/L)						
		Wet Weather Treatment Train Flow (mgd)						
		80	***200***	***380***	***470***	***540***	***900***	***1200***
#1) Vortex/Swirl Concentrators								
High Loading Rate:	100	38	52	64				
Low Loading Rate:	63	31	38				52	
#2) Conventional Clarifiers	74	38	52			71	79	
#3) CEPT w/ Conventional Clarifiers	47	28	32		37		41	
#4) CEPT w/ Plate Settlers	46	28	32				40	
#5) Ballasted Flocculation	36	26	28				33	33

Notes: Based on the 95th percentile wet weather BOD concentration of 23 mg/L and a maximum of 330 MGD through the existing plant. Allowable daily blended effluent BOD concentration on wet weather days is 106 mg/L, based on permit limits.

It should be noted that at wet weather flows higher than 200 mgd, the blended effluent BOD concentrations for Trains #1 and #2 exceed the NPDES permit Instantaneous (daily composite) Maximum Discharge Limitation of 60 mg/L (Exhibit 10-2). While this limit is stated in the permit, there are currently no reporting requirements for this specific data point.

In addition, with an estimated removal efficiency of 30 percent at high loading rates, the vortex/swirl treatment train does not meet removal efficiencies of primary clarification (55 percent).

As described in Section 3.1, the maximum flow through all the treatment trains, with the exception of the vortex swirl at high loading rates, 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 exceeding monthly TSS permit limits.

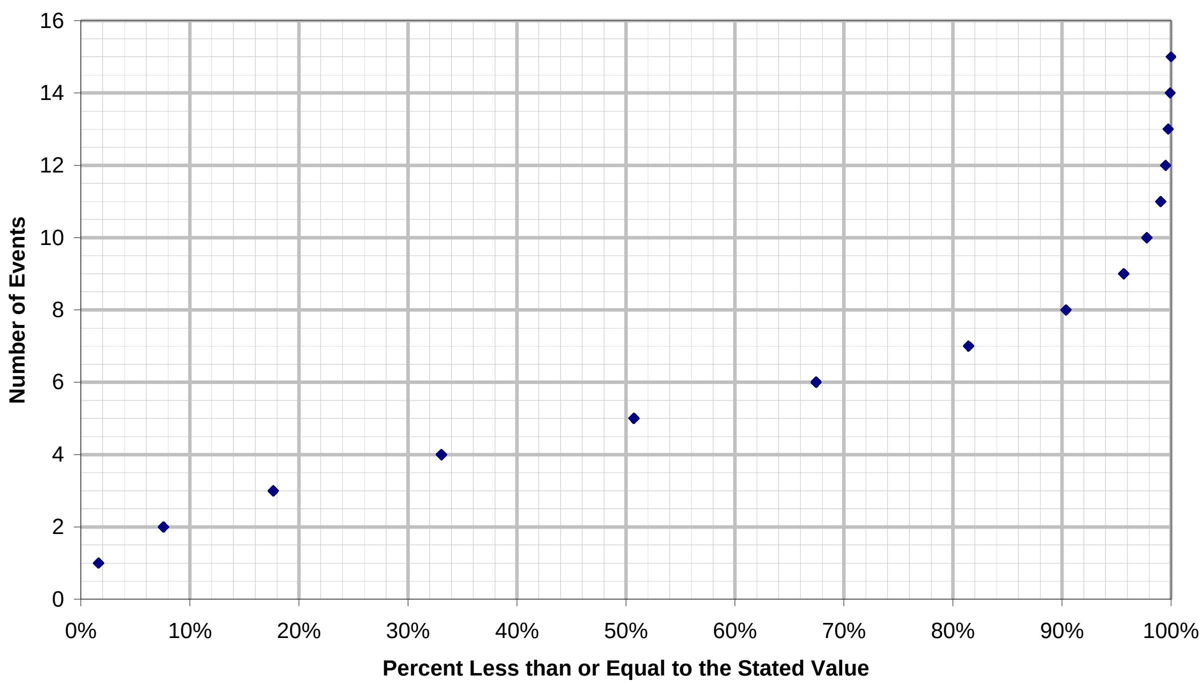
A frequency plot of the number of wet weather events per month and the duration of each event is shown in Exhibits 10-4 and 10-5 for comparison purposes. As shown, wet weather events have occurred at a historical maximum of 15 per month. This suggests that CEPT, CEPT with Plates, and Ballasted Flocculation have a very low probability of exceeding permit limits. Exhibit 10-5 also shows that approximately 95% of events do not last as long as 24 hours, which is the event duration assumed in this study. 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 10-3
Allowable Number of Operating Days of Wet Weather Treatment Train

	Maximum Allowable Number of Operating Days per Month[1]						
	Wet Weather Treatment Train Flow (mgd)						
Treatment Train	***80***	***200***	***380***	***470***	***540***	***900***	***1200***
#1) Vortex/Swirl Concentrators							
High Loading Rate:	13	9	7				
Low Loading Rate:	18	15				11	
#2) Conventional Clarifiers	17	13			10	9	
#3) CEPT w/ Conventional Clarifiers	23	21		20		20	
#4) CEPT w/ Plate Settlers	23	21				19	
#5) Ballasted Flocculation	U N L I M I T E D						

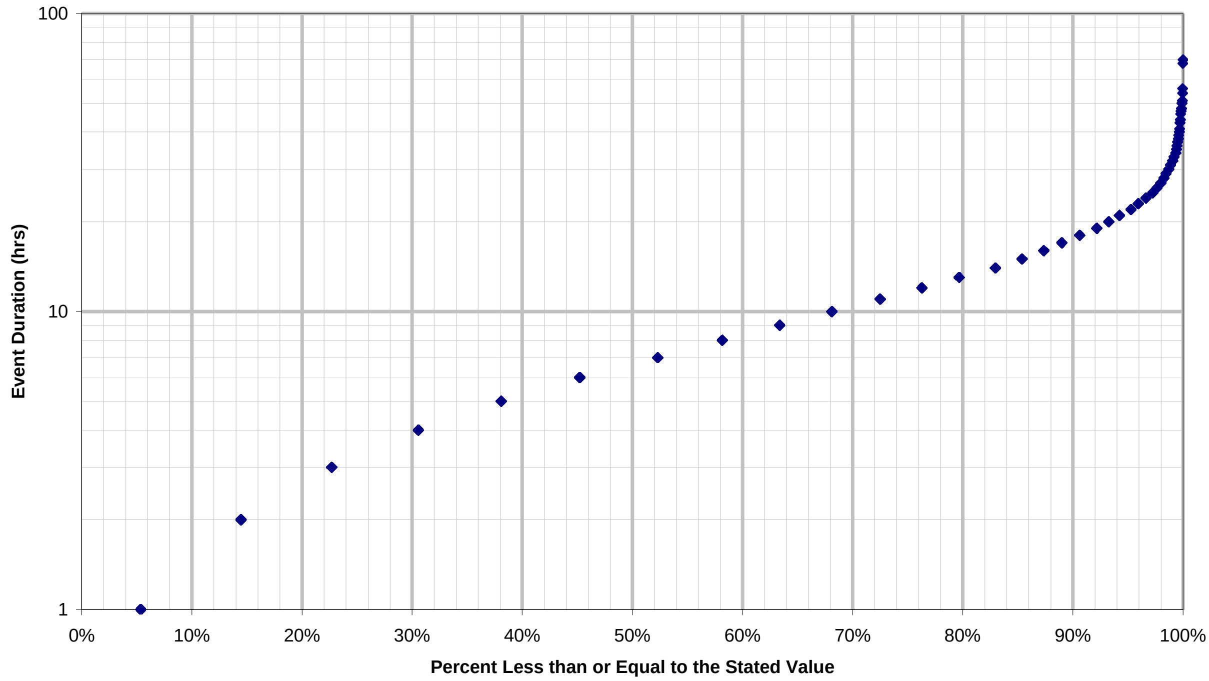
Notes:
(1) Allowable number of operating days without exceeding permit limits for monthly TSS concentrations. Assumes entire plant operates at maximum capacity during every wet weather event.

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)

EXHIBIT 10-5
Cumulative Frequency Plot of Wet Weather Event Duration



10.2 Capital, O&M and Life-Cycle Costs

The capital cost estimates for the five treatment trains are shown in Exhibit 10-6. Train #4, CEPT with Plates, is the most expensive, followed by Train #1, vortex/swirl at low loading rates. Trains #2, 3, and 5 appear to have similar costs throughout the entire flow range, with Train 5 being slightly less costly. Translated into a cost per volume treated, all trains appear to become more cost effective as flow capacity increases (Exhibit 10-7).

The comparison of O&M costs for each treatment train is shown in Exhibit 10-8. As expected, the O&M costs are lowest for vortex swirls at high loading and conventional clarifiers, which do not require chemical settling aids. Vortex swirls at low loading rates has the highest O&M costs for repair and maintenance of the large number of vortex units and gravity thickeners required.

Taking construction, non-construction, and O&M costs into consideration, Exhibit 10-9 shows the present value of the total cost of each wet weather treatment train. Train #4, CEPT with Plates, remains most costly since it requires the highest capital and O&M costs. Train #1, vortex/swirl concentrators, appears to be least costly from the life-cycle cost perspective, especially at lower flows. This is due to its low chemical usage and minimal operations and maintenance needs.

EXHIBIT 10-6
Comparison of Capital Costs for All Treatment Trains

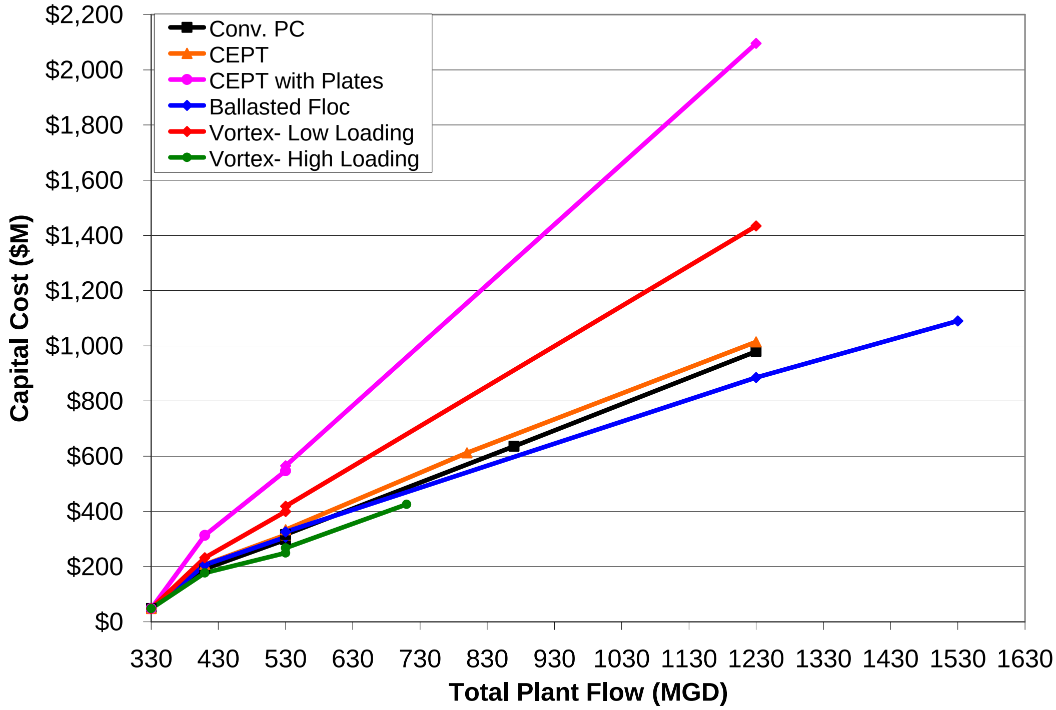


EXHIBIT 10-7
Comparison of Cost Effectiveness for all Treatment Trains

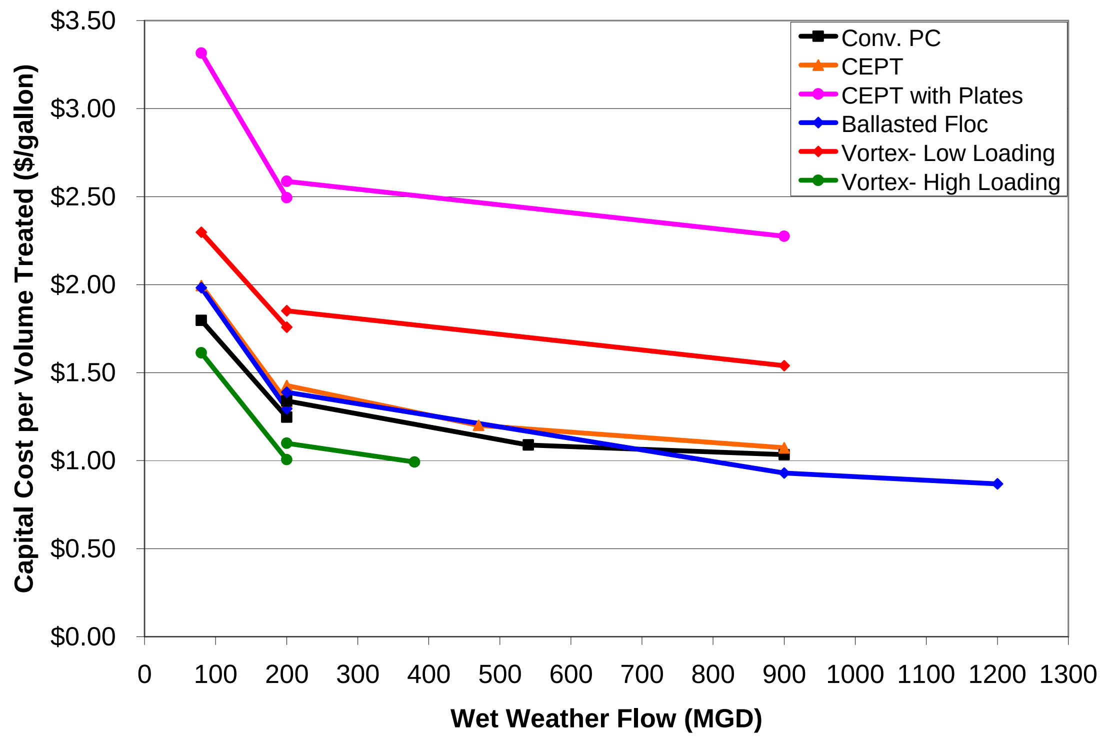


EXHIBIT 10-8
Comparison of Operations and Maintenance Costs for all Treatment Trains

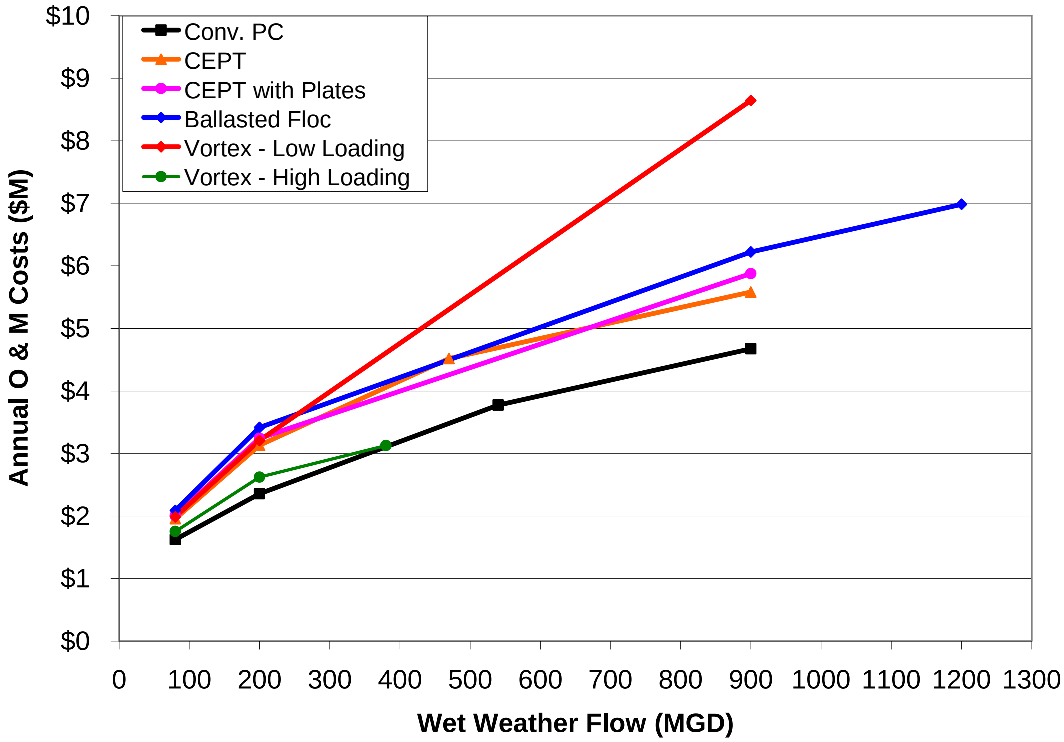
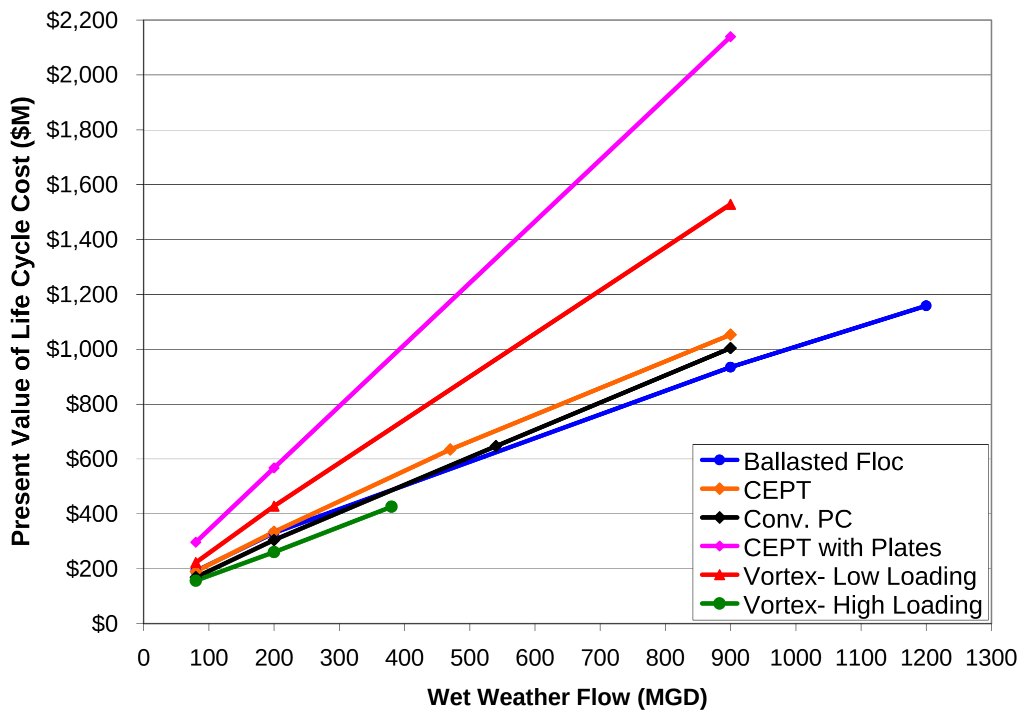


EXHIBIT 10-9
Comparison of Life-Cycle Costs for all Treatment Trains



10.3 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, 2008). Several key advantages and disadvantages of Treatment Trains #1 - #5, as evaluated in this report, are described in Exhibit 10-10.

EXHIBIT 10-10
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	• Only cost competitive at high loading rates and low removal efficiencies. • Maximum design flow may decrease if the assumed number of operating days is greater than 7.
Train #2: Conventional Clarifiers	• Simple operation • Same technology as existing plant –operators familiar with equipment	• Space limited • May exceed instantaneous blended effluent BOD concentration at high flows • Maximum design flow may decrease if the assumed number of operating days is greater than 7.
Train #3: CEPT	• Lower chlorine dose possible due to high TSS removal efficiencies	• Operators unfamiliar with technology • Space limited • Uses chemicals • Can treat less flow on existing site than conventional clarifiers • Operators unfamiliar with technology

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

Treatment Train	Pros	Cons
Train #4: CEPT with Plates	• Can treat 900 mgd with available land on site • Lower chlorine dose possible due to high TSS removal efficiencies • Unlimited number of operating days per month	• Highest capital and O&M costs • Operators unfamiliar with technology • Labor intensive to clean plants • Uses chemicals
Train #5: Ballasted Flocculation	• Can treat up to 1200 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 • Second most labor intensive • Uses chemicals

The costs for wet weather treatment at the SE 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 SE-3.1

Breakdown of Capital and O&M Costs

SE WPCP Wet Weather Treatment Train Alternatives: Capital Cost Estimates

Train	Train #1: Vortex/Swirl (High Loading)			Train #1: Vortex/Swirl (Low Loading)			Train #2: Conventional Clarifiers				Train #3: CEPT				Train #4: CEPT with Plates			Train #5: Ballasted Flocculation			
Flow (mgd)	**80**	**200**	**380**	**80**	**200**	**900**	**80**	**200**	**540**	**900**	**80**	**200**	**470**	**900**	**80**	**200**	**900**	**80**	**200**	**900**	**1200**
Influent Pump Station	$2,122,627	$5,631,906	$9,388,002	$2,122,627	$5,631,906	$22,010,403	$2,122,627	$5,631,906	$13,045,081	$22,010,403	$2,122,627	$5,631,906	$12,756,816	$22,010,403	$2,122,627	$5,631,906	$22,010,403	$2,122,627	$5,631,906	$22,010,403	$29,225,910
Bar Screens, Grit Removal, and Fine Screens	$2,174,459	$3,571,408	$6,321,003	$2,174,459	$3,571,408	$16,274,338	$2,671,182	$4,393,646	$12,552,412	$18,730,269	$2,671,182	$4,393,646	$12,552,412	$18,730,269	$4,202,721	$6,921,999	$29,376,212	$4,146,536	$6,921,999	$29,376,212	$39,121,478
Vortex Swirl	$4,544,219	$8,559,632	$17,182,263	$18,992,110	$44,494,973	$162,023,952	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Flocculation Tanks	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1,834,779	$2,948,232	$7,174,443	$13,080,486	$1,232,049	$2,292,811	$8,535,466	$0	$0	$0	$0
Primary Clarifiers	$0	$0	$0	$0	$0	$0	$5,260,886	$13,952,342	$33,916,953	$56,426,292	$4,998,354	$10,348,111	$23,829,752	$45,513,491	$31,218,084	$68,171,521	$310,824,165	$0	$0	$0	$0
Actiflo System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$6,712,290	$13,938,850	$61,514,152	$81,881,502
Chemical Feed	$884,228	$1,341,043	$1,412,064	$884,228	$1,341,043	$1,697,079	$884,228	$1,341,043	$1,537,520	$1,697,079	$2,548,832	$4,454,101	$5,428,866	$6,503,527	$2,501,908	$4,394,173	$6,889,386	$2,586,797	$4,504,520	$7,366,049	$7,493,387
Chlorine Contact Chamber [1]	$5,785,202	$2,995,062	$5,350,790	$5,785,202	$2,995,062	$6,247,533	$5,785,202	$2,995,062	$6,247,533	$6,247,533	$5,785,202	$2,995,062	$5,871,000	$6,247,533	$5,785,202	$2,995,062	$6,247,533	$5,785,202	$2,995,062	$6,247,533	$6,247,533
Gravity Thickeners	$2,101,375	$5,188,585	$9,548,932	$2,101,375	$5,188,585	$23,626,401	$1,159,641	$2,336,314	$2,295,689	$2,413,240	$1,300,370	$3,688,352	$3,680,418	$4,537,578	$1,334,570	$3,652,905	$3,791,428	$2,197,719	$4,685,560	$4,607,787	$4,952,167
Yard Piping (large)	$87,258	$4,542,120	$10,949,456	$87,258	$4,542,120	$31,387,935	$351,671	$5,101,234	$15,891,273	$31,387,935	$305,074	$4,972,860	$13,333,799	$29,259,107	$345,950	$4,990,074	$25,038,634	$361,619	$5,185,832	$20,620,767	$26,705,083
Digesters at SW WPCP	$6,242,029	$6,224,117	$6,224,117	$6,200,750	$6,289,794	$6,307,706	$6,307,706	$6,271,882	$6,271,882	$6,283,824	$6,254,027	$6,367,471	$6,355,472	$6,379,355	$6,373,384	$6,349,501	$6,379,355	$6,248,000	$6,373,384	$6,403,238	$6,403,238
Subtotal Project Cost	$23,941,397	$38,053,873	$66,376,627	$38,348,009	$74,054,891	$269,575,347	$24,543,143	$42,023,429	$91,758,343	$145,196,575	$27,820,447	$45,799,741	$90,982,978	$152,261,749	$55,116,495	$105,399,952	$419,092,582	$30,160,790	$50,237,113	$158,146,141	$202,030,298
Additional Project Costs:																					
General Demolition	$239,414	$380,539	$663,766	$383,480	$740,549	$2,695,753	$245,431	$420,234	$917,583	$1,451,966	$278,204	$457,997	$909,830	$1,522,617	$551,165	$1,054,000	$4,190,926	$301,608	$502,371	$1,581,461	$2,020,303
Overall Sitework	$1,915,312	$3,044,310	$5,310,130	$3,067,841	$5,924,391	$21,566,028	$1,963,451	$3,361,874	$7,340,667	$11,615,726	$2,225,636	$3,663,979	$7,278,638	$12,180,940	$4,409,320	$8,431,996	$33,527,407	$2,412,863	$4,018,969	$12,651,691	$16,162,424
Plant Computer System	$2,035,019	$3,234,579	$5,642,013	$3,259,581	$6,294,666	$22,913,904	$2,086,167	$3,571,991	$7,799,459	$12,341,709	$2,364,738	$3,892,978	$7,733,553	$12,942,249	$4,684,902	$8,958,996	$35,622,869	$2,563,667	$4,270,155	$13,442,422	$17,172,575
Yard Electrical	$1,915,312	$3,044,310	$5,310,130	$3,067,841	$5,924,391	$21,566,028	$1,963,451	$3,361,874	$7,340,667	$11,615,726	$2,225,636	$3,663,979	$7,278,638	$12,180,940	$4,409,320	$8,431,996	$33,527,407	$2,412,863	$4,018,969	$12,651,691	$16,162,424
Yard Piping	$1,197,070	$1,902,694	$3,318,831	$1,917,400	$3,702,745	$13,478,767	$1,227,157	$2,101,171	$4,587,917	$7,259,829	$1,391,022	$2,289,987	$4,549,149	$7,613,087	$2,755,825	$5,269,998	$20,954,629	$1,508,040	$2,511,856	$7,907,307	$10,101,515
Subtotal with Additional Project Costs	$31,243,523	$49,660,304	$86,621,498	$50,044,152	$96,641,633	$351,795,828	$32,028,802	$54,840,575	$119,744,638	$189,481,530	$36,305,683	$59,768,662	$118,732,786	$198,701,582	$71,927,026	$137,546,937	$546,915,820	$39,359,831	$65,559,432	$206,380,714	$263,649,539
Subtotal with Contractor Markups (1)	$47,363,228	$75,281,917	$131,312,777	$75,863,806	$146,502,675	$533,300,488	$48,553,661	$83,134,884	$181,525,387	$287,242,157	$55,037,147	$90,605,556	$179,991,483	$301,219,180	$109,036,876	$208,512,560	$829,090,200	$59,667,044	$99,384,002	$312,860,264	$399,676,223
Subtotal with Escalation (2)	$56,741,147	$91,241,684	$159,938,963	$90,884,840	$177,561,242	$683,691,225	$58,167,286	$100,759,479	$224,909,954	$368,244,446	$65,934,502	$109,813,934	$223,009,448	$386,162,989	$130,626,177	$252,717,223	$1,062,893,637	$71,481,118	$120,453,411	$401,086,858	$512,384,918
Subtotal with Local Adjustment Factor (3)	$65,365,802	$105,110,420	$184,249,685	$104,699,336	$204,550,551	$787,612,292	$67,008,714	$116,074,920	$259,096,267	$424,217,602	$75,956,546	$126,505,652	$256,906,884	$444,859,763	$150,481,356	$291,130,241	$1,224,453,469	$82,346,248	$138,762,329	$462,052,060	$590,267,425
Dewatering	$478,828	$761,077	$1,327,533	$766,960	$1,481,098	$5,391,507	$490,863	$840,469	$1,835,167	$2,903,932	$556,409	$915,995	$1,819,660	$3,045,235	$1,102,330	$2,107,999	$8,381,852	$603,216	$1,004,742	$3,162,923	$4,040,606
Structural Piles	$15,304,402	$36,018,756	$61,498,606	$17,521,109	$41,718,838	$134,290,191	$23,497,058	$57,161,259	$127,318,237	$184,492,705	$25,059,764	$58,398,412	$113,675,451	$186,934,310	$20,643,141	$47,658,253	$131,502,609	$17,970,287	$40,803,944	$89,729,825	$102,658,755
Subtotal - Construction Cost, including Market Adjustment Factor (4)	**$93,321,386**	**$163,173,792**	**$284,137,197**	**$141,435,516**	**$284,913,060**	**$1,066,388,087**	**$104,646,130**	**$200,188,144**	**$446,487,122**	**$703,356,374**	**$116,808,627**	**$213,693,067**	**$428,262,293**	**$730,065,204**	**$198,060,851**	**$392,030,967**	**$1,568,988,620**	**$116,057,714**	**$207,656,668**	**$638,186,529**	**$801,511,805**
Total Construction Cost + Non-Construction Costs (5)	**$121,317,802**	**$212,125,929**	**$369,378,356**	**$183,866,171**	**$370,386,978**	**$1,386,304,514**	**$136,039,969**	**$260,244,588**	**$580,433,258**	**$914,363,286**	**$151,851,216**	**$277,800,987**	**$556,740,981**	**$949,084,766**	**$257,479,107**	**$509,640,257**	**$2,039,685,206**	**$150,875,028**	**$269,953,668**	**$829,642,488**	**$1,041,965,346**
Land Acquisition Cost	-	-	-	-	-	-	-	-	-	$9,227,680	-	-	-	$9,227,680	-	-	-	-	-	-	-
Additional Sludge Force Main and Pump to SW (with standard markups)	$7,741,926	$7,741,926	$7,741,926	$7,741,926	$7,741,926	$7,741,926	$7,741,926	$7,741,926	$7,741,926	$7,741,926	$7,741,926	$7,741,926	$7,741,926	$7,741,926	$7,741,926	$7,741,926	$7,741,926	$7,741,926	$7,741,926	$7,741,926	$7,741,926
Total Capital Cost (with non construction costs)	**$129,059,728**	**$219,867,855**	**$377,120,282**	**$191,608,097**	**$378,128,904**	**$1,394,046,440**	**$143,781,895**	**$267,986,514**	**$588,175,184**	**$931,332,892**	**$159,593,142**	**$285,542,913**	**$564,482,907**	**$966,054,372**	**$265,221,032**	**$517,382,183**	**$2,047,427,132**	**$158,616,954**	**$277,695,594**	**$837,384,414**	**$1,049,707,272**
Total Capital Cost ($M)	$129	$220	$377	$192	$378	$1,394	$144	$268	$588	$931	$160	$286	$564	$966	$265	$517	$2,047	$159	$278	$837	$1,050
.+50% Capital Cost ($M)	$194	$330	$566	$287	$567	$2,091	$216	$402	$882	$1,397	$239	$428	$847	$1,449	$398	$776	$3,071	$238	$417	$1,256	$1,575
.-30% Capital Cost ($M)	$90	$154	$264	$134	$265	$976	$101	$188	$412	$652	$112	$200	$395	$676	$186	$362	$1,433	$111	$194	$586	$735
Cost Efficiency ($/gallon)	**$1.52**	**$1.06**	**$0.97**	**$2.30**	**$1.85**	**$1.54**	**$1.70**	**$1.30**	**$1.07**	**$1.02**	**$1.90**	**$1.39**	**$1.18**	**$1.05**	**$3.22**	**$2.55**	**$2.27**	**$1.89**	**$1.35**	**$0.92**	**$0.87**
Total cost w/o new outfall (200 mgd only) (6)	-	*$201,269,552*	-	-	*$359,530,601*	-	-	*$249,388,211*	-	-	-	*$267,027,800*	-	-	-	*$498,812,242*	-	-	*$259,095,577*	-	-

Notes:
1. Contractor markups - use 1.516 multiplier (see TM-SE3 Section 3.3)
2. Escalation - multiplier depends on duration of construction (see Exhibit 3-7 in TM-SE3 Section 3.3)
3. Local Adjustment Factor - use 1.152 multiplier (see TM-SE3 Section 3.3)
4. Market Adjustment Factor - use 1.15 multiplier (see TM-SE3 Section 3.3)
5. Non-construction costs - use 1.3 multiplier (see TM-SE3 Section 3.3)
6. For 200 mgd flow scenarios, cost assumes construction of new outfall conduits. The total capital cost of the 200 mgd scenario assuming no new outfall conduits is provided in the last line item of this table.

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

	Flow (mgd)	Labor	Sludge Disposal	Equipment Power [2]	Building Electrical/ Heating	Chemicals	Repair & Maintenance	Grit and Screenings Disposal	Other [3]	Total	Horsepower requirements (HP)
Train #1: Vortex/Swirls (low loading)	80	$699,027	$160,864	$39,449	$3,373	$60,573	$936,611	$35,354	$50,819	$1,986,070	1,062
	200	$699,027	$402,160	$102,428	$4,659	$151,432	$1,707,719	$88,385	$50,819	$3,206,631	2,758
	900	$1,354,994	$1,578,767	$149,665	$8,908	$173,390	$5,176,807	$101,201	$101,639	$8,645,371	10,747
Train #1: Vortex/Swirls (high loading)	80	$699,027	$254,554	$40,563	$3,406	$60,573	$609,290	$35,354	$50,819	$1,753,587	1,092
	200	$699,027	$636,386	$97,229	$4,598	$151,432	$894,642	$88,385	$50,819	$2,622,518	2,618
	380	$699,027	$649,114	$143,541	$5,582	$154,461	$1,335,947	$90,153	$50,819	$3,128,643	4,352
Train #2: Conventional Clarifiers	80	$705,743	$137,424	$35,741	$3,496	$61,155	$594,635	$35,694	$51,308	$1,625,195	953
	200	$699,027	$340,290	$89,654	$4,648	$151,432	$930,707	$88,385	$50,819	$2,354,962	2,414
	540	$1,311,933	$347,095	$125,693	$6,852	$154,461	$1,636,960	$90,153	$101,639	$3,774,787	5,415
	900	$1,354,994	$389,632	$127,226	$8,900	$154,461	$2,436,369	$101,201	$101,639	$4,674,421	9,135
Train #3: CEPT	80	$699,027	$261,900	$37,484	$4,836	$241,031	$627,157	$35,354	$50,819	$1,957,609	1,009
	200	$699,027	$654,751	$93,636	$7,306	$602,577	$934,517	$88,385	$50,819	$3,131,019	2,521
	470	$1,311,933	$667,846	$132,579	$9,350	$614,629	$1,589,331	$90,153	$101,639	$4,517,459	5,613
	900	$1,354,994	$749,689	$132,579	$12,042	$689,951	$2,438,076	$101,201	$101,639	$5,580,170	9,520
Train #4: CEPT with Plates	80	$699,027	$261,900	$37,413	$5,044	$241,031	$667,025	$42,347	$50,819	$2,004,606	1,007
	200	$699,027	$654,751	$93,376	$7,429	$602,577	$1,029,275	$105,868	$50,819	$3,243,121	2,514
	900	$1,354,994	$749,689	$133,637	$14,753	$689,951	$2,710,235	$121,219	$101,639	$5,876,116	9,596
Train #5: Ballasted Flocculation	80	$699,027	$294,638	$50,690	$5,258	$241,868	$703,804	$42,347	$50,819	$2,088,452	1,365
	200	$699,027	$736,594	$122,797	$7,774	$604,670	$1,086,942	$105,868	$50,819	$3,414,492	3,307
	900	$1,354,994	$843,401	$182,122	$14,465	$692,347	$2,912,439	$121,219	$101,639	$6,222,625	13,077
	1200	$1,354,994	$843,401	$182,122	$15,759	$692,347	$3,674,634	$121,219	$101,639	$6,986,114	17,357

Notes:
1. All O&M costs are annualized costs based on escalation through a 30-year period. For flows of 470 mgd and higher, costs are based on an average flow of 337.5 mgd (see TM-SE3 Section 3.3)
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	Equipment Power	Building Electrical/ Heating	Chemicals	Repair & Maintenance	Grit and Screenings Disposal	Other
Train #1: Vortex/Swirls (low loading)	80	35.2%	8.1%	2.0%	0.2%	3.0%	47.2%	1.8%	2.6%
	200	21.8%	12.5%	3.2%	0.1%	4.7%	53.3%	2.8%	1.6%
	900	15.7%	18.3%	1.7%	0.1%	2.0%	59.9%	1.2%	1.2%
Train #1: Vortex/Swirls (high loading)	80	39.9%	14.5%	2.3%	0.2%	3.5%	34.7%	2.0%	2.9%
	200	26.7%	24.3%	3.7%	0.2%	5.8%	34.1%	3.4%	1.9%
	380	22.3%	20.7%	4.6%	0.2%	4.9%	42.7%	2.9%	1.6%
Train #2: Conventional Clarifiers	80	43.4%	8.5%	2.2%	0.2%	3.8%	36.6%	2.2%	3.2%
	200	29.7%	14.4%	3.8%	0.2%	6.4%	39.5%	3.8%	2.2%
	540	34.8%	9.2%	3.3%	0.2%	4.1%	43.4%	2.4%	2.7%
	900	29.0%	8.3%	2.7%	0.2%	3.3%	52.1%	2.2%	2.2%
Train #3: CEPT	80	35.7%	13.4%	1.9%	0.2%	12.3%	32.0%	1.8%	2.6%
	200	22.3%	20.9%	3.0%	0.2%	19.2%	29.8%	2.8%	1.6%
	470	29.0%	14.8%	2.9%	0.2%	13.6%	35.2%	2.0%	2.2%
	900	24.3%	13.4%	2.4%	0.2%	12.4%	43.7%	1.8%	1.8%
Train #4: CEPT with Plates	80	34.9%	13.1%	1.9%	0.3%	12.0%	33.3%	2.1%	2.5%
	200	21.6%	20.2%	2.9%	0.2%	18.6%	31.7%	3.3%	1.6%
	900	23.1%	12.8%	2.3%	0.3%	11.7%	46.1%	2.1%	1.7%
Train #5: Ballasted Flocculation	80	33.5%	14.1%	2.4%	0.3%	11.6%	33.7%	2.0%	2.4%
	200	20.5%	21.6%	3.6%	0.2%	17.7%	31.8%	3.1%	1.5%
	900	21.8%	13.6%	2.9%	0.2%	11.1%	46.8%	1.9%	1.6%
	1200	19.4%	12.1%	2.6%	0.2%	9.9%	52.6%	1.7%	1.5%