Supplemental Documentation Volume 9

Analysis of Wet Weather Treatment Alternatives for Northeast WPCP

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Final Tech Memo

Wet Weather Treatment Alternatives at Northeast, Southeast and Southwest WPCPs

NE2: Analysis of Wet Weather Treatment Alternatives for Northeast WPCP

Prepared for

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Executive Summary

Background and Project Summary

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

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

Conceptual treatment trains were developed for each treatment technology at various wet weather flows ranging from 69 million gallons per day (mgd) to 1100 mgd and cost curves for capital, operations and maintenance (O&M), and lifecycle costs were generated for each treatment train alternative.

Currently, the NE WPCP has a flow capacity of 435 mgd. With several process and hydraulic modifications, as identified in the 2001 Stress Testing Report and the NE WPCP Flow Study, the capacity of the existing plant can potentially reach 650 mgd (CH2M HILL, 2001; CH2M HILL, 2008a, d). This work includes the construction of a 250-mgd secondary bypass from the existing primary sedimentation tanks to the chlorine contact chamber. In sizing the wet weather treatment trains, it was assumed that these upgrades, costing $98.1M, will have been completed, increasing the plant's capacity to a minimum of 650 mgd (Section 2). Any wet weather flow in excess of 650 mgd would be diverted to the new wet weather facility.

To expand the flow capacity of NE WPCP beyond 650 mgd for the treatment of wet weather flows, a separate wet weather treatment train will be required. Wet weather flows in excess of 650 mgd will be diverted to one of the new treatment trains, listed above, eventually blending with effluent from both the secondary system and the bypass from the existing plant. Conceptual designs and cost estimates were performed for each treatment train at various design flows.

Flow Scenarios

Conceptual designs and cost estimates were developed at several design flows for each wet weather treatment train under evaluation (Exhibit ES-1). These flows were selected based on the ability to meet permit requirements, the land area available onsite, and the maximum expected flow from the upgraded collection system, as described in Section 4. The Vortex/Swirl and Conventional Clarification trains were both flow-limited by permit requirements.

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

Treatment Train	Design Flows Evaluated (mgd)
#1) Vortex/Swirl Concentrators	69, 183
#2) Conventional Clarifiers	160, 376
#3) CEPT w/ Conventional Clarifiers	150, 300, 1000
#4) Ballasted Flocculation	150, 500, 1100

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 9 in Exhibits 9-1 and 9-2, 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 while allowing the NE WPCP to continue to meet permit limits.

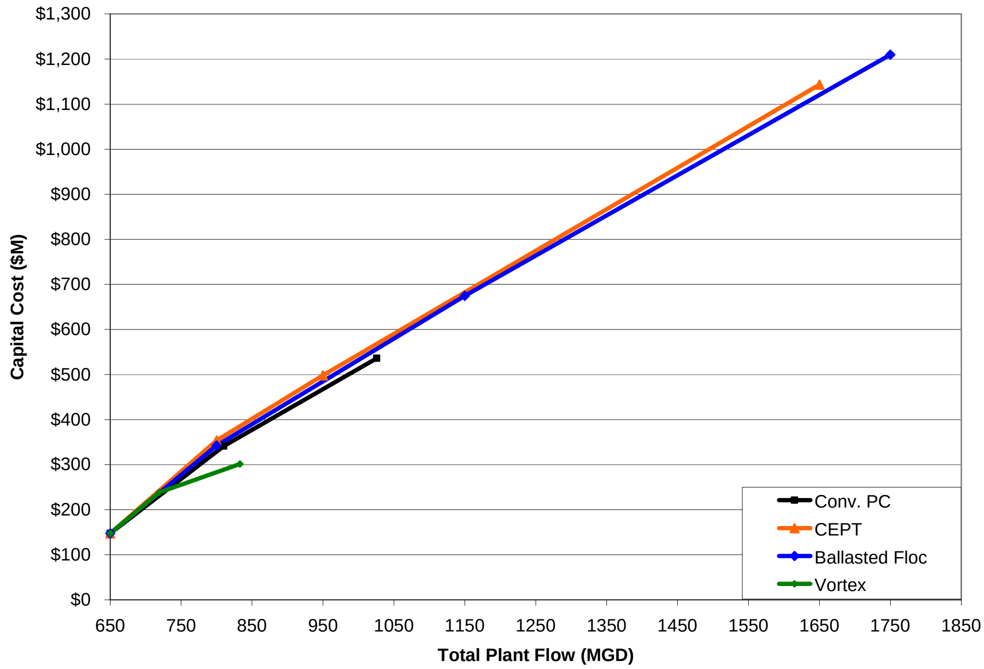
Capital and O&M Costs

As shown in Exhibit ES-2, the capital costs for Trains #2 - #4 track each other very closely, with CEPT being slightly more expensive. Train #1, the vortex/swirl, appears least expensive and most cost effective as flows increase (Exhibit ES-3). Train #3, CEPT, appears slightly less cost-effective than Train #4, Ballasted Flocculation, due to greater cost for piles due to its larger footprint.

The comparison of O&M costs for each treatment train is shown in Exhibit ES-4. As expected, the O&M costs for vortex swirls and conventional clarifiers, which do not require chemical settling aids, are the lowest. Ballasted Flocculation has the highest O&M costs due to the use of chemicals and the complexity of its system.

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. This graph suggests that there is negligible cost difference between Train #3, CEPT, and Train #4, Ballasted Flocculation at this plant. As expected, Trains #1 and #2 are least expensive due to its low chemical usage and minimal O&M costs.

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 ($147 M). Total plant flow includes flow from both the conventional plant and the wet weather treatment facility.

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

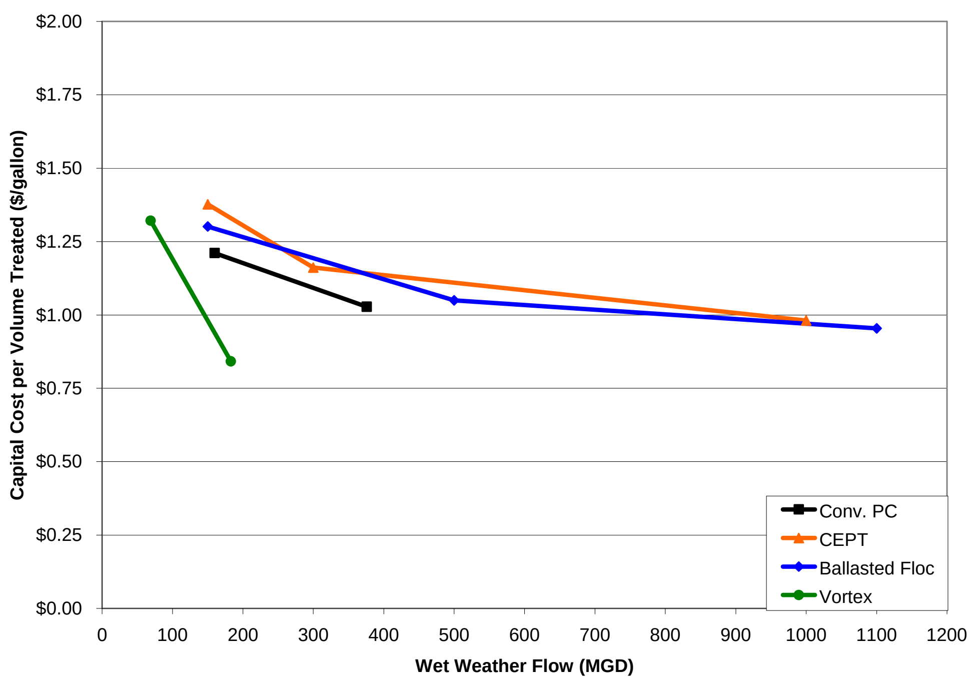


EXHIBIT ES-4
Comparison of Operations and Maintenance Costs for all Treatment Trains

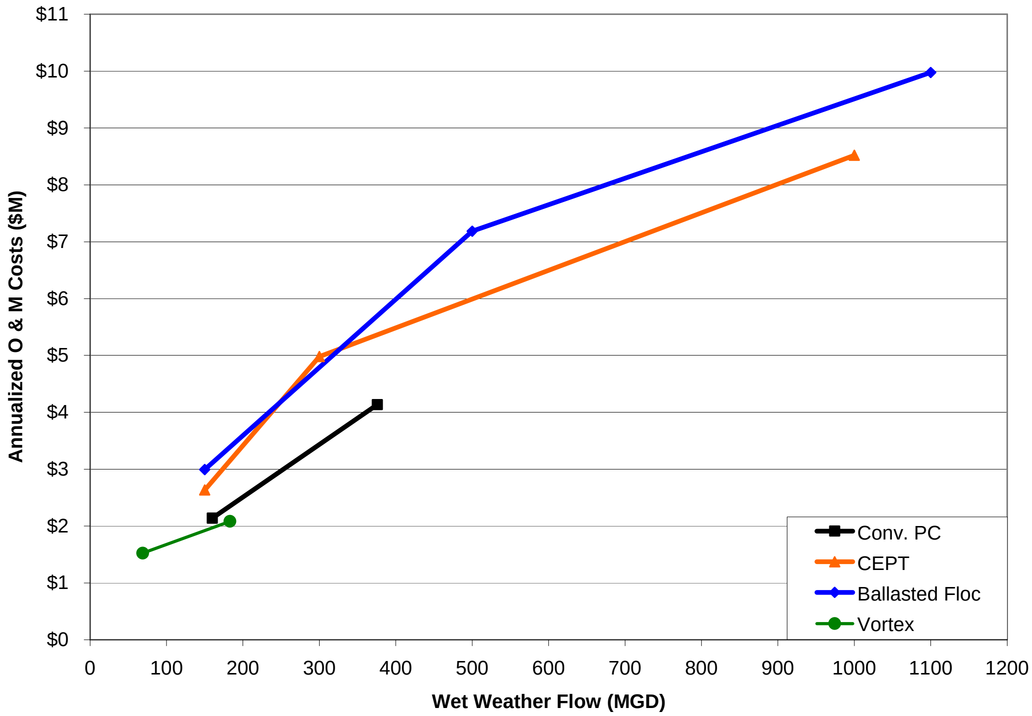
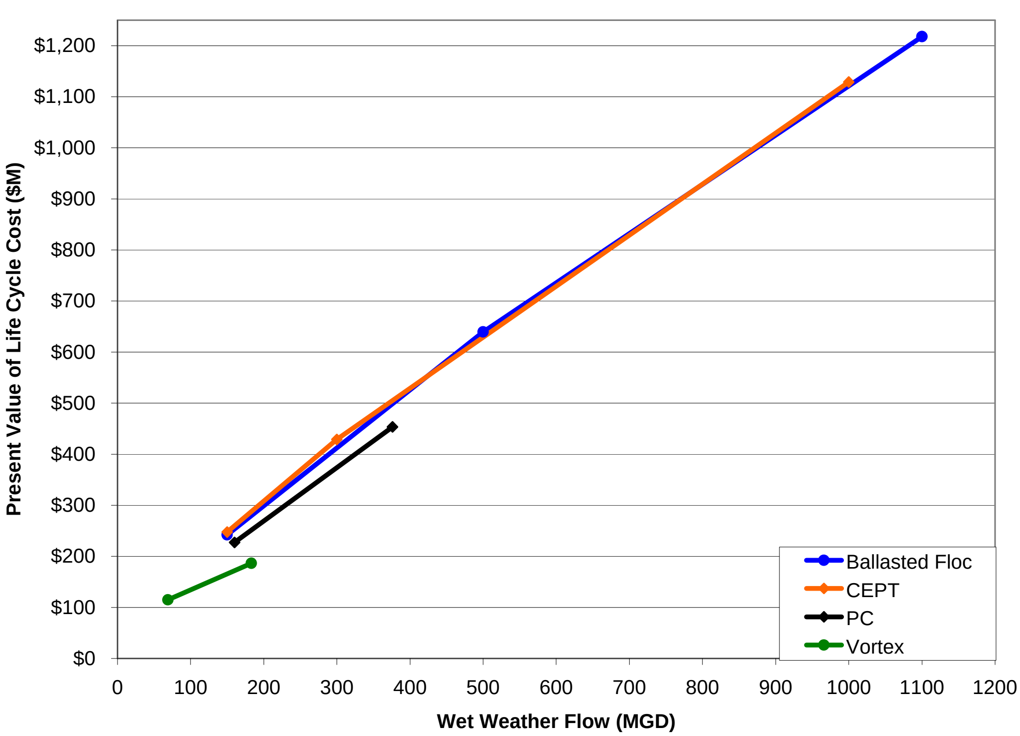


EXHIBIT ES-5
Comparison of Life-Cycle Costs for all Treatment Trains



Overall Comparison

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

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

Treatment Train	Pros	Cons
Train #1: Vortex/Swirl Concentrators	• Simple operation • Low maintenance requirements – no moving parts	• 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 • 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 • May be operated as Conventional Clarifiers if chemicals found to be unnecessary	• Operators unfamiliar with technology • Space limited • Uses two additional chemical systems for coagulation and flocculation • Maximum design flow may decrease if the assumed number of operating days is greater than 9.
Train #4: Ballasted Flocculation	• Can treat up to 1500 mgd with available land on site • Highest removal efficiencies • Unlimited number of operating days per month • Lower chlorine dose possible due to high TSS removal efficiencies	• Operators unfamiliar with technology • Most labor intensive and complex system • Uses two additional chemical systems for coagulation and flocculation

The costs for wet weather treatment at the NE 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

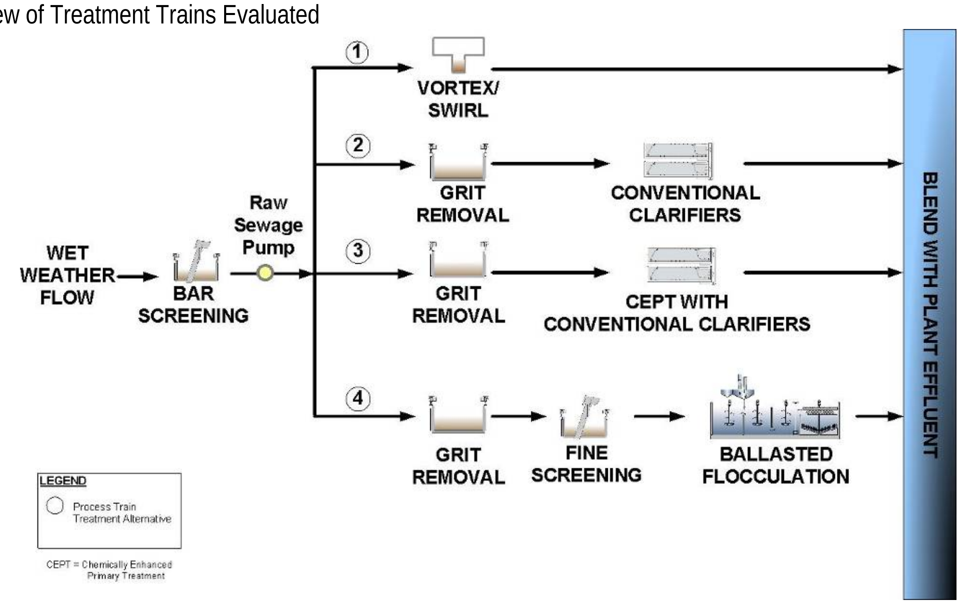
As part of the series of memoranda prepared for the Philadelphia Water Department's (PWD) Combined Sewer Overflow (CSO) Long Term Control Plan (LTCP) update, this report presents the conceptual design and cost analyses for four wet weather treatment alternatives for the Northeast Water Pollution Control Plant (NE 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 NE WPCP; survey of various potential wet weather treatment technologies; and site visits to three existing wet weather treatment facilities in Ohio (CH2M HILL, 2007b; CH2M HILL, 2008b). A treatment train utilizing CEPT with Plate Settlers was evaluated for the Southeast WPCP, but was subsequently eliminated due to its extremely high cost (CH2M HILL, 2008c).

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

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

Conceptual treatment trains were developed for each treatment technology at various wet weather flows ranging from 69 million gallons per day (mgd) to 1100 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 NE WPCP for wet weather conditions, the potential of maximizing flow through the existing plant must first be evaluated. From 2004 to 2007, the NE WPCP treated an average daily flow of 185 mgd with an instantaneous peak flow of 417 mgd (CH2M HILL, 2008b). Historically, plant operation has demonstrated that the secondary system can treat 435 mgd without experiencing catastrophic failure in the secondary clarifiers.

Since 2001, PWD has been actively planning to evaluate and implement options to increase the capacity of the NE WPCP to treat wet-weather flows. The 2007 Flow Study for the plant presented various options for hydraulic and process improvements that would increase plant capacity from 435 mgd to 535 mgd by incorporating a 100-mgd secondary bypass during wet weather events (CH2M HILL, 2007a). Subsequent studies indicated that it is possible to pass 650 mgd through the existing primary treatment system using a 215-mgd secondary bypass without exceeding permit limits (CH2M HILL, 2008d). A conceptual design project is currently underway for a pretreatment facility to treat an additional 250 mgd of flow (CH2M HILL, 2008e).

The improvements necessary to achieve a plant capacity of 650-mgd are presented in Exhibit 2-1. The majority of these improvements were identified in the 2001 Stress Testing Report and are based on results of stress tests on unit processes, long-term monitoring of the plant, hydraulic modeling, and input from NE WPCP plant staff (CH2M HILL, 2001). These improvements were also evaluated in further detail in the NE WPCP Flow Study (CH2M HILL, 2007a).

In sizing the wet weather treatment trains, it was assumed that the upgrades presented in Exhibit 2-1 will have been completed, increasing the plant's capacity to a minimum of 650 mgd. Thus, the baseline cost that is used in the wet weather treatment train cost estimates is $147.3 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 NE WPCP

	Improvement Description	Cost[1]
1	Frankford grit chamber bypass replacement to reduce hydraulic restriction	$3,057,279
2	Rehabilitation of Frankford high level second barrel	$11,421,413
3	New conduits between preliminary treatment building and the Set-1 primary sedimentation tanks	$2,500,000 [2]
4	Construction of new diversion chamber, conduit and new pretreatment system (screening, grit removal) upstream of Set 2 Primaries	$70,050,000 [3]
5	Installation of new influent baffles in Set-2 primary sedimentation tanks	$384,332
6	Removal of double-deck effluent channel in Set-2 final sedimentation tanks	$590,954
7	Construction of 215-mgd bypass conduit from Set-1 primary sedimentation tanks to the existing chlorine contact chamber	$26,347,571 [4]
8	Construction of four new gravity thickeners for thickening of primary sludge (tentative location north of existing digesters- NE-1.8 on Figure 3-4)	$32,895,246 [5]
	TOTAL	**$147,246,795**

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

(2) Based on PWD design cost estimates.

(3) See Northeast WPCP Pretreatment Facility Conceptual Design Report (CH2M HILL, 2008e)

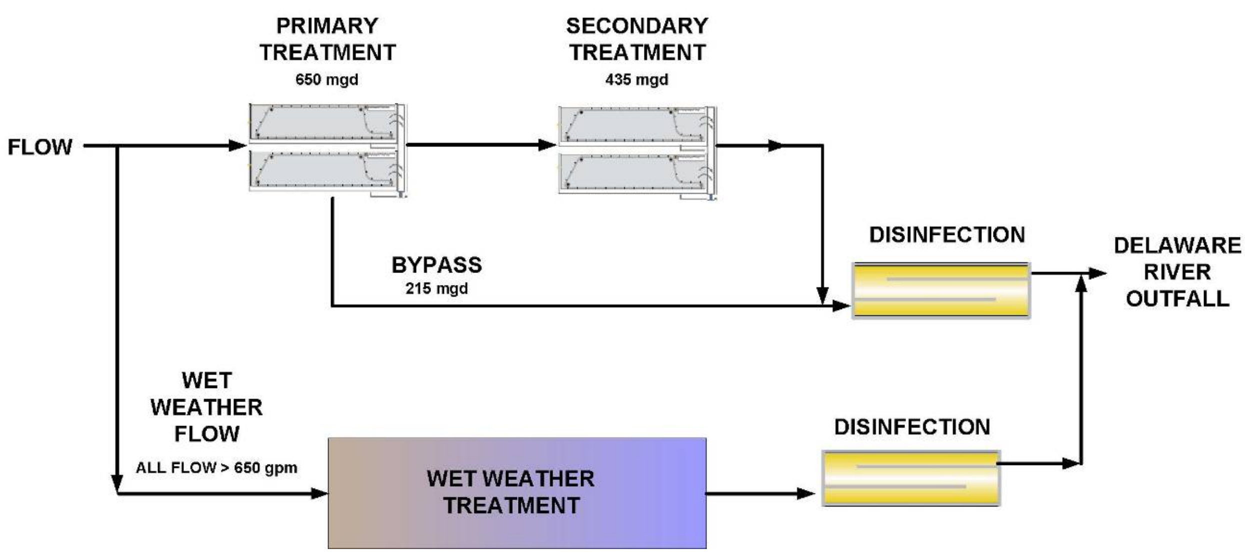
(4) Costs for these line-items were approximated by scaling the costs found in the Flow Study report for upgrades to 535 mgd only. More definitive costs for upgrades to 650 mgd can be substituted once they become available.

(5) See Flow Study Update memo (CH2M HILL, 2008d). New thickeners for the existing primaries will be located in the area of the abandoned digesters. This cost does not include remediation/demolition of the abandoned digesters.

3.0 Wet Weather Treatment Alternatives: Evaluation Methodology

To expand the flow capacity of NE WPCP beyond 650 mgd for the treatment of wet weather flows, a separate wet weather treatment train will be required. Wet weather flows in excess of 650 mgd will be diverted to this new treatment train, eventually blending with both secondary effluent and the secondary bypass effluent (Exhibit 3-1).

EXHIBIT 3-1
Anticipated Wet Weather Flow Pattern in NE WPCP



As depicted in Exhibit 1-1, the four wet weather treatment trains under evaluation for the new wet weather treatment facility are:

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

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

3.1 Design Flows

The design flows that were selected for evaluation for each treatment train in the new wet weather facility 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	69, 183
#2) Conventional Clarifiers	160, 376
#3) CEPT w/ Conventional Clarifiers	150*, 300, 1000
#4) Ballasted Flocculation	150*, 500, 1100

*The 150 MGD flow point for Trains #3 and #4 was selected arbitrarily to widen the range of the cost curves.

3.1.1 Design Flows by Permit Limits

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 NE 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 3-3 (CH2M HILL, 2008d).

EXHIBIT 3-3
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 Assuming 215-mgd Secondary Bypass(3) (mgd)	Maximum Allowable Flow Through Wet Weather Train Assuming No Bypass (3) (mgd)
#1) Vortex/Swirl Concentrators	30%	221	69	183
#2) Conventional Clarifiers	55%	142	161	376
#3) CEPT w/ Conventional Clarifiers	80%	63	Unlimited*	Unlimited*
#4) Fine Screening -> Ballasted Floc	91%	30	Unlimited*	Unlimited*

*The flow for Train #3 is unlimited assuming the wet weather treatment train operates for no more than seven days per month, an estimate provided by CDM (CH2M HILL, 2008). Since the effluent water quality for Train #4 exceeds permit requirements, it is truly unlimited in flow and frequency of operation. See Section 9.1.

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

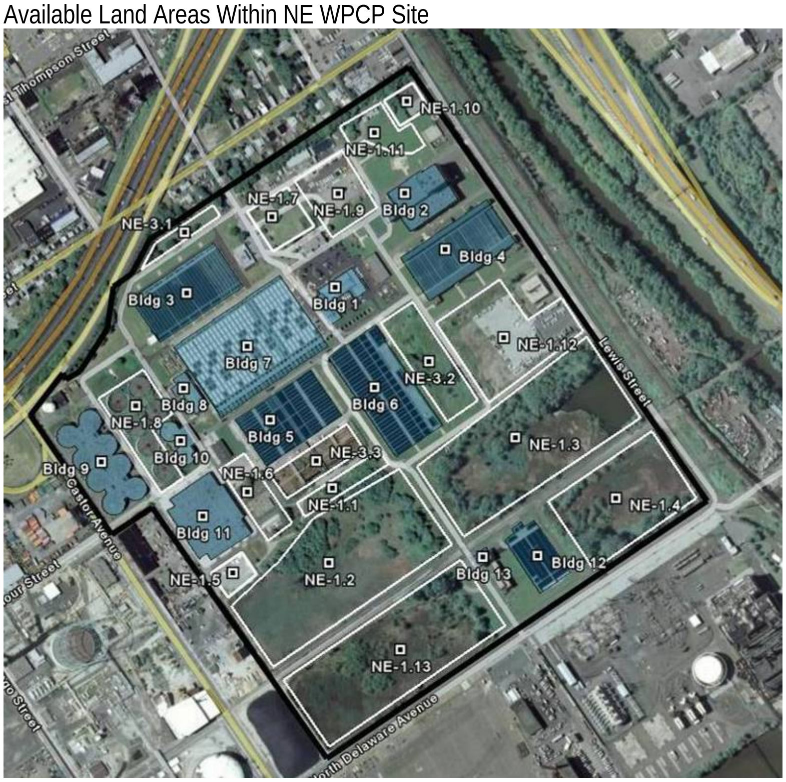
(2) Achievable effluent concentrations based on 95th percentile influent wet weather TSS concentration (316 mg/L)

(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, 2008b).

Both the vortex/swirl and conventional clarification trains are limited by permit requirements for this plant. The permitted flows are largely affected by the 215-mgd bypass, which undergoes only primary treatment, reducing the effluent quality of the conventional plant. Since the bypass has not been constructed yet, Exhibit 3-3 also includes the maximum allowable flow assuming no bypass. The permitted flows under both scenarios are used as design points for the vortex/swirl and conventional clarification trains in this report.

The trains with chemical addition obtain higher removal efficiencies and are considered unlimited by permit requirements. For CEPT, the flows are only unlimited if the wet weather treatment facility operates for no more than seven days per month. For the Ballasted Flocculation train, whose effluent quality exceeds that of permit requirements, both the flow and frequency of operation is unlimited (See Section 9.1). The design flow points for these "unlimited" trains were primarily based on the available land area on the existing plant site, as discussed below.

EXHIBIT 3-4
Available Land Areas Within NE WPCP Site



3.1.2 Design Flows by Available Land - Fleet Auction Lot: 300 MGD, 500 MGD

During discussions of land utilization at the existing site, it was agreed that the existing Fleet auction lot north of the lagoons would be the optimal location for the new wet weather facility (NE -1.12 in Exhibit 3-4). It was found that a 300-mgd CEPT facility, or a 500-mgd ballasted flocculation facility, could fit on this existing lot. This assumes that, if needed, the existing cogeneration building at the corner of the lot could be demolished to increase the land area available.

3.1.3 Design Flows by Available Land - Fleet Auction Lot and Sludge Lagoon: 1000 MGD

To expand beyond 300 and 500 mgd flow capacities, it was decided that only one section of the sludge lagoons would be utilized (NE-1.3 in Exhibit 3-4). This serves to minimize disturbance of the sludge lagoons, which would require remediation if used for construction. A small section in the NE-1.4 sludge lagoon was also set aside for the new chlorine contact chamber for the wet weather treatment train. The combination of the fleet auction lot and the NE-1.3 sludge lagoon provide sufficient area for a 1000-mgd CEPT facility or a 1500-mgd ballasted flocculation facility. Since 1500 mgd exceeds the expected collection system capacity, it is not evaluated as a design point (see following section).

3.1.4 Design Flows by Collection System Capacity Assumptions: 1100 MGD

According to CDM's assumptions on the capacity of the upgraded collection system, the collection system capacity for the NE WPCP could reach 1,740 mgd after transmission improvements, which is equivalent to three times the existing collection system capacity (Myers, 2007a). Assuming the existing plant will be able to handle 650 mgd, the maximum flow to the new wet weather facility would be 1090 mgd. The maximum design flow point used for the ballasted flocculation was thus 1100 mgd.

3.2 Key Design Assumptions

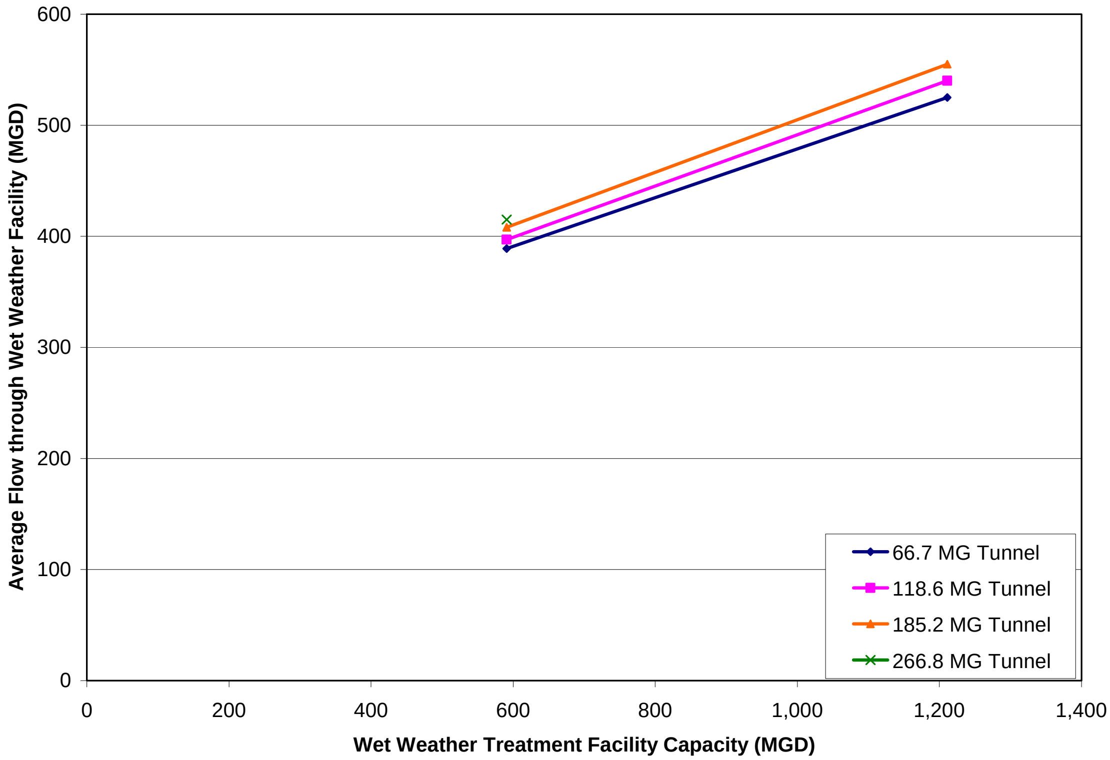
3.2.1 Average Design Flow

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 Northeast Drainage district (NEDD) 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 3-5).

Model runs for a 591-mgd and a 1,211-mgd wet weather facility generated an average flow of 415-mgd and 555-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 555-mgd. For the Ballasted Flocculation 500-mgd scenario, an average flow of 415-mgd was assumed. For trains with peak capacities less than 415 mgd, the average flow is assumed to be equivalent to the peak flow of the facility (Exhibit 3-6).

EXHIBIT 3-5
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 3-6
Average Design Flows

Maximum Design Flow (mgd)	Average Design Flow (mgd)
69	69
150	150
160	160
183	183
300	300
376	376
500	415(1)
1000, 1100	555(2)

(1) Model runs with a 591-mgd facility generated an average flow of 415-mgd.

(2) Model runs with a 1,211-mgd facility generated an average flow of 555-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, as described above, was used for sizing chemical storage facilities, storage for screenings and grit, and sludge handling facilities.

Preliminary Treatment

Each wet weather train evaluated in this report was sized to treat influent flow in excess of the plant's flow capacity of 650 mgd. For each case, the head of the new wet weather facility is located in the existing Fleet auction lot, southeast of the Set-1 primaries. A new influent conduit running south along Lewis Street will divert excess wet weather flow to the new preliminary treatment building (PTB) of the wet weather treatment facility. The new PTB will contain an influent wet well at a similar elevation to the existing low level 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 7.

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. The chlorine contact chamber is sized to provide a 20-minute detention time at peak flow, with the exception of the 1,000 mgd and 1,100 mgd flow scenarios. In these scenarios, the chamber is sized for a 10-minute detention time at peak flow, and it is assumed that the chlorine dosage will be increased correspondingly to provide adequate disinfection. Sodium bisulfite is then used for dechlorination at the end of the chlorine contact chamber.

Chemical Feed

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

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

Polymer is used as the flocculant and is stored in liquid form to allow immediate startup of the wet weather system.

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

Sludge Handling

Primary sludge from all treatment trains is pumped to new 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 3-6) with a 95 percentile influent solids concentration (316 mg/L) for a continuous period of 24 hours.

The thickened sludge will be pumped to the plant's anaerobic digesters for further treatment. The sludge will be screened through StrainPress® sludge cleaners to remove inert solids before entering the digesters. PWD is currently conducting a study of the existing digesters and expects that proposed improvements will generate capacity equivalent to two extra digesters. Capital costs for each treatment train include the cost of new digesters that may be required beyond this improved capacity. The digesters were sized to provide 20-day storage for solids, assuming average flow, a 95 percentile influent solids concentration (316 mg/L), an average wet weather event duration of five hours, and five events in 20 days.

Along with the four new thickeners for the existing plant, these new digesters will be located in the area of the abandoned digesters (Figure 3-4, NE-1.8). The cost of demolishing the abandoned digesters and removing the sludge contained is not included in the capital cost estimates. The design parameters that were assumed for all the treatment train processes are summarized in Exhibit 3-7. The process flows are described in further detail in each of the treatment train sections.

EXHIBIT 3-7
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)**		

EXHIBIT 3-7
Key Process Design Assumptions for Wet Weather Treatment Trains[1]

Vortex/Swirl	36,000 (25 gpm/sf)		
Conventional Clarifiers	2,400 [3]		
CEPT	3,000		
Ballasted Flocculation	84,600 (60 gpm/sf)		
Chlorine Contact			
Chlorine Contact Chamber	Detention Time	10 -20	Min

Chemical Feed

Chemical	**Purpose**	**Concentration**	**Storage (at avg flow)**
Ferric Chloride	Coagulation	60 mg/L	10 days
Liquid Polymer	Flocculation	2 mg/L	10 days
Sodium Hypochlorite	Chlorination	5 mg/L	10 days
Sodium Bisulfite	De-chlorination	1.5 mg/L[4]	10 days

Primary Sludge Generation[5]

Train	**% TSS Removal**	**% Solids in Sludge**
#1: Vortex/Swirl	30%	0.07%[6]
#2: Conventional Clarifiers	55%	0.5%
#3: CEPT	80%	0.5%
#4: Ballasted Floc	90%	0.3%

Sludge Thickening

Gravity Thickeners	Max Hydraulic Loading Rate (limiting factor for Trains #1 and #4)	900	gal/sf/day
	Max Solids Loading Rate (limiting factor for Trains #2, #3)	30.7	lb/sf/day
	% Solids of Thickened Sludge	3	% minimum
StrainPress® Sludge Screens	Sludge Throughput	200 – 400	gpm

Digesters

Anaerobic Digesters	Detention Time	20	days
	Diameter	115	ft
	Side Water Depth	25	ft
	Volatile Solids Destruction	50	%

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

(2) Estimated from 2004-2005 grit and screenings disposal records from the SE WPCP. It is assumed that

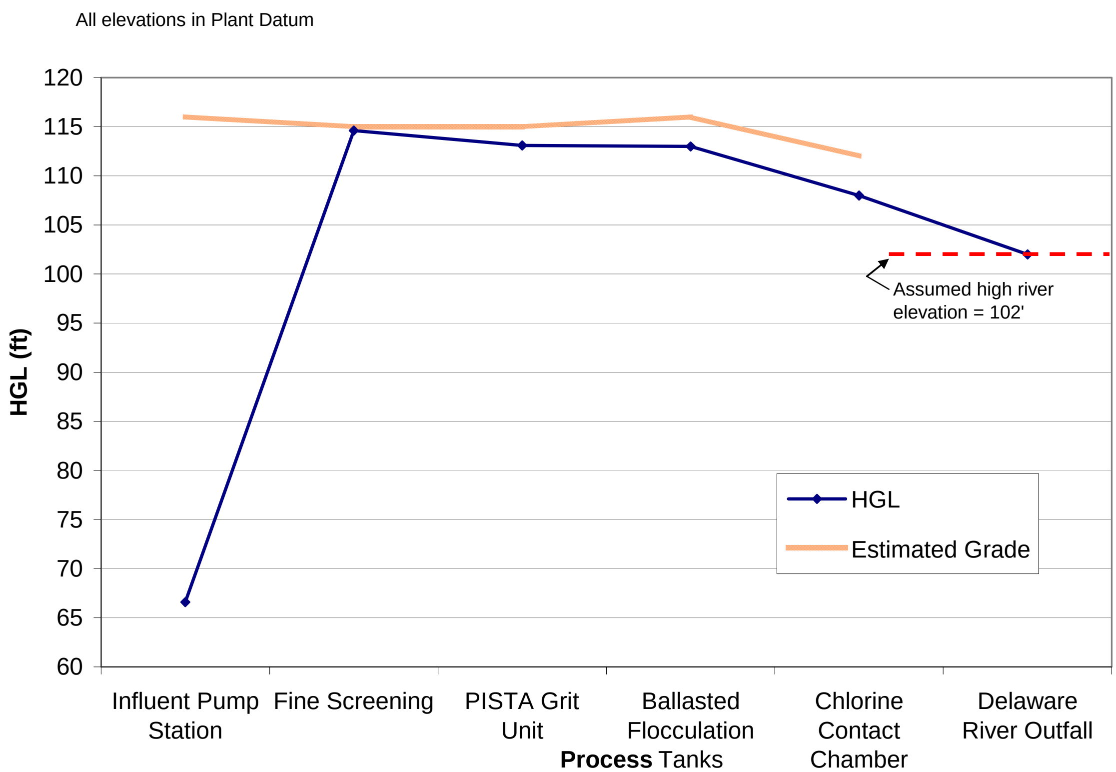
EXHIBIT 3-7
Key Process Design Assumptions for Wet Weather Treatment Trains(1)

the difference in grit and screenings quantities between the plants are negligible.
(3) Based on stress testing results on existing primary clarifiers
(4) Assumes 1 mg/L residual chlorine concentration at the end of the chlorine contact chamber
(5) Assumes 95 percentile influent TSS concentration of 316 mg/L, and volatile solids percentage of 70%
(6) Based on a 10% underflow from the vortex/swirl concentrator

3.2.3 Hydraulics

To eliminate the need for an 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 1100 mgd is shown in Exhibit 3-8 as an example of a maximum head loss scenario.

EXHIBIT 3-8
Preliminary Hydraulic Gradeline for the Ballasted Flocculation Treatment Train at 1100 MGD



As an initial condition, the high river elevation was assumed to be 102 feet. This is similar to the assumption made for the Delaware River in the Southeast WPCP memo (CH2M HILL, 2008c).

The water surface level of the chlorine contact chamber was assumed to be 2 feet higher than the top of the existing chlorine contact chamber (108 feet). The contact chamber was elevated from the existing chamber to avoid flooding of the chamber and the final sedimentation tank weirs, which the current plant occasionally experiences during high river level conditions. The estimated head-loss through the new outfall conduit is 3.2 ft (using Manning's Equation).

The elevation of the chlorine contact chamber sets the elevations of the upstream unit processes. As shown in Exhibit 3-8, the water surface elevations are slightly beneath the existing grade elevation. The hydraulic grade-line of the wet weather facility is higher than the existing plant due to its location on the east side, which is higher in elevation than the rest of the site. Capital cost estimates assume complete burial of all tanks.

3.2.4 Existing Site

In developing conceptual layouts of the wet weather treatment trains, several assumptions were made about the existing site:

- The cogeneration building in the Fleet auction lot (NE-1.12 of Exhibit 3-4) can be demolished to increase the land area available for the wet weather facility.
- The existing outfall pier (approximately 600-ft long) needs to be expanded to support the new outfall conduit. Pier expansion is included in the capital cost estimates.

3.2.5 Site Conditions

The site and soil conditions in the Fleet auction lot and the sludge lagoons were assumed to be similar to the rest of the NE 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 0.069 piles/sf and 30 feet were used for all water-bearing structures on site. A pile density and depth of 0.089 piles/sf and 50 feet were used for the outfall conduit to the Delaware River. T A pile density and depth of 0.0043 piles/sf and 30 feet were used for all other structures. These numbers were based on existing pile plans for the Northeast WPCP.
- Dewatering will be required for some buried structures. According to plant drawings, the groundwater elevation ranges from approximately 5-ft to 20-ft below grade at the NE 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 3-9. 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 3-10). This start-date was chosen since PWD's LTCP Update must be submitted by this date. A location adjustment factor of 15.2 percent was applied to the escalated construction cost, which is in agreement with the ENR 20-city Construction Cost Index (CCI).

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

EXHIBIT 3-9
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 3-10
Escalation Factors for Various Construction Scenarios

Flow Capacity of Wet Weather Treatment Train (mgd)	Estimated Construction Duration (months)[(1)]	Escalation Factor[(2)]
69	24	19.8%
150, 160	26	20.5%
183	27	21.2%
300	30	21.8%
376	32	22.5%
500	36	23.9%
1000, 1100	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 3-11.

EXHIBIT 3-11
Non-Construction Cost Factors

Non-Construction Expenditure	Factor*

EXHIBIT 3-11
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 Remediation

Under certain high-flow scenarios, the new chlorine contact chamber will be located next to the existing chamber, in an abandoned sludge lagoon. This capped sludge lagoon will need remediation before construction can begin. For the higher flows of 1000 and 1100 mgd, an additional 11.4 acres of abandoned sludge lagoons must also be utilized to provide enough space for the new facility.

The estimated cost of remediation is $1.14 M per acre, as estimated by PWD. This assumes a relatively low hazard level of the material being removed.

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 3-12. The O&M costs cover labor, power for equipment and buildings, chemicals, sludge and trash disposal, and repair, maintenance and replacement of structures and equipment. O&M costs are mainly based on average flows through the plant, as described in Section 3.2.1 and shown in Exhibit 3-6.

The additional labor required for each treatment train is dependent on the flow capacity of the train, as shown in Exhibit 3-13. 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 NE-2.1. It should be noted that all O&M costs presented for the treatment trains are annualized O&M costs that include escalation over the 30-year period.

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

EXHIBIT 3-12
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	51	days(2)
Duration of wet weather event	5	Hours(2)
Labor		
Hourly wage for plant operator	$50.44	including fringe benefits
Hourly wage for plant operator on overtime	$75.65	including fringe benefits
Hourly wage for maintenance worker	$52.35	including fringe benefits
Fringe benefits and overhead multiplier	2.7	applied on top of raw hourly rate
Number of working hours for full time operators at wet weather facility	2,080	hours per year per operator
Number of working hours for operators on overtime at wet weather facility	408	hours per year per operator (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
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

EXHIBIT 3-12
Assumed Factors for Life Cycle Cost Estimates

Factor	Value	
Equipment	1%	of capital cost of equipment
Instrumentation and Controls	5%	of capital cost of I&C
Mechanical	0.1%	of capital cost of mechanical work (incl. valves)
Electrical	1%	of capital cost of electrical equipment
Disposal		
Grit and Screenings Disposal and Hauling Costs	$100	per cubic yard
Final Sludge Disposal Costs(5)	$75	per wet ton
Other		
Other O&M Costs (including vehicles, lab tests, office equipment and other miscellaneous costs)	$10,000	per additional full-time operator and maintenance worker
Contingency		
Contingency applied to O&M costs	20	%

(1) Based on CCI Index

(2) The maximum average annual number of wet weather events with flows higher than 650 MGD is 51 under scenarios modeled by CDM. Similarly, the maximum average annual wet weather duration is 219 hours (CDM, 2008). The duration of each event is then assumed to be 5 hours.

(3) Equipment power costs estimated by PWD.

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

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

EXHIBIT 3-13
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)
69, 150, 160, 183	1	1	2
300, 376, 500	2	0	4
1000, 1100	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 408 hours per year.

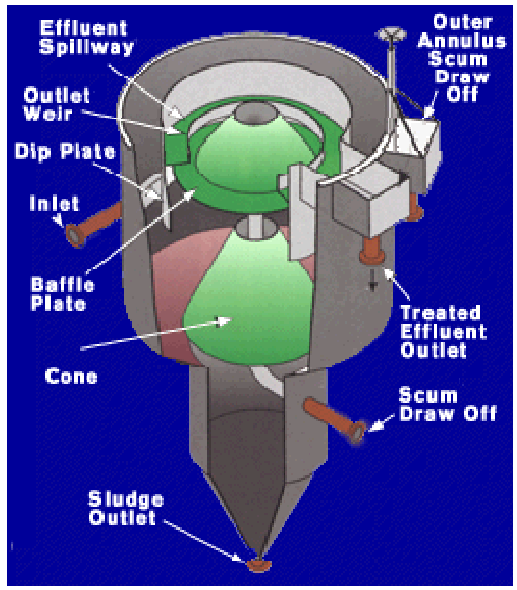
4.0 Treatment Train #1- Vortex/Swirl Concentrators

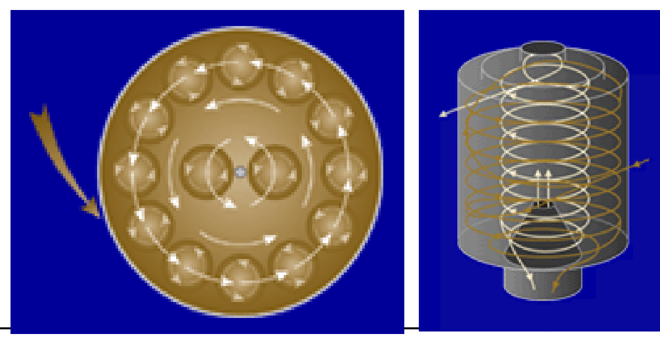
4.1 Process Flow Diagram

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.

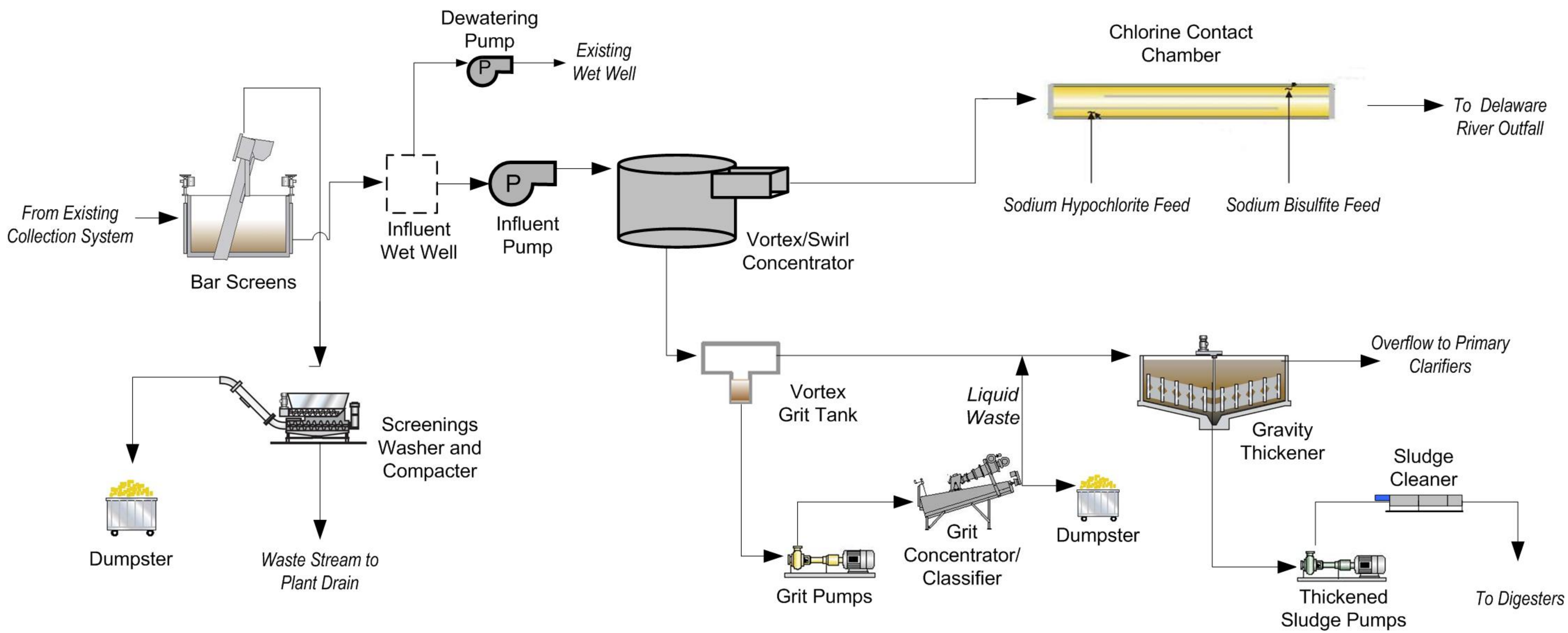
EXHIBIT 4-1
Diagrammatic Cutaway of Vortex/Swirl Device (Storm King®, H.I.L. Technologies)





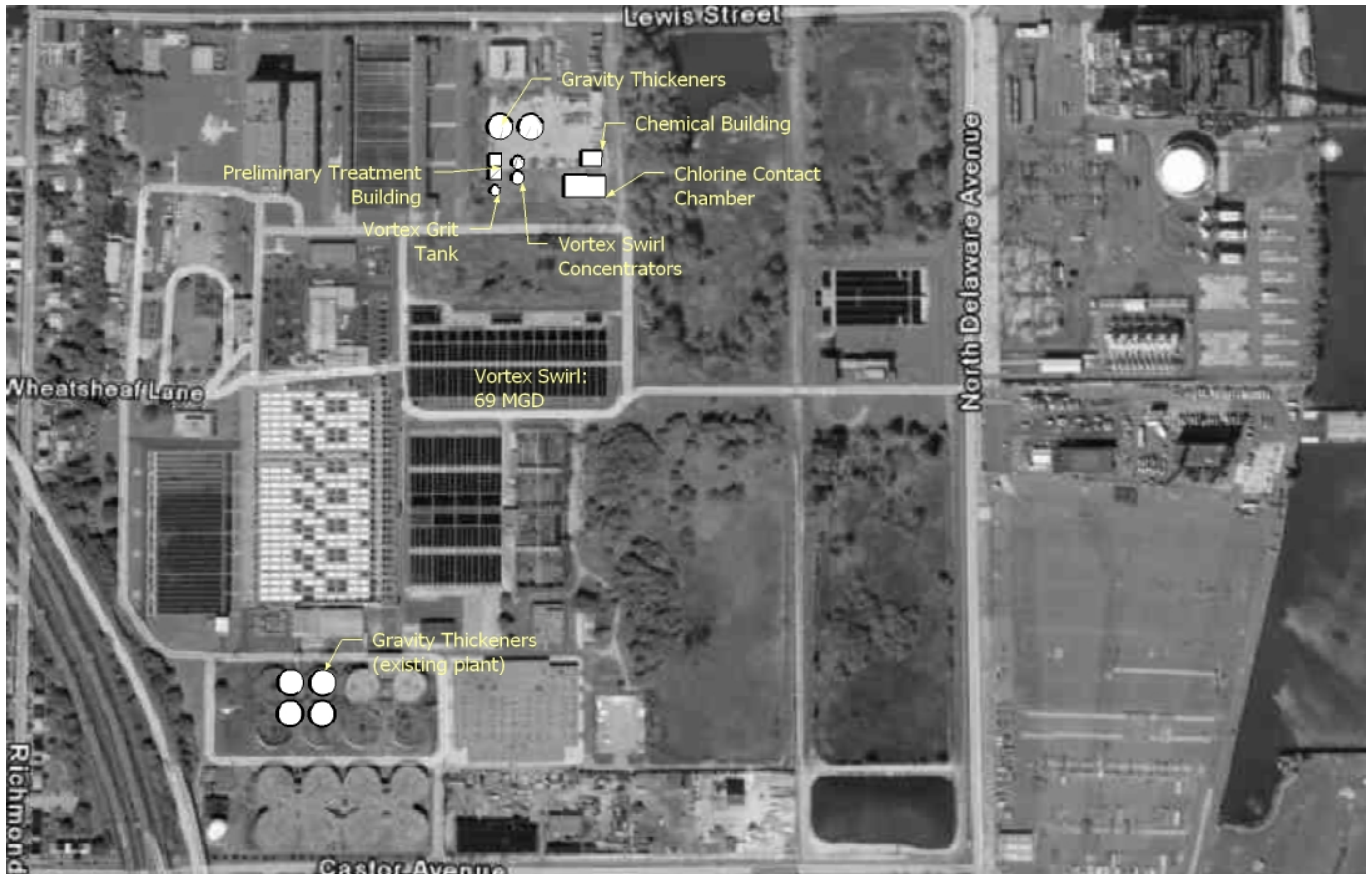
Flow Pattern Plan and Profile Views (H.I.L. Technologies)
The flow in vortex/swirl devices initially follows a path around the perimeter of the unit and is then directed into an inner swirl pattern with a lower velocity than the outer swirl. Solids separation is achieved by both centrifugal force and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

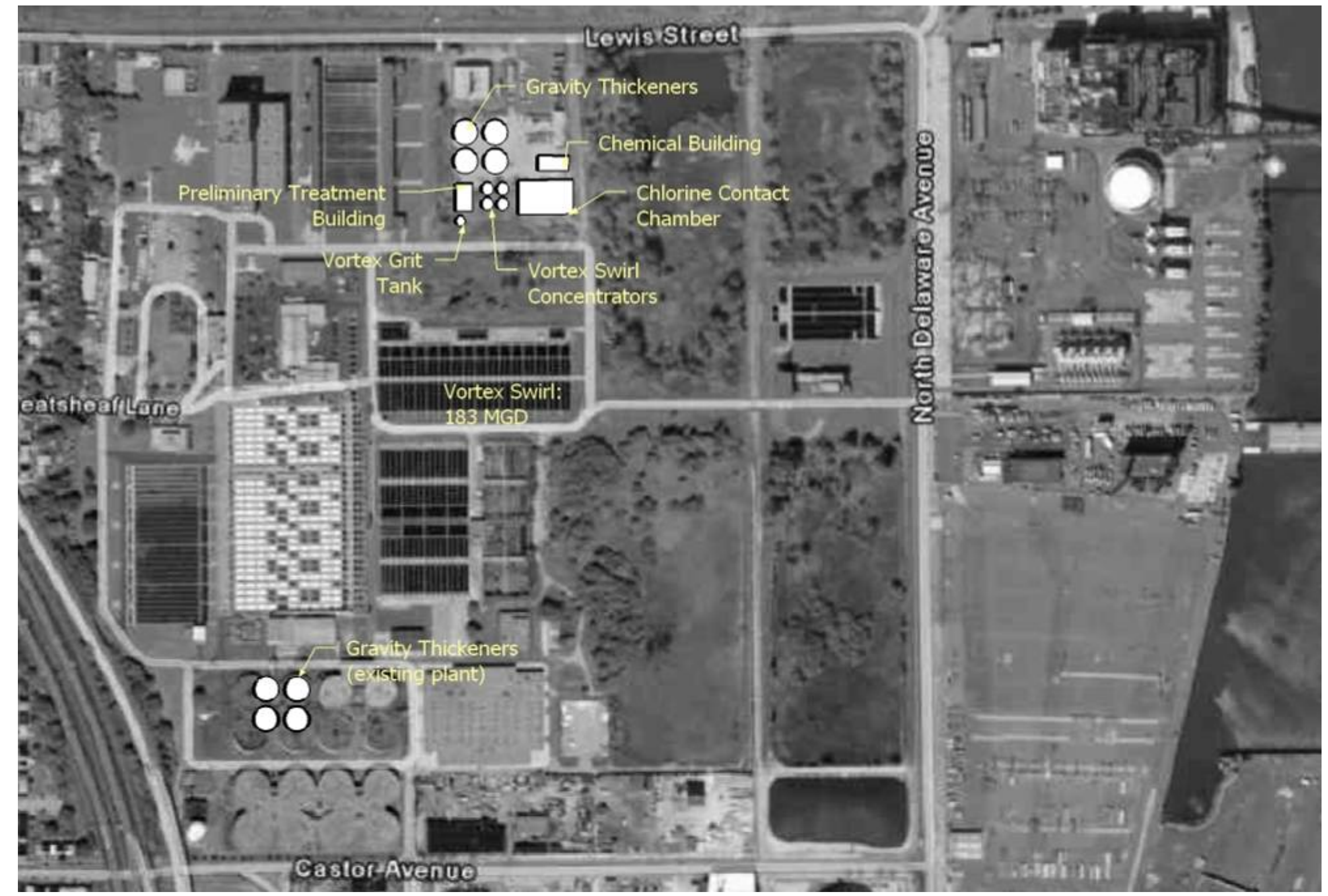
EXHIBIT 4-2
Process Flow Diagram and Key Process Design Parameters for Treatment Train #1: Vortex/Swirl Concentrators



	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
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
69	1	2	2	19.1	1	10	1	1	1	1	1	397	34,255	1	1	6,226	1	1	2	4	1	2	1	54,554	0
183	2	3	4	25.3	1	16	2	1	1	1	1	1,052	91,115	1	1	6,226	1	1	4	8	2	4	1	144,686	0

EXHIBIT 4-3
Conceptual Layout and Footprint for Treatment Train #1: Vortex/Swirl Concentrators
69 MGD (left), 183 MGD (right)





FLOW (mgd)	PTB	GRIT UNITS	VORTEX SWIRLS	CHEMICAL BUILDING	CCC	GRAVITY THICKENERS*	TOTAL FOOTPRINT (acres)	REMEDIATION FOOTPRINT (acres)
69	41’ x 27’ & 39’ x 39’	10’ (1 unit)	40’ (2 units)	61’ x 45’	67’ x 114’ (3 passes)	80’ (2 units)	0.6 acres	NONE
183	54’ x 42’ & 56’ x 39’	16’ (1 unit)	40’ (4 units)	101’ x 47’	109’ x 177’ (5 passes)	80’ (4 units)	1.3 acres	NONE

4.2 Conceptual Design and Site Layouts

A conceptual design and site layout was developed for a flow of 69 mgd, the maximum allowable flow to meet permit requirements assuming the 215-mgd secondary bypass, and for 183 mgd, the maximum allowable flow assuming no bypass. The main design parameters are shown in Exhibit 4-2 and the conceptual site layouts and footprints are shown in Exhibits 4-3. Since the entire facility can fit on the existing Fleet auction lot, no land acquisition or remediation will be required.

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.

The overflow from the gravity thickeners is conveyed to the head of the entire plant. The estimated overflow range from wet weather thickeners is 6 to 18 mgd. 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 are shown in Exhibit 4-4. Total capital costs and the capital costs per volume treated for all scenarios are shown in Exhibits 4-5 and 4-6. The estimated O&M costs by category are also presented in Exhibits 4-7. A more detailed breakdown of these costs is presented in Attachment NE-2.1.

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

	Wet Weather Flow (mgd)	
Cost	**69**	**183**
Capital Cost ($M)	$91	$154
Annual Operations and Maintenance Cost ($M)	$1.5	$2.1
Present Value of the Cost ($M)	$115	$186

EXHIBIT 4-5
Capital Costs for Treatment Train #1: Vortex/Swirl
Includes cost of upgrading existing plant capacity to 650 mgd

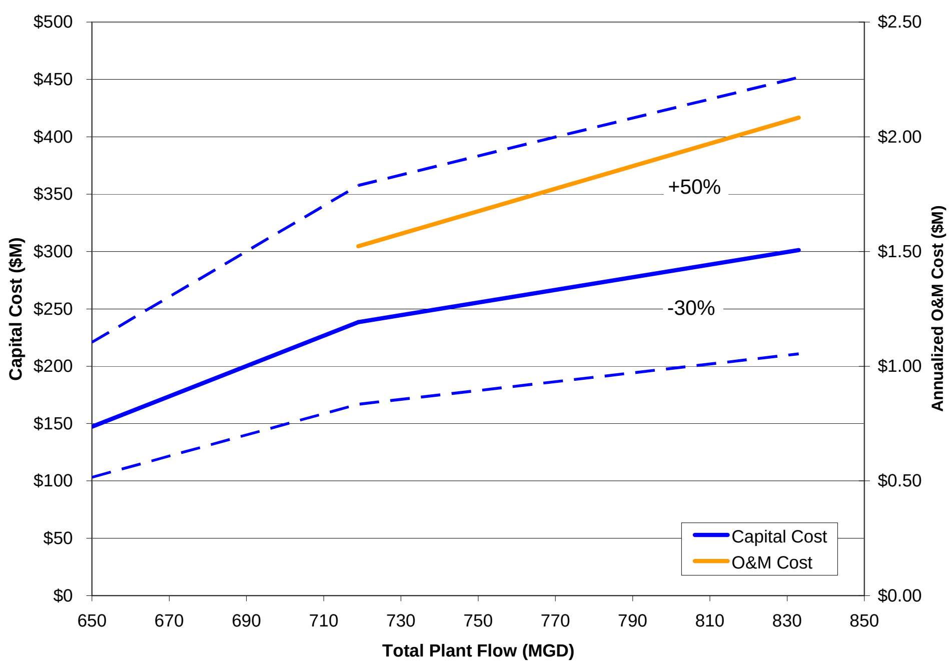


EXHIBIT 4-6
Capital Costs per Gallon Treated for Treatment Train #1: Vortex/Swirl

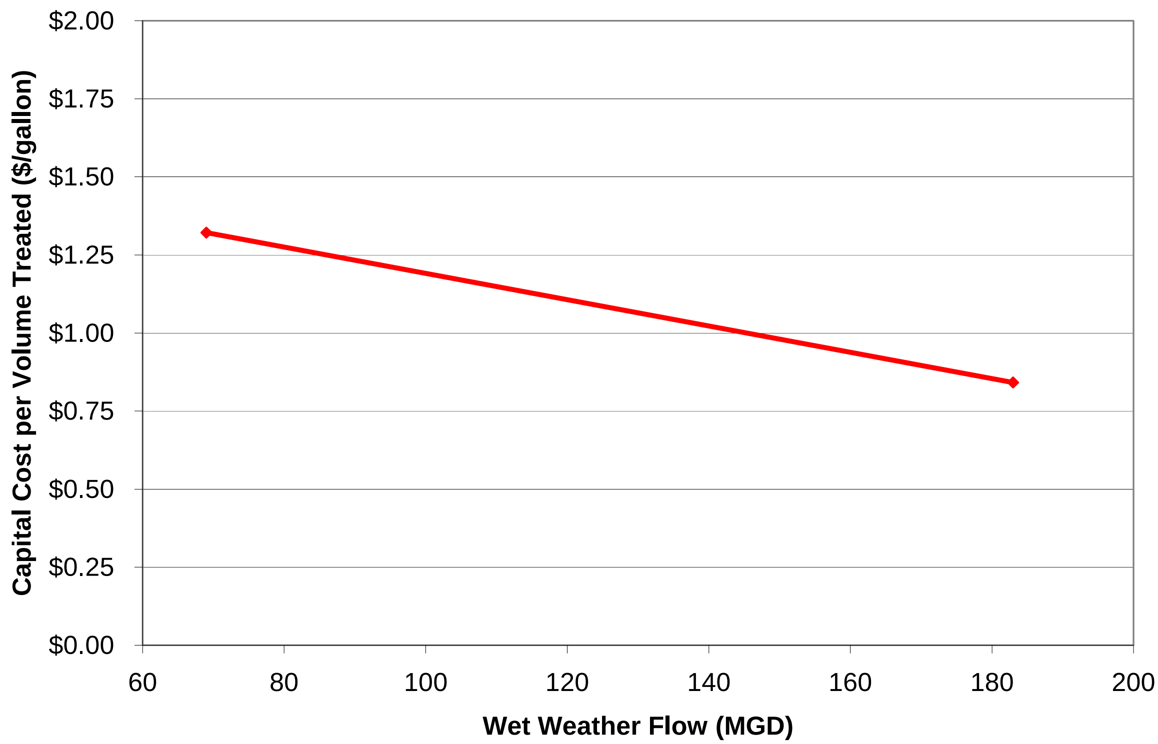
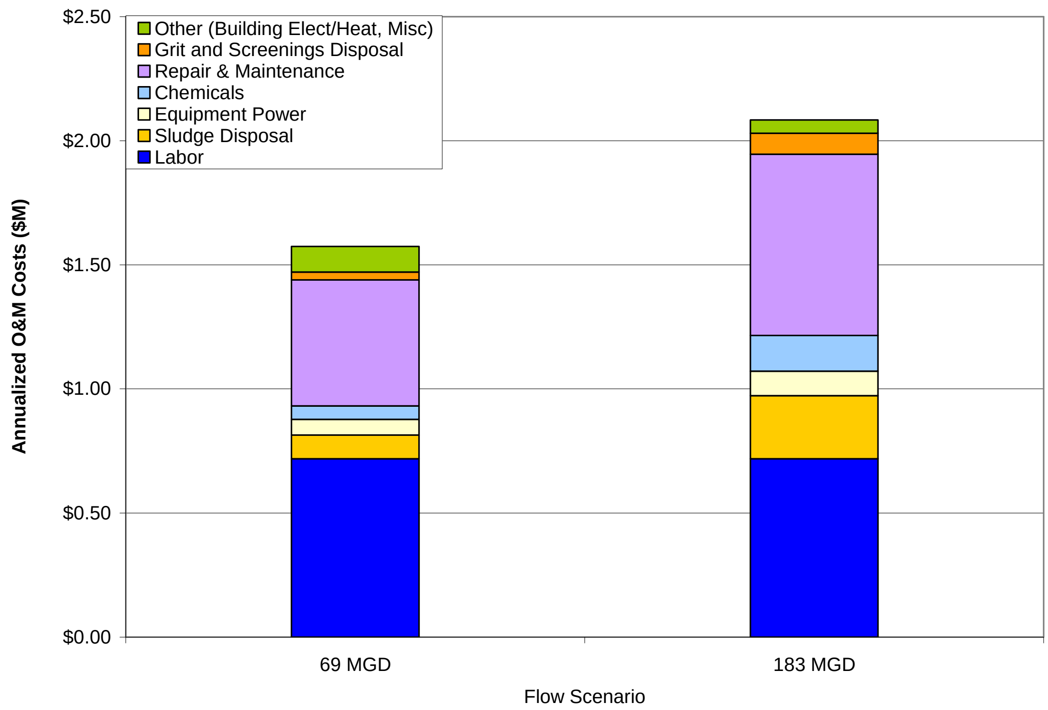


EXHIBIT 4-7
Operations and Maintenance by Category for Treatment Train #1: Vortex/Swirl



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 NE 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 for a flow of 160 mgd, the maximum allowable flow to meet permit requirements assuming a 215-mgd secondary bypass, and 376 mgd, the allowable flow assuming no bypass. Key design parameters at these flows are shown in Exhibit 5-1 and conceptual layouts are shown in Exhibit 5-2. No remediation will be required for the 160-mgd flow scenario since the entire facility can fit on the existing Fleet auction lot. For the 376 mgd flow scenario, remediation will be required to site the new chlorine contact chamber.

5.3 Operational and Technology-Specific Issues

5.3.1 Startup and Shutdown

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

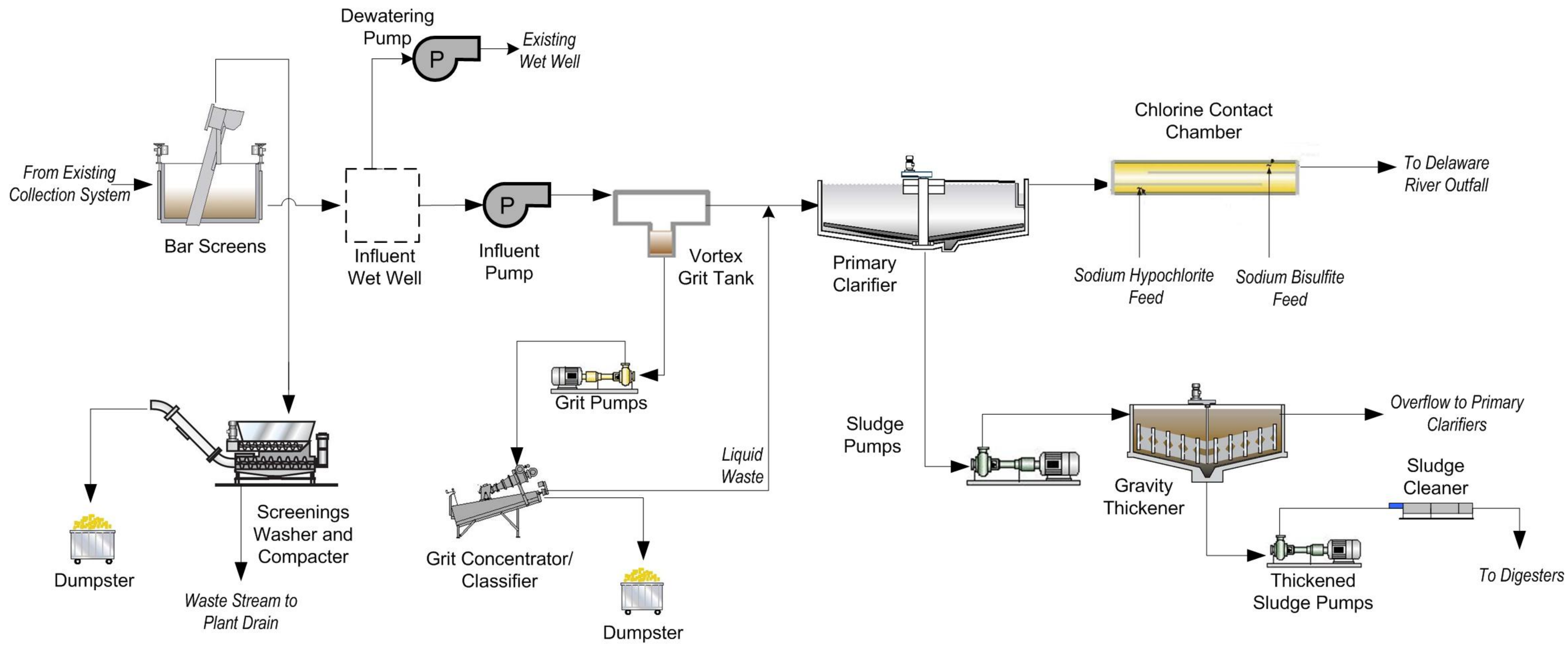
For shut down, the tank may be filled with treated effluent, or pumped down to the existing plant if freezing becomes an issue.

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 to the existing aeration basins, the new clarifiers could be used for treatment of dry weather flows.

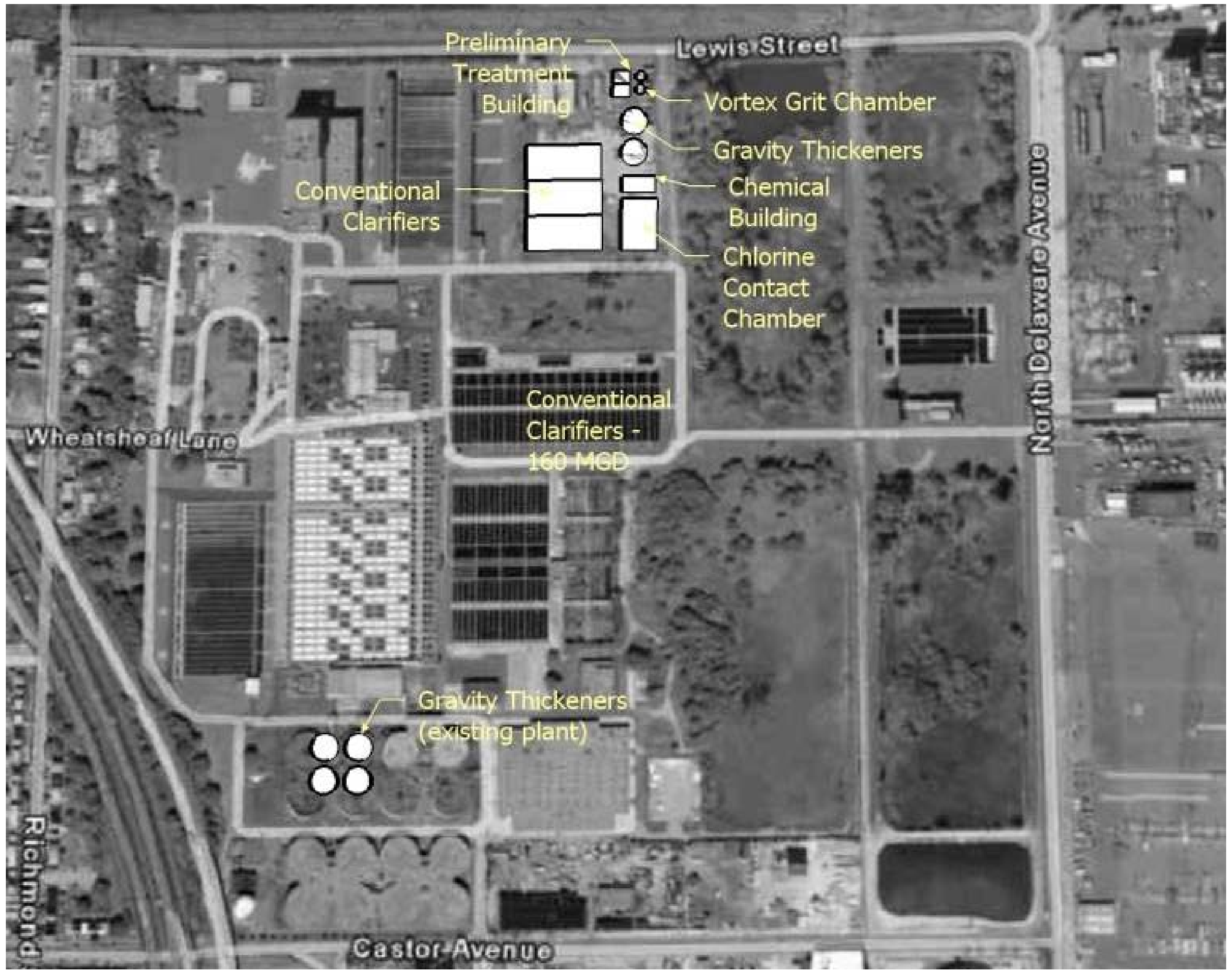
The waste streams generated by the screenings washer/compactor and the grit classifiers are sent to the primary clarifiers of the wet weather treatment train and will not affect the main plant. As with the other treatment trains, the overflow from the gravity thickeners will be conveyed to the head of the entire plant. The estimated overflow range from wet weather

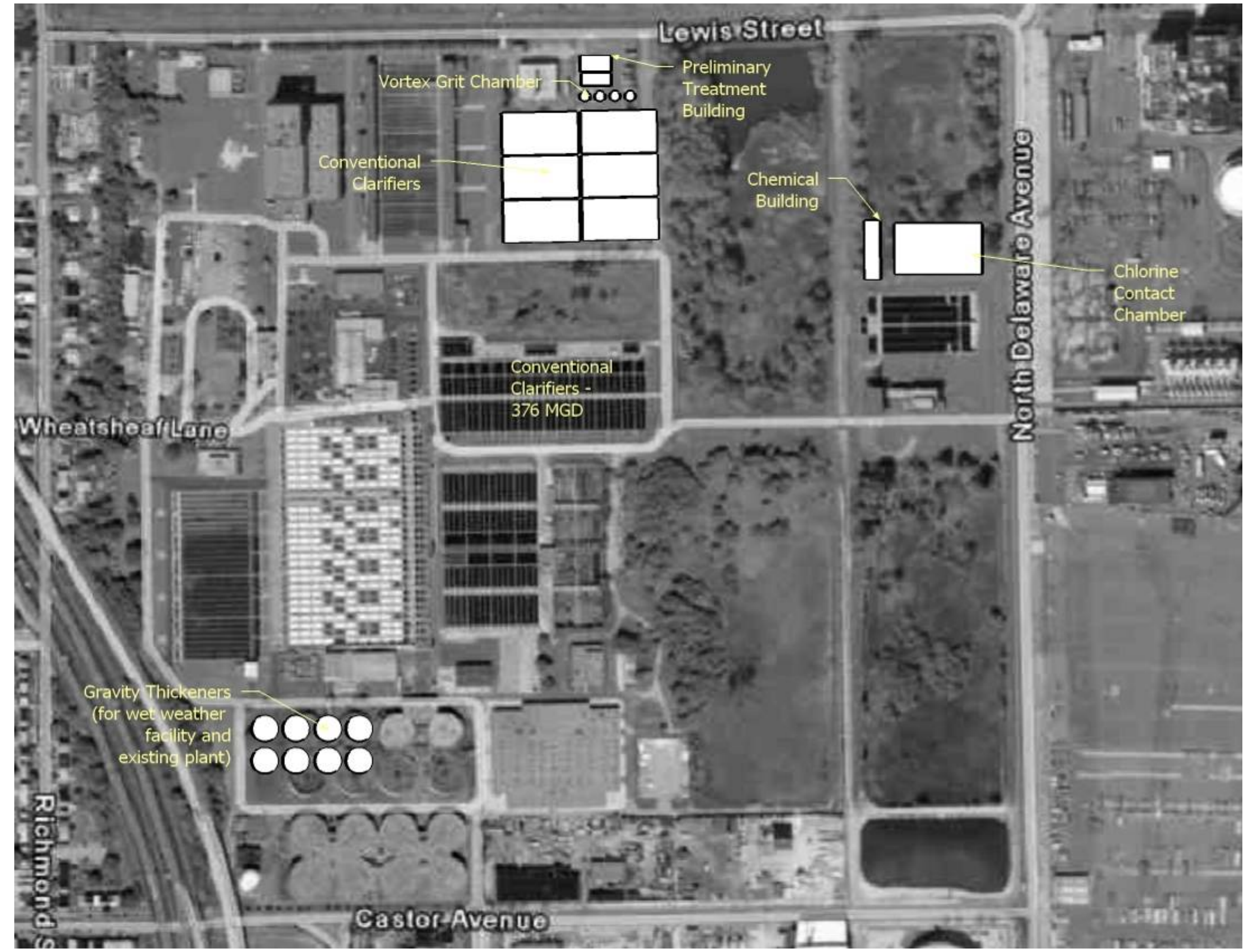
EXHIBIT 5-1
Process Flow Diagram and Key Process Design Parameters for Treatment Train #2: Conventional Clarifiers



Flow (mgd)	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
	# 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
160	2	3	2	32	2	2	1	2	1	920	79,663	1	1	6,226	1	1	3	2	3	1	2	1	231,919	0
376	4	6	6	32	4	4	1	4	1	2,185	187,208	1	1	10,847	1	1	6	4	6	2	4	1	545,009	0

EXHIBIT 5-2
Conceptual Layouts and Footprints for Treatment Train #2: Conventional Clarifiers 160 MGD
160 MGD (left), 376 MGD (right)





Flow (mgd)	PTB	Grit Units	Clarifier Tanks	Chemical Building	CCC	Gravity Thickeners	Digesters	TOTAL FOOTPRINT (acres)	REMEDIATION FOOTPRINT (acres)
160	54' x 39' & 56' x 39'	32' (2 units)	104' x 226' (3 tanks)	101' x 47'	109' x 156' (5 passes)	80' (2 units)	-	2.6	NONE
376	93' x 49' & 102' x 39'	32' (4 units)	129' X 231' (4 tanks)	177' x 47'	151' x 259' (7 passes)	80' (4 units)	-	6.3	2.3

thickeners only is 4 to 11 mgd. 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 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 NE-2.1.

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

	Wet Weather Flow (mgd)	
Cost	**160**	**376**
Capital Cost ($M)	$194	$389
Annual Operations and Maintenance Cost ($M)	$2.1	$4.1
Present Value of the Cost ($M)	$227	$453

EXHIBIT 5-4
Capital Costs for Treatment Train #2: Conventional Clarifiers
Includes cost of upgrading plant capacity to 650 MGD

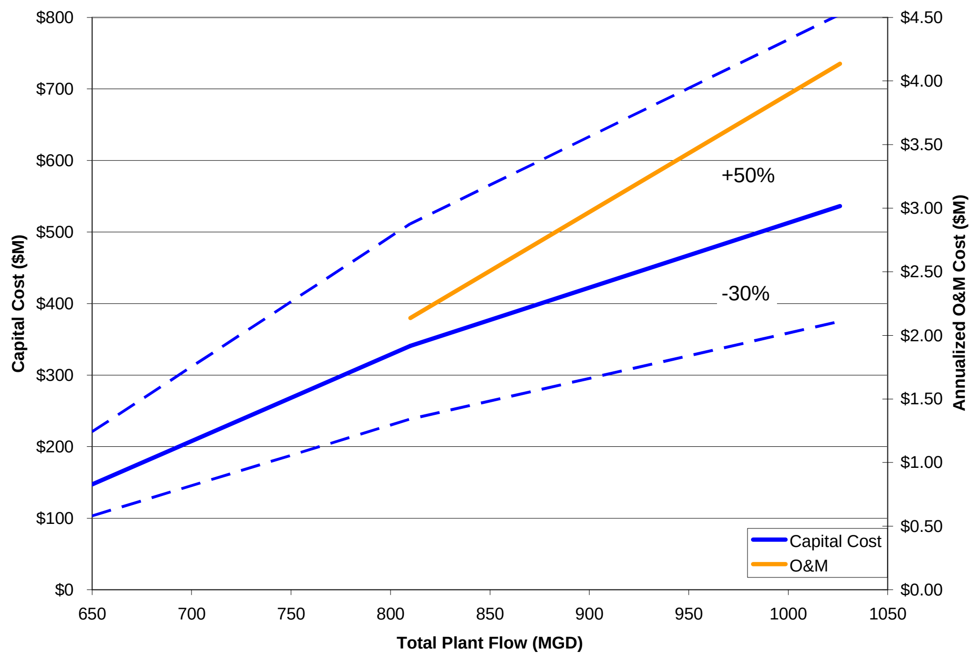


EXHIBIT 5-5
Capital Costs per Gallon Treated for Treatment Train #2: Conventional Clarifiers

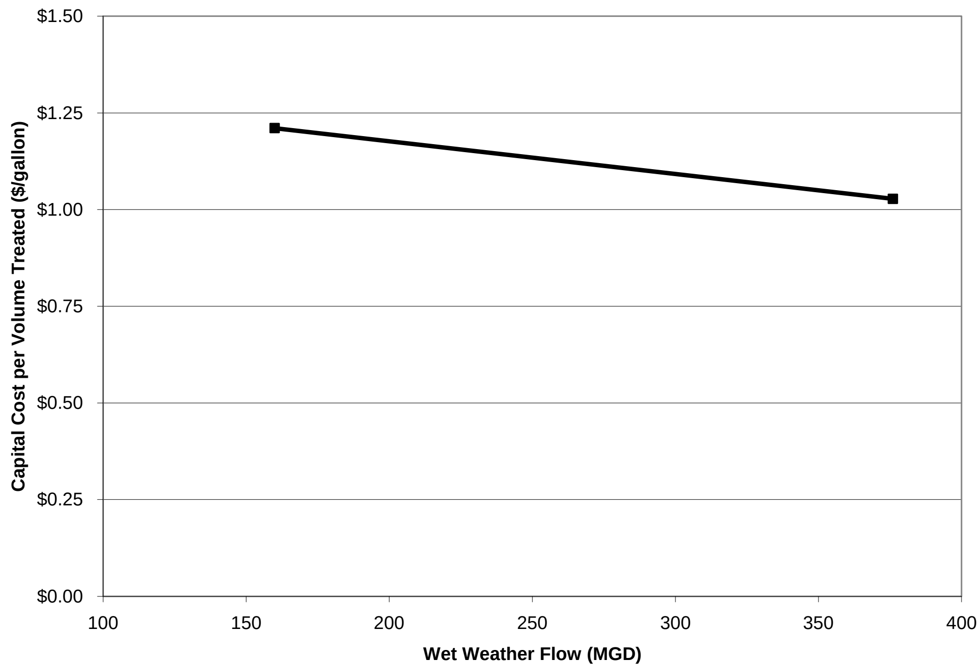
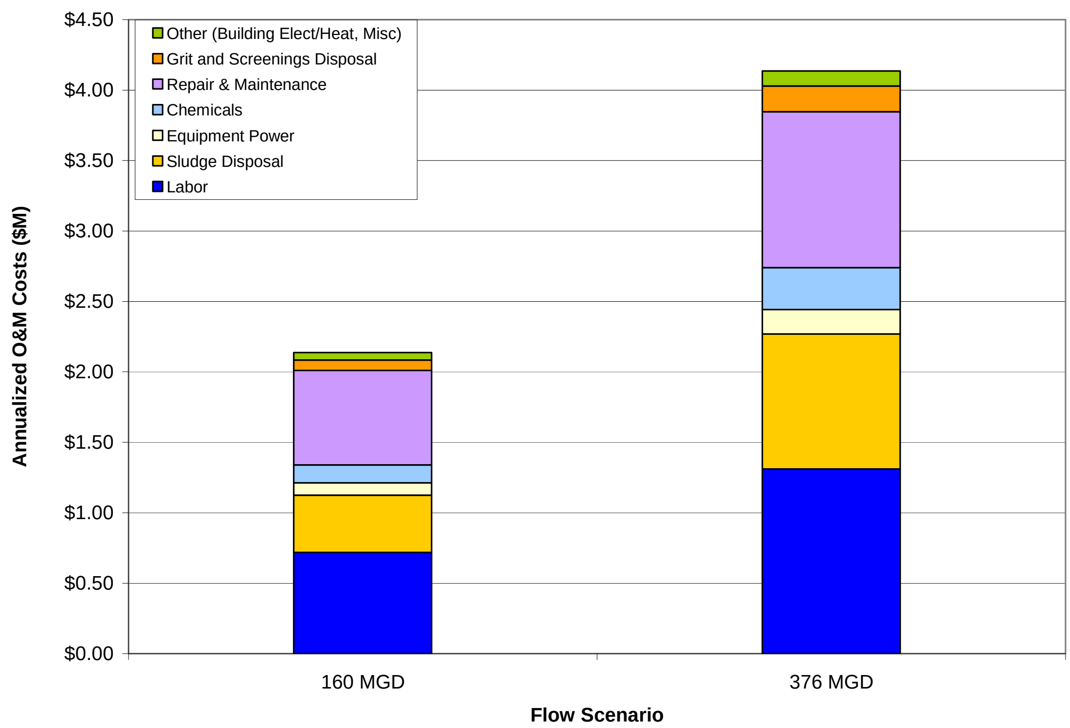


EXHIBIT 5-6
Operation and Maintenance Costs by Category for Treatment Train #2: Conventional Clarifiers



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 for three different flow scenarios for this train: 150, 300 and 1000 mgd. Key design parameters at these flows are shown in Exhibit 6-1. As shown in Exhibit 6-2, there is adequate space on the Fleet auction lot to treat up to 300 mgd of wet weather flow. Utilizing the adjacent sludge lagoon area allows an increased flow capacity to 1000 mgd. This sludge lagoon, as well as the lagoon area for the new chlorine contact chamber, will need remediation.

6.3 Operational and Technology-Specific Issues

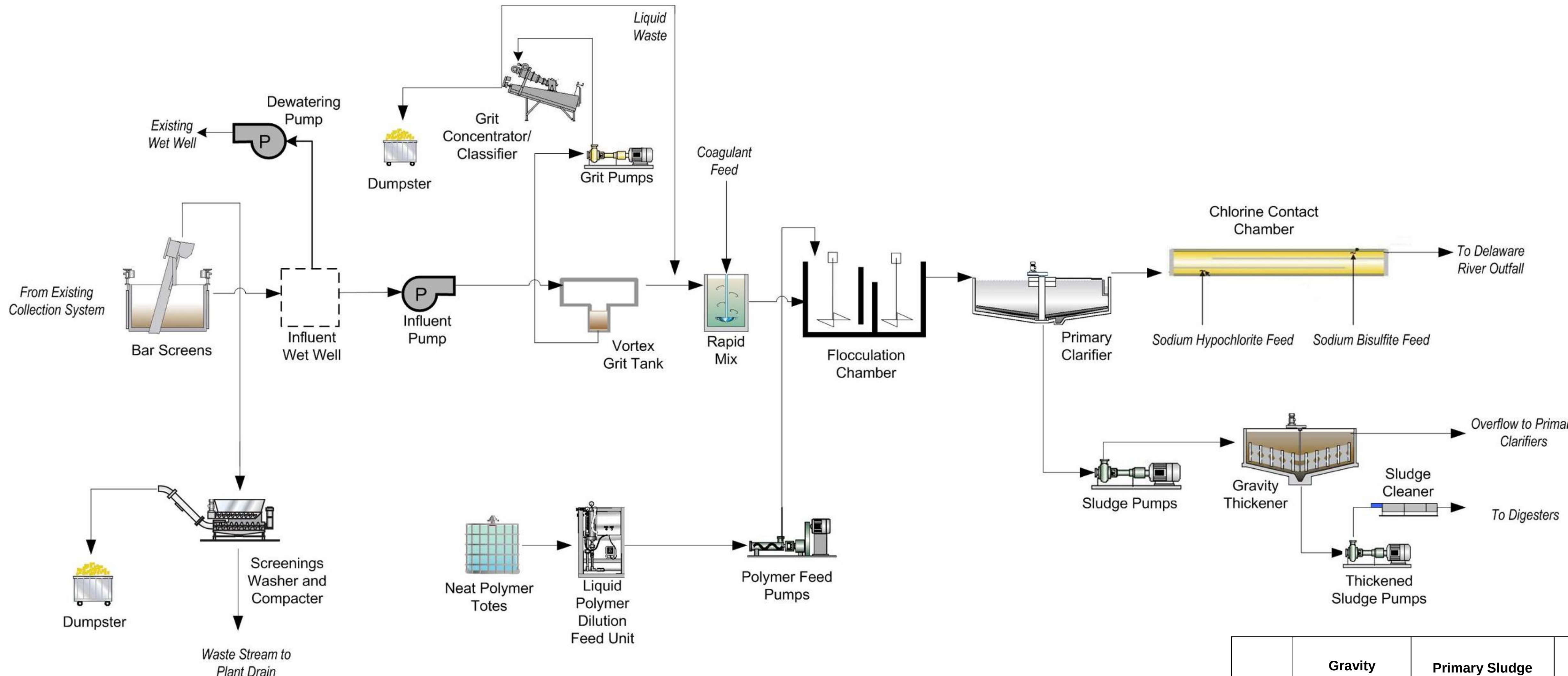
6.3.1 Startup and Shutdown

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

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

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

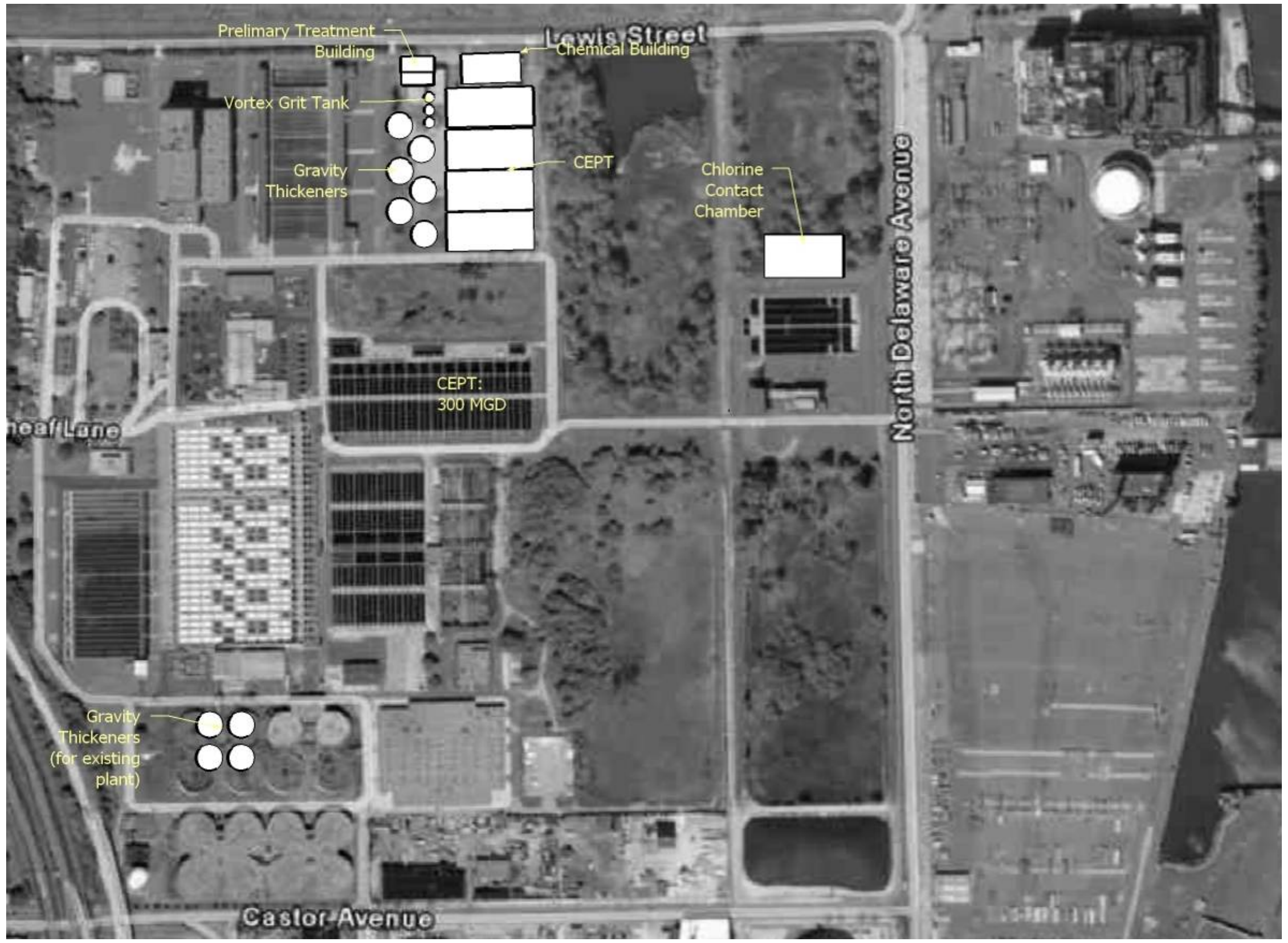
EXHIBIT 6-1
Process Flow Diagram and Key Process Design Parameters for Treatment Train #3: CEPT

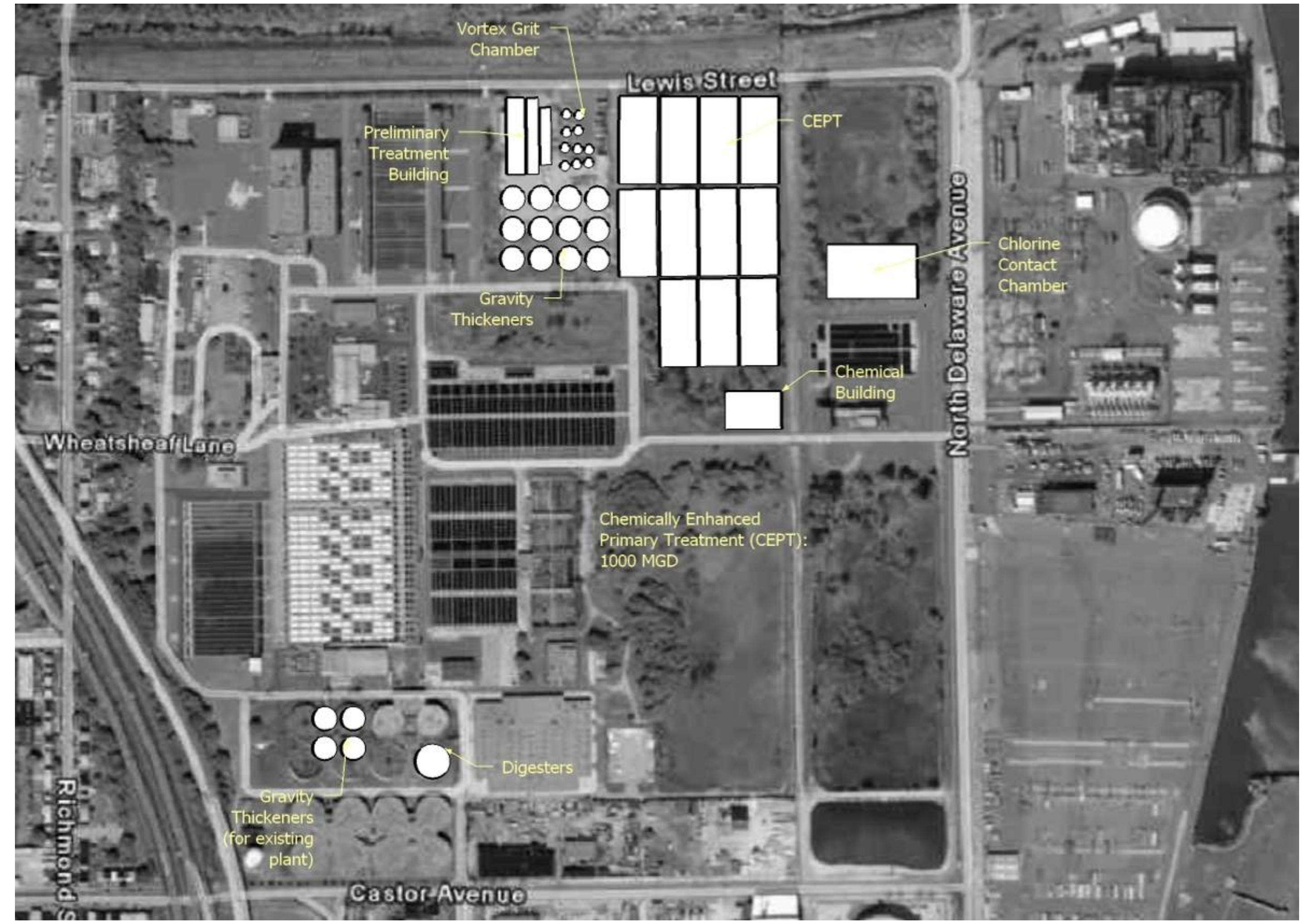


Flow (mgd)	Gravity Thickeners & Sludge Cleaners # Units	Primary Sludge Pumps		Thickened Sludge Pumps		Sludge Prod. (lb/day)	Digesters
		# Duty	# Standby	# Duty	# Standby		# units
150	3	3	1	3	1	355,168	0
300	6	4	1	6	2	724,905	0
1000	12	11	3	12	3	1,341,075	1

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			Sodium Hypochlorite			Sodium Bisulfite			Flocculation # Trains	Clarification # Trains
			# Units	DIA (ft)		# Duty	# Standby				Total Storage Vol (gal)	# Duty Pumps	# Standby Pumps	Total Storage Vol (gal)	# Duty Pumps	# Standby Pumps	Total Storage Vol (gal)	# Duty Pumps	# Standby Pumps	Total Storage Vol (gal)	# Duty Pumps	# Standby Pumps		
150	2	2	2	32	2	2	1	2	1	863	157,388	3	1	7,358	1	1	74,684	1	1	6,226	1	1	3	3
300	3	4	3	32	3	3	1	3	1	1,725	314,776	4	1	13,637	4	1	149,638	1	1	8,654	1	1	4	4
1000	10	14	10	32	10	10	3	10	3	3,191	582,335	11	3	25,229	11	3	276,331	1	1	16,.011	1	1	11	11

EXHIBIT 6-2
Conceptual Layouts and Footprints for Treatment Train #3: CEPT
300 MGD Layout (left), 1000 MGD (right)





Flow (Mgd)	PTB	Grit Units	Flocculation Tanks	Clarifier Tanks	Chemical Building	CCC	Gravity Thickeners	Digesters	TOTAL FOOTPRINT (acres)	Remediation Footprint (acres)
150	41' x 45' & 56' x 39'	32' (2 units)	107' x 51' (3 units)	107' x 164' (3 units)	101' x 100'	88' x 181' (4 passes)	80' (3 units)	-	2.7	0
300	67' x 53' & 80' x 39'	32' (3 units)	127' x 55' (4 units)	127' x 213' (4 units)	201' x 100'	130' x 239' (6 passes)	80' (6 units)	-	5.3	2.3
1000	197' x 58' & 188' x 39'	32' (10 units)	126' x 27' (11 units)	126' x 257' (11 units)	259' x 100'	172' x 297' (8 passes)	80' (12 units)	115' (1 unit)	13.3	13.5

6.3.2 Interaction with Main Plant

As described in the previous treatment trains, the overflow from the thickeners, ranging from 7 to 48 mgd depending on the flow scenario, is recycled back to the head of the plant for distribution across the main plant and the wet weather treatment train.

6.3.3 Impact on Plant Operations

CEPT requires the addition of chemicals, ferric chloride and polymer, that are not currently used at the NE 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 breakpoint in the O&M costs can be seen after a flow of 300-mgd. This is because O&M costs such as for chemical and sludge disposal are dependent on the average flow of the plant, not the peak. For example, while the 1000-mgd facility can treat a peak of 1000-mgd, the average flow through the facility is only 555 mgd, so the O&M (Section 3.2.1). Thus, facilities with peak flows greater than the average wet weather flow will experience a relatively smaller increase in O&M costs.

A more detailed breakdown of these costs is presented in Attachment NE-2.1.

EXHIBIT 6-3
Cost Summary for CEPT Train #3

	Wet Weather Flow (mgd)		
Cost	**150**	**300**	**1000**
Capital Cost ($M)	$207	$351	$996
Annual Operations and Maintenance Cost ($M)	$2.6	$5.0	$8.5
Present Value of the Cost ($M)	$248	$429	$1,129

EXHIBIT 6-4
Capital Costs for Treatment Train #3: CEPT
Includes cost to upgrade plant capacity to 650 MGD.

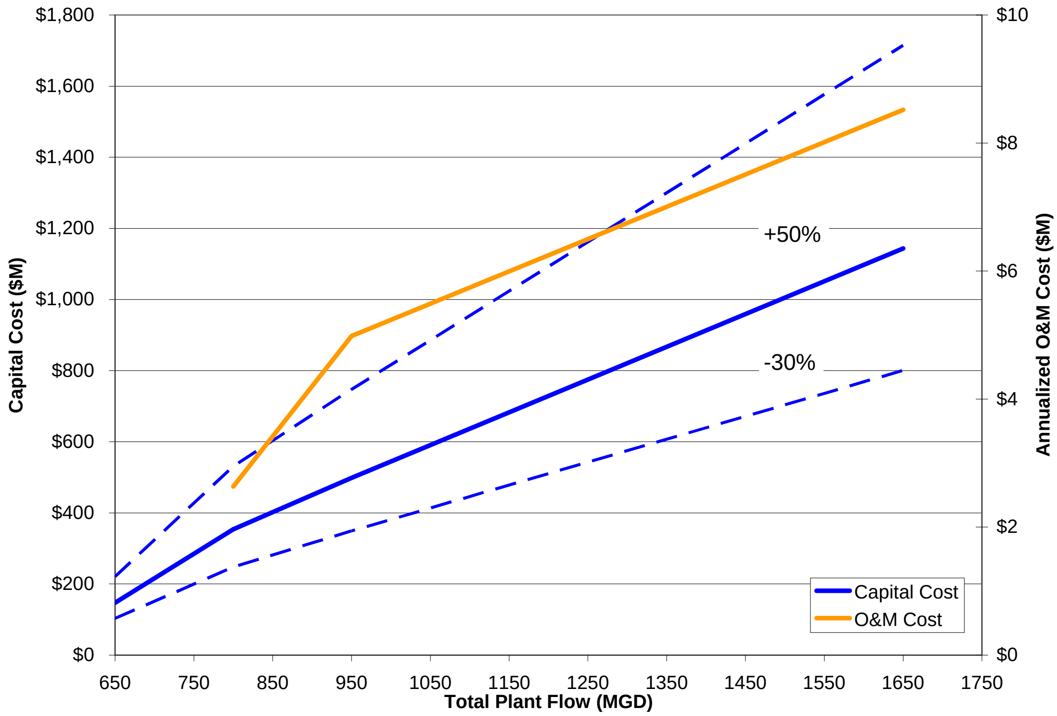


EXHIBIT 6-5
Capital Costs per Gallon Treated for Treatment Train #3: CEPT

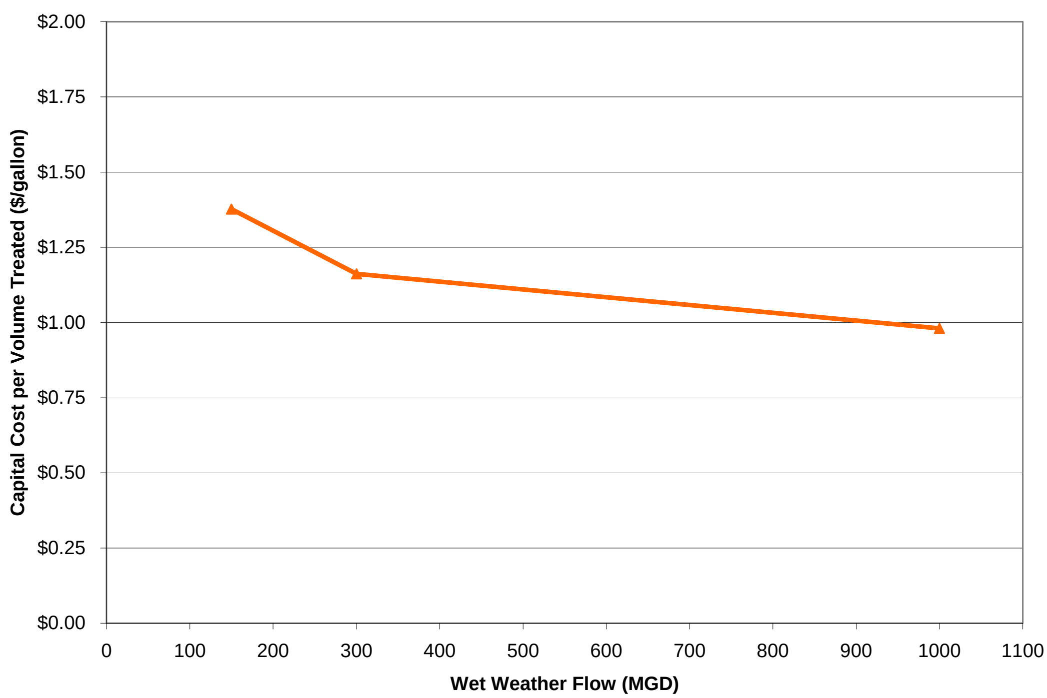
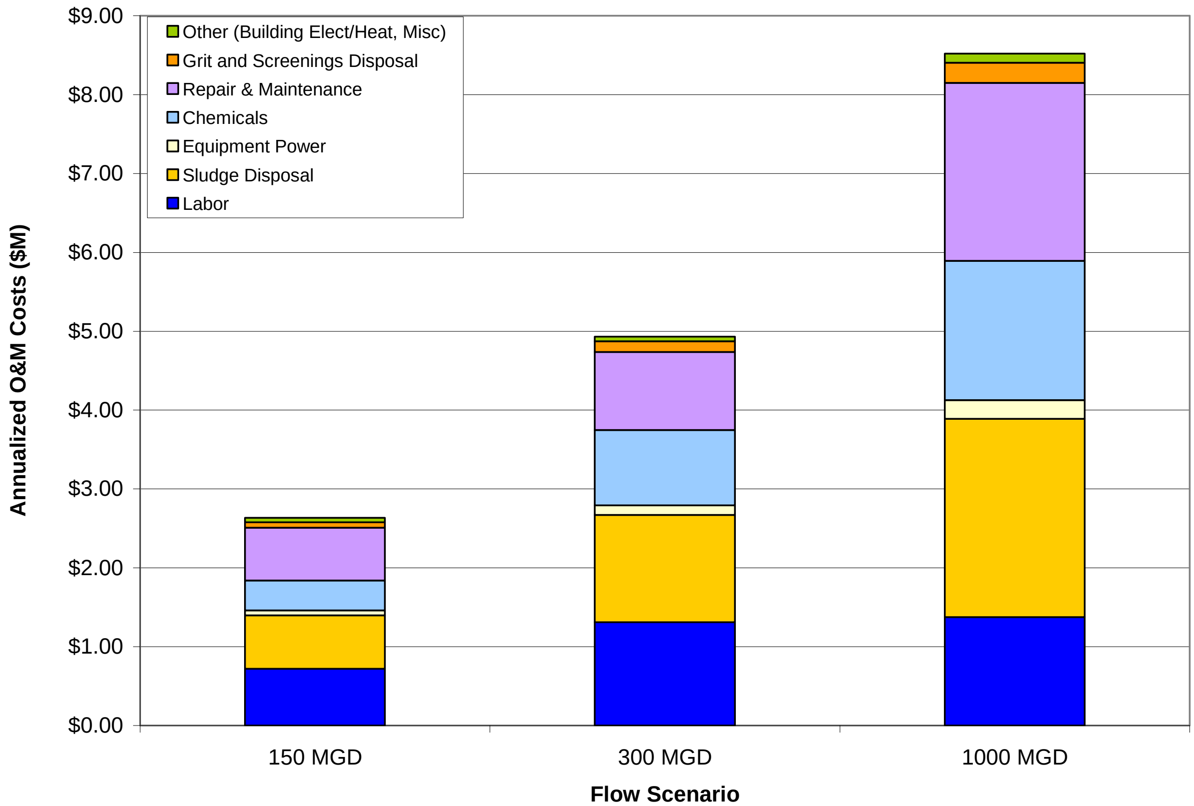


EXHIBIT 6-6
Operations and Maintenance Costs by Category for Treatment Train #3: CEPT



7.0 Treatment Train #4 - 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:

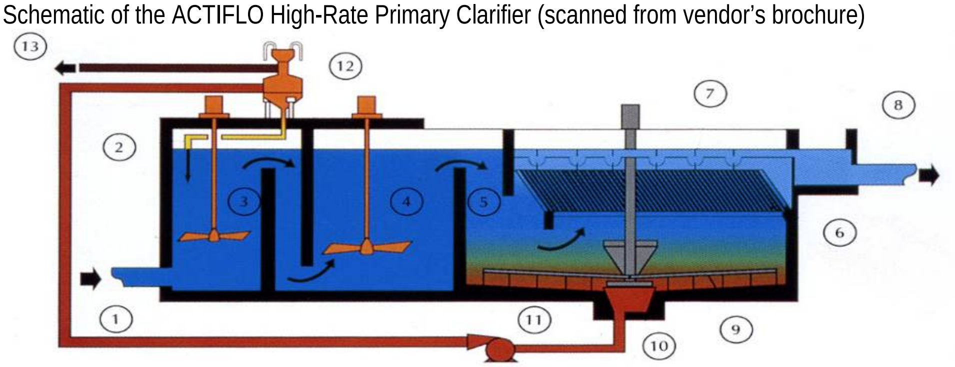
- Identification of influent wastewater constituents that may affect performance of either technology
- Determining suitable chemical dosages for the ballasted flocculation system
- Providing effluent quality information that can be used for design of downstream disinfection processes
- Assessing treatment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

7.1 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 7-2). A schematic of the Actiflo system is shown in Exhibit 7-1.

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

EXHIBIT 7-1
Schematic of the ACTIFLO High-Rate Primary Clarifier (scanned from vendor's brochure)



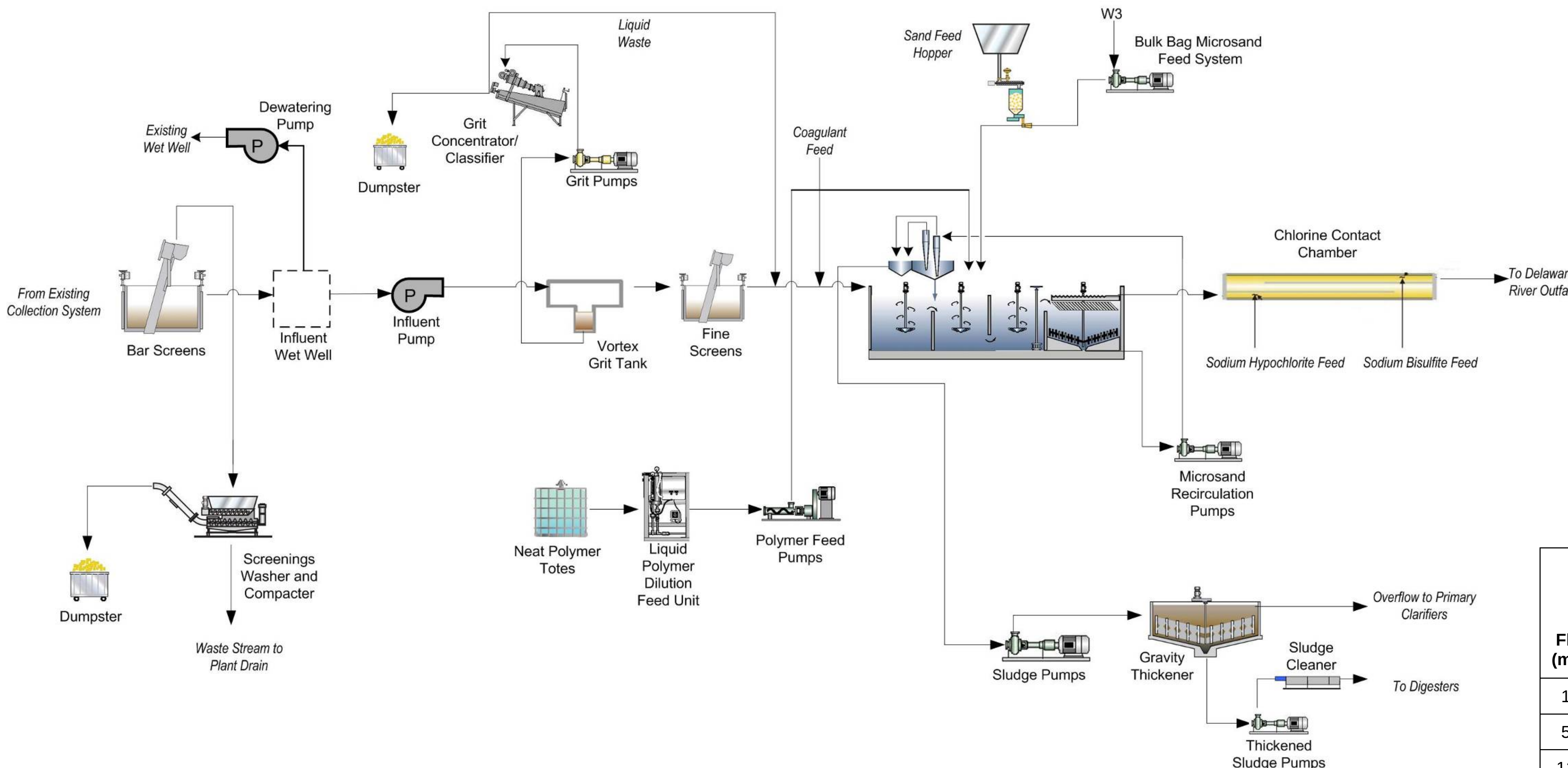
As shown in Exhibit 7-2, the sludge from the ballasted flocculation process is pumped to gravity thickeners to be thickened from 0.3 percent solids to 3-4 percent solids.

7.2 Conceptual Design and Site Layouts

Conceptual designs using the ballasted flocculation system were developed for flow capacities of 150, 500 and 1,100 mgd. The key design parameters are presented in Exhibit 7-2. As seen in the conceptual layouts in Exhibit 7-3, the Fleet auction lot provides adequate space for treating up to 500 mgd. With the adjacent sludge lagoon area, the flow capacity can reach 1500 mgd. However, since the upgraded collection system is not likely to convey more than 1100 mgd, the maximum design point for this train is 1100 mgd. Due to its extremely high surface overflow rate of 60 gpm/sf, ballasted flocculation has minimal space requirements compared to the other alternatives.

EXHIBIT 7-2

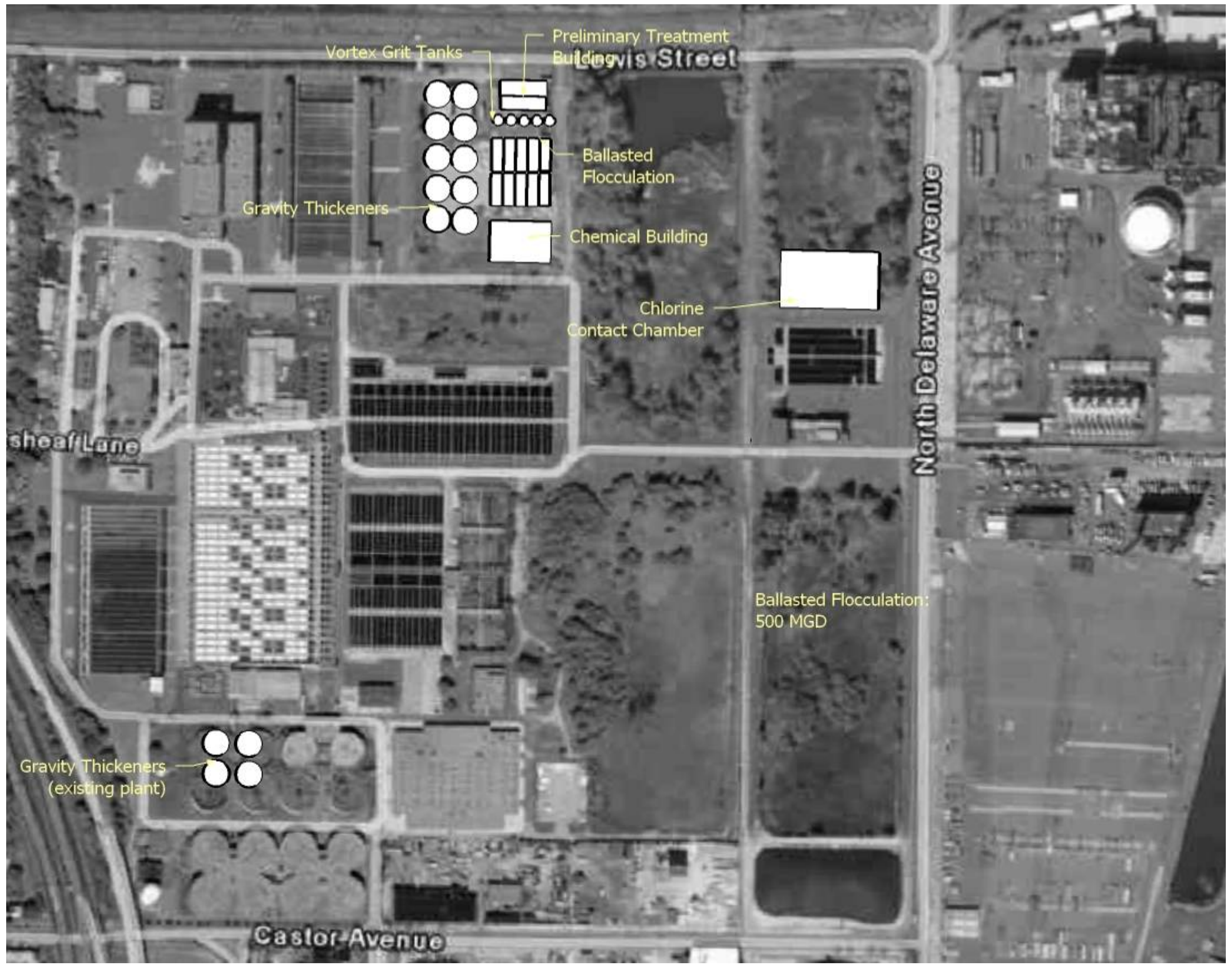
Process Flow Diagram and Key Process Design Parameters for Treatment Train #5: Ballasted Flocculation

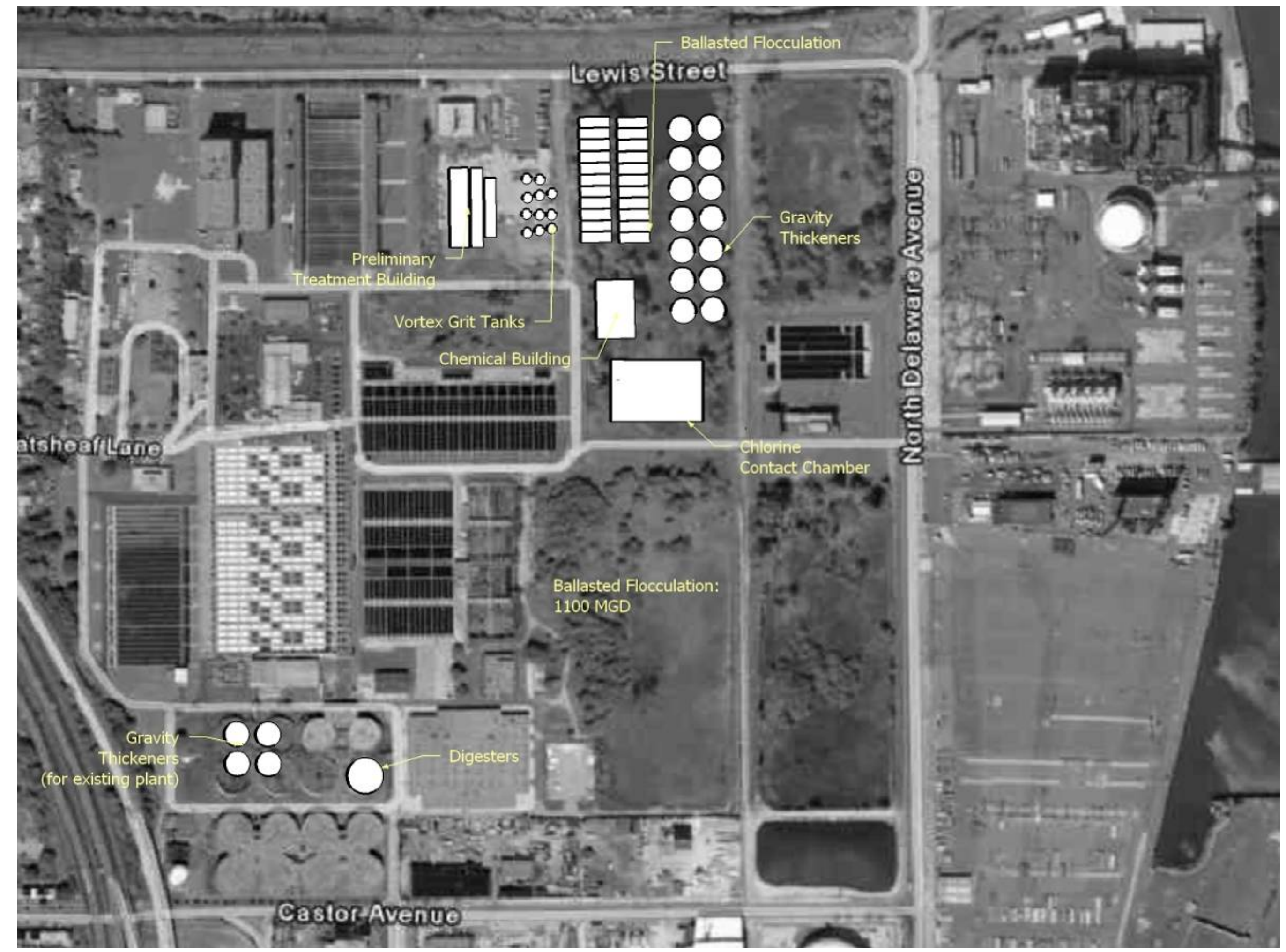


Flow (mgd)	Primary Sludge Pumps		Thickened Sludge Pumps		Sludge Prod. (lb/day)	Digesters
	# Duty	# Standby	# Duty	# Standby		# units
150	3	1	4	1	407,759	0
500	10	3	10	3	1,128,134	0
1100	22	6	14	4	1,508,709	1

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			Sodium Hypochlorite			Sodium Bisulfite			Actiflo	Gravity Thickeners & Sludge Cleaners
			# Units	Dia (Ft)			# Duty	# Standby				Total Storage Vol (Gal)	# Duty Pumps	# Standby Pumps	Total Storage Vol (gal)	# Duty Pumps	# Standby Pumps	Total Storage Vol (Gal)	# Duty Pumps	# Standby Pumps	Total Storage Vol (Gal)	# Duty Pumps	# Standby Pumps	# Trains	# Units
150	2	2	2	32	2	4	2	1	2	1	1,033	157,388	3	1	7,.358	3	1	74,684	1	1	6,226	1	1	3	4
500	5	7	5	32	5	10	5	2	5	2	2,953	435,440	10	3	18,865	10	3	206,626	1	1	11,972	1	1	10	10
1100	11	15	11	32	11	22	11	4	11	4	3,822	582,335	22	6	225,229	22	6	276,331	1	1	16,011	1	1	22	14

EXHIBIT 7-3
Conceptual Layouts and Footprints for Treatment Train #5: Ballasted Flocculation
500 MGD Layout (left), 1100 MGD (right)





Flow (mgd)	PTB	Grit Units	Fine Screening	Actiflo Units	Chemical Building	CCC	Gravity Thickeners	Digesters	TOTAL FOOTPRINT (acres)	Remediation Footprint (acres)
150	41' x 45' & 56' x 39'	32' (2 units)	37' x 38'	32' x 86' (3 units)	119' x 100'	88' x 181' (4 passes)	80' (4 units)	-	1.5	NONE
500	106' x 55' & 117' x 39'	32' (5 units)	77' x 38'	32' x 86' (10 units)	141' x 118'	172' x 297' (8 passes)	80' (10 units)	-	4.2	2.3
1100	210' x 60' & 232' x 39'	32' (11 units)	171' x 38'	32' x 86' (22 units)	141' x 118'	193' x 291' (9 passes)	80' (14 units)	115' (1 unit)	6.4	11.4

7.3 Operational and Technology-Specific Issues

7.3.1 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.

7.3.2 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 49 to 108 mgd, depending on the flow capacity of the treatment train.

7.3.3 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.

7.3.4 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.

7.4 Cost Analyses

The estimated capital, O&M, and lifecycle costs for each flow scenario are shown in Exhibit 7-4. Total capital costs and the capital costs per volume treated are also shown in Exhibits 7-5 and 7-6. Estimated O&M costs by category are presented in Exhibit 7-7. As described in the CEPT section, the breakpoint in the O&M costs at 500-mgd is due to the dependence on average flow, rather than peak flow, of the chemical and sludge disposal costs.

A more detailed breakdown of these costs is presented in Attachment NE-2.1.

EXHIBIT 7-4
Cost Summary for Ballasted Flocculation: Treatment Train #4

	Wet Weather Flow (mgd)		
Cost	**150**	**500**	**1100**
Capital Cost ($M)	$195	$527	$1,062
Annual Operations and Maintenance Cost ($M)	$3.0	$7.2	$10.0
Present Value of the Cost ($M)	$242	$639	$1,218

EXHIBIT 7-5
Capital Costs for Treatment Train #4: Ballasted Flocculation
Includes cost to upgrade plant capacity to 650 MGD

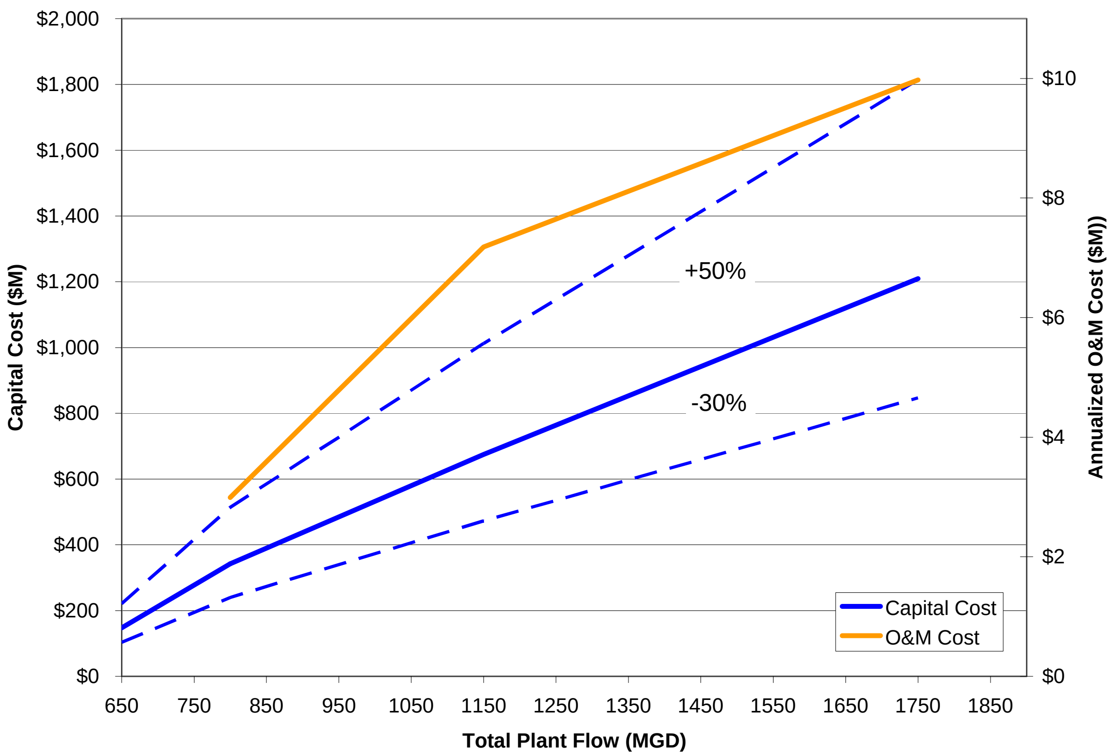


EXHIBIT 7-6
Capital Costs per Gallon Treated for Treatment Train #4: Ballasted Flocculation

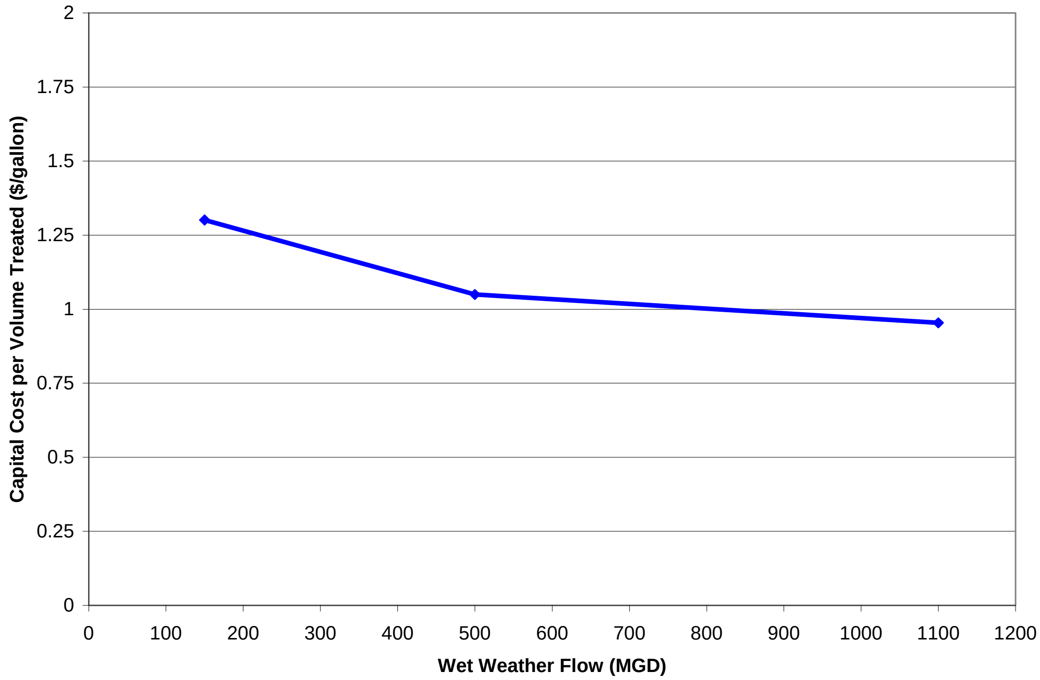
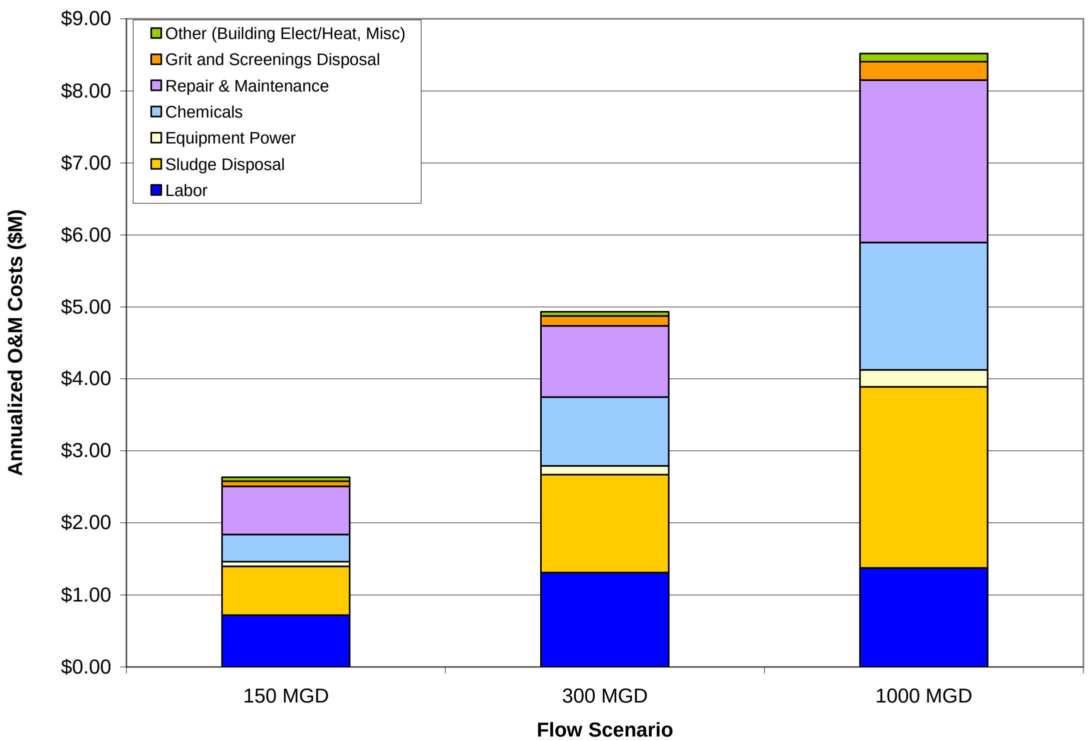


EXHIBIT 7-7
Operations and Maintenance Costs by Category for Treatment Train #4: Ballasted Flocculation



8.0 Alternatives for Optimizing Capital Costs

8.1 Ballasted Flocculation

As mentioned in Section 7, the costs presented for Treatment Train #4, Ballasted Flocculation, are based on the Actiflo system, which is similiar 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.

8.2 Refined Design Assumptions via Influent Sampling

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

9.0 Comparison of Treatment Alternatives

9.1 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 9-1 and 9-2, respectively.

EXHIBIT 9-1
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)								
		69	150	160	183*	300	376*	500	1000	1100
#1) Vortex/Swirl Concentrators	221	83			87					
#2) Conventional Clarifiers	142			83			82			
#3) CEPT w/ Conventional Clarifiers	63		67			66			65	
#4) Ballasted Flocculation	30		61					51		44

Notes: Based on the 95th percentile wet weather TSS concentration of 68 mg/L and a maximum of 650 MGD through the existing plant. Allowable daily blended effluent TSS concentration on wet weather days is 99 mg/L to meet monthly TSS permit limits.

*As discussed in Section 3.1, the Vortex-183 mgd and CEPT-376 mgd flow scenarios are only allowable assuming no secondary bypass at the plant. Thus, these concentrations assume a 95th percentile wet weather TSS concentration of 31 mg/L and a maximum of 435 MGD through the existing plant.

EXHIBIT 9-2
Blended Effluent cBOD Concentrations

Treatment Train	Wet Weather Treatment Train Effluent Conc. (mg/L)	Blended Effluent cBOD Concentration (mg/L)								
		Wet Weather Treatment Train Flow (mgd)								
		69	150	160	183*	300	376*	500	1000	1100
#1) Vortex/Swirl Concentrators	117	37			49					
#2) Conventional Clarifiers	91			41			53			
#3) CEPT w/ Conventional Clarifiers	66		36			41			51	
#4) Ballasted Flocculation	55		34					40		45

Notes: Based on the 95th percentile wet weather cBOD concentration of 29 mg/L and a maximum of 650 MGD through the existing plant.

*As discussed in Section 3.1, the Vortex-183 mgd and CEPT-376 mgd flow scenarios are only allowable assuming no secondary bypass at the plant. Thus, these concentrations assume a 95th percentile wet weather cBOD concentration of 20 mg/L and a maximum of 435 MGD through the existing plant.

As described in Section 3.1, Trains #1 and #2, Vortex/Swirl and Conventional Clarification, are limited in flow by permit conditions. Trains #3 and #4, CEPT and Ballasted Flocculation, are considered unlimited in flow if the number of wet weather days is less than 7 days per month. To illustrate the risk of exceeding permit limits at each flow scenario, Exhibit 9-3 presents the maximum number of days that the wet weather treatment train can operate at its maximum capacity without exceeding monthly TSS permit limits. The ballasted flocculation train is unlimited in frequency of operation since its effluent quality (30 mg/L TSS) surpasses permit limits without blending. The CEPT train can operate more frequently at higher flows since its effluent quality (63 mg/L TSS) is slightly better than the quality from the conventional secondary treatment plant (68 mg/L TSS)

A frequency plot of the estimated number of wet weather events per month is shown in Exhibit 9-4 (Myers, 2008b). As shown, wet weather events have occurred at a historical maximum of 15 per month. It should be noted that the wet weather event referred to in this plot occurs whenever rainfall exceeds 0.1 inch, and does not necessarily correspond to operation of the new wet weather treatment train. If the flow does not exceed the capacity of the conventional plant, the wet weather treatment train will not come online. Thus, the new wet weather treatment train is expected to operate less than 15 times per month.

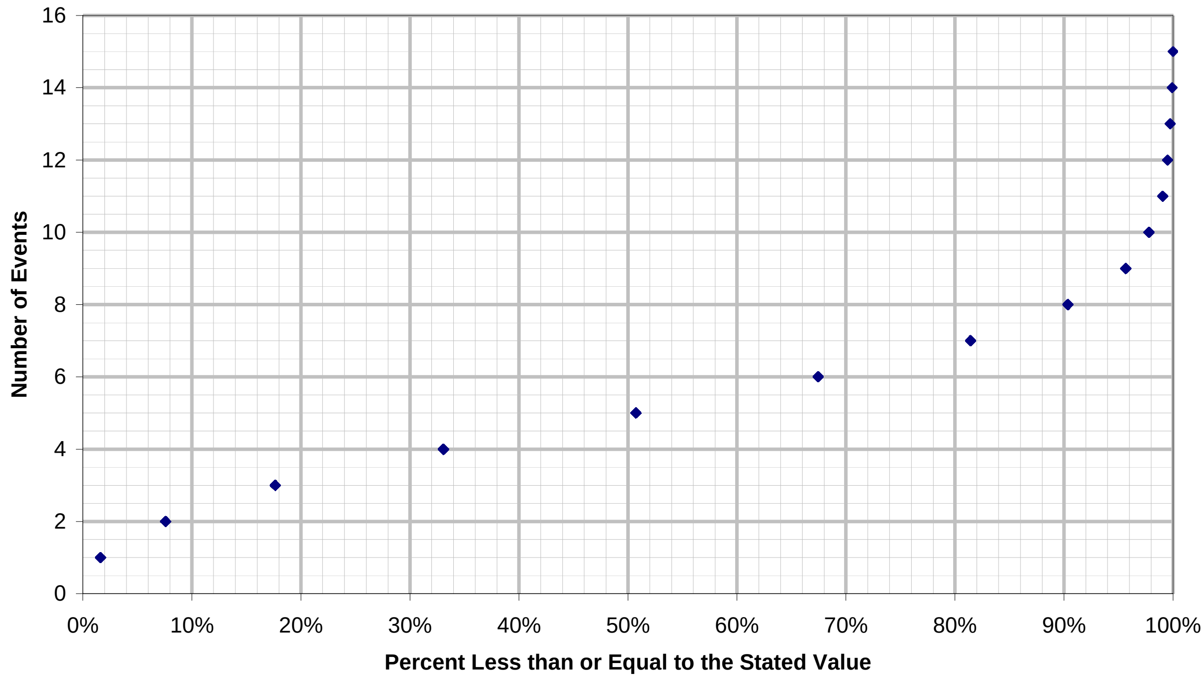
It should be noted that a continuous simulation-based approach would give a more accurate estimate of risk, and more detailed analyses should be performed during the facility planning and design phases.

EXHIBIT 9-3
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	***69***	***150***	***160***	***183****	***300***	***376****	***500***	***1000***	***1100***
#1) Vortex/Swirl Concentrators	7			7					
#2) Conventional Clarifiers			7			7			
#3) CEPT w/ Conventional Clarifiers		7			8			9	
#4) Ballasted Flocculation					UNLIMITED				

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

EXHIBIT 9-4
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)

9.2 Capital, O&M and Life-Cycle Costs

As shown in Exhibit 9-5, the capital costs for Trains #2 - #4 track each other very closely, with CEPT being slightly more expensive. Train #1, the vortex/swirl, appears least expensive and most cost effective as flows increase (Exhibit 9-6). Train #3, CEPT, appears slightly less cost-effective than Train #4, Ballasted Flocculation, due to greater cost for piles for its larger footprint.

The comparison of O&M costs for each treatment train is shown in Exhibit 9-7. As expected, the O&M costs for vortex swirls and conventional clarifiers, which do not require chemical settling aids, are the lowest. Ballasted Flocculation has the highest O&M costs due to the use of chemicals and the complexity of its system.

Taking construction, non-construction, and O&M costs into consideration, Exhibit 9-8 shows the present value of the total cost of each wet weather treatment train. This graph suggests that there is negligible cost difference between Train #3, CEPT, and Train #4, Ballasted Flocculation at this plant. As expected, Trains #1 and #2 are least expensive due to its low chemical usage and minimal O&M costs.

EXHIBIT 9-5
Comparison of Capital Costs for All Treatment Trains
Includes cost to upgrade plant capacity to 650 MGD

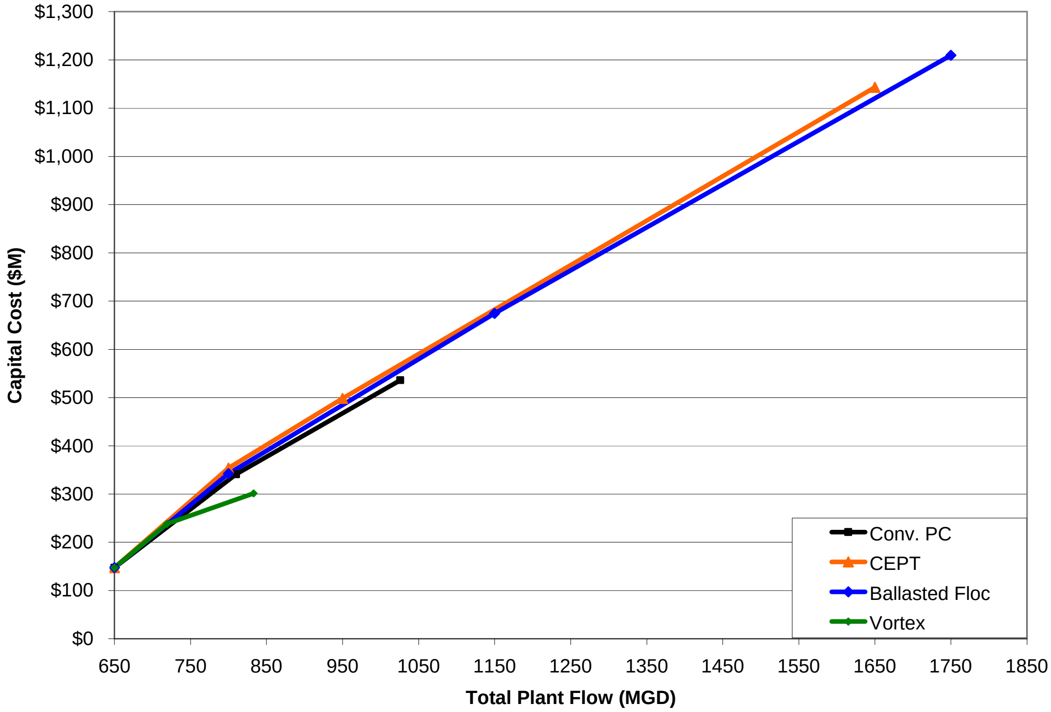


EXHIBIT 9-6
Comparison of Cost Effectiveness for all Treatment Trains

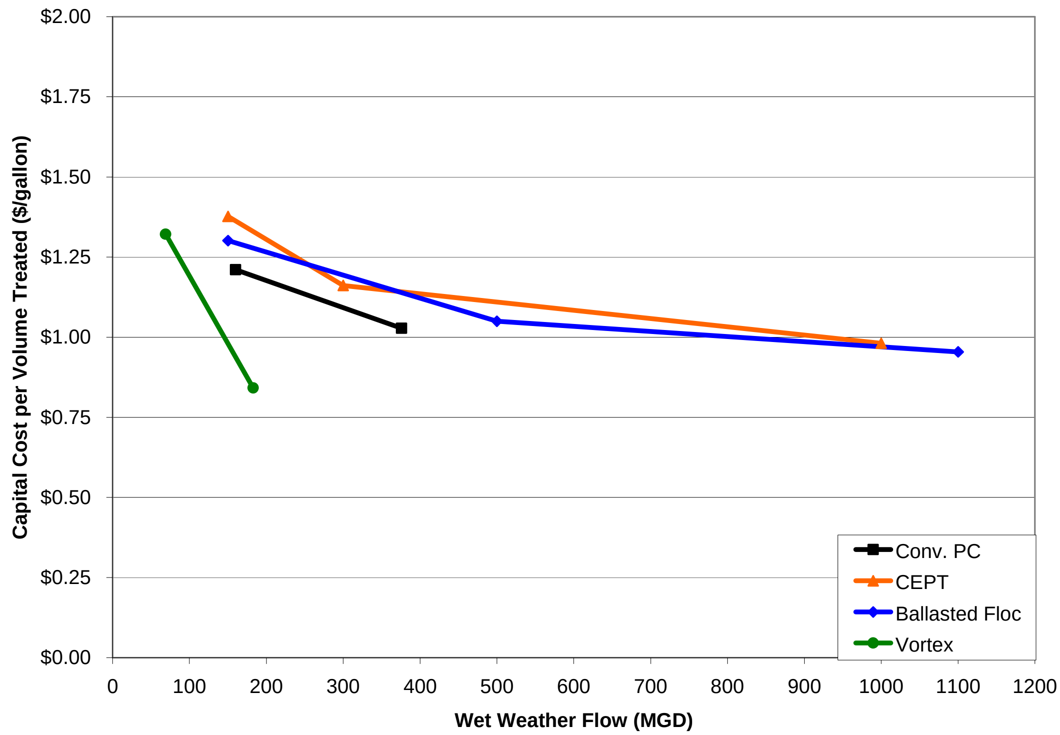


EXHIBIT 9-7
Comparison of Operations and Maintenance Costs for all Treatment Trains

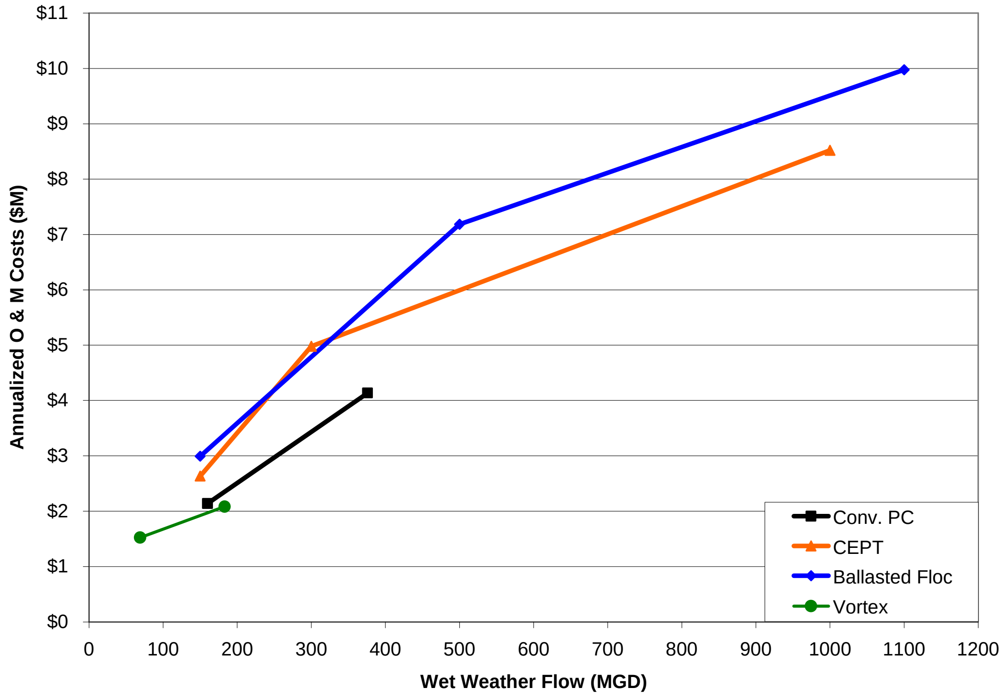
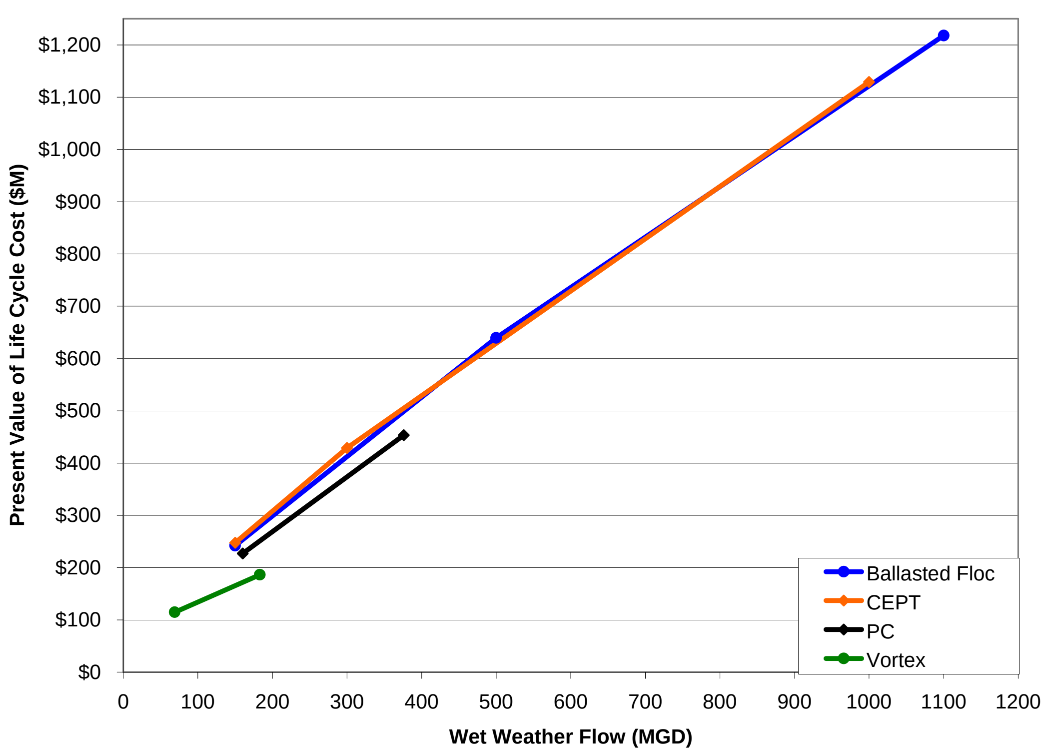


EXHIBIT 9-8
Comparison of Life-Cycle Costs for all Treatment Trains



9.3 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, 2008a). Several key advantages and disadvantages of Treatment Trains #1 - #4, as evaluated in this report, are described in Exhibit 9-9.

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

Treatment Train	Pros	Cons
Train #1: Vortex/Swirl Concentrators	• Simple operation • Low maintenance requirements – no moving parts	• 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 • 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 • May be operated as Conventional Clarifiers if chemicals found to be unnecessary	• Operators unfamiliar with technology • Space limited • Uses two additional chemical systems for coagulation and flocculation • Maximum design flow may decrease if the assumed number of operating days is greater than 9.
Train #4: Ballasted Flocculation	• Can treat up to 1500 mgd with available land on site • Highest removal efficiencies • Unlimited number of operating days per month • Lower chlorine dose possible due to high TSS removal efficiencies	• Operators unfamiliar with technology • Most labor intensive and complex system • Uses two additional chemical systems for coagulation and flocculation

The costs for wet weather treatment at the NE 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.

10.0 References

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Attachment NE-2.1

Breakdown of Capital and O&M Costs

NE WPCP Wet Weather Treatment Train Alternatives: Capital Cost Estimates

Train	Train #1: Vortex/Swirl		Train #2: Conventional Clarifiers		Train #3: CEPT			Train #4: Ballasted Flocculation		
Flow (mgd)	69	183	160	376	150	300	1000	150	500	1100
Influent Pump Station	$3,775,534	$5,825,465	$5,715,245	$11,155,330	$4,193,296	$7,848,029	$25,723,707	$4,193,296	$13,177,903	$27,627,105
Bar Screens, Grit Removal, and Fine Screens	$2,124,734	$3,518,520	$4,305,848	$7,963,022	$4,306,977	$6,027,362	$19,666,033	$6,805,293	$15,334,981	$34,703,082
Vortex Swirl	$4,544,219	$9,088,438	$0	$0	$0	$0	$0	$0	$0	$0
Flocculation Tanks	$0	$0	$0	$0	$3,044,901	$4,801,275	$10,067,713	$0	$0	$0
Primary Clarifiers	$0	$0	$8,593,891	$20,599,909	$7,205,748	$12,520,587	$41,843,098	$0	$0	$0
Actiflo System	$0	$0	$0	$0	$0	$0	$0	$10,562,312	$34,329,380	$75,008,712
Chemical Feed	$825,578	$1,315,461	$1,277,089	$2,268,957	$3,248,382	$5,093,207	$7,920,216	$3,457,211	$6,685,702	$8,641,618
Chlorine Contact Chamber (1)	$1,187,531	$2,764,885	$2,454,069	$5,350,790	$2,326,943	$4,314,045	$6,888,494	$2,326,943	$6,888,494	$7,525,878
Gravity Thickeners	$1,722,904	$3,491,350	$2,460,577	$4,035,149	$3,688,352	$7,347,645	$14,659,263	$4,720,858	$12,401,511	$17,179,717
Yard Piping (large)	$1,576,038	$1,608,050	$3,496,708	$5,681,538	$3,529,489	$5,502,651	$16,016,916	$3,516,500	$7,840,832	$18,796,161
Digesters	$0	$0	$0	$0	$0	$0	$6,501,580	$0	$0	$6,568,306
Subtotal Project Cost	$15,756,538	$27,612,169	$28,303,427	$57,054,695	$31,544,088	$53,454,801	$149,287,020	$35,582,413	$96,658,803	$196,050,579
Additional Project Costs:										
General Demolition	$157,565	$276,122	$283,034	$570,547	$315,441	$534,548	$1,492,870	$355,824	$966,588	$1,960,506
Overall Sitework	$1,260,523	$2,208,974	$2,264,274	$4,564,376	$2,523,527	$4,276,384	$11,942,962	$2,846,593	$7,732,704	$15,684,046
Plant Computer System	$1,339,306	$2,347,034	$2,405,791	$4,849,649	$2,681,247	$4,543,658	$12,689,397	$3,024,505	$8,215,998	$16,664,299
Yard Electrical	$1,260,523	$2,208,974	$2,264,274	$4,564,376	$2,523,527	$4,276,384	$11,942,962	$2,846,593	$7,732,704	$15,684,046
Yard Piping	$787,827	$1,380,608	$1,415,171	$2,852,735	$1,577,204	$2,672,740	$7,464,351	$1,779,121	$4,832,940	$9,802,529
Subtotal with Additional Project Costs	$20,562,282	$36,033,881	$36,935,972	$74,456,377	$41,165,035	$69,758,515	$194,819,561	$46,435,049	$126,139,738	$255,846,006
Subtotal with Contractor Markups (1)	$31,171,135	$54,625,111	$55,992,625	$112,871,214	$62,403,620	$105,749,549	$295,334,278	$70,392,632	$191,219,959	$387,846,554
Subtotal with Escalation (2)	$37,343,019	$66,205,634	$67,471,114	$138,267,237	$75,196,362	$128,802,951	$378,618,545	$84,823,122	$236,921,529	$497,219,282
Subtotal with Local Adjustment Factor (3)	$43,019,158	$76,268,891	$77,726,723	$159,283,857	$86,626,209	$148,381,000	$436,168,564	$97,716,236	$272,933,602	$572,796,613
Dewatering	$236,348	$414,183	$424,551	$855,820	$473,161	$801,822	$2,239,305	$533,736	$1,449,882	$2,940,759
Structural Piles	$17,721,821	$26,324,595	$51,392,989	$98,281,523	$51,073,762	$83,840,011	$217,557,438	$32,311,163	$76,635,890	$126,090,858
Subtotal - Construction Cost, including Market Adjustment Factor (4)	**$70,123,927**	**$118,458,818**	**$148,975,903**	**$297,184,381**	**$158,899,102**	**$267,976,257**	**$754,360,103**	**$150,145,305**	**$403,672,280**	**$807,102,464**
Remediation	$0	$0	$0	$2,591,727	$0	$2,591,727	$15,356,115	$0	$2,591,727	$13,000,000
Total Capital Cost (with non construction costs)	**$91,161,105**	**$153,996,464**	**$193,668,674**	**$388,931,422**	**$206,568,832**	**$350,960,861**	**$996,024,249**	**$195,188,897**	**$527,365,691**	**$1,062,233,203**
Total Capital Cost ($M)	$91	$154	$194	$389	$207	$351	$996	$195	$527	$1,062
.+50% Capital Cost ($M)	$137	$231	$291	$583	$310	$526	$1,494	$293	$791	$1,593
.-30% Capital Cost ($M)	$64	$108	$136	$272	$145	$246	$697	$137	$2	$744
Cost Efficiency ($/gallon)	**$1.32**	**$0.84**	**$1.21**	**$1.03**	**$1.38**	**$1.16**	**$0.98**	**$1.30**	**$1.05**	**$0.95**

Notes:
1. Contractor markups - use 1.516 multiplier (see TM-NE2 Section 3.3)
2. Escalation - multiplier depends on duration of construction (see Exhibit 4-7 in TM-NE2 Section 3.3)
3. Local Adjustment Factor - use 1.152 multiplier (see TM-NE2 Section 3.3)
4. Market Adjustment Factor - use 1.15 multiplier (see TM-NE2 Section 3.3)
5. Non-construction costs - use 1.3 multiplier (see TM-NE2 Section 3.3)

NE 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	69	$718,712	$95,734	$63,064	$1,570	$54,376	$507,250	$31,737	$50,819	$1,523,263	1,632
	183	$718,712	$253,902	$98,567	$2,622	$144,216	$730,715	$84,173	$50,819	$2,083,727	2,550
Train #2: Conventional Clarifiers	160	$718,712	$406,984	$87,585	$2,562	$126,090	$670,820	$73,594	$50,819	$2,137,167	2,266
	376	$1,311,933	$956,412	$174,523	$4,440	$296,313	$1,106,862	$183,525	$101,639	$4,135,647	4,515
Train #3: CEPT	150	$718,712	$679,707	$63,365	$4,170	$378,458	$669,393	$68,994	$50,819	$2,633,619	1,639
	300	$1,311,933	$1,359,414	$121,720	$6,384	$954,216	$988,988	$137,989	$101,639	$4,982,284	3,149
	1000	$1,374,679	$2,514,917	$237,786	$11,614	$1,765,300	$2,256,985	$255,279	$101,639	$8,518,198	11,084
Train #5: Ballasted Flocculation	150	$718,712	$764,671	$84,081	$4,895	$478,742	$808,568	$82,642	$50,819	$2,993,130	2,175
	500	$1,311,933	$2,115,589	$289,565	$8,698	$1,324,519	$1,796,046	$236,194	$101,639	$7,184,182	7,491
	1100	$1,374,679	$2,829,281	$319,038	$13,667	$1,771,345	$3,260,931	$305,774	$101,639	$9,976,354	16,359

Notes:

1. All O&M costs are annualized costs based on escalation through a 30-year period. For average flows, see Section 3.2.1 in TM-NE2
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 [2]	Building Electrical & Heating	Chemicals	Repair & Maintenance	Grit and Screenings Disposal	Other [3]
Train #1: Vortex/Swirls	69	47.2%	6.3%	4.1%	0.1%	3.6%	33.3%	2.1%	3.3%
	183	34.5%	12.2%	4.7%	0.1%	6.9%	35.1%	4.0%	2.4%
Train #2: Conventional Clarifiers	160	33.6%	19.0%	4.1%	0.1%	5.9%	31.4%	3.4%	2.4%
	376	31.7%	23.1%	4.2%	0.1%	7.2%	26.8%	4.4%	2.5%
Train #3: CEPT	150	27.3%	25.8%	2.4%	0.2%	14.4%	25.4%	2.6%	1.9%
	300	26.3%	27.3%	2.4%	0.1%	19.2%	19.9%	2.8%	2.0%
	1000	16.1%	29.5%	2.8%	0.1%	20.7%	26.5%	3.0%	1.2%
Train #5: Ballasted Flocculation	150	24.0%	25.5%	2.8%	0.2%	16.0%	27.0%	2.8%	1.7%
	500	18.3%	29.4%	4.0%	0.1%	18.4%	25.0%	3.3%	1.4%
	1100	13.8%	28.4%	3.2%	0.1%	17.8%	32.7%	3.1%	1.0%