PACE
Advanced Water Engineering

Technical Memorandum

Date:	July 13, 2010 *(May 21, 2010) – Revised*
To:	Keeton Kreitzer Consulting
cc:	County of Orange Department of Public Works
From:	Andrew Komor, MS, PE James Matthews, PE Andrew Ronnau, Ph.D
Re:	**Haster Retarding Basin Stormwater Treatment Process Evaluation** **# 9640E**

Objective:

This memorandum represents a technical review, opinion of concepts, and suggested modifications and alternative systems related to the February 2010 *Draft Stormwater Quality and Soils Evaluation Report - Haster Retarding Basin and Pump Station Project* prepared by AECOM. Included is a discussion of potential improvements to the suggested design features, evaluation of various alternatives, preliminary concept layouts, and rough order of magnitude construction costs.

Project Background:

The Haster Basin improvement project seeks to increase the flood capacity from a 5-year design storm event to a 100-year condition. To do so, a new stormwater pump station is proposed to lower the water level in the basin in order to improve the hydraulic driving head from upstream drainage areas. This will allow greater flowrates out of upstream areas, currently subject to flooding, and into the Haster Basin. Second, according to the AECOM report, the basin is to be re-graded and levels are to be lowered in order to increase the flood retention volume and reduce the quantity of pumping rate out of Haster Basin. Even if larger pumping rates were desired, the flood channel downstream of the pump station is too small to handle larger rates. Therefore, increased flood retention volume is necessary to store inflowing stormwater above the pumping rate.

Summary of Existing and Proposed Project Elements:

The existing basin configuration, which has a depth of approximately 12 feet deep, provides a larger area and volume than the proposed condition. The difference in area and volume between existing and proposed conditions has been estimated differently by AECOM, the County, and PACE. For example, the AECOM report appendix calculations showed an existing basin water surface area of 14.5 acres. The PACE-estimated existing basin area is approximately 9.3 acres as shown in Exhibit 1 based on the 100-foot contour. It is well-agreed that the proposed basin configuration is expected to be comprised of approximately eight acres of water surface area at low water, and a larger area at mid and high water conditions. Calculations and collected data show TSS removal of >75% in the existing condition, which represents relatively good sedimentation of particles contained in the inflowing stormwater and dry weather flows.

The water depth will change to 4-6 feet of depth in the proposed condition, which will decrease the TSS treatment efficiency. We understand the sedimentation efficiency is to be mainly dependent on surface area overflow rate for dynamic settling, but for quiescent settling, the shallower depth is expected to decrease TSS removal by nearly two-fold. Therefore, the combined TSS removal capacity will decrease

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under the proposed condition. A comparison of existing and proposed area, volume, removal efficiencies, and other related information are shown in Tables 1-3, with corresponding Exhibits 1-3.

In addition to sedimentation efficiency changes, the shallowed water depth which has high light penetration and increased temperatures, combined with concentrated dissolved nutrients, will cause excessive nuisance algae and eutrophication that may create additional oxygen demand for downstream receiving waters, thus degrading downstream water quality compared to existing conditions. When this photosynthetic material respires at night or dies and becomes oxygen demand for bacteria, the basin will be subject to problems including bacterial sulfate reduction to odorous sulfide gas which may cause public complaints. In recent studies on lakes and reservoirs in the Los Angeles area including the Santa Margarita Water District in Orange County, the oxygen depletion rate quadruples when increasing the temperature from 15 to 25 degrees C. Excessive algae will also increase the frequency of pump station wet well intake clogging.

Discussion of TSS Removal Changes and Need for Treatment:

For calculation purposes, the proposed design for Haster Basin is a relatively broad shallow wet pond. The design differs from a traditional wet pond because of its shallow configuration, but standard wet pond TSS removal calculations were performed by AECOM and the County to compare the performance of the proposed design with performance of the basin in the existing conditions. It was presumed, based on the parameters used, that AECOM used a method of calculation developed in *Minton, 2005*. It was presumed based on the parameters used that the County used a method of calculation developed in *Urbonas, 1990*. In either case, the calculations and tables appear to reference the method developed by *Driscoll, 1986*. It is expected that all three methodologies will converge on the same end value. For the purposes of comparing the results of AECOM, the County, and new PACE calculations contained in this memo, PACE used software derived from *Driscoll, 1986*.

The long-term TSS removal calculations are based hydrologic results for the mean storm on the treatment facility watershed. The peak flowrate and runoff volume resulting from the mean storm are used in a series of quasi-empirical equations to determine the basin removal rate during dynamic conditions (during storm inflow) and during quiescent conditions (dry weather periods between storms). The hydrologic results in both of the analyses in the report were also used in subsequent benchmark calculations by PACE as shown in Table 1.

Table 1 - Hydrologic Assumptions for TSS Removal Model Creation

Descritpion	Unit	Value
Peak Flow	cfh	272,395
Runoff Volume	Ft^3	3,187,024
Coefficient of Variation		1.16
Inter-Storm Duration	hrs	242 (536 - AECOM)

The TSS removal calculations are sensitive to key physical parameters of the wet pond. The dynamic removal rate is related to the hydraulic loading (Q/A) and thus the pond water surface area. The quiescent removal rate is related to the volume of the pond relative to the volume of the mean storm. PACE used existing and proposed conditions topograph to determine the pond surface area at the operating water surface elevations stated in the report. The surface areas determined by PACE differ substantially from those sited in the report. The surface areas used in the calculations are shown below. PACE assumed the existing water surface included the wet area at 100 feet above msl in the existing calculation. If this assumption is correct the wet area calculated, both existing and proposed, is only different by about 5% or 20,000 ft^2.

Table 2 - Water Surface Area Assumptions

Configuration	PACE (Ft^2)	OC (Ft^2)	AECOM (Ft^2)
Existing	405,200	516,545	631,327
Proposed	384,400	144,670	383,136

The pond volume used by PACE for the quiescent portion of the calculations were approximated by multiplying the measured surface area by the design depth, using operating water surface elevations from the report. To provide a design analysis alternative, PACE also developed an additional proposed conditions model in which the pond volume was increased substantially by lowering the pond invert for a mean depth of 9', as discussed under the alternative 0 treatment process evaluation. The basin volumes for all of the calculations are shown in Table 3 below.

Table 3 - Basin Volume Assumptions

Configuration	PACE (Ft^3)	OC (Ft^3)	AECOM(Ft^3)
Existing	2,595,600	4,418,407	5,366,280
Proposed*	1,509,600	350,570 (@ 2.4 ft depth)	383,136 (@ 1 ft depth)
83-92' Proposed (deepen FG 4' to 83' msl)	3,003,900	NA	NA
Proposed (deepen + HWL to 100')	6,361,900	NA	NA

Dimscale = 100; LTscale = 0.5; PSltscale = 1; Acad Ver. = 18.0s (LMS Tech); Visretain = 1

EXHIBIT	PACE Advanced Water Engineering 17520 Newhope Street, Suite 200 | Fountain Valley, CA 92708 P: (714) 481-7300 | www.pacewater.com	SCALE 1"=150' DESIGNED JAM DRAWN RRM CHECKED JAM DATE 5/21/10 JOB NO. 9640E	JOB HASTER RETARDING BASIN GARDEN GROVE CA	TITLE EXISTING CONDITIONS WATER SURFACE AREA AT EL. 100.0

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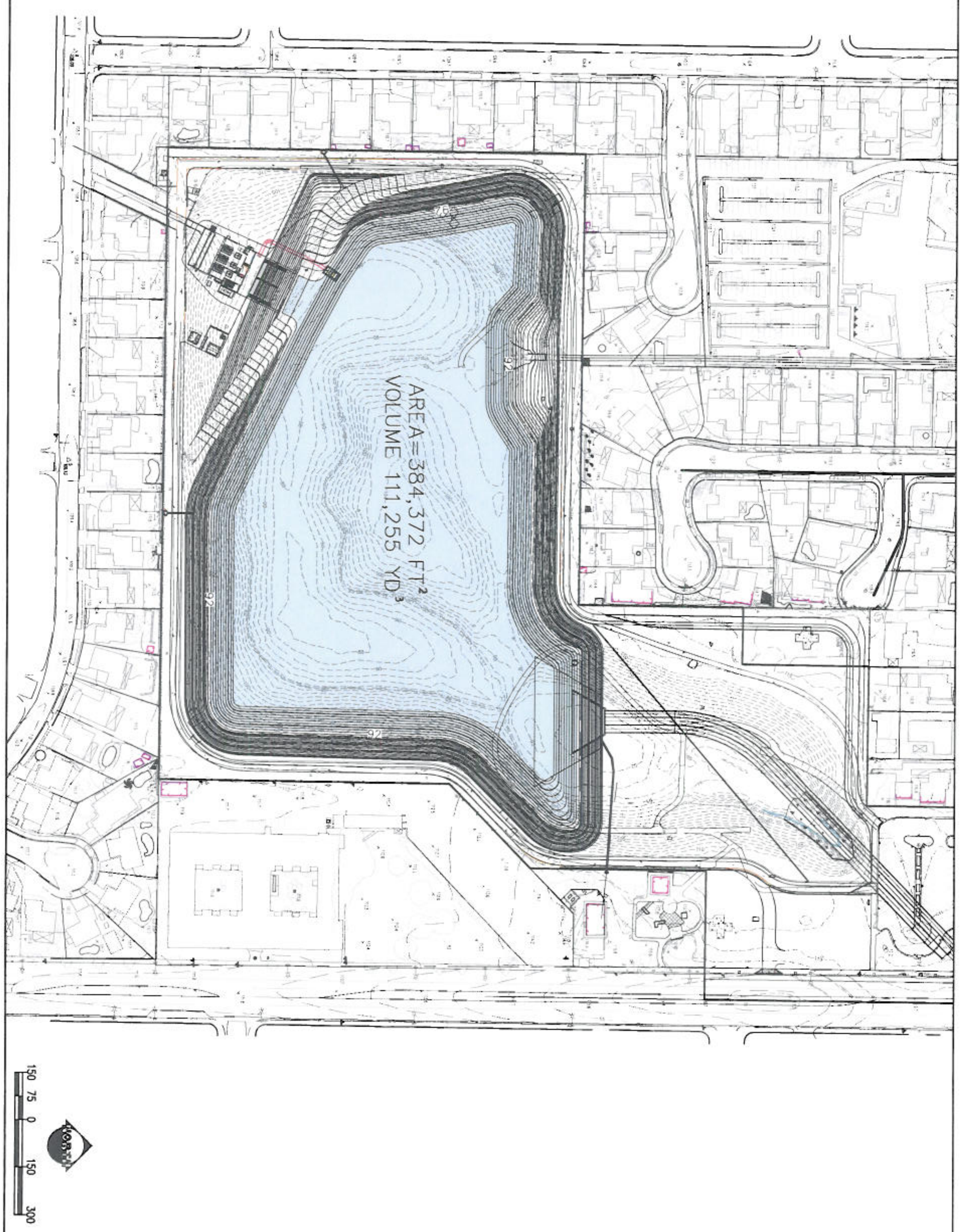

EXHIBIT 2	PACE Advanced Water Engineering 17520 Newhope Street, Suite 200 | Fountain Valley, CA 92708 P: (714) 481-7300 | www.pacewater.com	SCALE 1"=150' DESIGNED JAM DRAWN RRM CHECKED JAM DATE 5/21/10 JOB NO. 9640E	JOB HASTER RETARDING BASIN GARDEN GROVE CA
			TITLE PROPOSED BASIN INV EL. 83.0 WATER SURFACE ELEV. AT 92.0

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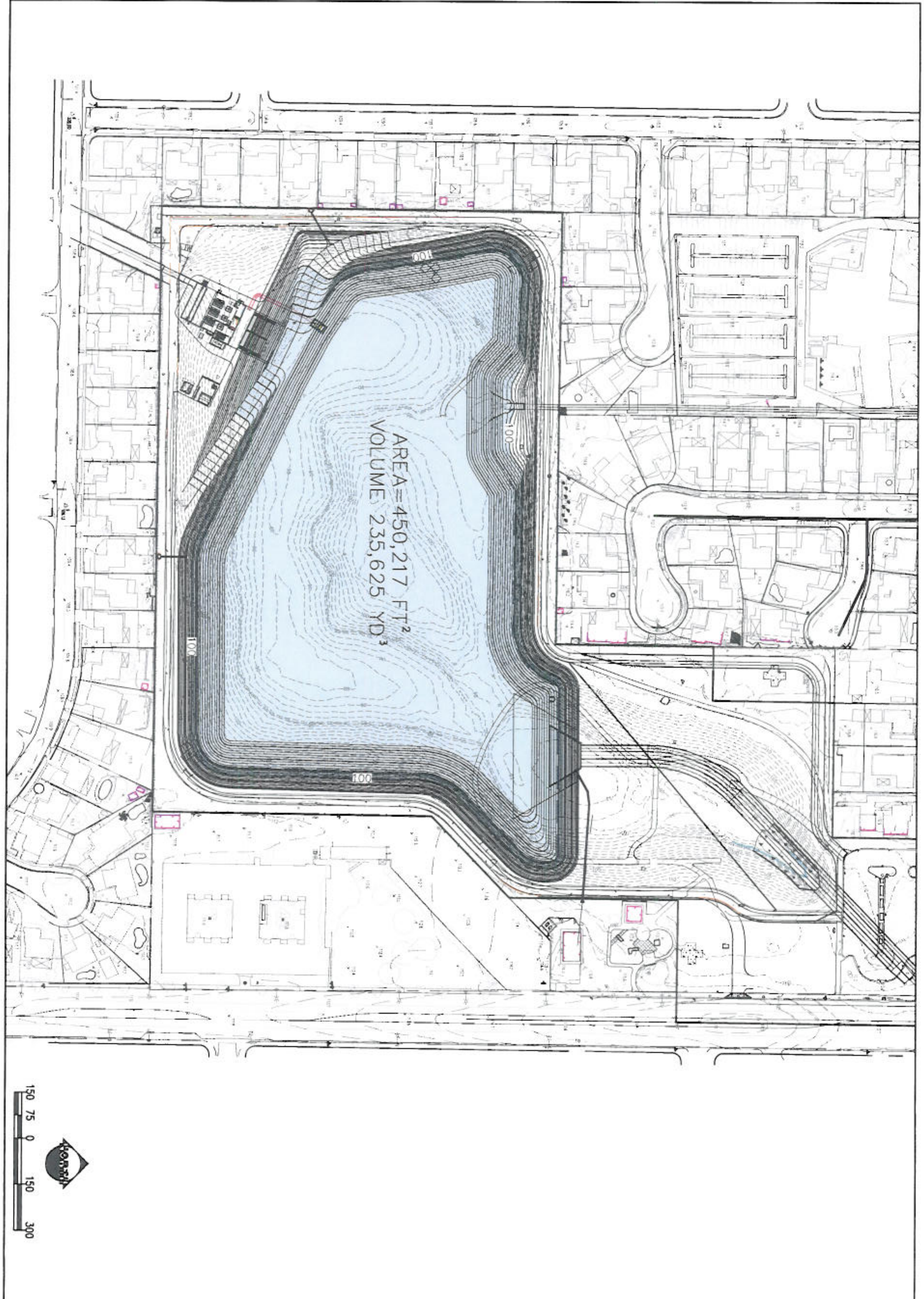

EXHIBIT	3	
PACE	Advanced Water Engineering	12520 Newhope Street, Suite 200 | Fountain Valley, CA 92708 P: (714) 481-7300 | www.pacewater.com
SCALE	1"=150'	
DESIGNED	JAM	
DRAWN	RRM	
CHECKED	JAM	
DATE	5/21/10	
JOB NO.	9640E	
JOB	HASTER RETARDING BASIN	GARDEN GROVE CA
TITLE	PROPOSED BASIN INV EL. 83.0 WATER SURFACE ELEV. AT 100.0	

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The long-term performance of the treatment pond or lake is a combination of dynamic performance and quiescent performance. The combined performance takes into account the inter-storm duration so that the weighted average performance is balanced toward quiescent performance of extended dry periods are expected. On examination, this figure seems small and further analysis is warranted. Calculations were performed for both conditions as shown in the report and as calculated by PACE. Note that calculations by PACE presume a uniform sediment size distribution, and no adjustments were made for fractional removal during the dynamic period. The results are compared in Figures 1 and 2 below.

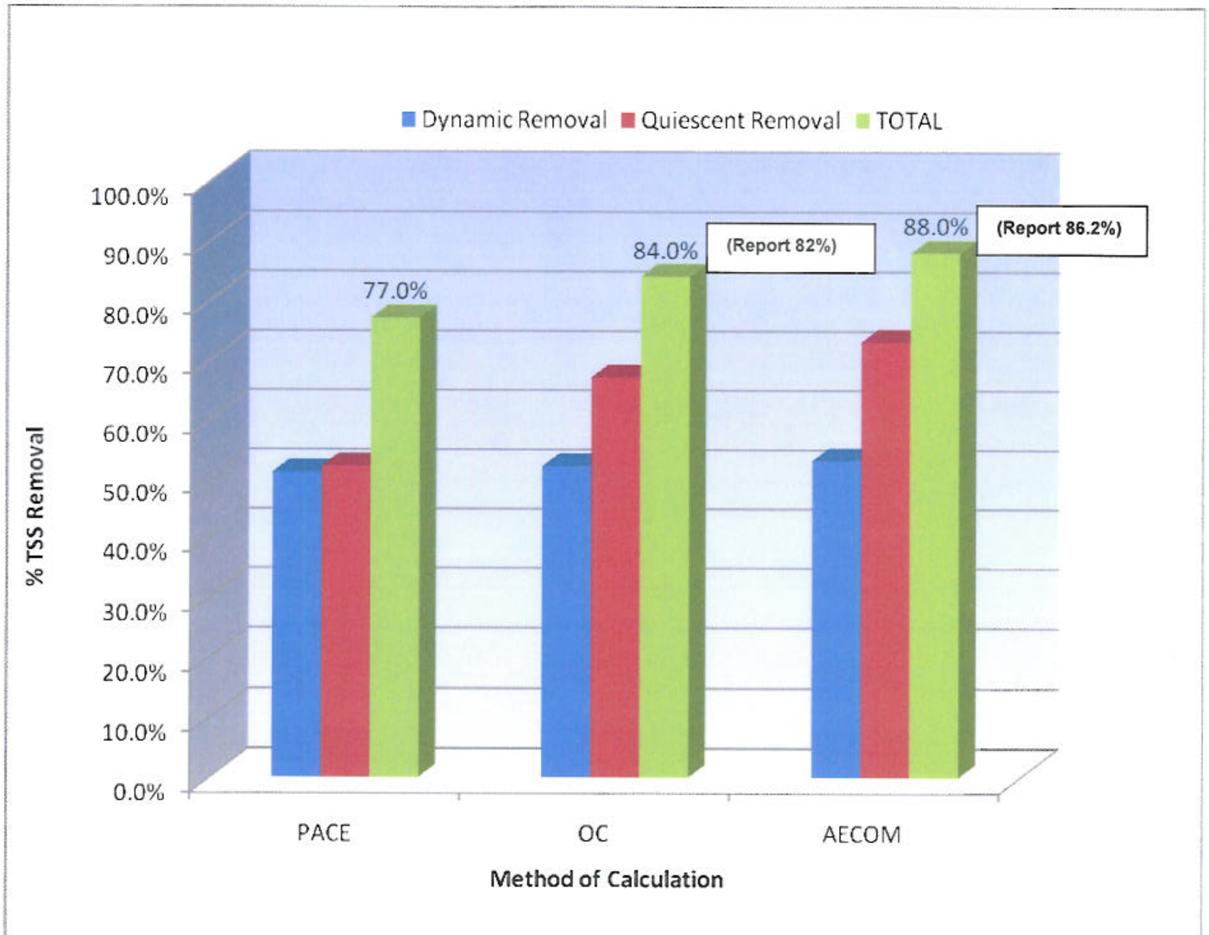


Figure 1 - Existing Basin Calculated TSS Removal

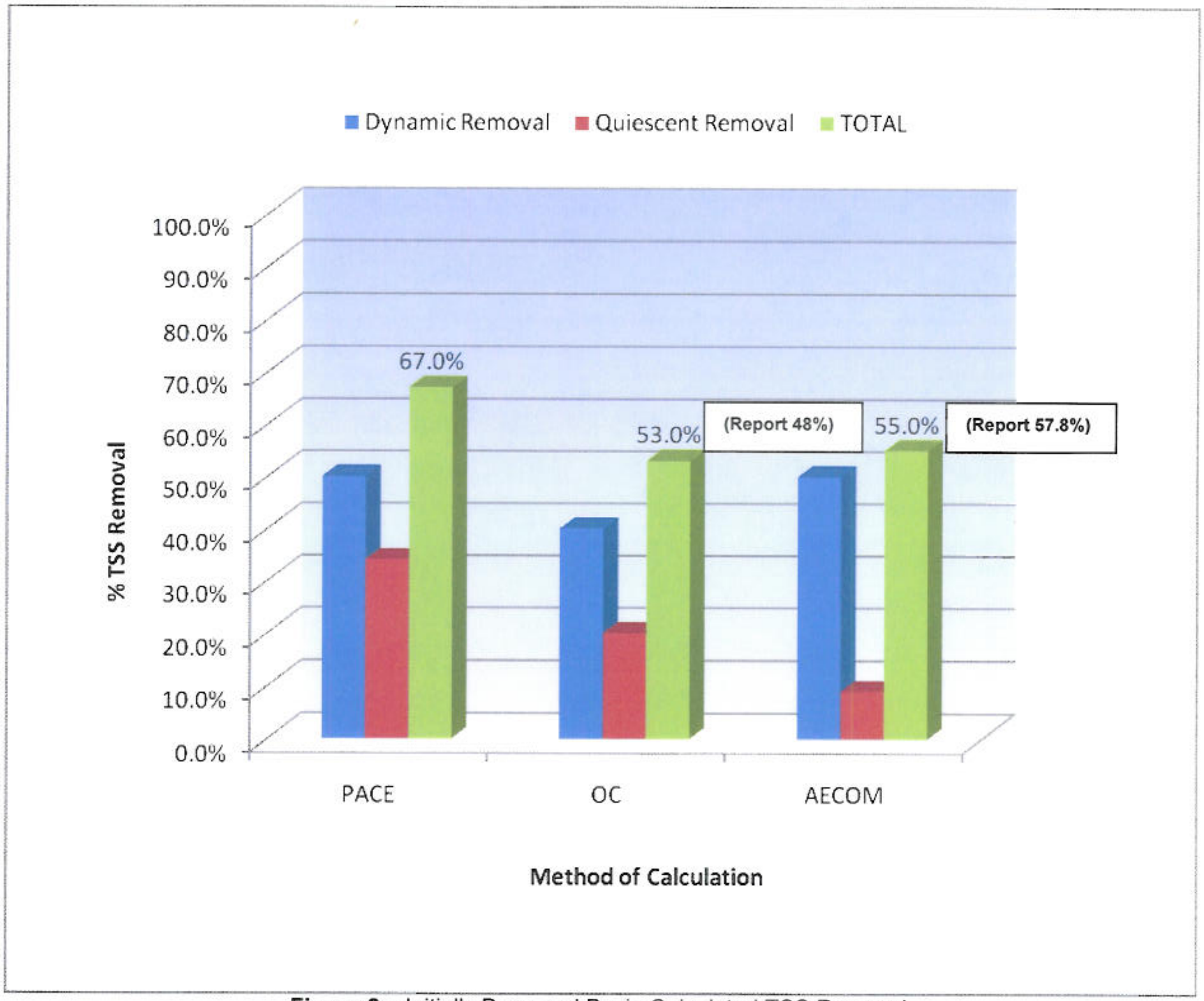


Figure 2 – Initially Proposed Basin Calculated TSS Removal

The difference in methodology results in somewhat different results calculated by each of the three analysts. Differences in input parameters (namely pond area) result variation in the results. Those analytical differences notwithstanding, some observations can be made regarding the lake design for stormwater quality control management. The area is crucial parameter with regards to dynamic treatment and removal performance. Since the design is constrained otherwise, no additional performance is likely to be gained from any design change. An accurate measure of the pond normal water surface area should be determined for the existing conditions and any proposed conditions to allow an accurate impact assessment.

Previously Proposed Project Elements to Account for Decreased TSS Removal:

To make up for the perceived large decrease in sedimentation efficiency with the new configuration, the proposed project recommended by AECOM consisted of treatment upstream of the basin and consisted of several components including:

1) Trash nets;
2) Grit sedimentation chambers; and
3) Sand media filtration.

The first process upstream consists of trash nets. Trash nets appear to be an economical, functional, and well-located treatment unit because they can provide trash removal for the entire flow entering Haster Basin without significant headloss. The second process of gravity grit chambers consists of centrifugal units, but since they are not driven my mechanical equipment, they rely on the radial velocity of incoming flow to provide removal of large sediments with a specific gravity of approximately 2.5 or greater. Our experience with these units is that due to their reliance on gravity to propel particles to the outside of the unit for removal, they are only effective in a narrow range of flows. In many cases, these gravity grit separation units are ineffective. The third process consists of sand media filters. Based on scaling of the exhibits provided within the report, it appears that the sand filters proposed were sized based on a flux of nearly 5 gallons per minute per square foot (gpm/ft^2). Although this flux is typical for the water and wastewater industry, for this stormwater application which likely does not have a good backwash system, it is expected that the filters will clog and have excessive backwash on a frequent basis.

Because there are two major inlets to the basin, a 96" diameter stormdrain from Oertly and a 9 x 6 feet storm drain from EGGWC, two separate treatment systems were planned in the AECOM configuration. Each treatment system was planned to have all three treatment processes. The flow was to be metered using hydraulic weirs into the treatment systems.

General Discussion of PACE Proposed System Enhancements:

Despite the proposed project being feasible and able to meet the primary goals of the project including enhanced flood control and water quality, the following general improvements are suggested to improve water quality, operability, reliability, capital cost, and basin aesthetics:

1. ***Raise operating depth of basin when possible and consider adding mixing elements for water quality and aesthetic enhancement.*** In addition to deepening the basin bottom as described in the following section, the water surface is recommended to be raised above 92-93 feet when possible such as the summer dry periods or periods of the winter when no precipitation is forecast for a long duration. A deeper pool will enhance quiescent settling and will reduce algae production. Also, to prevent stagnant water which depletes oxygen content most rapidly, it is recommended to install a small mechanical mixing system to the basin. The mixing system may include propeller mixers, diffused aeration, or pumped water.

2. ***Move any treatment elements other than the trash nets downstream of the basin and pump station.*** Under normal operation scenarios, flows will need to be pumped from the basin to the downstream gravity channel regardless of the treatment system location, and it is easier to control the flow to the treatment system by using a pump versus attempting to regulate using valves. Second, by locating the treatment system downstream of the basin and pump station, only one system will be necessary instead of the two in the current proposal. Third, relocating the treatment system downstream of the basin and pump station allows beneficial use of the basin for initial sedimentation pretreatment. Fourth, if desired, the treatment system can be used to internally treat the basin water during dry weather periods and treated water can be discharged back to the basin. Fifth, there is more space available, better access, and better security near the proposed pump station. The main disadvantage is that flows entering the basin initially will be untreated except for trash removal.

3. ***Increase the number of pumps and decrease the size of pumps.*** Instead of three 133 cfs pumps, it is suggested to have three 110 cfs pumps with three 23 cfs pumps for many reasons. Each pump shown in the proposed plan has 133 cfs of flow capacity. Assuming each pump was outfitted with variable flow capabilities, approximately 65 cfs would be the lowest flowrate achievable. The dry weather and small storm flowrates are expected to be less than 10 cfs, and the large pumps will overwhelm a treatment system planned for downstream of the pump station. As shown in the following section, the treatment system modules are planned for three modules, and one pump for each module would provide optimal control of the system based on varying conditions. The three smaller pumps can be located within the upstream end of the wet well in the low flow sump, without reconfiguring the proposed pump station structural work.

PACE Suggested Enhancements for Enhanced TSS Treatment:

A total of five process alternatives are considered including alternative 0 which includes no additional treatment, and four alternatives including additional mechanical treatment equipment. Alternatives have been identified below and are analyzed in this memo. All five alternatives proposed will fit within the Haster Basin property without decreasing the size of other proposed infrastructure or grading. In the treatment systems considered, they have all been located downstream of the basin adjacent to the pump station. This will allow initial primary treatment within the basin, followed by polishing treatment in the treatment system proposed. The pump station is used in all treatment systems to drive the treatment systems, such that the flow rate can be directly controlled for optimal treatment.

Alternative 0 – Deepen the Basin Four Feet to 83.0' msl & Add Coagulation Injection

Excavate additional 52,000 yd^3 below the existing basin bottom & add coagulation injection

Alternative 1 – In-Basin Riverbank Infiltration Gallery

1,100 lineal feet of perforated piping galleries installed along basin banks below the water level

Alternative 2 – Inclined Plate (Tube Settler) Clarification with Coagulation

Two 140' x 30' concrete basins filled with plastic inclined plate media and chemical feed

Alternative 3 – High Efficiency Mechanically Propelled Grit Vortex with Coagulation

Two 20' diameter circular concrete basins with vortex propulsion equipment and chemical feed

Alternative 4 – Cloth, Screen, or Fabric Gravity Filtration

Four 40' x 12' steel vessels filled with disks containing various filtration materials

Alternative Treatment Process Evaluation

Alternative 0 – Deepen the Basin Four Feet to 83.0' msl

It is understood that proposed shallow water depth configuration was used to create a large amount of retention volume and because of high groundwater, which causes deepening to require dewatering which can be costly and challenging. Based on our experience with similar high-groundwater projects in Northern California and Palm Desert, the installation of approximately 10-20 small diameter shallow wells will likely dewater the site effectively in order to grade the basin deeper. Also, the site will likely need some dewatering regardless of deepening to allow for re-grading. Increased depth will enhance water quality and reduce the occurrence of oxygen depletion by decreasing light penetration, cool the water temperature, and better settle nutrients including phosphorus. Recirculation of the basin would add the benefit of re-aeration of oxygen from the air into the water column to reduce pockets of low oxygen.

Shallow well dewatering is an effective means of lowering the groundwater table the necessary depth in order to excavate under dry conditions. This method is the one considered in the cost estimates included herein. The disadvantage of this method is the potential for land subsidence along the perimeter of the basin, which could potentially cause unwanted land settlement and possible damage to surrounding residential structures. Figure 3 provides a conceptual schematic of the shallow dewatering system for the Basin deepening construction. A geotechnical monitoring program would be necessary during dewatering to make sure that excessive land settlement doesn't occur. Otherwise, a second method of excavation in saturated soils consists of dredging. Dredging is more expensive, but is not estimated to cause land subsidence.

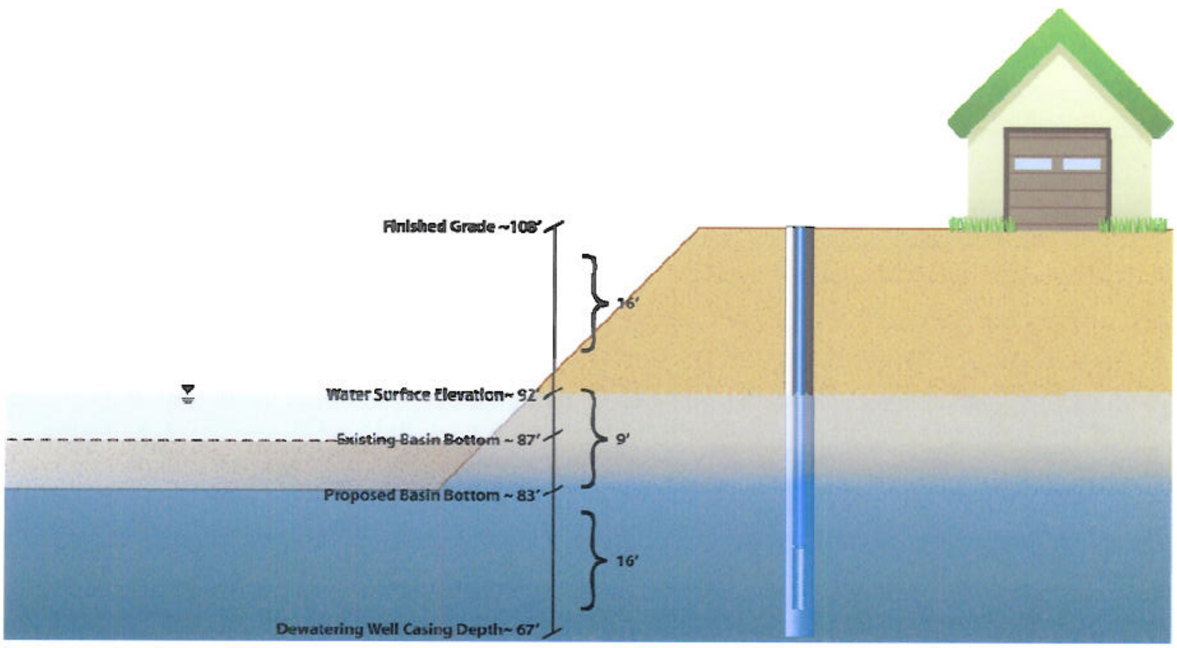
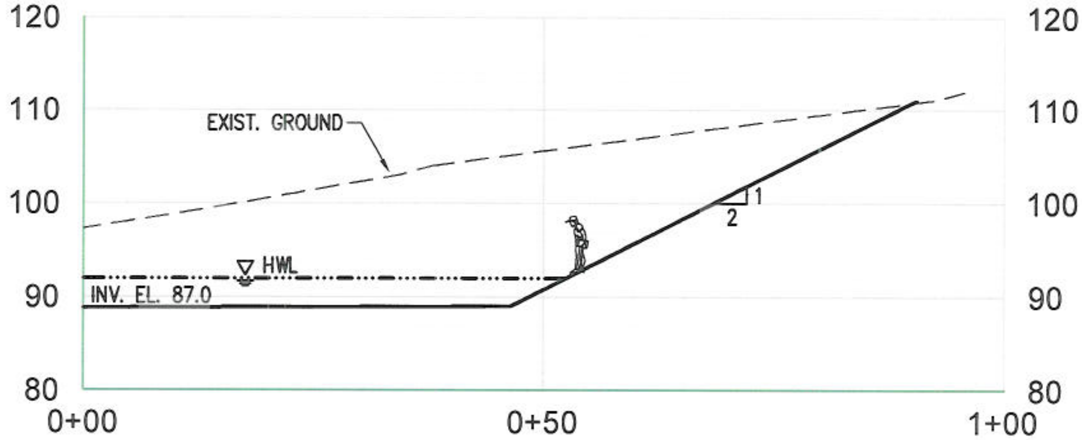
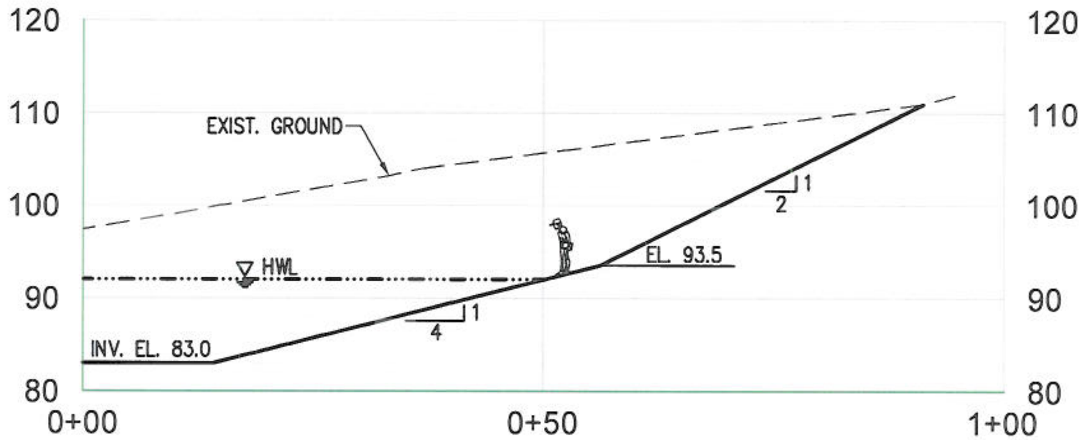


Figure 3– Conceptual Schematic of Shallow Dewatering System

Refer to Exhibit 4 for the typical existing cross-section and proposed deepened cross-section views for the Basin. It is recommended to shallow the slope near the water surface to reduce erosion and allow for better maintenance accessibility for operations staff.



ORIGINAL PROPOSED TO 87.0' MSL



PROPOSED 4' DEEPER TO 83.0' MSL

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The pond volume is the most important parameter for quiescent water TSS treatment performance. Given the quiescent removal rate as calculated by PACE for the three configurations, increasing the depth to nine feet will increase the quiescent phase performance and help to bring the overall system performance of the proposed conditions to that of the existing conditions. This system will have improved quiescent conditions performance because of increased volume ratio. As stated previously, the ratio of pond volume to mean storm runoff volume is a parameter that correlates positively with increased quiescent performance. Figure 4 shows expected TSS removal if the basin was deepened to nine feet.

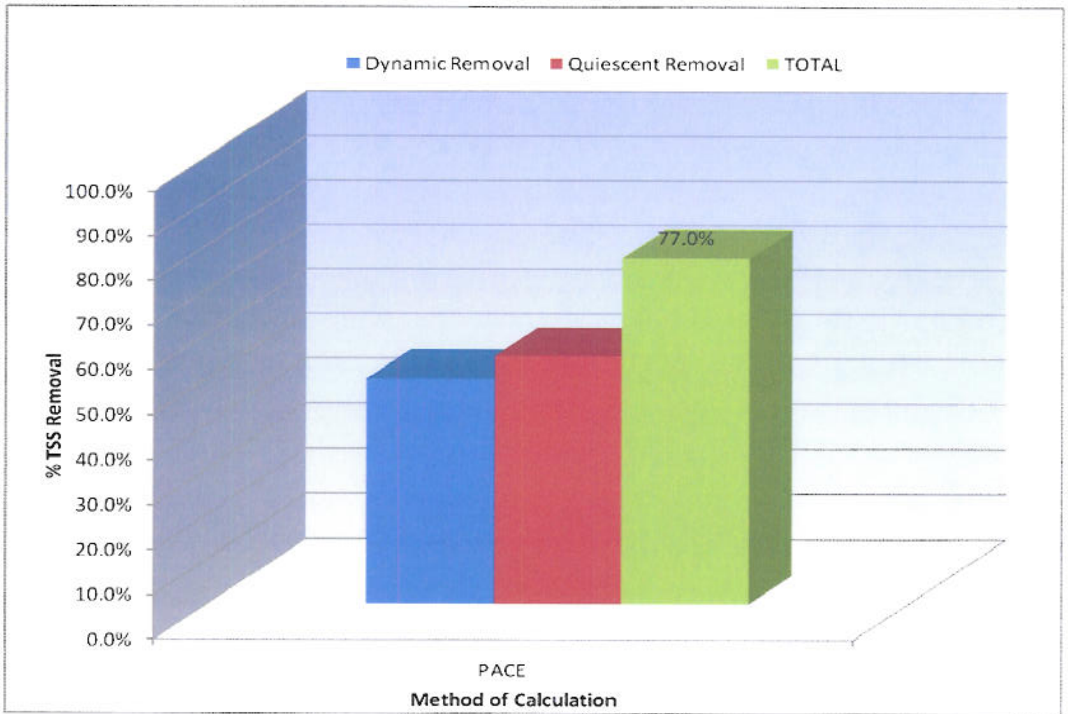

Figure 4 - Proposed Nine Feet Deep Basin Calculated TSS Removal

The increased quiescent settling of TSS between storm events causes the overall removal of TSS to be the same in the proposed condition as it is in the existing condition; however, the dynamic settling during storm events is slightly lower than existing conditions. Thus, a chemical coagulant feed system is proposed on both inlets to the basin to enhance dynamic sedimentation during storm events in the event of very frequent storms without sufficient quiescent settling duration. The coagulant feed could also be used by the County to enhance basin water quality and aesthetics during periods of high park use or as a proactive means of reducing phosphorus, which benefits water quality by reducing algae proliferation.

Many coagulants are used in the stormwater industry, including standard water treatment coagulants such as alum (aluminum sulfate or polyaluminum chloride), but for aquatic safety other coagulants are often considered including:

1) Aluminum Chlorohydroxide (Al2Cl(OH)5)
2) Diallydimethyl Ammonium Chloride (DADMAC)
3) Mimosa Bark
4) Chitosan shells

The appendix shows a technical paper by ProTech General Contracting Services comparing the dose, aquatic safety, and performance of these four coagulants. In general, DADMAC works the best, with nearly

98% removal efficiency of turbidity with moderate doses (25 ppm). The cost of the DADMAC chemical is more expensive per gallon of material compared to alum, estimated to be $35 per million gallons treated per 1 ppm, but the dose versus efficiency is far greater than alum or the other stormwater coagulants. It is anticipated that an average of about 2.5 ppm would be necessary to achieve a consistent removal of >85% of the TSS, based on jar testing provided by ProTech which shows >95% reduction in turbidity at doses of 25 ppm. Conversations with ProTech personnel indicated that 2-3 ppm of coagulant would be necessary to achieve good reduction in TSS such as >85%.

Construction cost, operation and maintenance cost, and life cycle cost estimates for this alternative #0 are shown in Tables 4a, 4b, and 4c.

Table 4a - Alternative #0 Deepened Basin Construction Cost Estimate

PRELIMINARY COST ESTIMATE				
Item	**Unit**	**Quantity**	**Unit Price**	**Total**
Site Work and Grading*				***$ 1,238,250***
Additional Pond Excavation for Additional 4' Depth (includes hauling to Brea)	CY	52,000	$ 15	$ 780,000
Dewatering Well Installation	LS	20	$ 15,000	$ 300,000
Dewatering During Excavation (15% of EW Cost, includes power)	LS	1	$117,000	$ 117,000
12" Dia Dewatering Discharge Piping	LF	1,650	$ 25	$ 41,250
Dewatering Monitoring Program	MO	12	$ 10,000	$ 120,000
Chemical Injection Facilities				***$ 80,000***
Chemical Injection Building, Pumps, Tubing, Tanks, Metering, Power	LS	2	$ 40,000	$ 80,000
Sub-Total				**$ 1,318,250**
3% Bonding & Insurance				$ 39,548
15% Contingency				$ 197,738
TOTAL ESTIMATED CAPITAL COST				**$ 1,555,535**

Table 4b - Alternative #0 Deepened Basin Operations and Maintenance Cost Estimate

PRELIMINARY OPERATIONAL COST ESTIMATE				
Item	**Unit**	**Quantity**	**Unit Price**	**Total**
Electrical Power/MG Treated				***$ -***
30 x 2 HP Feed Pumps	KWH/MG	0	$ 0.17	$ -
2 x 5 HP Waste Sludge Pumps	KWH/MG	0	$ 0.17	$ -
NA	KWH/MG	0	$ 0.17	$ -
2 x 3 HP Classifier / Dewatering	KWH/MG	0	$ 0.17	$ -
NA	KWH/MG	0	$ 0.17	$ -
Polymer Addition				***$ 88***
Chemical Solution DADMAC	LS	1	$ 88	$ 88
Sludge Hauling / Disposal				***$ -***
Sludge Cake @ 100 TSS	YD^3/MG	0	$ 35	$ -
Capital Replacement Over 50 Years $2.47M				***$ -***
Equipment	LS	0	$ 53	$ -
Labor/Maint Treating 585 MG/year @ $30,000/year				***$ 51***
Operator	LS	1	$ 51	$ 51
Sub-Total				**$ 139**
10% Contingency				$ 14
TOTAL / MG				**$ 152**
ESTIMATED ANNUAL OPERATIONAL COST @ 585 MG TREATED PER YEAR				***$ 89,125***

Table 4c - Alternative #0 Deepened Basin 20-Year Life Cycle Cost Estimate

20-YEAR NET PRESENT VALUE		
Capital Cost	**Ops Cost**	**NPV 20-Years**
$ 1,555,535	$ 89,124.75	**$2,666,535**

Alternative 1 – In-Basin Riverbank Infiltration Gallery

Riverbank filtration has been widely used for more than 50 years in European countries and is becoming increasingly popular in the United States. Many desalination plants are using such systems for intake water due to its inherent advantages. Riverbank infiltration is typically used with production wells to reduce and remove turbidity and particles, biodegradable compounds, bacteria, viruses, protozoa, and other hazardous pollutants from potable river source waters by using a river's natural soil as a filter media. Using similar reasoning, one feasible alternative stormwater mitigation measure would be to install a network of perforated pipes underneath an engineered fill material along the banks of the Haster Basin to remove suspended solids and other pollutants from the Basin prior to discharge downstream.

Refer to Exhibit 5 and Figure 5 for the preliminary plan-view and profile layout schematics for the proposed riverbank infiltration gallery alternative. Construction of this alternative consists of standard piping and construction materials and no specific vendor has to supply materials for this alternative.

The fill material for the bank infiltration gallery would consist of a one-foot layer of crushed gravel overlain with about a two-foot layer of a uniform sandy material wrapped in a geotextile/filter fabric. Plastic perforated pipes will be installed within the gravel layer for optimal hydraulics. The pipe network/galleries would be installed along the south bank of the Basin to utilize the Basin itself as a forebay for initial removal of the source water TSS and pollutants and to reduce short-circuiting. This layout allows for an efficient use of both the Basin and for the bank infiltration galleries. Typical sand filters used in stormwater management and treatment practices have shown to have TSS removal efficiencies around 85% and can remove particles down to 40-microns in diameter. In this case, due to the process being a slow sand type system, the removal rates of TSS are expected to be very good, on the order of 90% of greater.

Water will be drawn through the bank infiltration media and galleries via head pressure from the basin water surface and discharged into a wet well where it would be pumped to the downstream discharge channel. Utilizing pumps for this treatment alternative allows for both operator flexibility and efficient control of the treatment flow and application rate compared to that of a hydraulic control structure. The network would be configured so that branches within the system could be backwashed with treated water.

The AECOM report notes that the normal operating water surface elevation would be set to 92-feet above msl, with pumps activated at 93 feet. We understand that this low operational depth would only be maintained during the rainy months out of the year, and would be allowed to increase during the other months. Because both dry weather nuisance flow and wet weather stormflow requires treatment by the proposed treatment systems, it is necessary to install the infiltration galleries below this elevation. The design of the infiltration galleries will be sized for a flux of 1 gpm/ft^2 to allow for a reasonable amount of clogging over time. This design is expected to require cleaning not more than once every three years, and less frequent with the installation of simple backwash capabilities. The cost estimates provided do not include backwashing at this time.

Construction cost, operation and maintenance cost, and life cycle cost estimates for this treatment alternative #1 is shown in Tables 5a, 5b, and 5c.

Table 5a - Alternative #1 Infiltration Gallery Construction Cost Estimate

PRELIMINARY COST ESTIMATE						
Item	**Unit**	**Quantity**		**Unit Price**		**Total**
Site Work and Grading					***$***	***2,231,340***
Additional Pond Excavation for Additional 8' Depth (includes hauling to Brea)	CY	109,840	$	15	$	1,647,600
Dewatering During Excavation (15% of EW Cost)	LS	1	$	247,140	$	247,140
36" Dia Collection Piping	LF	1,620	$	180	$	291,600
48" Pump Station Discharge Piping	LF	200	$	225	$	45,000
NA	LS	0	$	-	$	-
Bank Infiltration Units					***$***	***459,110***
Piping & Lateral Systems	SF	31,000	$	7	$	217,000
Engineered Fill (Gravel)	CF	20,770	$	3	$	62,310
Engineered Fill (Sand)	CF	31,000	$	5	$	155,000
Geotextile	SF	31,000	$	0.80	$	24,800
NA	CF	0	$	-	$	-
Mechanical Pumping System					***$***	***541,000***
23 CFS Pump (11,000 gpm @ 24' TDH) 90 HP	LS	3	$	75,000	$	225,000
Deduct for 133 cfs vs 110 cfs Main Pumps	LS	3	$	(50,000)	$	(150,000)
Deepen Wetwell Concrete Structure	CY	200	$	750	$	150,000
Additional Backfill & Compact	CY	9,500	$	8	$	76,000
Additional Piping & Fixtures	LS	3	$	30,000	$	90,000
Additional Electrical & Controls	LS	1	$	150,000	$	150,000
NA	LS	0	$	-	$	-
Sub-Total					**$**	**3,231,450**
3% Bonding & Insurance					$	96,944
15% Contingency					$	484,718
TOTAL ESTIMATED CAPITAL COST					**$**	**3,813,111**

Table 5b - Alternative #1 Infiltration Gallery Operation and Maintenance Cost Estimate

PRELIMINARY OPERATIONAL COST ESTIMATE						
Item	Unit	Quantity		Unit Price		Total
Electrical Power/MG Treated					***$***	***19.74***
3 x 90 HP Feed Pumps	KWH/MG	116	$	0.17	$	19.74
2 x 5 HP Waste Sludge Pumps	KWH/MG	0	$	0.17	$	-
NA	KWH/MG	0	$	0.17	$	-
2 x 3 HP Classifier / Dewatering	KWH/MG	0	$	0.17	$	-
NA	KWH/MG	0	$	0.17	$	-
Polymer Addition					***$***	***-***
Chemical Solution	LS	0	$	88	$	-
Sludge Hauling / Disposal					***$***	***-***
Sludge Cake @ 100 TSS	YD^3/MG	0.0	$	35	$	-
Capital Replacement Over 50 Years $2.47M					***$***	***130***
Equipment	LS	1	$	130	$	130
Labor/Maint Treating 585 MG/year @ $30,000/year					***$***	***51***
Operator	LS	1	$	51	$	51
Sub-Total					**$**	**201**
10% Contingency					$	20
TOTAL / MG					**$**	**221**
ESTIMATED ANNUAL OPERATIONAL COST @ 585 MG TREATED PER YEAR					***$***	***129,411***

Table 5c - Alternative #1 Infiltration Gallery 20-Year Life Cycle Cost Estimate

20-YEAR NET PRESENT VALUE		
Capital Cost	**Ops Cost**	**NPV 20-Years**
$ 3,813,111	$ 129,410.88	**$5,426,111**

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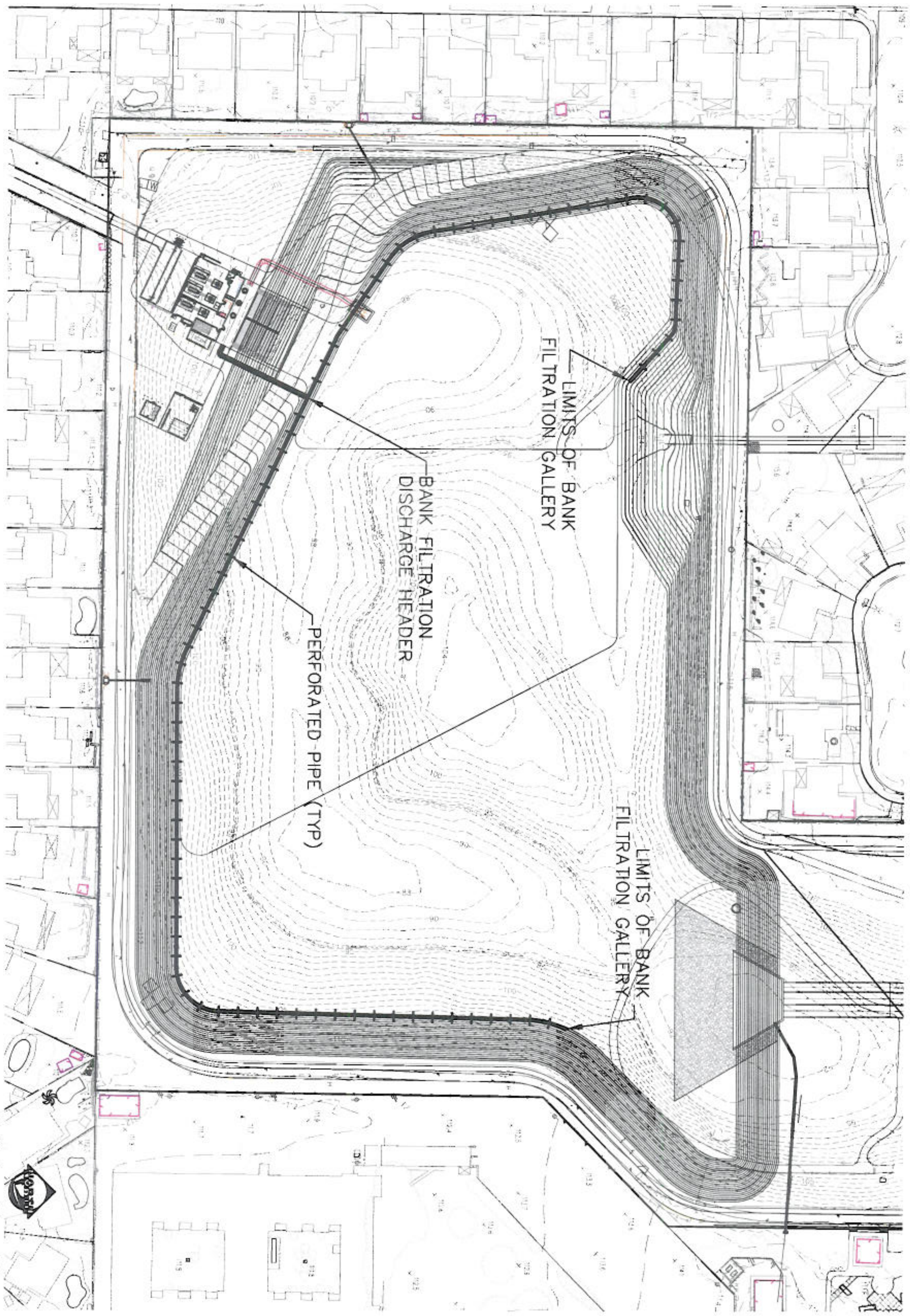

EXHIBIT 5	PACE Advanced Water Engineering 17520 Newhope Street, Suite 200 | Fountain Valley, CA 92708 P: (714) 481-7300 | www.pacewater.com	SCALE: AS NOTED DESIGNED: JAM DRAWN: RRM CHECKED: JAM DATE: 5/21/10 JOB NO.: 9640E	JOB: HASTER RETARDING BASIN GARDEN GROVE CA	TITLE: TREATMENT ALTERNATIVE 1: BANK FILTRATION GALLERIES

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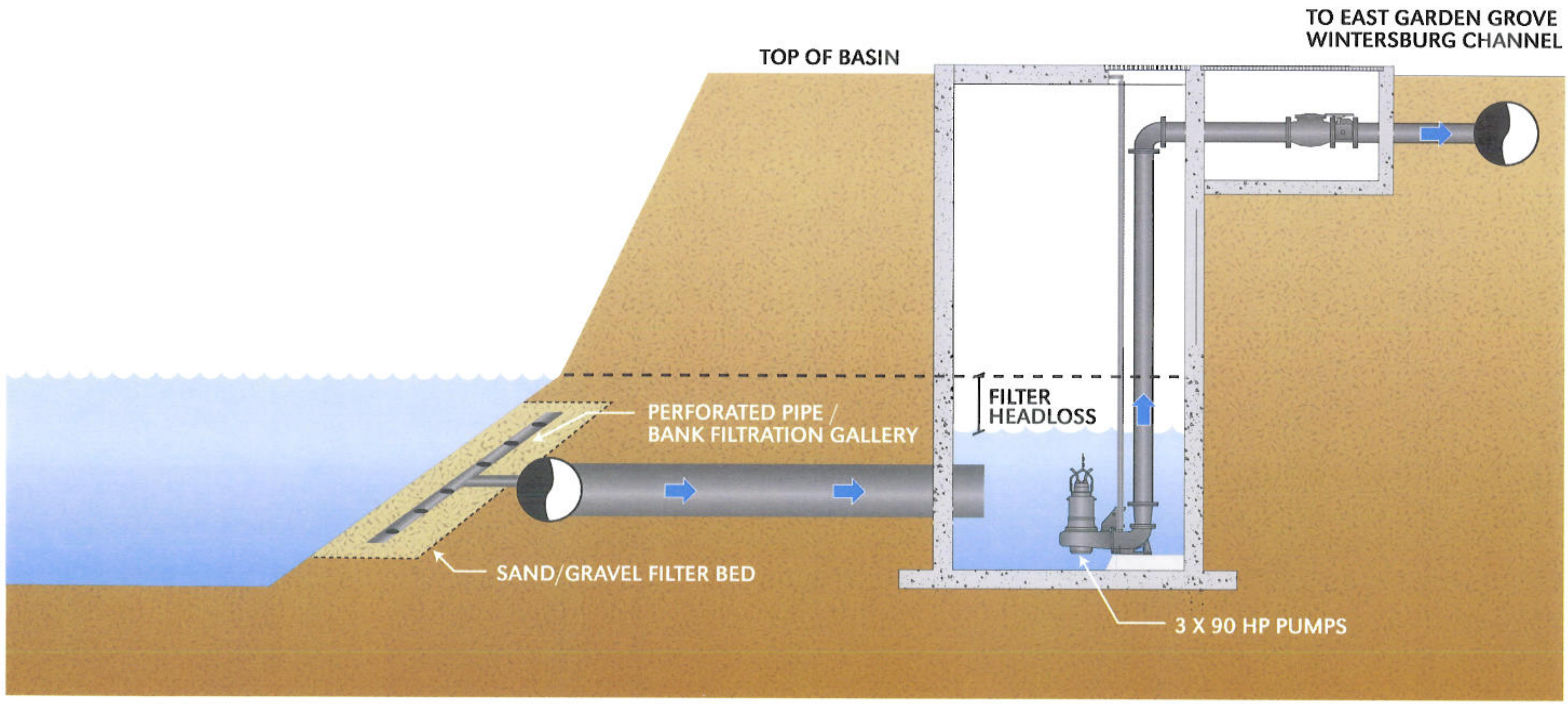

Figure 5 - Conceptual Cross Section for Bank Infiltration System

Alternative 2 – Inclined Plate (Tube Settler) Clarification with Coagulation

Inclined plates or tube settlers are very effective in removing suspended solids from high turbidity source water. Tube settlers are corrugated PVC plastic porous media blocks that sit within a clarification basin. Flow enters the basin and travels from the base of the blocks up and through, the solids are trapped on the edges of the media, and clarified water overflows the top of the basin. Tube settler's work by increasing the effective surface area of a treatment basin and by reducing the distance suspended solid particles travel to a basin floor. The appendix contains specific information and photographs of tube settler installations. The City of Seattle, Washington Best Management Practices Handbook lists inclined plate tube settlers in Chapter 2.10 Part IV as an approved method of treating contaminants contained in stormwater runoff. Manufacturers including Brentwood Industries Accu-Pac and MRI provide such tube settler systems.

The proposed inclined plate tube settler system design for Haster Basin includes two 140 feet long by 30 feet wide concrete clarifier basins filled with tube settler media capable of clarifying up to 34 cfs (22 MGD) each for a total of 68 cfs (44 MGD). The basins will fit on the existing site as shown in Exhibit 6. Flows will be pumped from the basin and will discharge into the clarification basins. Flow will gravity out of the basins and enter the downstream discharge channel. One train can be shut down during dry weather periods when flows are decreased for sustained periods. Both trains could be shut down for maintenance at any time without disrupting performance when the units are brought back into service.

A good understanding of particle distribution from the source water also allows for a good estimate of the percent removal for this type of system, but generally manufacturers claim inclined plate tube settlers achieve two to four times the clarification rate as compared to traditional gravity sedimentation basin. Much greater TSS and turbidity removal can be achieved if the influent source is seeded with a coagulant and or flocculent, which improves the settling of the smaller, lighter organic particles out of the source water. These particles are often present in dry weather flows in particular, but also are present as organic colloids in stormwater inflow. Inclined plate tube settlers generally use about ½ of the coagulant dose necessary in a traditional gravity sedimentation basin. A discussion of types of coagulants considered for this system is included in the Alternative 3 discussion. In Alternative 2, coagulant addition is considered unnecessary to achieve discharge water quality better than the existing condition (>80% TSS removal). Coagulant could be added if desired during poor influent water quality periods, such as during the summer when highly-polluted dry weather flows enter the basin.

The solids that are removed accumulate on the media. The clarification basins can be drained, either back to the basin or to a sanitary sewer, and spray washed to completely remove accumulated solids. Under normal operation, solids will slough off to the bottom of the basin once they increase in size, and a mechanical vactoring system will be installed to automatically pump out solids to a sanitary sewer or other disposal means.

UV light can cause algae to grow on the media, which can cause degraded water quality and excessive maintenance. To prevent algae accumulation, the basins could be covered, with plastic or aluminum closed grating. Otherwise, during the hot and sunny dry season, the treatment trains can be rotated in and out of service so that they are periodically dried completely to kill and remove algae accumulation. The cost estimates do not include covers at this time.

Construction cost, operation and maintenance cost, and life cycle cost estimates for this treatment alternative #2 is shown in Tables 6a, 6b, and 6c.

Table 6a - Alternative #2 Inclined Plate Clarification Construction Cost Estimate

PRELIMINARY COST ESTIMATE						
Item	**Unit**	**Quantity**		**Unit Price**		**Total**
Site Work and Grading					***$***	***1,331,750***
Excavation for Clarifier Tanks	CY	3,800	$	6	$	22,800
Backfill & Compact	CY	1,050	$	8	$	8,400
Concrete Tank Structure	CY	700	$	750	$	525,000
48" Clarifier Influent Piping	LF	250	$	225	$	56,250
48" Clarifier Discharge Piping	LF	250	$	225	$	56,250
Clarifier Internals & Sludge Collection Systems					***$***	***1,166,750***
Plate/Tube Packing Materials (Enviropak)	SF	7,750	$	45	$	348,750
Plate/Tube Support Racking	LS	1	$	75,000	$	75,000
HS20 Cover (18" Thick Precast Plank/Cast-in Place Deck)	CY	500	$	900	$	450,000
FRP Launders and Weirs	LF	960	$	50.00	$	48,000
Clarivac Mechanical Sludge Collection	LS	2	$	85,000	$	170,000
Sludge Waste Pumping System	LS	1	$	75,000.00	$	75,000
Mechanical Pumping System					***$***	***165,000***
23 CFS Pump (11,000 gpm @ 24' TDH) 90 HP	LS	3	$	75,000	$	225,000
Deduct for 133 cfs vs 110 cfs Main Pumps	LS	3	$	(50,000)	$	(150,000)
Deepen Wetwell Concrete Structure	CY	NA	$	750	$	-
Additional Backfill & Compact	CY	NA	$	8	$	-
Additional Piping & Fixtures	LS	3	$	30,000	$	90,000
Additional Electrical & Controls	LS	1	$	150,000	$	150,000
Sub-Total					**$**	**2,663,500**
3% Bonding & Insurance					$	79,905
15% Contingency					$	399,525
TOTAL ESTIMATED CAPITAL COST					**$**	**3,142,930**

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Table 6b - Alternative #2 Inclined Plate Clarification Operations and Maintenance Cost Estimate

PRELIMINARY OPERATIONAL COST ESTIMATE						
Item	**Unit**	**Quantity**		**Unit Price**		**Total**
Electrical Power/MG Treated					***$***	***20.91***
3 x 90 HP Feed Pumps	KWH/MG	116	$	0.17	$	19.74
2 x 5 HP Waste Sludge Pumps	KWH/MG	4	$	0.17	$	0.73
NA	KWH/MG	0	$	0.17	$	-
2 x 3 HP Classifier / Dewatering	KWH/MG	3	$	0.17	$	0.44
NA	KWH/MG	0	$	0.17	$	-
Polymer Addition					***$***	***-***
Chemical Solution	LS	0	$	88	$	-
Sludge Hauling / Disposal					***$***	***60***
Sludge Cake @ 100 TSS	YD^3/MG	1.7	$	35	$	60
Capital Replacement Over 50 Years $2.08M					***$***	***107***
Equipment	LS	1	$	107	$	107
Labor/Maint Treating 585 MG/year @ $30,000/year					***$***	***51***
Operator	LS	1	$	51	$	51
Sub-Total					**$**	**239**
10% Contingency					$	24
TOTAL					**$**	**263**
ESTIMATED ANNUAL OPERATIONAL COST @ 585 MG TREATED PER YEAR					***$***	***153,708***

Table 6c - Alternative #2 Inclined Plate Clarification 20-Year Life Cycle Cost Estimate

20-YEAR NET PRESENT VALUE		
Capital Cost	**Ops Cost**	**NPV 20-Years**
$ 3,142,930	$ 153,707.97	**$5,058,930**

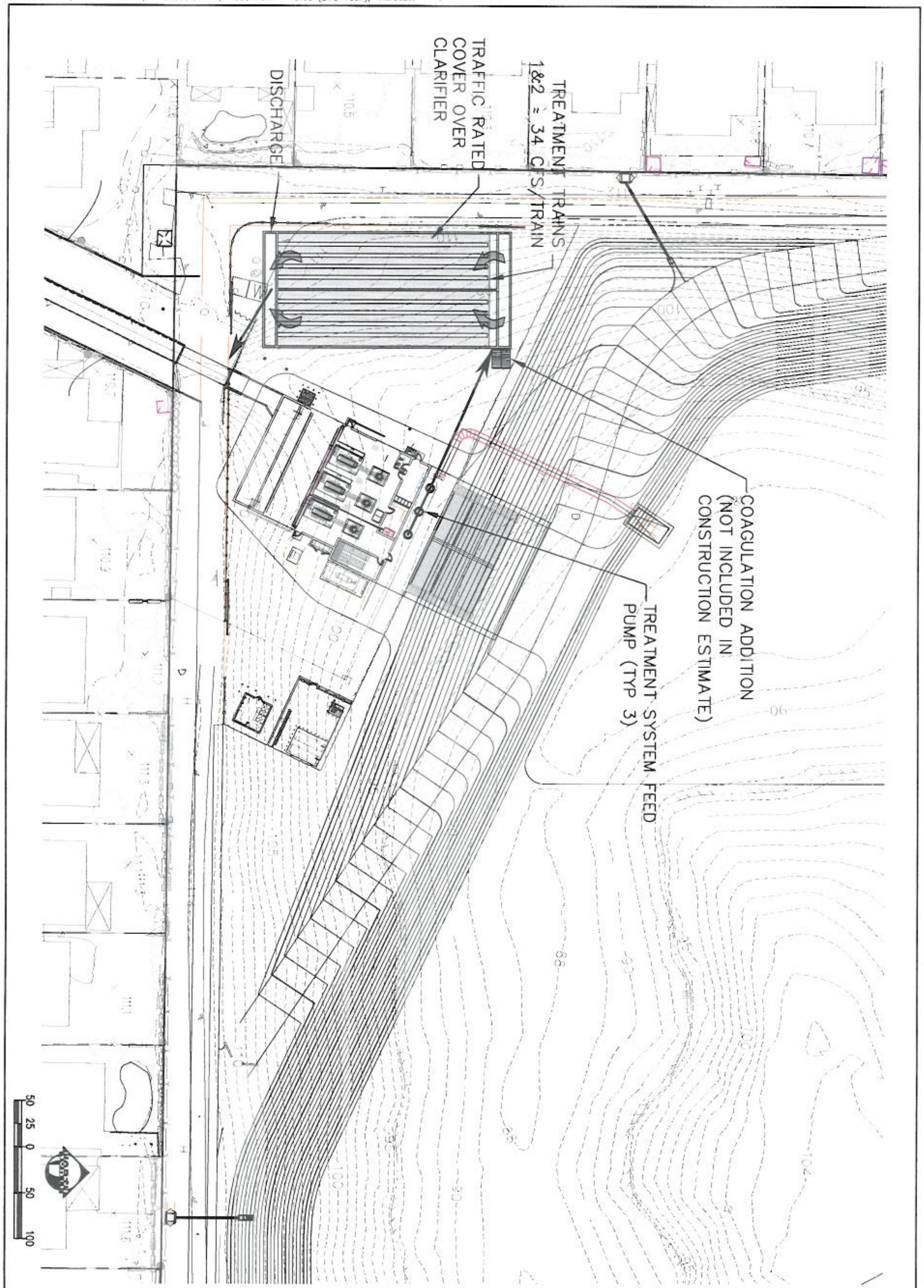

EXHIBIT 6	PACE Advanced Water Engineering 17520 Newhope Street, Suite 200 | Fountain Valley, CA 92708 P: (714) 481-7300 | www.pacewater.com	SCALE: AS NOTED DESIGNED: JAM DRAWN: RRM CHECKED: JAM DATE: 5/21/10 JOB NO.: 9640E	JOB: HASTER RETARDING BASIN GARDEN GROVE CA

TITLE: TREATMENT ALTERNATIVE 2: HIGH RATE CLARIFICATION

Alternative 3 – High Efficiency Mechanically Propelled Grit Vortex with Coagulation:

A traditional mechanically-propelled circular grit removal system is used in municipal wastewater and industrial applications to consistently remove inorganic particles of size over 250 microns. High efficiency models with baffles, shrouds, and other materials are able to achieve removal of particles over 150 microns in size. The goal of such equipment in the wastewater and industrial industries is to remove inorganics without removing organic material. The organic material is to be removed further downstream in other unit processes. However, in the case of stormwater treatment, these systems can be oversized, with enhanced hydraulic forces created by greater radially force and mechanical equipment that remove finer, lighter material such as organics, algae, and colloids.

A mechanically-propelled vortex system provides optimal radial force regardless of inflow rate, which is an important benefit over hydrodynamic separators. Depending on the manufacturer, the mechanical equipment described includes an air jet system or a paddle-wheel capable of creating a strong radial force to centrifugally separate materials from water. The process is low footprint, but relatively high energy compared to gravity sedimentation or filtration due to the equipment needed to create the centrifugal forces required to separate materials typical in stormwater. Fluidyne, Westech, and Eutek are three manufacturers of high efficiency mechanically-propelled grit vortexes. Hydrodynamic vortex units are an approved Best Management Practice in the State of California under Manufacturer Proprietary (MP) Number 51. A high efficiency mechanically propelled grit vortex is generally accepted as an upgraded system compared to a hydrodynamic vortex.

This alternative has been designed to include two 20-foot diameter units constructed out of concrete. Exhibit 7 shows a proposed layout for this alternative. Normally one 20-foot diameter unit is capable of removing inorganic material for up to 50 MGD in the wastewater industry. By providing two of these sized units for this application, the centrifugal forces will be doubled which will carry finer, lighter, and organic-type materials to the outside of the vortex where they will settle to the base of the cone. The vortexing equipment may be upsized further upon selection of this alternative to enhance removal efficiency. The flow will be pumped to the vortex units from the basin. Flow from the vortexes will discharge by gravity to the downstream channel. Solids that are directed to the bottom of the cone-shaped base of the vortex will be periodically pumped by an integrated air lift pumping system to a dewatering scroll where the solids will be discharged to a sludge storage container. Unlike wastewater applications, the solids removed will not be washed to remove organics from the inorganic material.

A good understanding of particle distribution from the source water also allows for a good estimate of the percent removal for this type of system without coagulation. Because the system is generally not optimized for removing light-weight organic materials, some coagulant addition is included in this alternative for treating high flows with high turbidity.

Construction cost, operation and maintenance cost, and life cycle cost estimates for this treatment alternative #3 is shown in Tables 7a, 7b, and 7c.

Table 7a - Alternative #3 Grit Vortex with Coagulation Construction Cost Estimate

PRELIMINARY CAPITAL COST ESTIMATE						
Item	Unit	Quantity		Unit Price		Total
Site Work and Grading					*$*	*250,680*
Excavation for Vortex Tanks	CY	2,130	$	6	$	12,780
Backfill & Compact	CY	1,050	$	8	$	8,400
Concrete Tank Structure	CY	130	$	900	$	117,000
48" Vortex Influent Piping	LF	250	$	225	$	56,250
48" Vortex Discharge Piping	LF	250	$	225	$	56,250
Vortex Internals & Sludge Collection Systems					*$*	*460,000*
Vortex Internals (Fluidyne - FHG-50HE)	LS	2	$	200,000	$	400,000
FRP Baffles & Deflectors	LS	2	$	30,000	$	60,000
Solids Classifiers and Dewatering Equipment	LS	2	Incl		$	-
6 HP blowers	LS	2	Incl		$	-
Sludge Waste Pumping System	LS	2	Incl		$	-
Mechanical Pumping System					*$*	*165,000*
23 CFS Pump (11,000 gpm @ 24' TDH) 90 HP	LS	3	$	75,000	$	225,000
Deduct for 133 cfs vs 110 cfs Main Pumps	LS	3	$	(50,000)	$	(150,000)
Deepen Wetwell Concrete Structure	CY	NA	$	750	$	-
Additional Backfill & Compact	CY	NA	$	8	$	-
Additional Piping & Fixtures	LS	3	$	30,000	$	90,000
Additional Electrical & Controls	LS	1	$	150,000	$	150,000
Chemical Injection Facilities					*$*	*40,000*
Chemical Injection Building, Pumps, Tubing, Tanks, Metering, Power	LS	1	$	40,000	$	40,000
Sub-Total					**$**	**915,680**
3% Bonding & Insurance					$	27,470
15% Contingency					$	137,352
TOTAL ESTIMATED CAPITAL COST					**$**	**1,310,502**

Table 7b - Alternative #3 Grit Vortex with Coagulation Operation and Maintenance Cost Estimate

PRELIMINARY OPERATIONAL COST ESTIMATE						
Item	**Unit**	**Quantity**		**Unit Price**		**Total**
Electrical Power/MG Treated					***$***	***21.64***
3 x 90 HP Feed Pumps	KWH/MG	116	$	0.17	$	19.74
2 x 5 HP Vortex Circulator	KWH/MG	4	$	0.17	$	0.73
2 x 5 HP Air Lift Pump	KWH/MG	4	$	0.17	$	0.73
2 x 3 HP Classifier / Dewatering	KWH/MG	3	$	0.17	$	0.44
NA	KWH/MG	0	$	0.17	$	-
Polymer Addition					***$***	***88***
Chemical Solution DADMAC	LS	1	$	88	$	88
Sludge Hauling / Disposal					***$***	***60***
Sludge Cake @ 100 TSS	YD^3/MG	1.7	$	35	$	60
Capital Replacement Over 50 Years $1.05M					***$***	***45***
Equipment	LS	1	$	45	$	45
Labor/Maint Treating 585 MG/year @ $30,000/year					***$***	***51***
Operator	LS	1	$	51	$	51
Sub-Total					**$**	**264**
10% Contingency					$	26
TOTAL					**$**	**291**
ESTIMATED ANNUAL OPERATIONAL COST @ 585 MG TREATED PER YEAR					***$***	***170,171***

Table 7c - Alternative #3 Grit Vortex with Coagulation 20-Year Life Cycle Cost Estimate

20-YEAR NET PRESENT VALUE		
Capital Cost	**Ops Cost**	**NPV 20-Years**
$ 1,310,502	$ 170,171.33	**$3,431,502**

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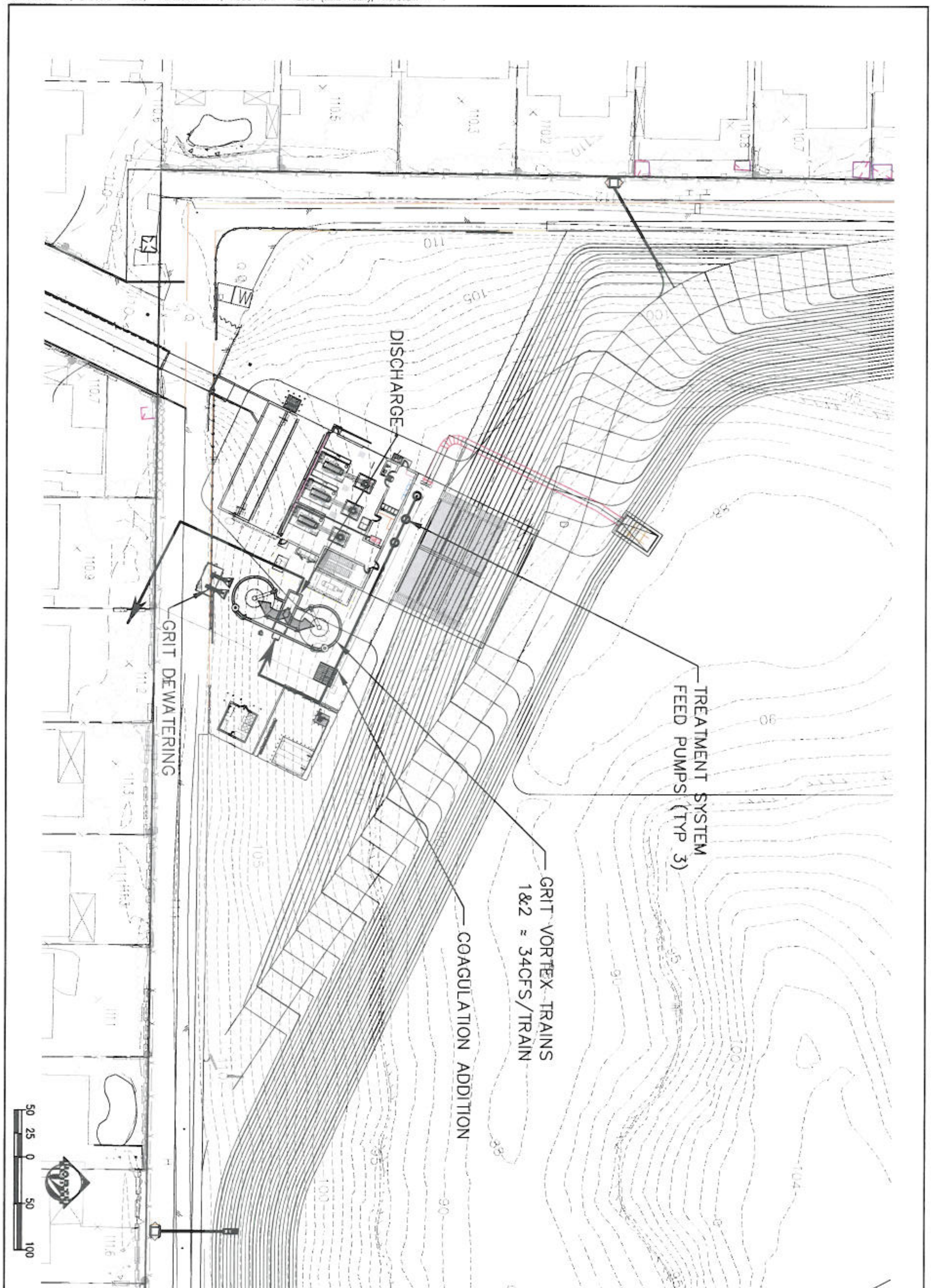

EXHIBIT 7

PACE
Advanced Water Engineering
17520 Newhope Street, Suite 200 | Fountain Valley, CA 92708
P: (714) 481-7300 | www.pacewater.com

SCALE	AS NOTED
DESIGNED	JAM
DRAWN	RRM
CHECKED	JAM
DATE	5/21/10
JOB NO.	9640E

JOB
HASTER
RETARDING BASIN
GARDEN GROVE CA

TITLE
TREATMENT
ALTERNATIVE 3:
HIGH EFFICIENCY
VORTEX SEPARTOR

Alternative 4 – Cloth, Screen, or Fabric Gravity Filtration

The biggest challenge with filtering large storm flows is the inability to backwash without excessive capital expense. Using a cloth, screen, or fabric filter instead of sand or other media offers advantages because it is easier to backwash and often less surface area is necessary to backwash. Several vendors were contacted to provide information and costing for cloth, screen, or fabric filtration. In each alternative, the filtration systems were provided within either concrete or steel basins that fit within the existing site without having to move equipment or change grading of the site. Manufacturers considered for this alternative included Shrieber Fuzzy Filter, Fluidyne FFP cloth plate filters, Aqua Aerobic diamond cloth filters, or Nova stainless steel mesh filters.

Exhibit 8 shows a layout of the Fluidyne FFP system including 96 rectangular plates with cloth media. Flows are directed to the inside of the plate, and flow through the plate to the outside. The water within the tank is filtered, and used periodically for backwash. The backwash volume is estimated to be about 7% of the inflow, which represents a high quantity of water that needs to either be sent to the sewer or potentially recycled back to the basin. Sending it back to the basin might not be realistic due to accumulation of solids and re-treatment required.

The water quality from such a filtration system is anticipated to be the best of all alternatives. TSS and turbidity removal is expected to be on the order of >90%. The capital cost, however, is relatively high, estimated to be on the order of $4 million for any of the manufacturers listed. The maintenance will also be high, because of several dozen backwash valves. Because of the high costs associated with this alternative, it was not considered further.

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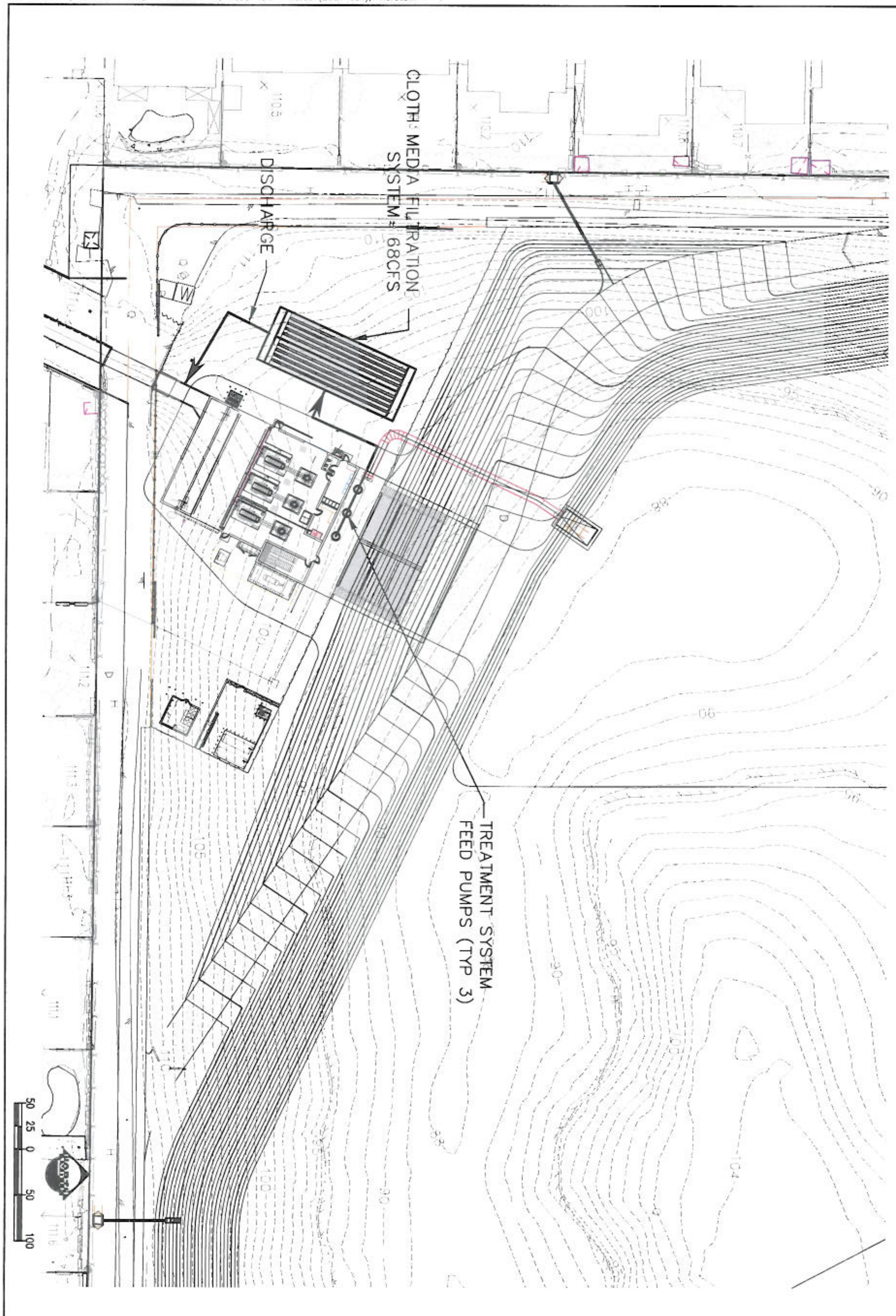

EXHIBIT 8	PACE Advanced Water Engineering 17520 Newhope Street, Suite 200 | Fountain Valley, CA 92708 P: (714) 481-7300 | www.pacewater.com	SCALE AS NOTED DESIGNED JAM DRAWN RRM CHECKED JAM DATE 5/21/10 JOB NO. 9640E	JOB HASTER RETARDING BASIN GARDEN GROVE CA	TITLE TREATMENT ALTERNATIVE 4: CLOTH MEDIA FILTRATION

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Treatment Alternatives Discussion and Recommendations

Assuming the final alternative is not considered due to excessive cost, the first four alternatives offer unique advantages and disadvantages that need to be carefully considered for selection. Alternative 0 has the lowest life cycle cost and requires the least amount of maintenance. It is most similar to the existing basin operation. Alternative 0 estimates assume that shallow well dewatering is feasible without causing excessive land subsidence. Otherwise, the capital cost for alternative 0 would increase by an estimated 25-50%. Refer to Figure 6 below for cost comparison of the treatment alternatives.

Of the alternatives that consider treatment, the 20-year life cycle cost of alternative 3, the grit vortex system with coagulation, is the lowest by nearly 20% even though it has the highest operations and maintenance cost. The water quality with alternative #3 is predicted to be the lowest of the three alternatives, but it is expected to meet the requirements of the project, which we understand to be achievement of >77% removal of TSS similar to calculated existing removal rates. The operations and maintenance cost of alternative 3 is the highest of the alternatives, but it is highly dependent on chemical coagulation addition. The coagulant addition system is assumed to use an average of 2.5 ppm. The calculations were based on five design storms per year plus a constant dry weather flow of two cfs running constantly for the entire year.

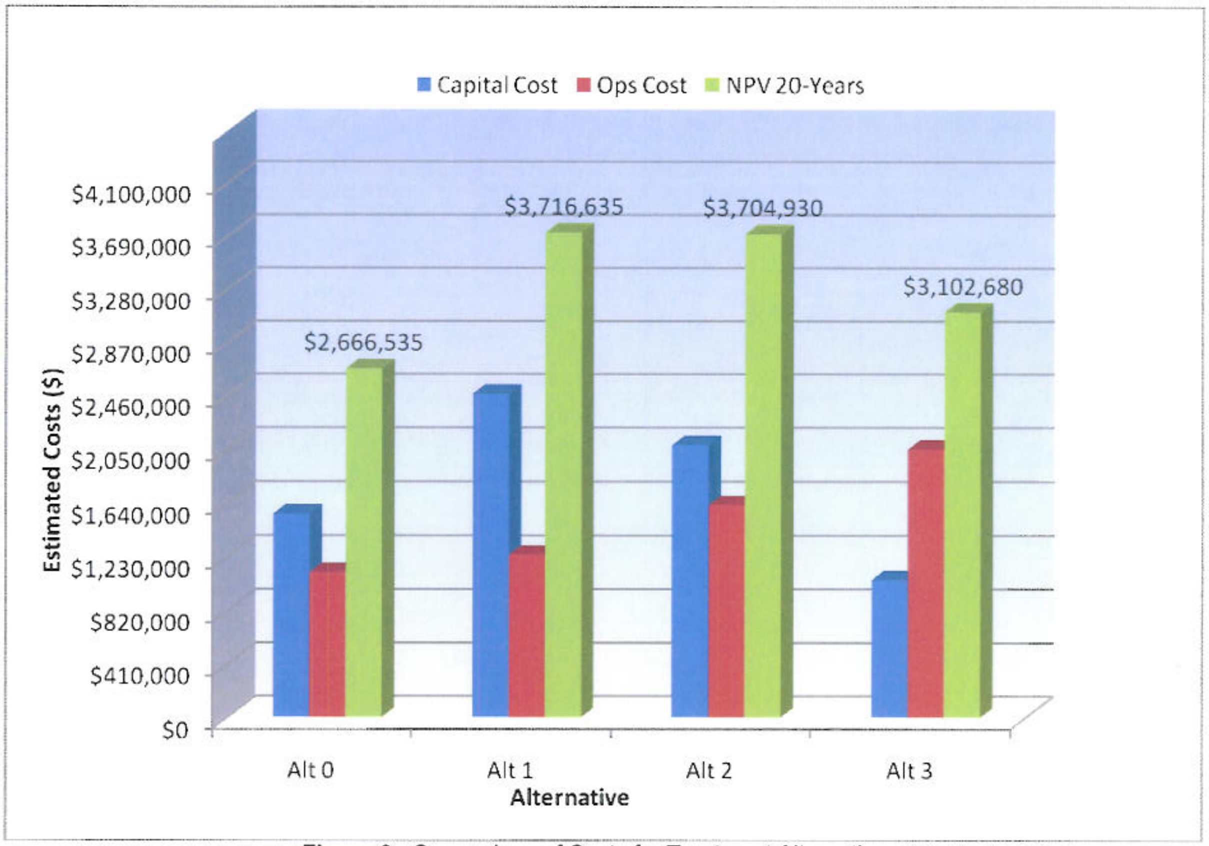

Figure 6 - Comparison of Costs for Treatment Alternatives

When evaluating the three treatment alternatives, a total of six criteria were evaluated including:

1) Capital cost
2) Operation and Maintenance cost
3) Water quality
4) Ease of maintenance
5) Reliability
6) Low visual and site impacts

An importance-weighting factor was applied for each alternative. When comparing the alternative treatment systems to the originally proposed treatment system, the evaluation in Table 8 shows that the alternative treatment systems likely have some important project benefits. When choosing the optimal treatment alternative of the three described, they all scored similarly. Depending on a fine adjustment to the weighting criteria or scoring, the outcome could be altered. However, based on our initial investigation, it appears that alternative #0 provides the greatest value and benefit for the project. It has a similar capital cost to the other alternatives, but essentially no additional maintenance, and water quality which meets the desired project goals. It also will improve water quality in the park during dry weather periods. The water quality can be enhanced by application of additional chemical coagulant treatment if desired. The suggested coagulant is an aquatically safe product called DADMAC that has been shown to be very effective in turbidity removal in small doses.

Table 8 - Treatment System Evaluation Matrix Scoring

	Capital Cost	O&M Cost	Water Quality	Ease of Maintain	Reliability	Low Visual & Site Impacts	Total Score
Weighting Factor	**5**	**4**	**5**	**3**	**2**	**2**	**84**
Proposed Process							
CDS + Sand Filters (AECOM)	2	1	4.5	1.5	2	3	**51**
Alt #0 Deepening Basin	4	5	1.5	5	4	4.5	**79.5**
Alt #1 Bank Filtration	1	4	4.5	1.5	2	4.5	**61**
Alt #2 High-Rate Clarification	3	3	3	3	3.5	1	**60**
Alt #3 High Eff. Vortex w/ Chem	5	2	1.5	4	3.5	2	**63.5**

Proposed Project Technical Review and Opinion of Concepts

Crucial Problem Analysis:

With only a few exceptions which are described in detail within this section, based on the information reviewed in the AECOM report the proposed project appears to be technically feasible and appears to meet the primary objective of conveying additional flood flows beyond the 5-year storm runoff.

Whether the 100-year flood flows can be conveyed effectively could not be determined from the information in the report because a hydrograph was not included showing the flow versus time into the basin during such an event. We would recommend careful analysis of the required basin retention volume so that it is accurately designed and optimized for aesthetics of the park. To see if the proposed design was reasonable, we performed a rough model and analysis of the proposed basin volume versus the estimated 100-year 24-hour storm event occurring over 1850 acres of watershed in order to quickly evaluate the suggested retention volume necessary in the Haster Basin. The calculated retention volume was then compared to the estimated retention volume from the proposed design since the finished retention volume was not listed in the report. A flood routing analysis was performed using the *County Hydrology Manual of Orange (1986)*. The results from this analysis are in the Appendix.

Based on Figures 7 and 8, the level in the basin is estimated to stay below 108 feet above mean sea level (msl) during a 100-year 24-hour runoff event, but only if the following is provided:

1. All three pumps are operated at low basin levels (below the main screened intake to the wet well) similar to the sequence described in the AECOM report such as pump 1 at 92.5 feet, pump 2 at 93.5 feet, and pump 3 at 94.5 feet above msl. This means all 400 cfs would need to flow through the low-flow pipe until the basin level reached the invert of the main screened intake of approximately 96 feet above msl.
2. The volume of retention storage needed above the dead storage is calculated to be about 175 AF. The average area appears to be about 850 feet by 550 feet (11 acres), based on scaling of the drawings, which provides 171 AF of retention storage below a basin level of 108' above msl. Thus, the provided retention storage volume in the AECOM report appears to be about correct.

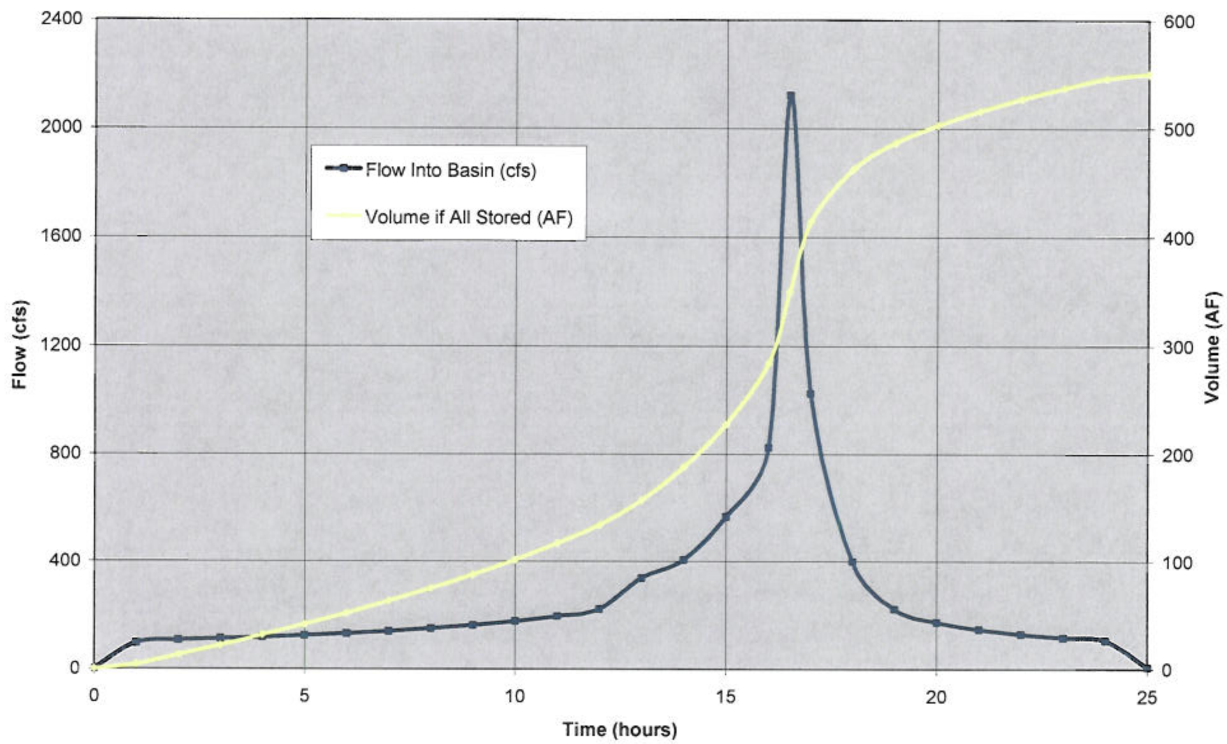

Figure 7- Modeled 100-Year 24-Hour Hydrograph Inflow and Volume

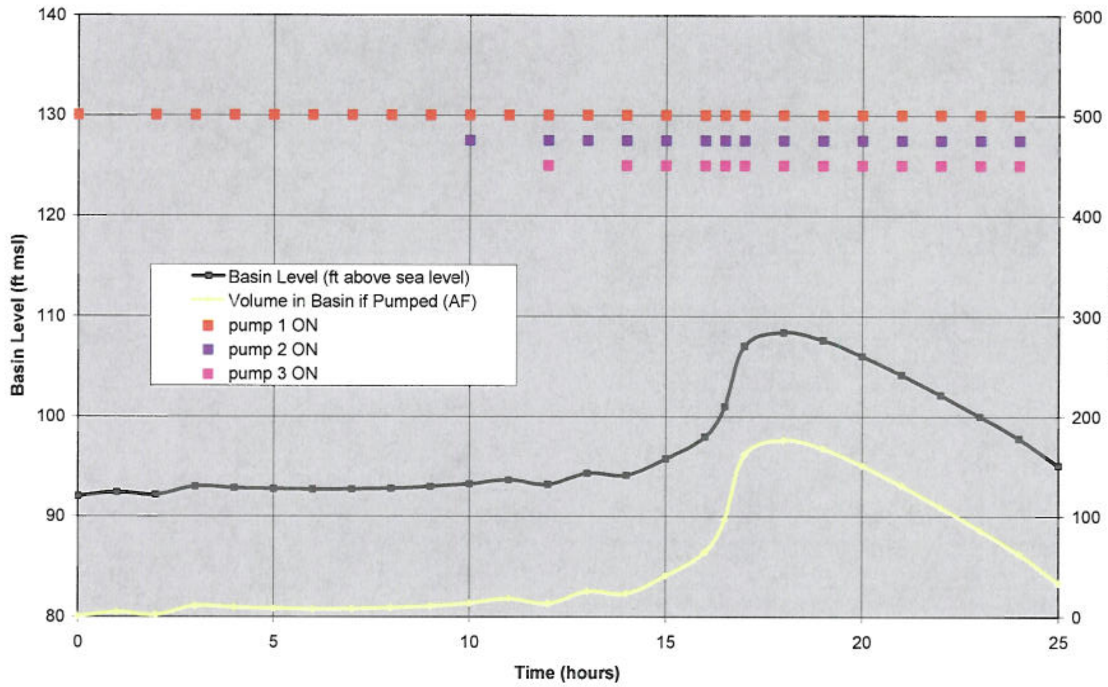

Figure 8 - Modeled Basin Level and Volume Using Three 133 cfs Pumps

As discussed above, from a rough analysis of the proposed project, the flood capacity design appears reasonable. The exceptional crucial problems noticed during the review were the following:

1. The basin ***grading of 2:1 side slopes will be subject to problematic erosion*** without careful consideration of bank protection materials and installation.

2. The ***low-level intake pipe appears too small*** to accommodate more than one pump running and may cause one or more of the following problems:

   a) Since the pipe is directed perpendicular to the direction of flow of the wet well, high velocities will be created during pumping which may cause excessive swirl and limit pump performance or damage the pumps. Velocities are estimated to be 8.4 ft/sec with 1 pump running, 16.8 ft/sec with two pumps running and 25.2 ft/sec with three pumps running assuming the pipe is 54" in diameter which was estimated by scaling the drawings provided.

   b) The wet well levels will lower and rise too quickly, which may cause pump damage due to air being drawn in to the pump cavity or rapid dynamic head changes.

   c) Air may be drawn into the intake from vortices due to shallow water, which may decrease hydraulic flow to the pump station.

APPENDICES FOLLOW