Appendix F

WATER QUALITY ASSESSMENT WHITE PAPER

WATER QUALITY ASSESSMENT AND QUANTIFICATION MODEL FOR FLOOD CHANNEL MAINTENANCE
WHITE PAPER

1.0 INTRODUCTION

This White Paper provides a model for assessment and quantification of potential water quality impacts due to flood channel maintenance within the City of San Diego (City). There are three critical points in the development of the water quality assessment and quantification model. These are based on the roles of sediment and the allied vegetative community in protecting water quality under the varying conditions in the storm water channels, while ongoing maintenance programs and services are facilitated by the City. Based on the three key critical points, a water quality management model was developed to identify the quantifiable parameters from which water quality benefits and/or potential impacts from channel maintenance activities could be estimated and compared. This model provides a threshold by which mitigation measures are to be implemented, and provides specific pollutants and pollutant load reductions to address the defined water quality impacts. This water quality management model can subsequently be applied to any flood control maintenance project under the City's jurisdiction based on site-specific water and sediment quality, dry weather flows and sediment/vegetation system measured field and analytical data collected as part of water quality quantification and modeling process. Potential mitigation measures are also provided to address water quality impacts that are pollutant specific and integrated into the City's overall storm water management program.

There are relationships between water quality, habitat, and the potential sorption/retention capacity of the vegetated community established within a channel section. There are also water quality benefits (or off-sets) created by habitat mitigation projects required under the Master Storm Water System Maintenance Program. In addition, offsets are created by the implementation of watershed best management practice (BMP) projects in accordance with the City's Storm Water National Pollutant Discharge Elimination System (NPDES) Permit and Total Maximum Daily Loads (TMDL) requirements. For each channel maintenance project, this water quality model can provide a method by which impacts and benefits to water quality can be evaluated and quantified to subsequently develop mitigation measures that address the defined impacts to water quality protective of designated beneficial uses. Potential mitigation measures are presented in this paper that can be coordinated with the City's NPDES and TMDL Programs (Integrated Water Quality Program), including source control measures, structural BMPs, and restoration projects. Selection of mitigation measures will depend on site-specific conditions and results of the proposed model. When these mitigation measures are coordinated with the Integrated Water Quality Program, they are to be implemented to correspond to the period the impact is occurring and be in addition to measures that have already been established or implemented prior to water quality measurements performed as part of the quantification and modeling process outlined in this paper. This White Paper presents methods to quantify water quality consistent with current technical literature.

Critical Point 1: Both dry and wet weather conditions need to be considered for the ability of plants and sediment to retard downstream migration of and retain potentially harmful constituents in storm water and urban runoff flows. Higher storm flows do not allow for sufficient retention time for either sediments to deposit or plants to adsorb pollutants.

2.0 WATER QUALITY ASSESSMENT - CRITICAL POINTS

The ability of plants and sediment to help facilitate desirable transfers and transformations and decrease mobility of potentially harmful constituents will vary greatly from dry weather (low flow) to wet weather (high flow) conditions. In discussion of water quality benefits of existing plants and sediment in the channels, dry and wet weather conditions need to be considered in determining water quality impacts due to the removal of existing plants and sediment from the City's storm water channels. Water quality benefits from the presence of vegetation and sediment that are realized during dry weather and low flow wet weather conditions may be lost during high, wet weather storm flows when the ability to remove pollutants is hindered. Higher storm flows do not allow for sufficient retention time for either sediments to deposit or plants to adsorb pollutants. As flows increase under storm conditions, retention times significantly decrease and the capacity of the sediment and plants to attenuate pollutants diminishes. Also, the high velocity of a storm event may result in mobilization of detained constituents in sediment and plants, resulting in adverse impact(s) to downstream water and sediment quality. The conditions under which impacted sediments are mobilized and considered in the model are further discussed under Critical Point 3. Changes in flow affect sediment deposition and plant growth, affecting how pollutants are removed and/or released in these manufactured storm water channels. Figure 1 presents an assimilation timeline for a flood control channel that includes both dry and wet weather flow conditions.

During dry weather and low flow wet weather events, sediment will "drop out" and accumulate (i.e., sedimentation and deposition). During sedimentation, pollutants bound to these sediments will accumulate, the sediment acting as a reservoir or sink. Where conditions allow, various storm water channel communities may include plants that absorb certain constituents (e.g., nutrients, metals, pesticides) depending on the plant type and density. Sorption (i.e., adsorption and absorption) requires sufficient detention time under low flow conditions to allow these desirable transfers to occur. However, plants go through cycles of aging, decay, and re-growth that may release constituents back into the channel flows under certain conditions (overgrowth, scour of vegetation, etc.).

During high-flow, wet weather conditions, the retention times are not sufficient to allow for existing plants to absorb pollutants. In addition, under high velocity flows fine-grained sediment that is associated with impacted sediment does not drop out of the water column. Thus this water quality assessment and quantification model uses higher retention conditions under dry weather and low wet weather conditions to calculate potential pollutant removal capacity of existing sediment and plants within the channel. The model also assesses the conditions under higher velocity wet weather flows. Under these conditions, there is a potential for re-mobilization of pollutants as impacted sediments are carried back into the water column. This model does consider low flow wet weather conditions as still providing a level of pollutant removal. This is a conservative approach, but addresses the varying conditions in both lined and natural channels. This is conservative because the flood control channels are not designed to retain dry or low flow wet weather flows required to allow for the full sorption capacity of the plant and sediment community under longer retention times.

Critical Point 2: Removing impacted sediments that may cause water quality impacts when mobilized, provides a water quality benefit.

Sediment in impaired waterways will continue to accumulate pollutants that, if not removed, may further impact water quality during wet weather flows as previously discussed. During storm events these sequestered pollutants retained by channel sediment and flora could be released back into the channel flow. The released constituents could become a source of adverse water quality impacts requiring periodic removal. Removal of impacted sediments via channel maintenance and in coordination with the Integrated Water Quality Program (NPDES Permit and TMDL implementation programs which vary between watersheds) provides water quality benefits that are considered in the model. Conditions where these water quality benefits are considered are based on site-specific sediment sampling and analysis to determine pollutant levels and grain size. The pollutant concentrations are used to estimate the specific pollutant load removed from the system. The grain size analysis is used to assess the scour potential of the impacted sediments under storm flows that would occur between maintenance periods.

Sediment within channels moves through transmission of shear stress from water flowing over channel bed materials. The County of San Diego *Hydromodification Management Plan* (HMP) states that a shear stress threshold (critical shear stress, Qc) must be exceeded for the movement of channel bed materials. The HMP looked at two typical channels in the region and determined the Qc to be 10% of the pre-development 2-year storm event peak flow. A similar study was conducted in Fairfield, California and determined the Qc to be 20% of the pre-development 2-year storm event peak flow (Brown and Caldwell, 2010). The typical Qc documented in the HMP is very low in comparison to the peak 5-year and 10-year flows that channels have a high probability of being exposed to in the time frame between maintenance periods. Based on the flows that channels will most likely be exposed to and the low Qc values calculated by the HMP, this paper assumes that larger storm events (5-year or larger) have the potential to transport accumulated sediments downstream. This assumption is supported by the document *Habitat Value of Natural and Constructed Wetlands Used to Treat Urban Runoff: A Literature Review*, which states that consistent inflow to treatment wetlands, through the use of a forebay, is necessary to minimize scouring of sediment and vegetation in the wetland thus reducing transport of pollutants to downstream areas (Sutula and Stein, 2003). Engineered and natural flood control channels (also referred to as storm water facilities) do not have forebays, thereby have pulsed flow during each storm event, and have the potential to transport contaminates downstream. To further ensure that this assumption is valid, the velocities associated with peak flows, as determined through the hydraulic modeling of channels, shall be reviewed for channels and compared to Table 1 and Table 2 below, as applicable. If the potential peak velocity for the design storm is below the maximum permissible velocity listed for the applicable material / cover, then the load removal benefits from the removal sediment should not be applied to the benefit-impact assessment calculations (i.e., maintenance may involve the removal of sediment, but load removal shall not credited as a benefit of sediment removal). In general, velocities above 5 feet per second will cause scour in most channels.

Table 1. Permissible Velocities for Unlined Channels

Type of Material	Maximum Velocity (feet per second)	
	Intermittent Flow	Sustained Flow
Fine sand, colloidal	2.5	2.5
Sandy loam, noncolloidal	2.5	2.5
Silt loam, noncolloidal	3.0	3.0
Fine loam	3.5	3.5
Volcanic Ash	4.0	3.5
Fine gravel	5.0	4.0
Stiff Clay (Colloidal)	6.0	4.5
Graded Material		
Loam to Gravel	6.5	5.0
Silt to Gravel	7.0	5.5
Gravel	7.5	6.0
Coarse Gravel	8.0	6.5
Gravel to Cobble (under 6 inches)	9.0	7.0
Gravel to Cobble (over 8 inches)	1.0	8.0

Source: (City of San Diego Drainage Design Manual)

Table 2. Permissible Velocities with Grass Cover[1]

Cover	Slope Range	Permissible velocity on	
		Erosion resistant soil	Easily eroded soil
	Percentage	Feet per second	Feet per second
Bermudagrass	0-5	8	6
	5-10	7	5
	Over 10	6	4
Buffalograss Kentucky bluegrass Smooth brome Blue gamma	0-5	7	5
	5-10	6	4
	Over 10	5	3
Grass Mixture	0-5	5	4
	5-10	4	3
Lespedeza sericea Weeping lovegrass Yellow bluestem Kudzu Alfalfa Crabgrass	0-5	3.5	2.5
Common lespedeza Sudangrass	0-5	3.5	3.5

[1] From *Handbook of Channel Design for Soil and Water Conservation*, National Resource Conservation Service

Source (City of San Diego Drainage Design Manual)

The reaches of Alvarado Channel that are slated for sediment and vegetation removal (one of two example channels in this study), during the 2-year storm event, will experience flow velocities of over 6 feet per second. The substrata for these reaches of the channel are comprised of fine sands, silty sands, and silt to gravel. The maintenance period for this channel is 3 years. Therefore, the sediment slated for removal is susceptible to erosion and would most likely be transported downstream during the maintenance period if not excavated through maintenance activities. These site specific sampling, analysis and modeling provide a scientifically based approach to determining the water quality benefits used in the assessment model. Benefits are considered only for those conditions where measured pollutants are anticipated to be mobilized between maintenance periods.

In order to ensure that wetland systems provide adequate retention time for adsorption and assimilation, wetland systems must be of adequate size. As flows increase through wetland systems there is diminishing absorption, and potential release, of pollutants. Constructed or engineered natural treatment systems are typically designed to receive flows generated by 0.2 inches per hour precipitation and have enough volumetric storage capacity for at least a 24-hour retention (or flow through duration). In order to achieve these conditions, the surface area of wetlands should be at least 1% of the watershed drainage area (Storm waterCenter.Net, 2010). Some standards call for a surface area of 2% to 3% of the drainage area. The two channels (storm water facilities) considered in this paper have a total surface area of about one acre each. The existing watercourse, or natural treatment systems, occupy less than half of the total surface area and are approximated at 0.5 acres each. Therefore, the maximum drainage area that each could receive dry and wet weather runoff from and effectively treat (assuming properly configured to do) is about 50 acres (50 acres * 1% = 0.5 acres). The drainage areas to each of these channels are significantly greater than 50 acres (see hydraulic analysis conducted for Maintenance Plan). The inherent functions of a wetland begin to break down and the wetland may become degraded or destroyed when the flow through the wetland exceeds the assimilative capacity of a wetland (Sutula and Stein, 2003). Based on the large drainage areas in comparison to the small surface area of the existing natural treatment systems within the two channels evaluated for each example watershed, it is assumed that storm events greater than 0.2 inch and following 72 hours will exceed that capacity of the existing natural treatment system.

As water quality improves through watershed activities conducted as part of the Integrated Water Quality Program, sediment quality will also improve. This changing condition will be accounted for in this process for determining water quality impacts and benefits through the site specific sediment sample collection and analysis as part of the assessment process. Until, water quality is improved, pollutants may be retained by sediment and plants, and potentially released during high flow velocities and seasonal plant die-offs. These waterways and channels have an appreciable ability to retain constituents during dry and low flow wet weather conditions; and, until the quality of storm water runoff entering receiving waters improves, this ability is important to limiting downstream risk(s) (Maestri and Lord, 1987). As described above, there are also storm conditions when impacted sediment is mobilized and can result in pollutants entering the water column and impacting water quality. Periodic removal of impacted sediments therefore provides a benefit to water quality that is considered part of the integrated water quality assessment and quantification process. Therefore, quantification of sediment removal benefits and impacts is considered a significant part of this water quality assessment and quantification model.

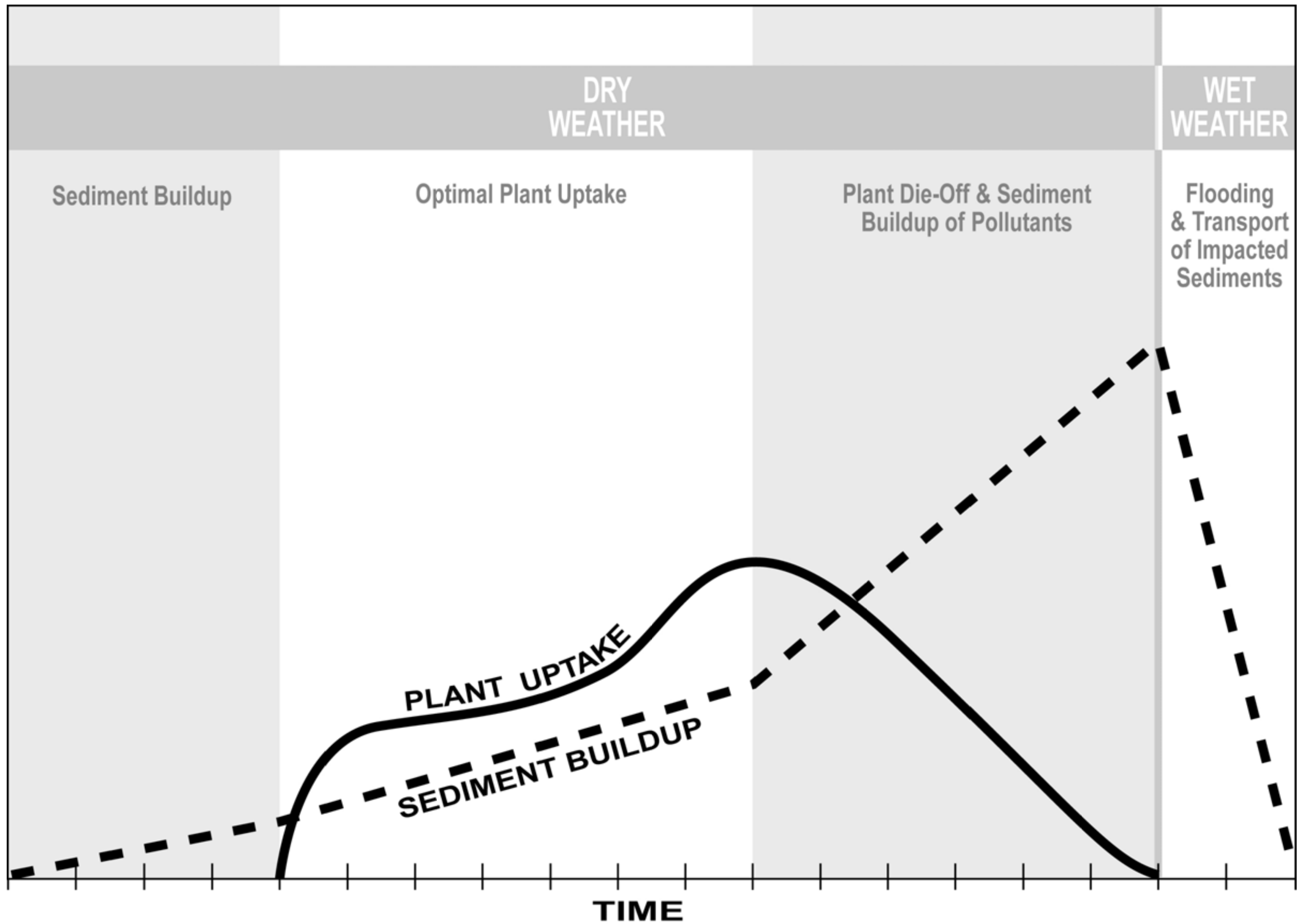

Figure 1. Pollutant uptake and release cycles in the City's flood control channels.

Critical Point 3: The City's flood control channels (also referred to as storm water facilities) were not designed as engineered treatment systems that maximize pollutant removal through long retention times, and therefore have varying pollutant removal efficiencies depending on flow, capacity of the existing sediment and plant system to adsorb and retain pollutants, and the quality of the water and sediment. Natural treatment systems designed for pollutant removal also need to be periodically maintained through the removal of impacted sediment and harvesting of plants that have reached sorption capacity.

The City's flood control (storm water) channels are not designed to be treatment systems, so they do not retain pollutants under the varied flow conditions as effective as constructed treatment systems. Engineered natural treatment systems and/or watershed BMPs outside of the flood channels are in various stages of planning, design and construction under the Integrated Water Quality program on a localized scale within prioritized areas of selected watersheds. Therefore at this current phase of the program, to decrease accumulated pollutant concentrations, impacted sediment needs to be removed from existing storm water channels. Maintenance involving vegetation and sediment removal will minimize potential migration of harmful constituents and associated risks to downstream water bodies during high flow conditions. Furthermore, maintenance within these channels has been limited over the past several decades, and much of the resident biomass is mature and at full capacity (K). Due to this maturation of the City's flood control channels, these systems that were not engineered for pollutant treatment require a greater level of maintenance in order to achieve any appreciable adsorption/retention capacity. These maintenance events will need to occur more frequently in channels with higher constituent loading, until pollutant loading is reduced. This maintenance is needed in order to remove impacted sediments and restore plant community sorption capacity that has been reached. Natural treatment systems designed for pollutant removal require this periodic maintenance to sustain their pollutant retention and sorption properties.

The City's flood control systems do not have designed flow reduction structures that are required for constructed natural treatment systems to control sediment accumulation within the vegetated treatment system and to maintain adequate retention time for maximum pollutant retention and adsorption. Thus, without these flow retention and reduction structures such as online or offline fore-bays and flow controls, the existing storm water channel accumulate sediment, and promote limited plant diversity. This further results in the establishment of invasive more aggressive plants that have out-competed other potentially more desirable species. Under these conditions, the channels are generally not providing optimal treatment performance (i.e., substantive transfers and transformations of pollutant constituents). Additionally, the City's flood control channels receive episodic flushes of storm water that originates in highly urbanized settings, likely containing numerous and variable mixtures and concentrations of pollutants. Engineered natural treatment systems are used throughout the world to treat wastewater and more recently storm water, under controlled flow conditions with a prescribed operation and maintenance program. These operation and maintenance programs are designed to facilitate desirable transfers and transformations of potential pollutants within the treatment system under a variety of environmental conditions. Operation and maintenance (O&M) plans for these systems may include harvesting of vegetation, removal of accumulated sediments, and other management tools in order to maintain the desired hydrology (i.e., hydraulic retention time), biota, and sediment character.

In certain circumstances the City's flood control channels, though not engineered natural treatment systems, can have varying characteristics of these constructed treatment systems. Like engineered systems, the City's channels require periodic maintenance including removal of plants and sediments that have reached their sorption/retention capacity. As previously stated, the benefit achieved from the removal of impacted sediments is an important aspect of this water quality quantification model. Also, the potential impact from the loss of the sediment and plant community's temporary sorption/retention capacity following maintenance needs to be quantified. This capacity may be estimated based on literature values for engineered natural treatment systems. The results of the literature search are presented in Section 4. Engineered systems use combined sediment and plant systems and flow controls to maximize pollutant removal. Furthermore, because these systems operate under controlled conditions, pollutant removal efficiencies can be more accurately measures compared to highly variable natural systems. For this reason, there is a greater amount of literature on removal efficiencies for engineered systems compared to natural wetlands which can vary greatly. Both engineered and natural systems' (where available) potential pollutant removal capacities are presented in the literature review. Since the existing channels are not engineered with controlled flow, retention times for treatment functions, or specified plant communities, an actual sorption/retention capacity or value is needed to determine potential impact. This pollutant sorption/retention value is discussed below.

The existing sediment and plant system pollutant retention and adsorption capacity is based on published removal efficiencies of engineered natural treatment systems that are then adjusted for site-specific conditions. The adjusted value is based on a scoring system using both literature values and actual site specific conditions measured in the field. This scoring system is discussed in greater detail in the next section. The potential temporary sorption/retention capacity loss due to the removal of sediment and plant systems following maintenance activities for specific constituents is compared to the benefit achieved from sediment removal. This comparison is used to determine if the benefit off-sets any temporary loss. Should the impact be greater than the benefit, consideration needs to be made to site-specific mitigation and/or anticipated watershed BMP off-sets during the next phase of the Integrated Water Quality Management Program. This is the foundation for the water quality quantification model outlined in the following section.

3.0 WATER QUALITY MANAGEMENT AND QUANTIFICATION MODEL

Based on the key elements previously discussed, a water quality management model was developed to identify the quantifiable parameters from which water quality benefits and potential impacts from channel maintenance activities could be estimated and compared. This water quality management model can subsequently be applied to any flood control maintenance project under the City's jurisdiction. Figure 2 presents the water quality management conceptual model proposed for flood control maintenance projects. As highlighted, dry weather/low flow conditions are assumed to determine the potential sorption/retention capacity of the sediment and plants within the channel consistent with Critical Point 1. In derivation of the model, it was also assumed that fluvial (stream or river systems) geomorphological (related to sediment erosion and transport processes) characteristics of the watershed (e.g., slope, topography, particle size distribution, sediment load, channel bottom, etc.) remained constant as these characteristics would not change due to maintenance activities. The water quality management model draws from a similar approach for the assessment of mitigation and/or BMP effectiveness to decrease pollutant loads.

A standard operating procedures (SOP) has been drafted in order to standardize the process of assessing whether or not potential water quality impacts may result from performing channel maintenance. The SOP also provides details on estimating the mitigation efforts that may be implemented to off-set potential water quality impacts. The SOP is included in Appendix A.

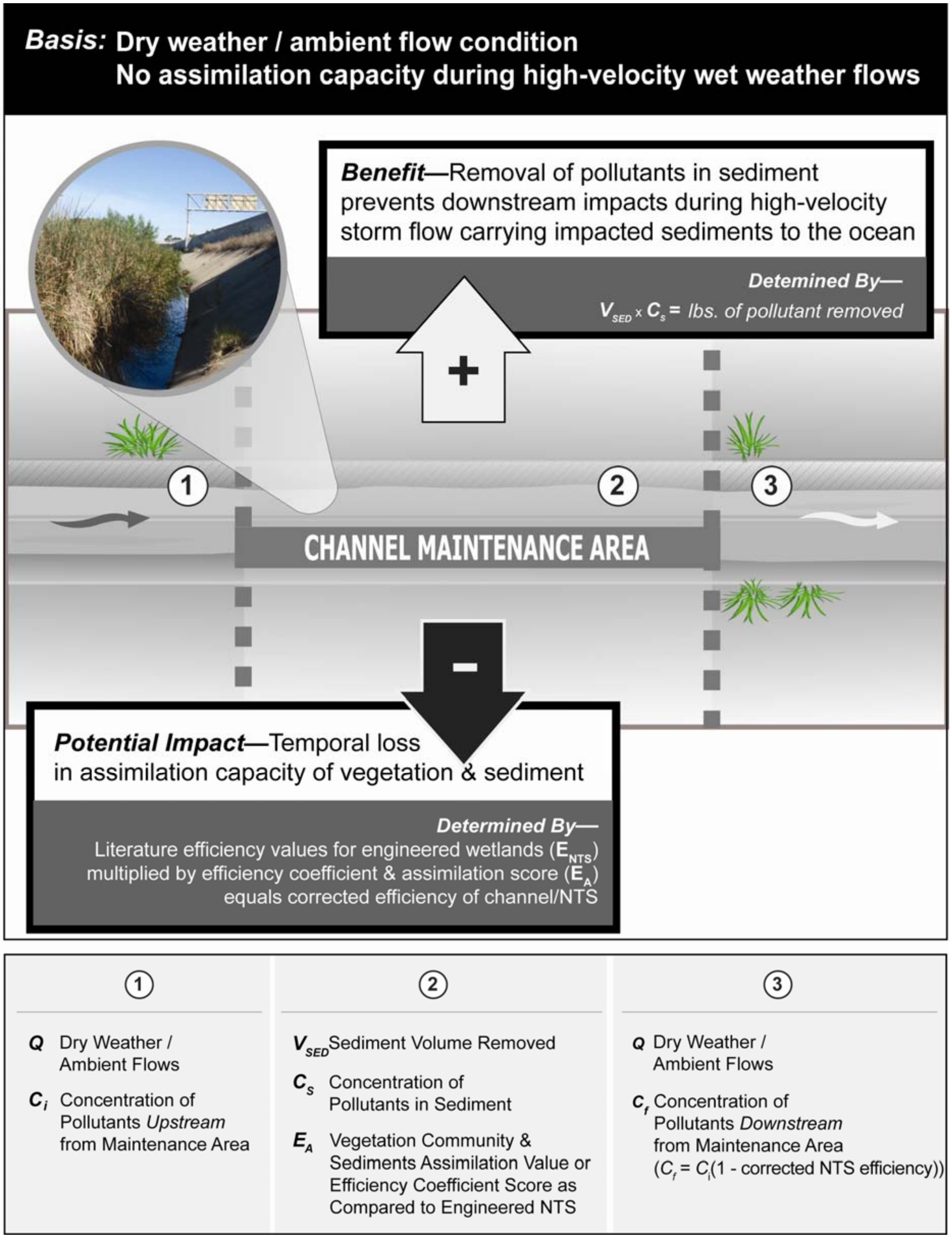

Figure 2. Water quality management model

Similar to a mitigation and BMP effectiveness assessment, pollutant loads associated with the influent storm water flow are determined based on available storm water quality data from the channel section identified for maintenance. Targeted pollutants for this assessment are based on the constituents that are monitored under the NPDES Copermittee regional monitoring program, which includes §303d listed pollutants (see Appendix A for complete list). The benefit provided by the removal of impacted sediment is then calculated based on concentrations in the channel sediments and volume of sediment scheduled to be removed. The potential sorption/retention capacity lost is based on a published removal efficiency of an engineered treatment system adjusted with a conversion factor to calculate the actual sorption/retention rates of the plants and sediments present in the existing storm water channel. This conversion factor is calculated by estimating the plant density and measuring sediment chemistry (e.g., redox, pH, and TOC) compared to an engineered treatment system. The water quality model subsequently compares the benefit(s) realized from the removal of impacted sediments for these targeted pollutants against potential impact(s) from the removal of sediment and allied plant communities that provide sorption/retention capacity for these targeted pollutants.

The water quality quantification model is outlined in a flow chart in Figure 3. This model includes collection of field observations and sediment chemistry data in order to model actual channel conditions using best available science. The process begins with field verification of dry weather flows. Consistent inflow to a treatment wetland is important to allow the system processes (flocculation, denitrification, oxygenation, and nitrification) to occur and for achieving predictable treatment efficiencies (Sutula and Stein, 2003). If no flow is observed, then there is no quantifiable impact due to re-mobilization of deposited pollutants. If observed, flow and water quality chemistry should be measured to determine pollutant loads and potential for remobilization of pollutants. The **benefit(s)** of sediment removal is quantified from the measured pollutant concentrations and the volume of sediment scheduled for removal. The potential **impact(s)** are quantified using the framework previously discussed, starting from a conservative estimate of potential pollutant removal using published data on engineered natural treatment systems. As previously mentioned, actual site conditions within existing channels are not designed to be as effective as an engineered treatment system, therefore a plant and sediment community value or scoring system has been developed (discussed in section 5.0). The quality score is used to adjust the published removal efficiency of an engineered treatment system to determine the potential sorption/retention capacity or impact of the City's storm channel. Based on the comparison of the benefits and potential impacts of channel maintenance, a determination of no further action or consideration of planned BMP tradeoffs can be made.

Example Calculations – Alvarado Channel (Total N & Cadmium)

Sediment

Parameter Values: Removal Volume (V_S)= 1,200 cubic yards
Percent Solid by weight ($\%_{Solid}$) = 59.6%
Cadmium C_S = 0.731 µg/g
Total N C_S = 3,125 mg/Kg
ρ_{solid} = 165.4 lbs/ft^3
ρ_{water} = 62.4 lbs/ft^3

$$\rho_{dry\ insitu} = \frac{(\%_{Solid}) * \rho_{water} * \rho_{solid}}{\rho_{solid} - (\%_{Solid}) * \rho_{solid} + (\%_{Solid}) * \rho_{water}} = 59.1 \text{ lbs/ft}^3$$

Sediment Mass = Removal Volume * $\rho_{dry\ in\text{-}situ}$ = 1,915,000 lbs

Load Removal = Sediment Mass * C_S
= 1.4 lbs (Cadmium)
= 5,966 lbs (Total N)

Engineered Natural Treatment System (NTS)

Parameter Values: Treatment Flow = 10,800 ft^3/year (see Plate C-1)
Cadmium C_I = 0.1080 mg/L
Total N C_I = 2.15 mg/Kg
Cadmium NTS Removal Efficiency (E_{NTS}) = 63%
Total N NTS Removal Efficiency (E_{NTS}) = 40%
Existing Score = 5 (Appendices A & B)
Recovery Score = 4 (Appendices A & B)
Maintenance Period = 3 years

Existing Efficiency Coefficient = 0.1 + Existing Score * 0.1 = 60%

Corrected E_{NTS} = E_{NTS} * Efficiency Score
Corrected E_{NTS} = 38% (Cadmium)
Corrected E_{NTS} = 24% (Total N)

Existing NTS Load Removal = Flow * C_I * Corrected E_{NTS}
Existing NTS Load Removal = 27.5 lbs/year (Cadmium)
Existing NTS Load Removal = 349 lbs/year (Total N)

$$\text{Yearly Recovery Score} = \frac{n_{year}}{\text{Maint. Period} * \text{Recovery Score}}$$
= 1.3, n_{year} = 1
= 2.7, n_{year} = 2
= 4.0, n_{year} = 3

Yearly Efficiency Coefficient = 0.1 + Yearly Recover Score * 0.1
= 23%, n_{year} = 1
= 37%, n_{year} = 2
= 50%, n_{year} = 3

Year	Corrected E_{NTS} (Cadmium)	NTS Load Removal (Cadmium)	Corrected E_{NTS} (Total N)	NTS Load Removal (Total N)
1	14.7%	10.7	9.3%	135.9
2	23.1%	16.8	14.7%	213.5
3	31.5%	23.0	20.0%	291.1
Total		50.5		640.5

Results

Load Removal (Existing Condition)

Cadmium	27.5 lbs/year * 3 years =	82.6 lbs / Maint. Period
Total N	349 lbs/year * 3 years =	1,048 lbs / Maint. Period

Load Removal (with Channel Maintenance)

Cadmium	Sediment Load Removal =	1.4 lbs / Maintenance Period
Cadmium	Maintained NTS Load Removal =	50.5 lbs / Maintenance Period
Total		51.9 lbs / Maintenance Period
Total N	Sediment Load Removal =	5,966 lbs / Maintenance Period
Total N	Maintained NTS Load Removal =	640.5 lbs / Maintenance Period
Total		6,607 lbs / Maintenance Period

Comparison	**Maintained Channel – Existing Condition**
Cadmium	51.9 lbs – 82.6 lbs = –30.7 lbs (potential water quality impact)
Total N	6,607 lbs – 1,048 lbs = 5,559 lbs (potential water quality benefit)

If the pollutant reduction due to sediment removal (benefit) is greater than the estimated loss of temporary sorption/retention capacity (impact), then no further action is needed (benefit>impact)**.** If the pollutant reduction due to sediment removal is less than the estimated loss of temporary sorption/retention capacity (benefit<impact), then there may be a need to off-set this loss with site-specific mitigation and/or BMPs in the watershed in coordination with the integrated water quality implementation plan. BMP implementation planning can be prioritized based on this quantification process as well as scheduling of channel maintenance. Examples using this quantification process are presented in later sections.

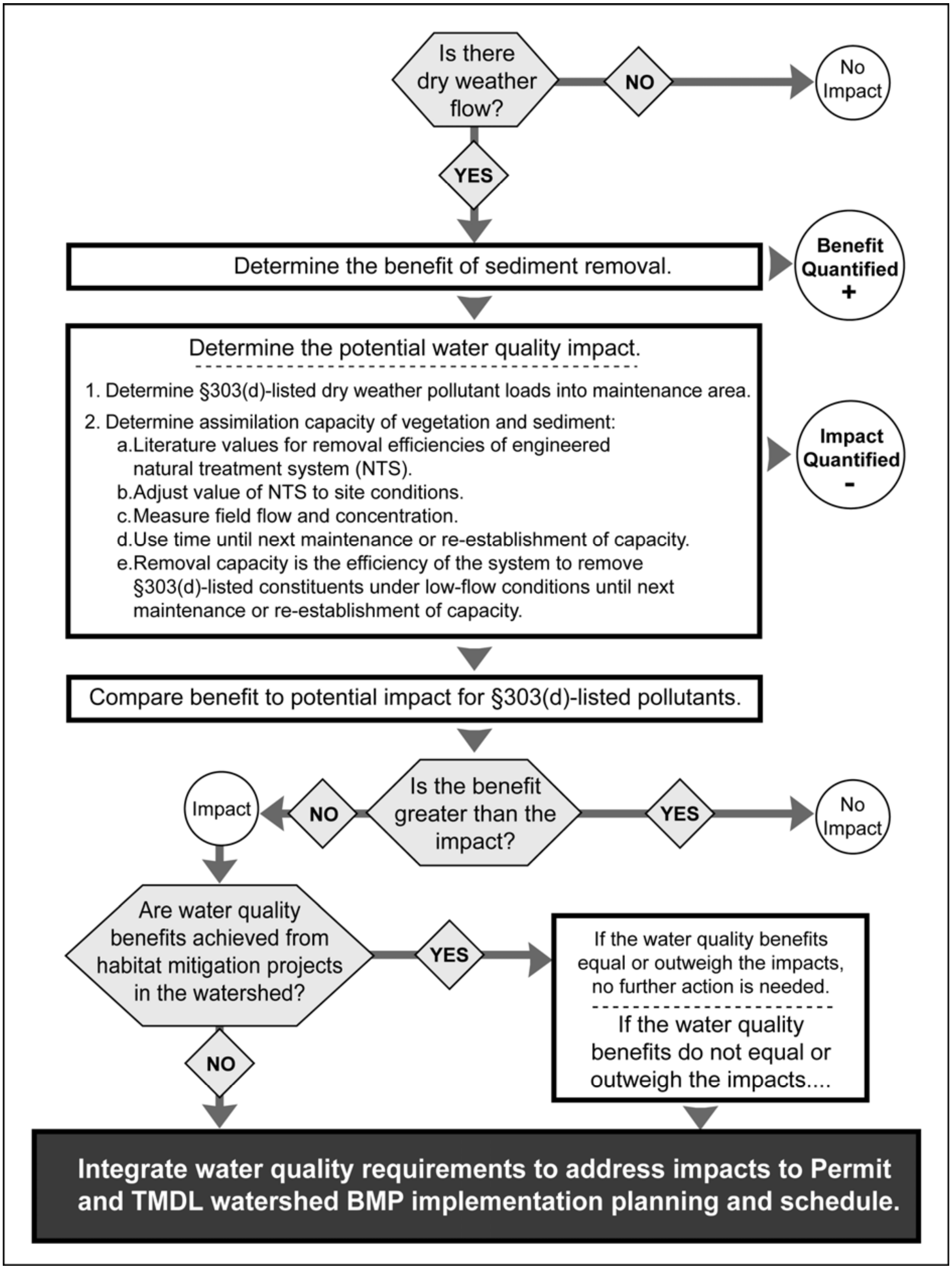

Figure 3. Water quality management quantification process

4.0 LITERATURE REVIEW

This section provides a summary of the published data and studies used as a basis for the water quality quantification model presented in this White Paper. The intent of this section is to provide an overview of the best available science on the ability of plant communities and sediments to sorb and retain pollutants and how these characteristics apply to the City's flood control channels. As highlighted in the discussion below, quantification of potential impacts from channel maintenance activities requires using available literature values for engineered systems, even though the channels were not designed for pollutant removal. There are literature values for the performance of natural wetland systems to assimilate nutrients (i.e. nitrogen and phosphorus), but studies to measure transfers and transformations of anthropogenic constituents in natural systems are not common. Therefore, a scoring or value system to better assess the potential contribution of existing plant communities and sediment in the flood channels has been developed by Weston scientists to determine a more accurate representation of these existing channel systems to remove pollutants (section 5.0).

Summary of Literature Review

Several management techniques have been investigated for mitigation of pollutants associated with storm water runoff in agricultural and urban environments. Storm water management practices, including street cleaning, catch basin inserts and filters, dry detention basins, porous pavements, and filtration devices for suspended solids, possess varying levels of effectiveness for decreasing pollutant loads associated with runoff (Maestri and Lord, 1987). More cost effective and less maintenance intensive techniques include vegetative controls (e.g., grassed channels and overland flows), use of vegetated surfaces for erosion, and sediment control. Engineered and well maintained vegetative controls typically decrease runoff velocity, filter suspended solids, and enhance sedimentation and deposition.

Variations of these more cost effective approaches include wet detention basins (i.e., a permanent pool of water is maintained) or infiltration systems that increase detention time, enhance sedimentation and biological processes, and promote ground water infiltration. Engineered natural treatment systems are also used to promote sediment retention and vegetative uptake. Natural treatment system are characterized by their high flora conductivity and nutrient needs, high decomposition rates, low oxygen content in their sediments, and large adsorptive surfaces within the substrate, optimal characteristics for assimilation of nutrients (e.g., nitrogen and phosphorus) and deposition of hydrophobic constituents associated with fines that mobilize during storm events.

Constituents of concern in Southern California storm waters include metals, pesticides, nutrients, PCBs, PAHs, and other materials associated with urbanization and large areas of impermeable surfaces for accumulation of impacted suspended solids that mobilize during storm events. Within an engineered natural treatment system, metals, pesticides, and other hydrophobic constituents in storm water are potentially transferred from the water column by flow modification (i.e., sedimentation and deposition), sorption, retention, and infiltration (Rodgers and Dunn, 1992).

Potential transformations of these chemical classes within the natural treatment system include volatilization, photolysis, hydrolysis, precipitation, cation exchange reactions, and biotransformation (Rodgers and Dunn, 1992; Vymazal et al., 1998). Additional mechanisms of nutrient (nitrogen and phosphorus) removal in these natural treatment systems include both bacterial transformations and physico-chemical processing including adsorption, absorption, precipitation, and sedimentation (Gersberg et al., 1986).

Emergent wetland plants (i.e., macrophytes) have several intrinsic properties that make them a key component of constructed natural treatment systems (Brix, 1994). Vegetation stabilizes the surface of the sediment beds, provides conditions for physical filtration, uptakes nutrients into biomass, decreases current velocity, prevents vertical flow systems from clogging, insulates against frost during winter, attenuates light, and provides an extensive surface area for microbial growth, habitat for wildlife, and desirable aesthetics.

Many natural treatment system plants are known to translocate O_2 from their shoots to their roots thus their rhizosphere offers an oxidized microenvironment in an otherwise anaerobic substrate, stimulating decomposition of organic matter and growth of nitrifying bacteria. In addition, macrophytes increase hydraulic conductivity of the soil/sediment through macropore formation, stabilizing within three years of planting within a newly constructed natural treatment system.

With sufficient dissolved carbon concentration, nitrogen (N), biological oxygen demand (BOD), and TSS removal efficiencies of several common constructed natural treatment system macrophyte standing crops were measured by Gersberg et al. (1986). Natural treatment system constructed with bulrush (*Scirpus*) for municipal wastewater treatment removed greater than 94-percent of influent N, BOD, and TSS concentrations compared to greater than 78-percent removal by natural treatment systems constructed with common reed (*Phragmites*), and greater than 28-percent by natural treatment systems constructed with cattails (*Typha*).

The efficiency of a biological treatment system is strongly affected by the contact time between pollutants and microorganisms (Hatano et al., 1992; Portier and Palmer, 1989 in Machate et al., 1997). In pilot-scale natural treatment systems designed for cationic metals removal and subsequent decrease in bioavailability, sediments had a reduction-oxidation potential (redox) of -75 to -200 mV, sediment oxygen demand (SOD) of 0.446 g $O_2/m^2/d$, an acid volatile sulfide concentration of 0.5 to 3.0 µmol/g that exceeded the simultaneously extractable metals concentration, and a sulfate-reducing bacteria population of 10,000 to 50,000 cfu/mL (Huddleston and Rodgers, 2004).

Under oxygen limited conditions, such as in wetland soils, decomposition of some detritus is sufficiently slow to allow organic matter to accrete over time (Mitsch and Gosselink, 1993). If detritus decay is too rapid, as with less lignin-containing wetland plants (e.g., *Typha*) which can completely decay in less than 180 days, a sufficient organic carbon reservoir may not be available to sustain desired metabolic processes such as dissimilatory sulfate reduction (i.e, utilization of sulfate as the terminal electron acceptor). Under certain redox conditions, microbial reduction of sulfate to hydrogen sulfide (H2S) is facilitated which preferentially binds and precipitates cationic metals (Wetzel, 1983; Morse, 1995).

Half life of giant bulrush (*Scirpus californicus*) detritus in a pilot-scale constructed natural treatment system was 275 days (Huddleston and Rodgers, 2002), indicating accretion over time, providing binding sites for copper and other divalent metals, and providing a continuous energy source for bacterial metabolic processes. Biomass of nonliving aquatic wetland plants also behaves as a weak cation exchange material, a primary mechanism responsible for ion uptake. At neutral pH, carboxyl groups are the main functional group in the ion exchange reactions at neutral pH that appear to be related to protein content. Schneider and Rubio (1999) reported sorption of dissolved copper from the water column to nonliving biomass (at a suppressed pH of 5.5) of several wetland plants including curly pondweed (*Potamogeton*) (95%), water fern (*Salvinia*) (94%), common water hyacinth (*Eichhornia*) (79%), water milfoil (*Myriophyllum*) (78%), fanwort (*Cabomba*) (46%), and hornwort (*Ceratophyllum*) (38%).

Machate et al. (1997) measured a 99-percent removal of phenanthrene from a simulated storm water influent within a constructed natural treatment system, 98-percent removed from the first 10-cm of the first cell's substrate of a five-cell system. Besides microbial degradation several other processes such as photodegradation, adsorption, and translocation into the plants were observed to contribute to removal of this mid-molecular weight PAH. Additional sorbent materials were also identified within the substrate including humic substances, residual plant material, biofilm and algae that were reported to enhance the adsorption of hydrophobic compounds (Tanner and Sukias, 1994; Murphy et al., 1990 in Machate et al., 1997).

Rodgers and Dunn (1992) identified design guidelines for constructed natural treatment systems to facilitate transfers (e.g., hydroperiod management, sorption, solubility, retention, and infiltration) and transformations (e.g., volatilization, photolysis, hydrolysis, and biotransformation) of pesticides from agricultural runoff. Pyrethroids are not particularly water soluble (10-20 ppb) and readily sorb to plants and sediment, thus systems that facilitate deposition of TSS and contain high concentrations of organic matter for sorption are most desirable for mitigation of pesticides.

Of the copper added to mesocosm-scale constructed natural treatment system, 2-percent and 6-percent was sorbed to the shoots and roots of *Scirpus*, respectively (Huddleston and Rodgers 2002). Cu adsorbed to *Scirpus* shoots increased to 0.34-2.03 mg/kg compared to 0.16 mg/kg for controls. Cu adsorbed to *Scirpus* roots increased to 0.44-2.33 mg/kg compared to 0.38 mg/kg for controls. Cu absorbed by *Scirpus* shoots increased to 2.26-4.95 mg/kg compared to 1.51 mg/kg for controls and Cu adsorbed by *Scirpus* roots increased to 5.27-28.66 mg/kg compared to 4.53 mg/kg for controls.

Similarly, Gillespie et al. (2000) measured a 38-percent and 65-percent removal of total recoverable Zn and soluble Zn, respectively in constructed natural treatment system designed to mitigate refinery effluent and remove metals. Zn absorbed and adsorbed to *Scirpus* roots after 144 days of treatment increased from 221 mg/kg to 406 mg/kg and 18 mg/kg to 236 mg/kg, respectively. Zn absorbed and adsorbed to *Scirpus* shoots after 144 days of treatment increased from 18 mg/kg to 259 mg/kg and 0.10 $\mu g/cm^2$ to 3.4 $\mu g/cm^2$, respectively. Zn adsorbed to sediments within the wetland after 144 days of treatment increased from 152 mg/kg to 3,150 mg/kg.

The potential rate of nutrient uptake by vegetation is limited by its net productivity (i.e., growth rate) and the concentration of nutrients in the plant tissue – maximum standing crop. Desirable plant traits include rapid growth, high tissue nutrient content, and capability to attain a high standing crop (biomass per unit area (Vymazal et al., 1998). If a standing crop of macrophytes within a natural treatment system is not regularly harvested, the vast majority of the nutrients that have been incorporated into plant tissue will be returned to the water by decomposition processes. The effect of increasing concentration of parameters from dormant (dead) plant matter during the cold winter months strongly suggest that for constructed natural treatment system to be effective in removal of pollutant mass, plant harvesting must be practiced in order to remove organic matter and nutrients from the system (Hill and Payton, 1998).

Periodic harvesting and sediment removal is required in engineered treatment systems that use vegetation with an affinity for absorption of a constituent(s) and subsequent accumulation in the plants' tissues (i.e., hyperaccumulaters). This maintenance is required to facilitate optimal uptake and sorption rates. The same is true for engineered systems that utilize flora to sorb available nutrients at an accelerated rate at particular life stages.

Additionally, sediment accumulation may affect water depth resulting in a shift in preferential flora composition and a change in reduction-oxidation potential (redox), both of which are key elements in performance of these treatment systems. Greater maintenance is required for systems with higher constituents loading. Systems like the City's flood control channels that are not designed as engineered treatment systems also require a greater frequency of maintenance to achieve any appreciated adsorption/retention capacity. These maintenance programs will need to occur more frequently in channels that have higher constituent loading, until pollutant loading is reduced

5.0 EXISTING CHANNEL CONDITION WATER QUALITY VALUE AND SCORE

Using the best available science from the literature review summarized in the previous section, a system to assign a value or score to an existing channel's plant and sediment community has been developed. The scoring is based on three categories, vegetation, hydrosoil and hydroperiod. Scoring is assigned to each of these categories based on a set of criteria summarized in Table 1 (Appendix A) that was subsequently used to develop a field worksheet (Table 2). This scoring system was used in the two examples presented in the following section (6.0) to demonstrate the water quality quantification model. Scoring is used in this process to more accurately estimate the pollutant removal potential of the existing plant community and sediment in the channel. This score or value is then compared to the removal efficiency of an engineered natural treatment system that is specifically designed for this function. As previously described, existing literature was used as a foundation for development of the criteria to establish an existing condition value or score.

6.0 QUANTIFICATION ANALYSIS EXAMPLES

An analysis of two channels that are currently identified for maintenance by the City was conducted to determine the potential benefits and impacts of performing such maintenance activities using the quantification model (Figure 3). The example areas are 3,000 linear feet of Chollas Creek and 1,120 linear feet of Alvarado Creek. City engineering and maintenance recommended both sites for removal of vegetation and sediment to improve the ability of the channels to convey large storm events. An estimated volume of sediment to be removed is 1,100 cubic yards and 1,200 cubic yards from Chollas and Alvarado Creeks, respectively.

In their current condition, each channel possesses characteristics that are similar to a natural treatment system during low flow conditions (i.e., sorption/retention capacity). Channel storage capacity was estimated using stadia height and the attached stream survey forms to estimate the maximum storm water flow rate that could be conveyed through the channels while still allowing for some measureable sediment deposition and pollutant retention, (Appendix B). The flow rate was calculated from a 24-hour composite sample of water passing through the designated area, unrelated to a storm event.

A field crew visited the Alvarado Creek maintenance area on October 28, 2010, approximately one week after a storm event (i.e., 0.2 inches). The field crew measured flow in the creek comparable to a maximum, assumed natural treatment system flow. The number of days per year that the channel may experience dry weather flows was estimated by subtracting the wet days (i.e., rainfall greater than or equal to 0.2 inches, including the subsequent 72 hours) from the total number of days during the wet season (October 1 to June 30). Please note that this assessment uses the conservative approach of applying 0.2 inches of rainfall as a threshold for wet weather, which is consistent with the threshold use by the San Diego County Department of Environmental Health's (DEH) to issue General Advisory to avoid contact with ocean and bay water within 300 feet on either side of any storm drain, river, or lagoon outlet. (SDRWQCB, 2008). This differs from the definition of wet weather in the San Diego County NPDES Permit, R9-2007-0001, and the federal NPDES regulations, which define a measurable storm event as 0.1 inches (SDRWQCB, 2007) (40CFR122.21). The maximum flow rate for all dry days during the wet season was used to estimate annual dry weather volume, conservatively assumed to be "treated" by the channel. This estimate is conservative because the channel experiences less dry weather flow, both lower velocity and fewer days than the maximum flow and dry weather days. Additional information may be collected throughout the year to better estimate the flow through Alvarado Creek to further assess benefits and impacts of performing channel maintenance. Both of the segments assessed do not have consistent and measurable dry weather flows during the summer months (June 30 to October 1). For additional details on assumptions and calculations see the Appendices A, ~~worksheets presented in Appendices~~ B, and C.

The Chollas Creek maintenance area is located downstream of the Chollas Creek Monitoring Station (CCMS). Flow monitoring data for the CCMS 2009-2010 wet season was used to calculate dry weather average flow. The volume of flow through the maintenance area was estimated by applying the average flow rate to all dry weather days during the wet season. A field crew visited the maintenance area on October 28, 2010, approximately one week after a wet weather storm event, and subsequently observed no surface flow (Appendix B).

The field crew used the attached scoring system (Appendix B) to obtain a **quality score** between zero and nine (e.g., nine is best case with a coefficient of 100-percent and zero is worst case with a coefficient of 10-percent). Published natural treatment system removal efficiencies were multiplied by the quality score coefficient (relative percentage) to calculate pollutant load reduction efficiencies that represent the existing channels compared to engineered-natural treatment system. Each channel load was multiplied by the estimated channel removal efficiency to calculate a potential pollutant load removal capacity of the channel (Appendix C).

The maintained channel will result in pollutant load reductions directly through the removal of sediment pollutants. Additional reductions will occur throughout the maintenance period by the channel functioning as a natural treatment system as the flora density increases. While onsite, the field crew also used a grading system to give each area a "score" between zero and nine to estimate the **recovery potential** of the channels to function as engineered-natural treatment system after maintenance (e.g., score of nine is best case with coefficient of 100% and zero is worst case with coefficient of 10%). Based on the given score, published removal efficiencies for engineered-natural treatment system were multiplied by the coefficient in order to provide removal efficiencies that more accurately represent the channels for each year between maintenance activities. The annual loads for the ~~§303d listed~~ constituents assessed through the channel were multiplied by the estimated channel removal efficiencies for each year between maintenance activities to determine the potential pollutant load removal capacities of the maintained channels. The total loads removed by maintained channels were estimated by summing the load removals due to sediment excavation and by the channel functioning as an engineered-natural treatment system after vegetation growth (Appendix C). Field scores followed by total load removal calculations form the basis of a standard operating protocol, to be developed as the next step in this water quality assessment and quantification model for the City of San Diego Flood Control System.

Subsequently, pollutant loads were estimated by multiplying the above-mentioned annual volumes by concentrations measured from the channel sediments. Pollutants targeted for this analysis were the same as those measured by NPDES monitoring and include those listed on the State Board §303d list for the specific water body/segment. Pollutant concentrations were confirmed for the two example sites through chemical analysis of sediment grab samples collected by Weston field staff (October 28, 2010) which were subsequently used to estimate pollutant loading. For Alvarado Creek, these results were compared to results previously obtained by averaging pollutant concentrations from four, dry weather, grab samples collected as part of the Surface Water Ambient Water Monitoring Program (SWAMP). Similarly, Weston's grab sample results were compared to mean concentrations from two dry weather sampling events previously collected at the Chollas Creek CCMS as part of the County Co-Permittee monitoring program. Results from the confirmatory samples from both sites were comparable to previously collected sediment concentrations. Annual loads were multiplied by the number of years between scheduled maintenance events to determine the total load per maintenance period. The recommended number of years between maintenance for the channels is proposed to be three and five years for Alvarado and Chollas Creeks, respectively (Appendix C).

The potential pollutant load removal from the existing channels due to sediment deposition and sorption was compared to the estimated load removals associated with maintained channels to determine if the maintenance activities will result in water quality benefits. The results of these analyses are summarized in Appendix C, demonstrating that for most of the constituents evaluated greater water quality benefits were achieved due to maintenance (i.e., sediment and associated pollutant removal) than without. Due to maintenance activities for Chollas Creek, there were 9 of 19 constituents that the benefits were not greater than the potential impacts. For Alvarado Creek, there were 4 of 19 constituents that the benefits were not greater than the potential impacts. These conditions will change overtime as greater pollutant reductions are achieved in these watersheds through the NPDES Permit and TMDL programs. These changes in water and sediment quality are addressed in this assessment process through the site-specific water and sediment quality sampling and analysis conducted prior to maintenance activities. Ongoing water and sediment quality sampling by the City and others between maintenance may also be used to provide the input into the process to reduce monitoring costs.

The off-set, or mitigation effort, for this potential impact would need to be addressed in coordination with the Department's Integrated Water Quality Program. When planned prior to maintenance, mitigation efforts (BMPs) within the same watershed could or will provide equal or greater pollutant removal compared to the estimated impact of maintenance. These mitigation effort projects will serve as the replacement to the estimated amount of lost sorption/retention capacity for the constituent(s) where the impact is greater than the benefit and may cause the constituent(s) to exceed the water quality threshold(s) (i.e., water quality objectives defined in the Basin Plan). In cases where the impact is greater than the benefit, but the maintained channel water column concentrations of the specific pollutants that are monitored under the NPDES Permit will be less than 25 percent below the water quality objectives, no risk to the beneficial uses exist, and therefore no mitigation is necessary. In the case where there is currently no pollutant removal mitigation effort planned within the watershed, the water quality impact could be addressed through the implementation of BMPs. Two example BMPs that may be used as mitigation efforts are provided in Appendix D and are provided as merely potential mitigation effort types. The City may choose other structural BMPs and source control BMPs where the effectiveness has been quantified to compensate for the estimated impact. Table 3 shows potential mitigation measures that may be used by the City. Appendix D provides a more comprehensive list of BMPs that include non-structural, low impact development and structural treatment type BMPs. Appendix D also provides the pollutants that are addressed for each BMP. The table may be expanded in the future to include other mitigation measures as technology improves and more information is available on various BMPs. The *County of San Diego LID Manual* provides guidance on site design and structural BMPs and may also be used as guidance when considering mitigation efforts.

Table 3. Mitigation Effort Type

▪ Detention Tanks and Vaults	▪ Infiltration Trench
▪ Dry/Wet Ponds	▪ Porous Pavements
▪ Extended Detention Basins	▪ Cartridge Filters
▪ Wetlands and Shallow Marsh Systems	▪ Catch Basin Inserts
▪ Green Roofs	▪ Hydrodynamic Devices
▪ Filtration and Disinfection Facilities	▪ Proprietary Biotreatment Devices
▪ Organic Media Filters	▪ Low Flow Diversions to Sanitary Sewers
▪ Surface Sand Filters	▪ Cisterns
▪ Underground Sand Filters	▪ Rain Barrels
▪ Bioretention	▪ On-site Storage and Reuse
▪ Infiltration Basin	▪ Vegetated Swales

For these examples, two BMPs were used to estimate the quantity and costs of installation and maintenance (Appendix D). The BMP example includes media-type inlet devices installed within the City's right-of-way in the upland tributary areas to the storm water channels. The other BMP approach was a modular wetland. These are potential options to address the site-specific constituents, concentrations, and flows in these examples. BMPs selected need to be designed and implemented to meet the site-specific conditions and results obtained from the water quality model. This White Paper provides a framework for future decision-making, to select site-specific BMPs, and evaluate their feasibility. This is a simplistic approach, and the actual BMPs used by the City will be coordinated with the City's Integrated Water Quality Program.

7.0 CONCLUSIONS

This White Paper provides a model for assessment and quantification of potential water quality benefits and impacts due to flood channel maintenance within the City of San Diego (City). Based on three key critical points, a water quality management model was developed to identify quantifiable parameters from which water quality benefits and/or potential impacts from channel maintenance activities could be estimated and compared. The critical points were:

- Both dry and wet weather conditions need to be considered for the ability of plants and sediment to retard downstream migration of and retain potentially harmful pollutants in storm water and urban runoff flows. Higher storm flows do not allow for sufficient retention time for either sediments to deposit or plants to adsorb pollutants.
- Removing impacted sediments that may cause water quality impairment when mobilize provides water quality benefits, The City's flood control channels (also referred to as storm water facilities) were not designed as engineered treatment systems that maximize pollutant removal through long retention times, and therefore have varying pollutant removal efficiencies depending on flow, capacity of the existing sediment and plant system to adsorb and retain pollutants, and the quality of the water and sediment. Natural treatment systems designed for pollutant removal also need to be periodically maintained through the removal of impacted sediment and harvesting of plants that have reached sorption capacity.

Based on these three key critical points, a water quality management model was developed to identify the quantifiable parameters from which water quality benefits and/or potential impacts from channel maintenance activities could be estimated and compared. This model provides a threshold by which mitigation measures are to be implemented, and provides specific pollutants and pollutant load reductions to address the defined water quality impacts. This water quality management model can subsequently be applied to any flood control maintenance project under the City's jurisdiction based on site-specific water and sediment quality, dry weather flows and sediment/vegetation system measured field and analytical data collected as part of water quality quantification and modeling process. Potential mitigation measures are also provided to address water quality impacts that are pollutant specific and integrated into the City's overall storm water management program.

The City's flood control channels are not designed to be treatment systems, so they do not retain pollutants under the varied flow conditions as effectively as constructed treatment systems. Therefore, periodic maintenance of the City's flood control (storm water) channels is needed to maintain flood capacity and may provide water quality benefits through the removal of impacted sediments, and restoration of plant community sorption capacity that have been reached without maintenance as required by treatment systems.

The removal of impacted sediment therefore provides a benefit that is one of the basis for the model. In order to determine the potential impact or loss of pollutant removal capacity in the channels during dry weather and low wet weather flows, existing sediment and plant pollutant water quality values were compared to published removal efficiencies of engineered natural treatment systems. The engineered treatment system efficiencies are therefore adjusted to represent actual existing conditions based on field collected data to estimate the potential temporary sorption/retention capacity loss following maintenance activities for specific constituents under dry weather flows. This temporary loss was then compared to the benefit achieved from sediment removal to determine if the benefit off-sets any temporary loss.

If the pollutant reduction due to sediment removal (benefit) for constituents monitored as part of the regional NPDES Permit is greater than the estimated loss of temporary sorption/retention capacity (impact), then no further action is needed (benefit>impact). If the pollutant reduction due to sediment removal is less than the estimated loss of temporary sorption/retention capacity (benefit<impact), then there may be a need to off-set this loss with BMPs in the watershed in coordination with the Integrated Water Quality Program.

This decision-making framework may be incorporated into the City's Master Storm Water System Maintenance Program in conjunction with the Integrated Water Quality Program to prioritize and schedule channel maintenance to address potential water quality impacts. The framework would include:

- Defining data requirements to be collected for model input,
- Methods for defining subsequent impacts (i.e., model assumptions and results),
- Define and refine decision-making triggers, and
- Potential selection of BMP options to address water quality beneficial uses.

Potential options to address quantified water quality impacts are presented in the examples that meet the site-specific constituents, concentrations and flows measured at these proposed maintenance sections. BMPs selected for addressing water quality impacts should be designed and implemented to meet site-specific conditions and coordinated with the Integrated Water Quality Program.

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APPENDIX A

Standard Operating Procedures To Conduct Water Quality Assessment And Quantification Model For Flood Control Channel (Storm water Facility) Maintenance

STANDARD OPERATING PROCEDURES TO CONDUCT WATER QUALITY ASSESSMENT AND QUANTIFICATION MODEL FOR FLOOD CONTROL CHANNEL (STORM WATER FACILITY) MAINTENANCE

This document details the standard operating procedures (SOP) to conduct water quality assessments and quantification models to estimate the potential benefits and/or impacts associated with the maintenance of flood control channels (***hereafter referred to as storm water facilities***). The document is presented so that an adequate and transparent assessment (based on sound science) of potential benefits compared to impacts can be completed for storm water facility segments planned for maintenance activities. The required qualifications, various equipment, and methods to conduct the water quality benefits/impacts assessment due to storm water facility maintenance are specified. The procedures detailed here shall be followed to allow for completion of the assessment process, site conditions may require modifications and these shall be appropriately documented (procedure, reason, and result of deviation) in the assessment report.

This SOP assumes that a basic, visual, assessment of the storm water facility segment has been conducted resulting in the determination that storm water facility maintenance has the potential to have an impact to water quality, in which further assessment, presented here, is necessary so that potential impacts can be quantified and mitigation effort for such impacts may be identified. Storm water facility maintenance has potential to create water quality impacts only if the following minimum conditions exist:

- Storm water facility segment has fairly consistent dry weather (low) flows.
- Storm water facility segment has vegetation capable of assimilation of pollutants (i.e., storm water facility segment is not completely concrete covered with sediment that merely needs to be removed).

The sections of the SOP follow the flow chart shown in Figure A-1. This flow chart should be reference as the other sections of the SOP are followed. Similarly, the overall SOP shall be well understood by the engineer performing the assessment in order to properly follow the flow chart.

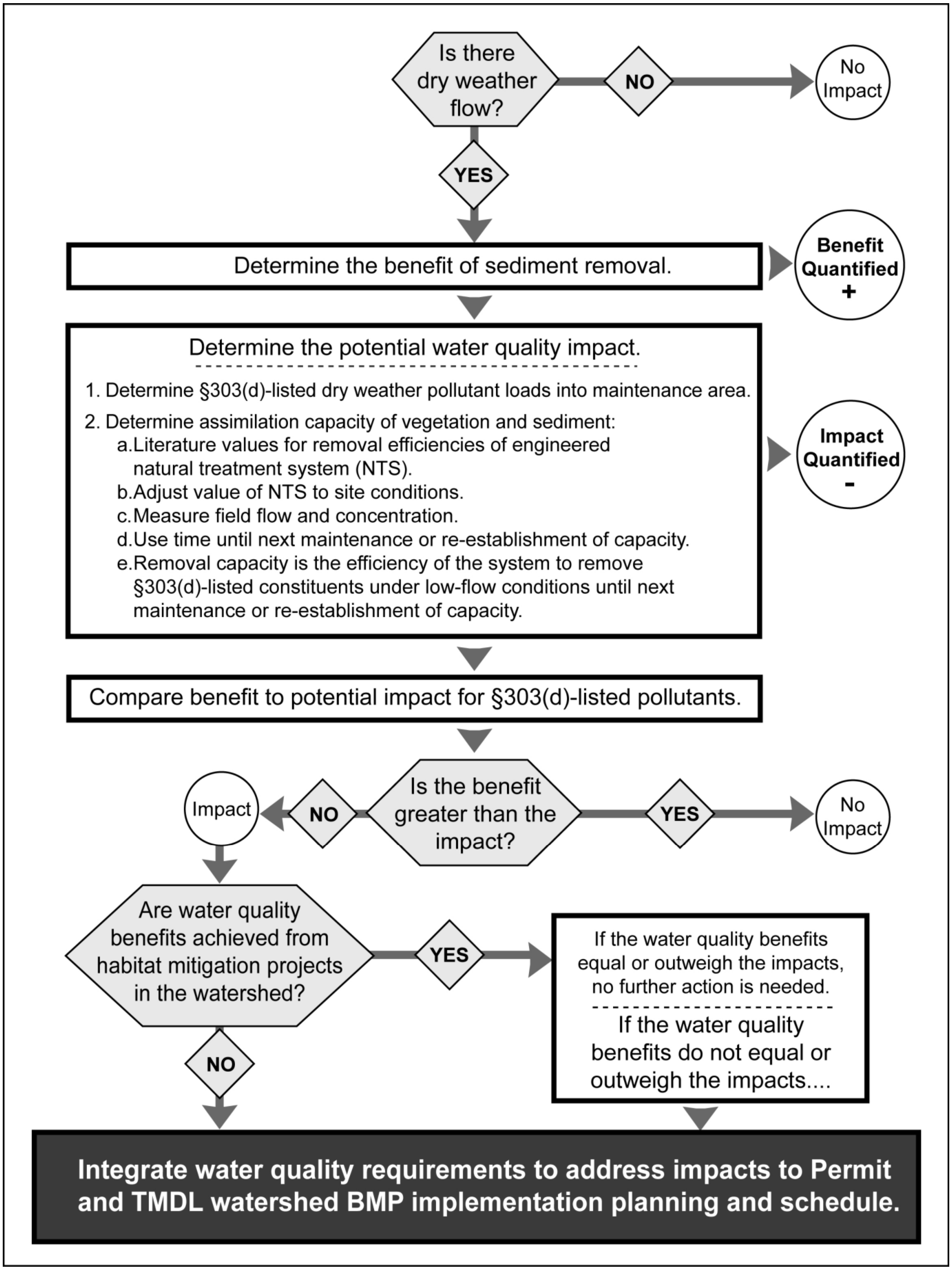

Figure A-1. Water quality management quantification process

Evaluating Sediment Removal Pollutant Loads (Benefits)

Evaluating the potential benefits from sediment removal includes calculations to determine approximate pollutant loading of sediment slatted for removal. These calculations are supported by collecting site specific samples and performing laboratory analysis. This work shall be performed under the direct supervision of professional civil engineer, with current California registration, with experience in fields of channel hydraulics, field surveying, laboratory analyses, and the current water quality issues of the region. The field work may be conducted, under the supervision of the registered civil engineer, by scientists and/or engineers with experience collecting samples and completing field forms. Samples shall be delivered and processed by California state certified laboratories following methods and detection limits outlined here.

Evaluation of Sediment Transport Potential

The velocities associated with peak flows, as determined through the hydraulic modeling of storm water facilities completed in support of maintenance, shall be reviewed for storm water facilities and compared to Table A-1 and Table A-2. Permissible Velocities with Grass Cover1 Formatte
~~Table A-2. Permissible Velocities with Grass Cover1~~
below, as applicable. If the flow velocities exceed values presented in the tables for the return period storm event approximately equal to the maintenance period for the storm water facility segment (e.g., for a 5-year maintenance period compare 5-year return period velocities), the sediment slated for removal is susceptible to transport downstream if not excavated through maintenance activities. Benefits are considered only for those conditions were measured contaminants are anticipated to be mobilized between maintenance periods. If the potential peak velocity for the design storm is below the maximum permissible velocity listed for the applicable material/cover, then the load removal benefits from sediment removal should not be applied to the benefit-impact assessment calculations (i.e., maintenance may involve the removal of sediment, but load removal shall not be credited as a benefit of sediment removal). In general, velocities above 5 feet per second will cause scour in most storm water facilities.

Table A-1. Permissible Velocities for Unlined Storm water Facilities

Type of Material	Maximum Velocity (feet per second)	
	Intermittent Flow	Sustained Flow
Fine sand, colloidal	2.5	2.5
Sandy loam, noncolloidal	2.5	2.5
Silt loam, noncolloidal	3.0	3.0
Fine loam	3.5	3.5
Volcanic Ash	4.0	3.5
Fine gravel	5.0	4.0
Stiff Clay (Colloidal)	6.0	4.5
Graded Material		
Loam to Gravel	6.5	5.0
Silt to Gravel	7.0	5.5
Gravel	7.5	6.0
Coarse Gravel	8.0	6.5
Gravel to Cobble (under 6 inches)	9.0	7.0
Gravel to Cobble (over 8 inches)	1.0	8.0

Source: (City of San Diego Drainage Design Manual)

Table A-2. Permissible Velocities with Grass Cover[1]

Cover	Slope Range	Permissible velocity on Erosion resistant soil	Permissible velocity on Easily eroded soil
	Percentage	Feet per second	Feet per second
Bermudagrass	0-5	8	6
	5-10	7	5
	Over 10	6	4
Buffalograss Kentucky bluegrass Smooth brome Blue gamma	0-5	7	5
	5-10	6	4
	Over 10	5	3
Grass Mixture	0-5	5	4
	5-10	4	3
Lespedeza sericea Weeping lovegrass Yellow bluestem Kudzu Alfalfa Crabgrass	0-5	3.5	2.5
Common lespedeza Sudangrass	0-5	3.5	3.5

[1] From *Handbook of Storm water facility Design for Soil and Water Conservation*, National Resource Conservation Service
Source (City of San Diego Drainage Design Manual)

Sediment Sampling

Sediment samples shall be collected for every 1,000 cubic yard of sediment removal, or a representative sample number based on soil conditions (a minimum one sample for each different type of soil), with a minimum of two samples for each maintenance project. The estimated cubic yards of removal shall be obtained from the Maintenance Plan for the specific storm water facility segment. Sediment cores shall be collected using piston core equipment. The piston core shall be equipped with a 3-inch outer diameter polycarbonate tube. Piston coring is the process of obtaining continuous well-preserved sediment core samples from water saturated, unconsolidated sediments. Penetration of the polycarbonate core tube shall be achieved by manually pushing the tube into the sediment via application of downward pressure on extensions attached to the piston core. To prevent compaction of the core during penetration, a plunger within the tube shall be set at the sediment water interface and maintained static pressure ensuring core integrity. To increase penetration, a hammering device may be utilized to drive the core deeper into sediments. To eliminate the possibility of cross contamination between stations, a new polycarbonate tube shall be utilized at each location.

The sediment samples shall be analyzed for the following constituents by certified laboratory (Table A-3). This list may be modified depending on the suspected pollutants and reported water quality issues.

Table A-3. Analytical Requirements (Sediment) for Conducting Water Quality Benefits / Impacts Assessment

Constituent	Method	Target Reporting Limit	Units
General Physical and Inorganic Non-Metals			
Total Dissolved Solids (TDS)	SM 2540C	20	mg/L
Percent Solid	EPA 160.3	0.1	dry weight
Total phosphorus	SM 4500PC	0.05	mg/L
Nitrate	EPA-300.0	0.1	mg/L
Nitrite	EPA-300.0	0.05	mg/L
Total Kjeldahl Nitrogen (TKN)	EPA 351.3 (m)	0.5	mg/L
Organics			
Diazinon	EPA 8270C(m)	0.05	µg/L
Chlorpyrifos	EPA 8270C(m)	0.05	µg/L
Malathion	EPA 8270C(m)	0.05	µg/L
Metals – Total			
Antimony (Sb)	EPA 6020(m)	0.05	µg/dry g
Arsenic (As)	EPA 6020(m)	0.05	µg/dry g
Cadmium (Cd)	EPA 6020(m)	0.05	µg/dry g
Chromium (Cr)	EPA 6020(m)	0.05	µg/dry g
Copper (Cu)	EPA 6020(m)	0.05	µg/dry g
Lead (Pb)	EPA 6020(m)	0.05	µg/dry g
Manganese	EPA 6020(m)	0.05	µg/dry g
Nickel (Ni)	EPA 6020(m)	0.05	µg/dry g
Selenium (Se)	EPA 6020(m)	0.05	µg/dry g
Zinc (Zn)	EPA 6020(m)	0.05	µg/dry g

For each storm water facility segment identified in the Maintenance Plan for sediment removal a bulk sample shall be collected (minimum of 2 cubic feet). Sample shall be hand dug using shovel and bag method.

Estimate of Gravel and Cobble

Sediment sampling described will general include (account for) particles up to about 1.5 inches (course gravel) and not account for larger rock such as course gravel and cobble that provides for little, if any, load removal. Therefore, the portion of sediment to be removed comprised of 3-inch or larger cobble shall be estimated and total sediment to be removed shall be adjusted (corrected) to account for the cobble.

The bulk grab sample collected in the field shall be analyzed to determine percent by weight of particles greater than 1.5 inches. Grain size distribution (particle size analysis) on the bulk sample collected shall be performed in accordance with American Society for Testing and Materials (ASTM) D6913 – 04(2009), *Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis,* Method A. This test method is used to separate particles into size ranges and to determine quantitatively the mass of particles in each range using a square opening sieve criterion in determining the gradation of soil between the 3-inch (75-mm) and No. 200 (75-µm) sieves (i.e., particles larger than 3 inches retained on 3-inch sieve and gradation determined down to fine particles, No. 200 sieve). Testing shall be completed by a laboratory certified to perform testing procedure.

<u>Correction Factor for Cobble Larger Than 1.5 Inches Equation</u>:

Parameter: Removal Volume ($V_{S\text{-}Total}$) specified in Maintenance Plan
%Finer (1.5-inch) Percent finer than 1.5-inch sieve determined by sieve analysis
$\rho_{dry\ insitu} = 85\ lbs/ft^3$ (conservative estimate of the average dry density of sediment to be removed)
$\rho_{solid} = 165.4\ lbs/ft^3$
$\rho_{water} = 62.4\ lbs/ft^3$

$$CF_{cobble} = \frac{\dfrac{\%Finer}{\rho_{dry\ insitu}}}{\dfrac{\%Finer}{\rho_{dry\ insitu}} + \dfrac{(1\text{-}\%Finer)}{\rho_{solid}}}$$

Sediment Pollutant Loading Estimate

The load removal resulting from sediment removal shall be estimated using the equations below. For storm water facility reaches where two samples are collected the mean value of the analytical results shall be used, unless each sample represents different sub strata (e.g., primarily clayey section verses section comprised primarily of silty sand), in which case two different calculations shall be performed by applying analytical results to the portion of sediment removed represented by the sample analyzed. If more than two sediments samples are analyzed, calculations shall be performed for each sediment sample to estimate to loads within the corresponding sediment represented by the sample, and the total loads within the sediment slated for removal shall be determined by summing the individual estimates (e.g., if 3,600 CY slatted for removal, analyze four uniformly distributed sediment samples, perform four loading estimates based on results with each applied to 900 CY, and sum the four load estimates).

<u>Sediment Load Equations</u>:

Parameter: CF_{cobble} Correction Factor to account for cobble
Removal Volume ($V_{S\text{-}Total}$) specified in Maintenance Plan
$\rho_{dry\ insitu} = 85\ lbs/ft^3$ (conservative estimate of the average dry density of sediment to be removed)
Concentration C_S (µg/g or mg/Kg)

$$\text{Sediment Mass} = CF_{cobble} * V_{S\text{-}Total} * \rho_{dry\ in\text{-}situ}$$

$$\text{Load Removal} = \text{Sediment Mass} * C_S$$

Water Column Sample Collection and Analysis

Collecting water column samples and performing analytical testing shall be conducted to estimate the existing pollutant loading of the flows entering storm water facilities scheduled for maintenance. During low flow conditions, the storm water facilities may function similar to engineered constructed wetlands, often referred to as natural treatment systems (NTS). The load removal capability of NTS is based on published removal efficiencies, load entering systems, and how well the system functions (scores) compared to constructed wetlands (scoring is discussed in detail in Section 0). After maintenance activities, the NTS may score less and therefore have a diminished ability to remove pollutant loading, which may result in an impact to water quality if not properly identified and mitigated for. Therefore, determining the pollutant concentrations, and estimating pollutant loading, is a critical component of the overall water quality benefits/impact assessment.

Collecting water column samples shall be performed by scientists and/or engineer properly trained to follow sampling protocols and who have a thorough understanding of the health and safety plan for sampling. (Note: The firm or agency conducting sampling shall be responsible for establishing a health and safety plan and ensuring personal performing work understand and follow plan.) The professional civil engineer, with current California registration, who is also responsible for completing the overall assessment calculations and drafting the assessment report shall also supervision the collection of samples to ensure process is properly done. Staff collecting samples shall complete chain-of-custody sheets. Samples shall be delivered and processed by California state certified laboratories following methods and detection limits outlined (

Table A-4~~Table A-4~~).

Samples shall be collected from the horizontal and vertical center of the channel if possible and kept clear from uncharacteristic floating debris. The sampling location shall be at the upstream edge of storm water facility segment schedule for maintenance. In additional to the upstream edge of the storm water facility segment, a second, optional location may be sampled corresponding to the downstream edge of the storm water facility segment. This second sample location will provide a means to compare the upstream and downstream water quality, or the actual pollutant removal capacity of the NTS under the conditions (flow, vegetation, etc.) present during sampling. The collection of samples at the downstream edge of the storm water facility segment shall be used with best professional judgment and an understanding of the overall wetland processes and this assessment to aid in verifying the scoring system and calculation of flow, volume, and retention time.

In accordance with USEPA sampling protocols, all samples collected shall be stored in the appropriate container type for the analytical method to be performed. Additionally, all samples shall be stored chilled in ice-chests for transfer to the laboratory and between laboratories. Use sample containers certified as clean and sterile by the laboratory performing the analyses. Chain-of-custody forms shall be completed for each sample and accompany the samples to the laboratories and between laboratories at all times.

Sample methods and holding time requirements for each analytical measurement are provided in Table A-4 and are based on the recommendations by the Standard Methods for the Examination of Water and Wastewater and the USEPA methods. Grab samples shall be collected at each location and analyzed for the constituents listed in Table A-4. The list of constituents may be modified depending on the reported water quality issues, results of the sediment samples and State §303d listings for the subject receiving water segment.

Table A-4. Analytical Requirements (Water Column) for Conducting Water Quality Benefits / Impacts Assessment

Constituent	Volume Required	Method	Target Reporting Limit	Units	Max Holding Time
General Physical and Inorganic Non-Metals					
Total Suspended Solids (TSS)	100 mL	SM2540D	20	mg/L	7D
Total hardness	150 mL	SM 2340B	10	mg/L	6M
Total phosphorus	250 mL	SM 4500PE	0.05	mg/L	28D
Nitrate	200 mL	SM4500NO3E	0.1	mg/L	48H
Nitrite	200 mL	SM4500NO2B	0.05	mg/L	48H
Total Kjeldahl Nitrogen (TKN)	500 mL	SM4500C	0.1	mg/L	28D
Organics					
Diazinon	1 liter	EPA 625	0.05	µg/L	14D
Chlorpyrifos	1 liter	EPA 625	0.05	µg/L	14D
Malathion	1 liter	EPA 625	0.05	µg/L	14D
Metals – Total					
Antimony (Sb)	75 mL	EPA 200.8	0.002	mg/L	6M
Arsenic (As)	75 mL	EPA 200.8	0.001	mg/L	6M
Cadmium (Cd)	75 mL	EPA 200.8	0.001	mg/L	6M
Chromium (Cr)	75 mL	EPA 200.8	0.005	mg/L	6M
Copper (Cu)	75 mL	EPA 200.8	0.001	mg/L	6M
Lead (Pb)	75 mL	EPA 200.8	0.001	mg/L	6M
Manganese	75 mL	EPA 200.8	0.001	mg/L	6M
Nickel (Ni)	75 mL	EPA 200.8	0.002	mg/L	6M
Selenium (Se)	75 mL	EPA 200.8	0.002	mg/L	6M
Zinc (Zn)	75 mL	EPA 200.8	0.02	mg/L	6M

Evaluating System Flow and Volume

Calculating the flow through the storm water facility segment scheduled for maintenance, the holding capacity of the storm water facility segment, and the resulting retention time is very importing and used in this assessment to evaluate; (1) how the system works in relating to a constructed wetland and (2) providing flows that will be combined with chemistry results to estimate the pollutant loading through the system. This work shall be performed under the direct supervision of professional civil engineer, with current California registration, with experience in fields of channel hydraulics, field surveying, laboratory analyses, and the current water quality issues of the region. The field work shall be conducted, under the supervision of the registered civil engineer, by scientists and/or engineers with experience conducting surveys and completing field forms.

The storm water facility segment shall be visited and evaluated during dry periods when flows are low enough to provide adequate retention time for the various wetland processes. If the low flows vary greatly during dry periods, it may be necessary to measure flow several times in order to properly estimate the average low flow condition of the storm water facility segment. Typically, the low flow condition is met approximately 72 hours after rainfall has ceased; however, for larger watersheds, it may take longer.

System Flow

To measure instantaneous flows during low flow and base flow conditions, one of the following two velocity measurement instruments shall be used (or equivalent based on equal or superior manufacturer specifications): (1) a Marsh-McBirney Model 2000 Portable Flow Meter connected via a cable to an electromagnetic open channel velocity sensor, and (2) **the SonTek (YSI) FlowTracker** Acoustic Doppler Velocimeter. The FlowTracker is a high-precision, shallow-water velocity/flow meter that measures velocity in 3 dimensions and features an automatic discharge computation.

The velocity sensors shall be attached to a stainless steel top-setting wading rod. To make an instantaneous flow measurement, a tape measure shall be stretched across the stream, perpendicular to flow and secured on both banks of the stream. The tape shall be positioned so that it is suspended approximately one foot above the surface of the water. The distance on the tape directly above the waterline (where the water met the bank) shall be recorded as the initial point. The first measurement is then made at the first point where there is adequate water depth (at least 0.2 feet) and measurable velocity. At this point, three measurements shall be made: water depth, velocity, and distance from the bank (the initial point). Subsequent depth, velocity, and distance measurements shall be made incrementally across the entire width of the channel so that a minimum of ten points are measured per site. Water depth shall be determined from calibrations on the wading rod in tenths of feet. Velocity measurements shall be made at each point along the transect by positioning the velocity sensor perpendicular to flow at 60% of the water depth (from the surface) to attain an average velocity. The top setting wading rod is designed so that the sensor can be conveniently positioned at the appropriate depth. Water velocity shall be measured in feet per second.

Data from the field measurements shall be entered into a computer model (excel worksheet) that calculates the stream's area based on cross-sectional profile of the depth and distance from bank measurements (see equations below). Total flow across the channel shall be determined by integrating the velocity measurements to the areas for entire cross-section of the stream channel (see equations below). The result is an instantaneous flow measurement in cubic feet per second.

$$\text{Area}_1 = \frac{\text{Distance}_{0\text{ to }1} * \text{Depth}_1}{2}$$

$$\text{Area}_n = \frac{\text{Distance}_{n-1\text{ to }n} * (\text{Depth}_{n-1} + \text{Depth}_n)}{2}$$

$$\text{Flow } (Q_{NTS}) = \text{Area}_1 * \text{Velocity}_1 + \dots \text{Area}_n * \text{Velocity}_n$$

<u>To estimate annual pollutant load through the system, the annual flow shall be estimated based on the empirical data obtained in this assessment. Monitoring equipment may be installed to log stream level, and head verse flow tables can be created based on stream geometry to calculate annual dry flow through the system. This may be particularly applicable when there is evidence of intermittent flows in a system. In lieu of installing equipment (when flow is fairly consistent), the daily flow shall be estimated by multiplying the instantaneous measured flow (Q_{NTS}) by 24 hours and the conversion factor of 3,600 seconds per hour. The assessor shall estimate the</u>

number of days per year the system meets the dry weather flow condition. A thorough understanding of how a system responds to storm events shall obtained through reviewing available annual dry weather monitoring, MS4 monitoring, receiving water monitoring, regional NPDES monitoring, SMC, and third party data a combined with field verification (how long after storm event is there flow, is there summer flows, etc.). The assessor may estimate the annual dry weather days by subtracting the wet days per year. A wet day is when flow in the system is significant enough to cause retention time of water through the system to be minimal, such as a few minutes. Constructed wetlands recommend a retention time of approximately 24 hours to be effective. Thus, when retention time of the system is reduced to minutes, the vegetation in the system undergoing root uptake of pollutants will not result in measurable differences in water quality improvement and is considered negligible. In some cases, the assessor may assume wet days include storm events of 0.2 inches of rainfall within a 24-hour period and the following three calendar days (or less if systems drops back to minimal flow prior to the three day period), which is consistent with the threshold use by the San Diego County Department of Environmental Health's (DEH) to issue General Advisory to avoid contact with ocean and bay water within 300 feet on either side of any storm drain, river, or lagoon outlet. (SDRWQCB Amendment to the Water quality Control Plan for the San Diego Basin (9), dated 2008). These calculations are conservative for two reasons: (1) storm events less than 0.2 inches still produce runoff, which would reduce retention time (in other words by not including storm events less than 0.2 inches, the calculations would assume benefits of the existing system when would not be a benefit during these storms causing higher flows) and (2) watersheds typically have relatively high flows, when compared to flows associated with 24-hour retention times, for longer than three days after storm events, especially larger events (greater than 0.5 inches) and/or larger watershed. Additionally, flow in these systems typically tapper off to minimal (or zero) as more time elapses from the last storm event of the wet season. Assuming the calculated daily flow exists in the system until the end of the wet season (June 30) is also conservative, because this higher than actual flow will estimate a higher than actual pollutant load and the associated pollutant removal ability of the existing system which is scheduled for maintenance (impact). Some systems may have significant amounts of dry weather flow through the summer months from sources such as over irrigation, foundation drains, natural groundwater seepage, and other non-storm water sources (sometimes referred to as urban runoff). In this case (flow in dry season), the daily flow for the system during the summer months (June 30 to October 1) should be estimated and added to the annual flow for the system.

System Volume

To estimate NTS volume, or capacity, in the storm water facility segment scheduled for maintenance accurate surveys of channel cross sections shall be performed. Survey equipment capable of providing relative elevations of the channel features to an accuracy of +/- 0.1 feet shall be used. Cross section surveys of the storm water facility segment shall be performed at a minimum of every 50 linear feet (e.g., if segment is 1,000 feet, minimum of 21 cross sections shall be surveyed). For smaller wetted channels (less than 10 feet across), depth and distance from bank shall be measured at approximately 1-foot interval. For larger wetted channels (greater than 10 feet across), depth and distance from bank shall be measured at approximately 2-foot intervals.

Data from the field measurements shall be entered into a computer model (excel worksheet) that calculates the area (ft^2) of each cross-sectional profile from the depth and distance from bank measurements. The same model shall be used to calculate the overall volume of water in the system by the Average End Area Technique (basic equation below).

$$\text{Volume } (V_{NTS}) = \frac{(\text{Area}_1 + \text{Area}_2) * \text{Distance}_{1\text{ to }2}}{2} + \ldots \frac{(\text{Area}_{n-1} + \text{Area}_n) * \text{Distance}_{n-1\text{ to }n}}{2}$$

Retention Time

The retention time is average time it will take water to flowing through system (upstream to downstream). Constructed wetlands, and the removal efficiencies applicable to constructed wetlands, are design for a minimum retention time of 24 hours. The following equation shall be used to estimate retention time.

$$\text{Retention Time } (t_{Retention}) = \frac{\text{Volume } (V_{NTS})}{\text{Flow } (Q_{NTS})} * \text{Unit Conversion } \frac{1\text{ hour}}{3{,}600\text{ seconds}}$$

Evaluation of System Capacity

In order to ensure that wetland systems provide adequate retention time for adsorption and assimilation, constructed wetland systems are designed with adequate size. As flows increase through wetland systems there is diminishing adsorption, and potential release, of pollutants. Systems are typically designed to receive flows generated by continuous 0.2 inches per hour precipitation and have enough volumetric storage capacity for at least a 24-hour retention (or flow through duration). Dry weather (low) flows through storm water facility segments scheduled for maintenance shall be compared to the standard 24-hour retention time. If low flows are conveyed through the system in a shorter period than 24 hours, a correction factor shall be applied to the pollutant removal efficiencies. In wetland systems, there are numerous processes that take place that affect the pollutant removal capacity of the system. Determining which processes are more sensitive to a shorter retention time and the resulting diminished pollutant load removal efficiencies associated with each process is not feasible. A simplified correction factor shall be calculated based on a linear relationship between retention time and removal efficiencies as shown below. An estimated retention time of greater than 24 hours shall result in no correction factor being applied to the removal efficiencies.

$$\text{Correction Factor } (C_{Retention\ Time}) = \frac{\text{Retention Time } (t_{Retention})}{24\text{ hours}}$$

Annual Low Flow Volume Estimation

In order to estimate the annual flow through the storm water facility segment in a low flow condition (acting as NTS), the average number of days per year that the storm water facility may experience dry weather flows shall be estimated by subtracting the "wet days" (i.e., rainfall greater than or equal to 0.2 inches and the 72 hours following) from the total number of days during the wet season, which is from October 1 to June 30, unless if system flows during summer months in which case the those days would also be added. Rainfall data may be obtained from County of San Diego Project Clean Water website (http://www.projectcleanwater.org/html/wg_susmp.html). If dry weather flows continue through the summer months, those days shall be added to the annual number of dry weather days. Additional information may be collected throughout the year to better estimate the flow through storm water facility segment so that more accurate loading calculations can be perform. Assuming low flow is continuous year round on all days not considered "wet days" is conservative, because this assumption over estimates the flow and pollutant loads, and thus the pollutant load removal ability of the unmaintained storm water facility.

Annual Low Flow Volume Equations:

Parameter: Annual Volume — Estimated annual low flow volume through storm water facility segment.

Q_{NTS} — Calculated low flow through the natural treatment system in cubic feet per second.

$Days_{dry}$ — Average number of dry days per year

$$\text{Annual Volume} = Q_{NTS} * Days_{dry} * \text{(Unit Conversion) } 86{,}400 \ \frac{\text{seconds}}{\text{day}}$$

Existing Storm water facility Rating in Compared with Constructed Wetlands

A wetland value scoring system was developed in order to compare the ability of the existing storm water facilities to potentially decrease/increase the sorption and deposition rates for potential constituents of concern (COCs) to wetland systems specifically designed for sustainable treatment. The three key macrofeatures of a treatment wetland system are vegetation, hydrosoil, and hydroperiod. The following scoring system and criteria was developed to allow an evaluator to make observations in the field about the existing wetland macrofeatures and score their observations independent of the systems' ability to influence sorption, deposition, and other transfers and transformations. If necessary, additional water and sediment quality characteristics (e.g., redox, pH, particle size distribution) may be measured in order to refine the value score, but are not required in this scoring system. Evaluators are encouraged to take pictures and make additional notes of their field observations that may have influenced their scoring.

The person(s) that conducts this assessment needs to be familiar with the location and accessibility of the storm water facilities scheduled for maintenance, be able to identify local vegetation and understand its general physiology, as well as have a fundamental understanding of the dynamics of a wetland system. Important dynamics of a wetland system for this evaluation include a basic knowledge of the relationships between the vegetative community, hydroperiod, and hydrosoil in order to encourage or discourage primary transfers and transformations (e.g., sorption and deposition) of expected COCs within a watershed. Additionally, the evaluator needs to have some fundamental ability to envision the current system after maintenance (i.e., greater than 75-percent of the sediments and associated vegetation removed from a reach) in order to predict the rate of recovery within the reach.

EXISTING MAINTENANCE STORM WATER FACILITY - VALUE SCORING SYSTEM

Vegetation

The vegetation value of an existing maintenance storm water facility reach is evaluated and scored by estimating the surface area coverage, vertical density through the water column, and wetland species distribution.

A score of 0 corresponds to no visible vegetation within the storm water facility reach.

A score of 1 corresponds to a very young population of woody, terrestrial species with an overall low surface area coverage.

A score of 2 represents a mature wetland population near carrying capacity, overgrown with both submerged and emergent wetland species.

A score of 3 represents a young population of emergent and submerged wetland species that primarily reproduce through tubers and/or rhizomes (e.g., *Spartina, Typha, Scirpus, Phragmites*).

Hydrosoil

The hydrosoil value of an existing maintenance storm water facility reach is evaluated and scored by collecting and observing samples of surficial sediments for organic carbon and fines concentrations compared to sand concentration. If feasible, the evaluator should measure conductivity and pH of the *in situ* sediments to better understand the storm water facility's sediment conditions.

The importance of the hydrosoil to the storm water facility reach can be evaluated by estimating or measuring the organic carbon concentration, particle size distribution, nutrient availability, and overall load removal of COCs. The evaluator must consider the water depth, flow, hydraulic retention time (HRT), and deposition/settling rates attributed to *in situ* hydrosoil characteristics and chemistry. Lastly, the evaluator should hypothesize how all of the above sediment chemistry relates to the health and success of the vegetative community to facilitate preferential transfers and transformations for COC removal and sequestration.

A score of 0 corresponds to a storm water facility reach with little to no sediment and the storm water facility is lined with concrete or another impermeable substrate.

A score of 1 represents that the hydrosoil consists of sand and cobble, with no visible deposition of fines. Additionally, the sediment pH is less than 6 or greater than 8 and the redox within the reach is positive (greater than +100 mV).

A score of 2 represents a heterogenous mix of sand and fines within the hydrosoil, some visible sedimentation, confirmation of the presence of organic carbon, neutral pH, and a redox ranging from -100 to +100 mV.

A score of 3 corresponds to a system consisting primarily of fines and organic carbon, very little sand, an area of high solids deposition, neutral pH, and a redox less than -100 mV.

Hydroperiod

The hydroperiod score of an existing maintenance storm water facility reach is evaluated by measuring and observing water flow and depth within the reach during the dry season and evaluating the hydrodynamic suitability of the reach for growth of emergent and submerged wetland vegetation, deposition of organic carbon and fines, and facilitating preferential conductivity and pH.

A score of 0 corresponds to no visible surface water within the storm water facility reach.

A score of 1 represents a system with either very deep (greater than 2 feet) or very shallow (less than 0.5 feet) areas, fast flowing water and/or observed effects of scouring and channeling, and/or no deposition of fines and organic carbon within the storm water facility reach.

A score of 2 corresponds to moderate water flow, intermittent/pulsed flow depending on inputs and effects of storm water events, a moderate HRT (less than 12 hours), shallow (0.5 to 1 foot deep), redox ranging from -100 to +100 mV, and some deposition of fines.

A score of 3 is awarded to a storm water facility reach with deep water (1 to 2 feet deep), slow flow with no evidence of scouring and/or channeling, a preferential HRT (greater than 12 hours), and measureable/observable deposition of fines.

The total value score for a storm water facility is derived by adding the ratings from all three categories (vegetation, hydrosoil, hydroperiod), with an overall score of 0 to 2 equaling a poor rating, 3 to 4 equaling fair conditions, 5 to 7 comparable to good wetland quality and health, and storm water facilities scoring an 8 to 9 representing the best conditions for sorption and deposition of suspended solids and associated COCs.

Existing Storm water Facility Recovery Scoring System

A scoring system was developed in order to evaluate the ability of the existing storm water facilities to recover to its existing conditions after maintenance (i.e., removal of greater than 75-percent of the *in situ* sediments and vegetation). The three key macrofeatures of a treatment wetland system are vegetation, hydrosoil, and hydroperiod. The following scoring system and criteria was developed to allow an evaluator to make observations in the field about the recovery potential of each of the wetland macrofeatures and score their predictions independent of the systems' ability to influence sorption, deposition, and other transfers and transformations. If necessary, additional water and sediment quality characteristics (e.g., flow rate, TSS, and deposition rate) may be measured in order to refine the value score, but are not required in this scoring system. Evaluators are encouraged to take pictures and make additional notes of their field observations that may have influenced their scoring.

EXISTING MAINTENANCE STORM WATER FACILITY - RECOVERY SCORING SYSTEM

Vegetation

The vegetation recovery score of a storm water facility reach is defined by the time the population would require to return to its current life-stage with an assumed removal of greater than 75-perent of the sediment and standing vegetative crop within the reach.

A score of 0 corresponds to an assumption that the current population will not recover to its current density after removal of the current standing crop.

A score of 1 assumes that the current population is comprised of trees and woody species and recovery would take greater than 5 years.

A score of 2 represents that the current standing crop is mature habitat with a mixed population of woody and leafy vegetation (both terrestrial and wetland species). Recovery to the current standing crop would require 1 to 5 years.

A score of 3 corresponds to a population comprised of primarily emergent and submerged wetland species and re-growth to the current species density and distribution in approximately 1 year.

Hydrosoil

Hypothetically, the importance of the hydrosoil to the storm water facility reach can be evaluated by hypothesizing how removal of greater than 75-percent of the sediments will affect the organic carbon concentration, particle size distribution, nutrient availability, and overall load removal of contaminants of concern (COCs). Observations/measurements of deposition rates and composition may be important in determining the rate of recovery. The evaluator must consider the effects of the potential hydrosoil removal on water depth, flow, hydraulic retention time (HRT), and deposition/settling rates. Lastly, the evaluator should hypothesize how the removal of *in situ* sediments would affect the potential for the re-growth of vegetation to current densities and distributions.

A storm water facility reach score of 0 represents a high flow or no flow area with little to no deposition likely.

A score of 1 corresponds to a reach with primarily sand deposition in the short-term. The likelihood of fines and/or organic carbon accumulating within the reach is low within the next five year period.

A score of 2 is related to a reach with a heterogenous mix of sand, organics, and fines depositing and accumulating in the next 1 to 5 years.

A score of 3 corresponds to a reach with a heterogenous mix of sand, organics, and fines depositing and accumulating within the reach in the next year.

Hydroperiod

The hydroperiod recovery score of a storm water facility reach is defined by the time it takes for the storm water facility to recover to an average, optimal depth of 1 to 1.5-ft deep of overlying water.

A score of 0 corresponds to no sediment deposition within the reach due to channel flow.

A score of 1 represents some slowdown of flow within the reach and thus some deposition of sand and other coarse grain materials.

A score of 2 for a storm water facility reach represents a wide spot in the storm water facility after maintenance, resulting in some deposition of fines, and an overlying water depth of less than 0.5-feet.

A score of 3 corresponds to a flood control reach with an overlying water depth greater than 1-foot, typically a wide spot in the storm water facility after maintenance, and associated deposition of fines and organics.

The total recovery score for a storm water facility is derived by adding the ratings from all three categories (vegetation, hydrosoil, hydroperiod), with an overall score of 0 to 2 equaling a poor rating, 3 to 4 equaling fair conditions, 5 to 7 comparable to good wetland quality and health, and storm water facilities scoring an 8 to 9 representing the best recovery for sorption and deposition of suspended solids and associated COCs.

Estimation of Potential Water Quality Impacts (Vegetation Removal) and Comparison to Benefits Provided by Sediment Removal

Data obtained from each of the previous sections of this SOP shall be used to estimate the potential impacts from vegetation removal and compare potential impacts to the benefits provided by sediment removal. These calculations shall be performed under the direct supervision of a professional civil engineer, with current California registration, responsible for the assessment. The basic procedure to perform this assessment is to: (1) estimate the average annual pollutant load removal capacity of the unmaintained storm water facility segment; (2) estimate the annual pollutant load removal capacity of the maintained storm water facilities for each year of the maintenance period; (3) compare the pollutant load removals during the maintenance period for existing condition (loads removed by NTS) with the maintain condition (loads removed by both sediment removal and NTS); and (4) evaluate potential mitigation effort that may be implemented to mitigate the potential impacts.

Pollutant load removal is directly related to the removal efficiencies of the systems. Based on literature review, wetland removal efficiencies are provided in Table A-5 and shall be used to complete the assessment.

Table A-5. Published Wetland Removal Efficiencies

Analyte	Published Removal Efficiency (%)[1]
Nitrate As N	67%
Nitrite As N	67%
Total Kjeldahl Nitrogen	15%
Total N	40%
Total Phosphorus	51%
Total Suspended Solids	78%
Chlorpyrifos	50%
Diazinon	50%
Malathion	50%
Total Antimony	63%
Total Arsenic	63%
Total Cadmium	63%
Total Chromium	63%
Total Copper	40%
Total Lead	63%
Manganese	63%
Total Nickel	63%
Total Selenium	63%
Total Zinc	54%

Note 1: Based on highest efficiency listed of literature reviewed. In metals where values not published, high value of lead, 63%, used. Published efficiencies not available for Chlorpyrifos, Diazinon, and Malathion (50% used). Coefficients between 10% and 100% shall be applied to published efficiencies base on "score" of wetland.

This section of the SOP provides the equations to model the pollutant loads removed by the NTS and complete the water quality benefits/impacts assessment. Example calculations are provided to provide further clarification of the assessment process. Existing storm water facility segments may have vegetation, scour pools, and other features similar to constructed wetlands. Maintenance of storm water facilities may reduce or temporary remove these features; and thus reduce the storm water facility segments ability to assimilate pollutants. The following equations and example calculations shall be used to estimate potential impacts.

Storm water Facility Segment/Natural Treatment System (NTS) Pollutant Removal Ability Example:

Parameter Values:
Treatment Flow = 10,800 ft^3/year (See Subsection 0)
Cadmium C_I = 0.1080 mg/L
Cadmium Water Quality Benchmark = 0.05 mg/L
Total N C_I = 2.15 mg/Kg
Total N Water Quality Benchmark = 1.0 mg/L
Cadmium NTS Removal Efficiency (E_{NTS}) = 63%
Total N NTS Removal Efficiency (E_{NTS}) = 40%
Existing Score = 5 (See Subsection 0)
Recovery Score = 4 (See Subsection 1.5)
Maintenance Period = 3 years
Load Removal (in Sediment) = 1.4 lbs (Cadmium) (See Subsection 0)
Load Removal (in Sediment) = 5,966 lbs (Total N) (See Subsection 0)
$C_{Retention\ Time}$ = 1.0

Existing Pollutant Load Removal Capacity

Existing Condition (Unmaintained Storm water facility Segment):

Existing Efficiency Coefficient = 0.1 + Existing Score * 0.1 = 60%

Corrected E_{NTS} = E_{NTS} * Existing Efficiency Coefficient
Corrected E_{NTS} = 38% (Cadmium)
Corrected E_{NTS} = 24% (Total N)

Existing NTS Load Removal = Flow * C_I * Corrected E_{NTS} * $C_{Retention\ Time}$
Existing NTS Load Removal = 27.5 lbs/year (Cadmium)
Existing NTS Load Removal = 349 lbs/year (Total N)

Load Removal per Maintenance Period (Existing Condition):

Cadmium	27.5 lbs/year * 3 years =	82.6 lbs / Maintenance Period
Total N	349 lbs/year * 3 years =	1,048 lbs / Maintenance Period

Maintained Storm water Facility Pollutant Load Removal Capacity

Maintained Condition:

$$\text{Yearly Recovery Score} = \frac{n_{year}}{\text{Maint. Period} * \text{Recovery Score}}$$
= 1.3, n_{year} = 1
= 2.7, n_{year} = 2
= 4.0, n_{year} = 3

Yearly Efficiency Coefficient = 0.1 + Yearly Recover Score * 0.1
= 23%, n_{year} = 1
= 37%, n_{year} = 2
= 50%, n_{year} = 3

Year	Corrected E_{NTS} (Cadmium)	NTS Load Removal (Cadmium)	Corrected E_{NTS} (Total N)	NTS Load Removal (Total N)
1	14.7%	10.7	9.3%	135.9
2	23.1%	16.8	14.7%	213.5
3	31.5%	23.0	20.0%	291.1
Total		50.5		640.5

Comparison of Results

Load Removal (Existing Condition):

Cadmium	27.5 lbs/year * 3 years =	82.6 lbs / Maintenance Period
Total N	349 lbs/year * 3 years =	1,048 lbs / Maintenance Period

Load Removal (with Channel Maintenance):

Cadmium	Sediment Load Removal =	1.4 lbs / Maintenance Period
Cadmium	Maintained NTS Load Removal =	50.5 lbs / Maintenance Period
Total		51.9 lbs / Maintenance Period
Total N	Sediment Load Removal =	5,966 lbs / Maintenance Period
Total N	Maintained NTS Load Removal =	640.5 lbs / Maintenance Period
Total		6,607 lbs / Maintenance Period

Comparison:

Constituent	**Maintained Channel – Existing Condition**
Cadmium	51.9 lbs – 82.6 lbs = –30.7 lbs / Maintenance Period (potential water quality impact)
Total N	6,607 lbs – 1,048 lbs = 5,559 lbs / Maintenance Period (potential water quality benefit)

If the pollutant reduction due to sediment removal (benefit) is greater than the estimated loss of temporary sorption/retention capacity (impact), then no further action is needed (benefit>impact). If the pollutant reduction due to sediment removal is less than the estimated loss of temporary sorption/retention capacity (benefit<impact), further evaluation of each constituent meeting this criteria shall be perform and there may be a need to off-set this loss with BMPs in the watershed in coordination with the integrated water quality implementation plan. In this example cadmium shall be further evaluated as detailed in Subsection 0.

Potential Mitigation Effort

Each constituent that the water quality benefit/impact assessment (detailed in Subsection 0) estimates that an impact may result from storm water facility maintenance shall be evaluated further to determine, first, if mitigation effort may be necessary and, second, the amount of mitigation effort that may be necessary to off-set such potential impacts. The additional evaluation is detailed in this subsection.

First, determine if mitigation may be necessary. The measured water column concentration of each constituent with a benefit less than impact (see Subsection 0) shall be compared to the water quality benchmark, or threshold. In the example shown here, the maintained storm water facility will result in a reduction of pollutant load removal (impact) of approximate 31 pounds of cadmium. The cadmium water column concentration was measured to be 0.1080 mg/L and the water quality threshold is 0.05 mg/L. Since the measured concentration is greater than the water quality threshold, the reduction in pollutant load removal should be mitigated for. In cases where the impact is greater than the benefit, but the measured concentrations are less than the water quality objectives established by the San Diego Basin Plan for the water body segment in which the maintenance would occur no risk to the beneficial uses exist. In order to take a conservative approach, maintained channels that result in water column concentrations of the specific pollutants that are monitored under the NPDES Permit that exceed, or are within 25 percent of the water quality objectives established by the San Diego Basin Plan for the water body segment in which the maintenance would occur should have mitigation. In cases where the impact is greater than the benefit, but the maintained channel water column concentrations of the specific pollutants that are monitored under the NPDES Permit will be less than the lower limits described above (25 percent below the water quality objectives), no risk to the beneficial uses exist, and therefore no mitigation is necessary.

In cases where mitigation may be necessary, BMPs may be implemented in the watershed in coordination with the Storm Water Department's Integrated Water Quality Program to off-set the loss in pollutant load removal capacity. BMP implementation planning can be prioritized based on this quantification process as well as scheduling of storm water facility maintenance. In this example, approximately 31 pounds of cadmium during the maintenance period (3 years), or about 10 pounds per year, would need to be mitigated (i.e., 10 pounds of cadmium per year shall be removed from the watershed through mitigation efforts/BMP implementation). In order to estimate the appropriate mitigation effort the following general process shall be followed: (1) select the type(s) of BMPs that may be used as mitigation effort; (2) estimate the approximate tributary watershed area that each BMP can effectively treat; (3) estimate the average annual pollutant load removal of selected BMP; (4) and estimate the total number of BMPs required to remove pollutant loads greater than the required mitigation effort.

There may be mitigation effort (BMPs) planned for the watershed where maintenance is occurring as part of the Storm Water Department's Integrated Water Quality Program. The pollutant load removal of the BMPs may be used as mitigation effort. In the case where there is currently no pollutant removal mitigation effort planned within the watershed, the water quality impact could be addressed through the implementation of further BMPs in coordination with the Storm Water Department's Integrated Water Quality Program. These mitigation effort projects will serve as the replacement to the estimated amount of lost sorption/retention capacity for the constituent(s) where the impact is greater than the benefit and may cause the constituent(s) to exceed (or further exceed) the water quality threshold(s). The City may choose structural BMPs and source control BMPs where the effectiveness has been quantified to compensate for the estimated impact. Table A-6 shows potential mitigation measures that may be used by the City. The table may be expanded in the future to include other mitigation measures as technology improves and more information is available on various BMPs. The *County of San Diego LID Manual* provides guidance on site design and structural BMPs and may also be used as guidance when considering mitigation efforts.

Table A-6. Typical Mitigation Effort Types

▪ Detention Tanks and Vaults	▪ Infiltration Trench
▪ Dry/Wet Ponds	▪ Porous Pavements
▪ Extended Detention Basins	▪ Cartridge Filters
▪ Wetlands and Shallow Marsh Systems	▪ Catch Basin Inserts
▪ Green Roofs	▪ Hydrodynamic Devices
▪ Filtration and Disinfection Facilities	▪ Proprietary Biotreatment Devices
▪ Organic Media Filters	▪ Low Flow Diversions to Sanitary Sewers
▪ Surface Sand Filters	▪ Cisterns
▪ Underground Sand Filters	▪ Rain Barrels
▪ Bioretention	▪ On-site Storage and Reuse
▪ Infiltration Basin	▪ Vegetated Swales

For the example shown here, media-type inlet device BMPs are selected to be installed within the City's right-of-way in the upland tributary areas to the storm water channels. BMPs selected need to be designed and implemented to meet the site-specific conditions and results obtained from the water quality model. This is provided as a framework for future decision-making, to select site-specific BMPs, and evaluate their feasibility. This is a simplistic approach, and the actual BMPs used by the City shall be coordinated with the City's Integrated Water Quality Program.

For each BMP selected, the maximum tributary drainage area shall be estimated. For systems that capture storm water runoff (e.g., infiltration basin) the 85th percentile precipitation shall be used to estimate the maximum effective tributary area in accordance with the *County of San Diego Hydrology Manual*. For systems that treat storm water runoff (e.g., filtration devices), the rainfall intensity of 0.2 inches per hour shall be used to estimate the maximum effective tributary area in accordance with the *County of San Diego Hydrology Manual*.

The annual pollutant load removal of the selected BMP(s) shall be estimated. First estimate the annual pollutant load that the BMP(s) may be generated on the tributary drainage area and pass through each BMP. Calculate the average annual precipitation based on the historic records of rainfall for the area (rain gauge closest to watershed). Rainfall data may be obtained from County of San Diego Project Clean Water website (http://www.projectcleanwater.org/html/wg_susmp.html). Estimate the constituent concentrations in storm water runoff. This may be estimated by water quality monitoring for the watershed or similar type watershed (preferred), using published typical storm water runoff event mean concentrations for various land uses, or concentrations measured in the channel water column (typically, the most conservative because of dilution of urban runoff with natural tributary area). The annual total pollutant load from the watershed shall be estimated using the Simple Method Model shown below.

Annual Pollutant Load from Tributary Area to BMP:

Parameter:		
Parameter:	Pollutant $Load_{Total}$	The total pollutant load generated on the BMP tributary drainage area that passes through BMP in units of pounds per year.
	P_{annual}	Annual precipitation based on historical rainfall data
	$Area_{Tributary}$	Tributary drainage area to the BMP
	Weighted "C"	Runoff Coefficient "C" weighted based on land use areas
	Pollutant EMC	Estimate pollutant concentration in runoff reaching BMP
	Pj	Fraction of annual rainfall that results in runoff (0.9)
	$Coeff_{BMP\ capacity}$	Coefficient to account for the limitation of the BMP. This may be computed using historic rainfall data and a continuous simulation model. The conservatively value of 0.85 may be used (BMP sized for 85th percentile storm event or smaller).

$$\text{Pollutant Load}_{Total} = P_{annual} * Area_{Tributary} * \text{Weighted "C"} * \text{Pollutant EMC} * Pj * Coeff_{BMP\ capacity}$$

The pollutant load removal efficiency of the selected BMP(s) shall be determined in order to estimate the pollutant load removal potential. The pollutant load removal efficiencies may be obtained from the BMP database website (http://www.bmpdatabase.org/) or other, accepted, published sources. Estimate the BMP pollutant load removal potential as shown here.

BMP Annual Pollutant Load Removal:

Parameter:	$BMP_{Load\ Removal\ Potential}$	Annual load removal potential of each selected BMP in units of pounds per year
	Pollutant $Load_{Total}$	Total pollutant load passing through selected BMP
	$BMP_{Removal\ Efficiency}$	Tributary drainage area to the BMP

$$BMP_{Load\ Removal\ Potential} = \text{Pollutant Load}_{Total} * BMP_{Removal\ Efficiency}$$

The total number of BMPs required to off-set, or mitigate, the potential impact of storm water facility maintenance shall be estimated.

Estimated Number BMPs to Provide Adequate Mitigation Effort:

Parameter:	BMP_{Number}	Number of BMPs required to mitigate potential impacts of storm water facility maintenance
	Required Mitigation	Based benefits/impacts assessment, amount of pollutant load required to be removed from watershed to offset potential impacts of storm water facility maintenance in units of pounds per year
	$BMP_{Load\ Removal\ Potential}$	Annual load removal potential of each selected BMP in units of pounds per year

$$BMP_{Number} = \frac{\text{Required Mitigation}}{BMP_{Load\ Removal\ Potential}}$$

Water Quality Assessment Report

A Water Quality Assessment Report shall be completed in order to properly document the activities, model results, and recommendations of each water quality assessment performed in support of storm water facility maintenance. A template for completing Water Quality Assessment Reports is provided in Appendix A. The report shall be completed under the direct supervision of a professional civil engineer, with current California registration, responsible for the assessment. The report shall be stamped and signed by the engineer responsible for completing the assessment.

APPENDIX B

Water Quality Assessment Report Template

INDIVIDUAL WATER QUALITY ASSESSMENT REPORT

Site Name/Facility: ______________________________

PEIR Map No: ______________________________

Civil Engineer (name, company phone number): ______________________________

____

____

Register Civil Engineer Number & Expiration Date (place stamp here):

Instructions: This form must be completed for each facility prior to the completion of the Individual Maintenance Plan and prior to any work being conducted in the facility. Attach additional sheets if needed.

Description of creek/channel geometry (length, width, and depth):
Description of Sediment Sampling Activities (location(s), depth, shipment/deliverer to laboratory(s)): Note: Attach Chain of Custody Sheet(s), Table of Chemical Analysis Results, and Laboratory Sieve Analysis Results
Description of Flow Measurement Activities (location(s) and equipment): Note: Attach Field Notes and Model Calculation Worksheets
Description of Volume Measurement Activities (interval, total number, equipment): Note: Attach Field Notes and Model Calculation Worksheets
Description of Water Quality Sampling Activities (location(s), shipment/delivery to laboratory(s)): Note: Attach Chain of Custody Sheet(s) and Table of Chemical Analysis Results

Description of Wetland Assessment (Existing) Activities (personnel, general conditions):

Note: Attach Field Notes and Scoring Sheet(s)

Description of Wetland Assessment (Recovery) Activities (personnel, general conditions):

Note: Attach Field Notes and Scoring Sheet(s)

Sediment Pollutant Loading Estimates:

Note: Attach Estimate of Gravel and Cobble Calculations and Sediment Pollutant Loading Calculations

Evaluation of Benefits / Impacts:

Are there constituents that have potential impacts greater than benefits?

Yes ☐ No ☐

If so, identify constituents here and compare measured concentrations to thresholds.

Note: Attach Model Calculation Worksheet showing all constituents.

If impacts are identified, list potential mitigation efforts (e.g., BMPs type(s) and number(s)) that may be implemented in the watershed:

Note: Attach Model Calculation Worksheet.

Additional Comments:

LIST OF ATTACHMENTS (Check All That Apply):

- ❑ Site Photos
- ❑ Chain of Custody Sheet(s) for Sediment Sampling
- ❑ Analytical Results of Sediment Sample(s)
- ❑ Chain of Custody Sheet(s) for Water Column Sampling
- ❑ Analytical Results of Water Column Sample(s)
- ❑ Flow Measurement Model
- ❑ Volume Measurement Model (Existing Condition)
- ❑ Wetland Land Assessment Scoring Sheet (Existing Condition)
- ❑ Wetland Land Recovery Assessment Scoring Sheet (Maintained Storm water facility)
- ❑ Sieve Analysis Laboratory Results
- ❑ Sediment Pollutant Loading Model (Load Removal in Sediment)
- ❑ Potential Water Quality Impacts Model and Comparison to Benftits
- ❑ Potential Mitigation Efforts Model

SITE PHOTOS

Date of Site Visit:

See notes below for picture locations and orientation.

1.	2.

3.	4.

Notes:____

SITE PHOTOS

Date of Site Visit:

See notes below for picture locations and orientation.

5.	6.

7.	8.

Notes:____

SITE PHOTOS

Date of Site Visit:

See notes below for picture locations and orientation.

5.	6.

7.	8.

- Notes:____
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CHAIN OF CUSTODY SHEET(S) FOR SEDIMENT SAMPLING CONDITION

ANALYTICAL RESULTS OF SEDIMENT SAMPLE(S)

CHAIN OF CUSTODY SHEET(S) FOR WATER COLUMN SAMPLING

ANALYTICAL RESULTS OF WATER COLUMN SAMPLE(S)

FLOW MEASUREMENT MODEL

VOLUME MEASUREMENT MODEL (EXISTING CONDITION)

WETLAND LAND ASSESSMENT SCORING SHEET (EXISTING CONDITION)

WETLAND LAND RECOVERY ASSESSMENT SCORING SHEET (MAINTAINED STORM WATER FACILITY)

SIEVE ANALYSIS LABORATORY RESULTS

SEDIMENT POLLUTANT LOADING MODEL (LOAD REMOVAL IN SEDIMENT)

POTENTIAL WATER QUALITY IMPACTS MODEL AND COMPARISON TO BENEFITS

POTENTIAL MITIGATION EFFORTS MODEL

APPENDIX C

Blank Field Sheet

WATER QUALITY VALUE

Vegetation – Vegetative cover of water surface, vertical density, & species diversity		
0	• No visible vegetation in wet areas	
1	• Young growth of new inhabitants • Woody and terrestrial species present • Minimal wetland species (submerged and/or emergent macrophytes) • Low surface area coverage and density	
2	• Mature population near carrying capacity • >50% coverage of wet areas • Both submerged and emergent wetland species	
3	• Young life-stage and population • >75% coverage of wet areas • Both submerged and emergent wetland species • Wetland species that reproduce through tubers and/or rhizomes (e.g., *Spartina, Typha, Scirpus, Phragmites*)	
Hydrosoil – Sample surficial sediments for ratio of sand to fines (Measure conductivity, redox, and/or pH)		
0	• Concrete or other impermeable substrate • No sand and/or fines, organic carbon, detritus, and/or nutrient source	
1	• Sand and cobble substrate • No visible deposition of fines, organic carbon, and/or detritus • pH<6 or >8 • Redox: +100 mV	
2	• Less than 50% sand • Some visible deposition of fines, organic carbon, and/or detritus • Neutral pH (6.0 to 8.5) • Redox: -100 to +100 mV	
3	• Less than 25% sand • Visible deposition of fines and other solids • Neutral pH (6.0 to 8.5) • Redox: < -100 mV	
Hydroperiod – Observe water flow, hydraulic retention time, and depth (Measure conductivity, redox, and/or pH)		
0	• No visible surface water	
1	• Very deep (> 2-ft) or very shallow (< 0.5-ft) • Fast flowing and channeling, no deposition of fines • Redox: > +100 mV	
2	• Shallow (0.5 to 1-ft) • Moderate and variable flow depending on volume inputs • Observable HRT, some deposition of fines • Redox: -100 to +100 mV	
3	• Moderate water depth (1 to 2-ft) • Slow flow with a significant HRT (> 1 h), deposition of fines • Redox: < -100 mV	
Total score from all three categories 0-2 = poor, 3-4 = fair, 5-7 = good, 8-9 = best		

RECOVERY VALUE & TIMELINE

Assumption: Removal of >75% of solids will result in:

- A change in vegetation density and population diversity?
- Decrease in available organic carbon, sand, nutrients, and detritus?
- Decrease in COC concentrations?
- A change in water depth, flow, HRT, deposition/settling rates?
- A change in substrate for vegetative repopulation?

Vegetation – Timeline to mature life-stage with removal of >75% of sediment and standing crop		
0	• Will not recover in less than 10 years	
1	• Primarily trees and woody species • Recovery: > 5 years • Shift to a less desirable species diversity than current species	
2	• Mature habitat with mix of terrestrial and wetland species • Recovery: 1-5 years • Return to current standing crop and diversity	
3	• Primarily emergent and submerged wetland species • Recovery: approximately 1 year • Return to species density and diversity	
Hydrosoil – What is the sedimentation rate and timeline to return to current depth?		
0	• High flow area, narrow and/or shallow channel • No deposition of organic carbon, nutrients and/or detritus	
1	• Flow is significant • Primarily sand deposition in the short-term • Fines and/or organic carbon will deposit over a > 5 year period	
2	• Heterogenous mix of sand, organic carbon, and fines in < 1 year	
3	• Heterogenous mix of sand, organic carbon, and fines in 1-5 years	
Hydroperiod – What is timeline for reaching optimal depth of 1 to 2-ft of overlying water?		
0	• Flow remains fast • No evidence of deposition or re-establishment of vegetation • No HRT	
1	• Some decrease of flow resulting in some deposition of sand and other coarse grain materials • Some revegetation • No HRT	
2	• Wide area of the channel • Some deposition of fines and evidence of revegetation • Overlying water depth is less than 1-ft • HRT < 1-h	
3	• Wide area of the channel • Deposition of fines and organics • Overlying water depth is greater than 1-ft • HRT > 1-h	
Total score from all three categories 0-2 = poor, 3-4 = fair, 5-7 = good, 8-9 = best		

APPENDIX D

Field Worksheets
Field Photos

APPENDIX E

Model Results for
Chollas and Alvarado Creeks

APPENDIX F

Potential Mitigation Measures (BMPs)