San Diego River Watershed Comprehensive Load Reduction Plan – Phase II

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1 Introduction

In 2012, a Comprehensive Load Reduction Plan (CLRP) was prepared for the San Diego River watershed, with San Diego County as the lead agency in coordination with the City of San Diego (City), and included the City as a Responsible Party (RP) (Geosyntec Consultants, 2012). This CLRP provided a best management practices (BMP) implementation strategy to achieve compliance with the *Revised Total Maximum Daily Loads for Indicator Bacteria, Project 1 – Twenty Beaches and Creeks in the San Diego Region* (Bacteria TMDL), which was approved by the San Diego Regional Water Quality Control Board (Regional Board) and took effect April 4, 2011 (SDRWQCB 2010). A BMP implementation strategy was proposed for the duration of the 20-year TMDL implementation period. The purpose of this CLRP Phase II is to:

- Review recommended BMPs in the CLRP for the City and propose improvements and modifications, as needed, that considered feasibility for implementation and further assurance of load reductions to meet wasteload allocations (WLAs).
- Based on the technical approach consistent with other City-led CLRPs for other watersheds (Chollas Creek, Tecolote Creek, and Scripps), modeling and cost-optimization of BMPs to quantify load reductions to support evaluation of WLA compliance and selection of the most cost-effective BMP strategy for implementation within the City.
- Adjustments of cost estimates and scheduling of BMPs for the City to meet interim and final load reduction targets to meet WLAs.

These analyses provide reasonable assurance that BMPs recommended for the City are cost-effective and meaningful, while providing essential information needed to support the City's parallel effort to develop a stormwater asset management plan. The result is that information developed from this CLRP Phase II effort will be consistent with other CLRPs where the City is an RP, provide consistency in approaches among CLRPs to facilitate overall programmatic feasibility for implementation, and result in assurance that the proposed BMPs and their schedule for implementation are optimal in terms of cost-effectiveness.

Final recommendations for the BMPs and their associated costs and implementation schedule for the City's portion of the CLRP should be based on the Phase II results reported here, which should be considered as a refinement to all recommendations made in the 2012 CLRP. As such, this CLRP Phase II report should be considered as a companion document to the original 2012 CLRP as the City strategizes implementation efforts.

Given the timing of new requirements of the Municipal Separate Storm Sewer System (MS4) permit and the associated required Water Quality Improvement Plan (WQIP), the results presented here also provide an ideal opportunity for the City to consider how modeling results can contribute to the load reduction analysis required in the WQIP for TMDL pollutants, and how results can be presented in the WQIP.

2 Technical Approach Summary

2.1 Modeling Overview

Modeling provides information about the expected performance of BMPs and projections about the extent of management required to achieve instream water quality objectives. The CLRPs follow a cost-effective BMP implementation strategy that begins with enhancements to existing nonstructural BMP programs and development of new programs in some cases. This step is followed by structural BMP development on public land, and finally by structural BMP development on private land acquired by the City if necessary to meet TMDL reduction objectives. Implementation of a green streets program was also evaluated as a more cost-effective alternative to centralized structural BMP development on acquired private land. Figure 2-1 presents a conceptual diagram that shows each of these management levels along a cost-effectiveness curve. Each management level describes a set of BMP practices (and degree of implementation) that was evaluated using the modeling system. Successive management levels are comprised of different individual practices, and are considered to be inclusive of or additive to the previous level.

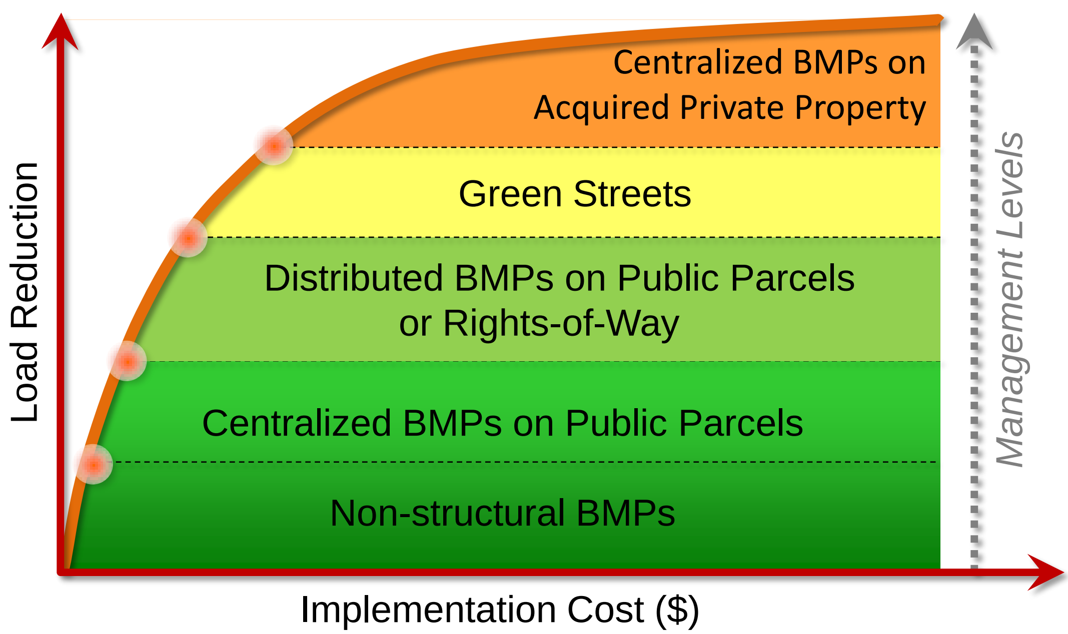

Figure 2-1. Conceptual cost-benefit curve and management levels

The first two levels include practices that are the least expensive and easiest to implement. For example, centralized BMPs on public parcels are likely among the most cost-effective options because (1) there is no associated land acquisition cost, and (2) they provide economies of scale by treating a larger area where runoff originates from both private and public parcels. In addition, nonstructural practices such as street sweeping and catch basin cleaning reduce pollutant loads upstream of the BMPs, thereby reducing the required size and/or number of structural BMPs. The third level includes distributed BMPs on public land that, although cost-effective, are often limited in their overall contribution to watershed load reductions due to the limited availability of publicly owned parcels for implementation.

After considering centralized and distributed options on public lands, the potential benefits from an expanded green streets program were evaluated at the fourth level. Green streets represent a public BMP option that has the benefit of treating runoff from adjacent private lands and can help offset centralized BMPs on acquired private land. Centralized structural BMPs on acquired private land represent the last level because of potential land acquisition costs and the logistical challenges of ensuring proper maintenance on private land. These BMPs are assumed to be the most expensive option because the costs associated with purchasing large parcels of land for constructing centralized BMPs will typically outweigh the benefits. Additional information on each of these management levels and associated BMP types is provided in Sections 3 and 4 below and in Appendix A.

The modeling system that was used to quantify and evaluate the various BMP types and management levels incorporates a watershed loading model to estimate baseline water quality and flow conditions, a site-scale BMP optimization model, and a non-linear watershed-scale optimization model to assist with evaluating multiple BMP scenarios concurrently. The modeling approach builds on the information and modeling efforts that were completed during Phase I CLRP development. Existing Loading Simulation Program in C++ (LSPC) (Shen et al. 2004; Tetra Tech and USEPA 2002; USEPA 2003) watershed models were updated and standardized in Phase II to (1) establish a level of consistency and comparability for areas with similar physical characteristics, and (2) provide reasonable assurance that the modeled existing condition is a representative baseline condition from which to measure the cost and benefits of BMP implementation. The revised models were also used to update the water quality composite scores referenced in the Phase I CLRPs (Appendix D). For each subwatershed, dry and wet weather composite scores were calculated based on the average annual modeled pollutant loads which were then ranked in order from high to low and grouped into quintiles. A score of 5 indicates that the subwatershed pollutant loading was in the top 20th percentile (high pollutant loading); whereas a score of 1 represents a subwatershed loading in the bottom 20th percentile (low pollutant loading). Bacteria was selected as the focus because of the priority in addressing bacteria loads. Individual quintiles scores for enterococci, fecal coliform, and total coliform were averaged for dry and wet weather separately to develop composite scores. An overall composite water quality score was also calculated based on the sum of the dry and wet composite scores.

The modeled baseline condition implicitly represents current benefits of existing BMPs (including recent BMPs that may be providing water quality benefits that were not accounted for in TMDL development); therefore, any and all recommended BMPs derived through this modeling effort are considered above and beyond what is currently in place. The LSPC model for each watershed provided the foundation for BMP optimization analyses in later stages and for estimating the required TMDL load reductions that are discussed in Section 2.2. LSPC was also used to help estimate the pollutant reduction and flow benefits from the proposed nonstructural BMP enhancements and new programs that were developed in collaboration with the City. This information was derived based on the anticipated level of implementation of each BMP type within each watershed and represents the nonstructural BMP baseline. The aggregate benefits from the nonstructural BMPs provided the starting point for evaluating additional structural BMP implementation needs to meet the load reduction objectives.

Successive management levels representing structural BMPs were evaluated, starting with site-scale analyses using the System for Urban Stormwater Treatment and Analysis INtegration (SUSTAIN) (USEPA 2009). SUSTAIN was used to model BMP performance and cost-benefit optimization within representative subwatersheds using time-series input from the LSPC watershed models. During optimization, BMP sizing was adjusted to optimize the treatment of upstream impervious areas and consider the 85th percentile storm event consistent with existing structural BMP programs. SUSTAIN incorporates BMP cost functions that allow for cost-benefit evaluation and optimization of management alternatives.

2.2 Determination of TMDL Reduction Objectives

The primary goal of the CLRP modeling effort is to optimize the implementation of BMPs (number, type, size, and location) for compliance with TMDLs, while quantifying the load reduction achieved for other priority pollutants. The San Diego River watershed is subject to bacteria TMDLs for the river. This first step in the load reduction analysis is the interpretation of the TMDLs and their associated numeric goals and WLAs and applying the CLRP watershed model for determining necessary pollutant load reductions to meet those objectives.

Numeric goals were calculated for each parameter based on the difference between the modeled load and calculated TMDL load for Water Year (WY) 2003. WY 2003 was selected based on an analysis of rainfall data collected within the region from 1990 through 2010. This year represents typical wet and dry weather conditions and provides an appropriate benchmark to use in defining numeric goals and the resulting BMP implementation needs. Modeled loads above the TMDL load were considered as a required reduction and subtracted from the model baseline load to develop an instream load reduction target.

Each parameter has special considerations based on how the Basin Plan Water Quality Objectives (WQOs) are expressed as well as the associated TMDL requirements, and other regulatory requirements. Key compliance elements and the calculated numeric goals and reduction targets are presented in the following sections.

2.2.1 Bacteria

WQOs and TMDL Numeric Targets

The Bacteria TMDL is expressed as both a concentration-based and load-based target. Determination of MS4 compliance, as described in the Basin Plan Amendment, is based on both receiving water conditions and measurements of bacteria loading from MS4 outfalls. The concentration-based receiving water component of the TMDL is reflected by the TMDL targets, which are separated into a dry weather component, based on the geometric mean WQOs, and a wet weather component, based on the single sample WQOs. These targets are used to generate “Receiving Water Limitations” in the TMDL, which means the MS4s are assigned much of the responsibility for attaining the TMDL targets (or, at a minimum, demonstrating that non-MS4 sources are responsible for non-attainment). The San Diego River watershed is subject to those targets assigned to freshwater creeks (Table 2-1).

Table 2-1. Receiving water limitations for creeks from the Bacteria TMDL

	Wet Weather Days		Dry Weather Days	
Indicator Bacteria	Wet Weather Numeric Objective (MPN/100mL)	Wet Weather Allowable Exceedance Frequency	Dry Weather Numeric Objective (MPN/100mL)	Dry Weather Allowable Exceedance Frequency
Fecal Coliform	400	22%	200	0%
Enterococcus	61 (104*)	22%	33	0%

* if designated as a “moderate to lightly used area” or less frequent usage frequency in the Basin Plan

Fecal coliform was used to represent bacteria in the load reduction calculations. The TMDL load for fecal coliform was calculated by multiplying the WQOs by the daily modeled streamflow. Modeled daily loads greater than this threshold were flagged as an exceedance. Modeled daily loads were also classified as occurring on either wet days or dry days because of different compliance requirements. A wet day is defined as a day with at least 0.2 inch of rainfall plus the three following days. Any day not classified as a wet day was considered a dry day. For wet weather, the Bacteria TMDL specifies an allowable exceedance frequency of 22 percent based on reference conditions, while no exceedances are allowed during dry weather. For WY2003, the number of wet days was 42, therefore the number of allowable wet weather exceedance days was 9 (rounded). The allowable exceedance load for wet weather was calculated by summing the top 9 days with the highest modeled daily loads. This load was then subtracted from the modeled wet weather total for the year. The difference between the remaining modeled load and the TMDL load represents the load reduction required for wet weather.

For dry weather, the WQOs represent 30-day geometric mean concentrations that require interpretation for use in developing the associated TMDL load. For the CLRP, a 30-day period in July 2003 was selected for modeling the dry period as it best represents a period unimpacted by rainfall and dominated by dry urban runoff. The 30-day geometric mean concentrations for each parameter were assumed for each dry day during this period and multiplied by the daily modeled flows to calculate the TMDL load. The dry weather load reduction was simply the difference between the modeled existing load and the TMDL load for the total number of dry days.

Interim Milestones and Compliance Schedule

The Bacteria TMDL includes interim compliance milestones to measure progress towards achieving final TMDL attainment (Table 2-2). Interim milestones are expressed in terms of exceedance frequency reduction. For the modeling analysis, compliance with the exceedance frequency milestones was based on achieving an equivalent load reduction for wet and dry weather conditions (50% and 100% of the load reduction targets).

Table 2-2. CLRP milestones and compliance schedule from the Bacteria TMDL

Compliance Year (year after TMDL effective date - 2011)	Exceedance Frequency Reduction Milestone
7 (by 2018)	50% for dry weather
10 (by 2021)	100% for dry weather 50% for wet weather
20 (by 2031)	100% for wet weather

2.2.2 TMDL Load Reduction Summary

Table 2-3 and Table 2-4 present the calculated wet and dry weather loads and load reductions required based on the assumptions discussed above. The critical bacteria constituent is fecal coliform bacteria based on wet weather conditions. The assumption used in the CLRP is that by focusing on the critical pollutants for load reduction analyses, other pollutants will be addressed (many of the BMPs address multiple pollutants). Regardless, load reductions for the other pollutants are verified later in the analysis to ensure that necessary reductions are demonstrated.

Table 2-3. Wet-weather pollutant loads and required reductions

Pollutant	Total Load	Non-Exceedance Load	Allowable Exceedance Load	Exceedance Load	Required Reduction
Fecal Coliform (Billion #/year)	1,494,873	64,568	912,229	518,076	34.7%
Enterococcus (Billion #/year)	10,734,720	65,267	7,643,082	3,026,371	28.2%

Table 2-4. Dry-weather pollutant loads and required reductions

Pollutant	Total Load	Non-Exceedance Load	Exceedance Load	Required Reduction
Fecal Coliform (Billion #/year)	16,102	198	15,904	98.8%
Enterococcus (Billion #/year)	188,973	230	188,742	99.9%

3 Quantitative Evaluation of Nonstructural Solutions

It is challenging to accurately quantify the benefits for most nonstructural BMPs in terms of pollutant load reductions because it often requires extensive survey and monitoring information. Nevertheless, on the basis of best available information, the Phase I CLRPs documented effectiveness and estimated future levels of implementation of the various nonstructural BMPs that will be implemented in the region over the next 20 years. Most of those BMPs included a focus on increased training and education and public outreach as a way to improve pollutant source control. The pollutant and flow reduction benefits from several nonstructural BMPs such as street sweeping, catch basin cleaning, rain barrels, downspout disconnections, and irrigation runoff reduction practices can be estimated using quantitative methods. Appendix A outlines the implementation level for each BMP and describes the modeling process. A conservative load reduction is allocated for those BMPs that are not represented in the model. The watershed model was run with a series of scenarios to quantify the effectiveness of each nonstructural BMP.

The purpose of this section is to summarize the extent to which each nonstructural BMP contributes to pollutant removal in the San Diego River watershed. Table 3-1 presents the baseline watershed model flow and loads for the modeled year and further breaks out the totals for wet and dry conditions for the City's jurisdiction within the watershed. In each of the subsequent sub-sections, the effectiveness of the BMPs are presented as a percent reduction relative to the baseline watershed model flow and loads presented in this table.

Table 3-1. Baseline flow and pollutant loads for wet and dry weather

Condition	Flow Volume (Million ft3/yr)	Total Sediment (tons/yr)	Total Copper (lbs/yr)	Total Lead (lbs/yr)	Total Zinc (lbs/yr)	Fecal Coliform (Billion #/yr)	Total Phosphorus (lbs/yr)	Total Nitrogen (lbs/yr)
Wet weather	210,999	4,372	1,472	1,282	9,752	1,494,873	23,931	120,623
Dry weather	1,484	18	13	11	83	16,102	1,132	225

3.1 Street Sweeping

Enhanced street sweeping activities provide direct, additional load reduction for specific pollutants. Sediment and other debris that collect on roadways, medians, and gutters are removed from the watershed with each sweeping, along with the associated mass of other pollutants. However, results presented in Appendix A indicated that street sweeping does little in terms of bacteria load reductions. Since bacteria are the only TMDL pollutant for San Diego River, this BMP is not recommended for the San Diego River watershed.

3.2 Catch Basin Cleaning

Enhanced catch basin cleaning programs provide direct, additional load reduction for specific pollutants. Sediment and other debris trapped in catch basins are removed from the collection system with each cleaning, along with the associated mass of other pollutants. However, results presented in Appendix A indicated that catch basin cleaning does little in terms of bacteria load reductions. Since bacteria are the only TMDL pollutant for San Diego River, this BMP is not recommended for the San Diego watershed.

3.3 Rain Barrels Incentive Program

Rain barrels act as mechanisms to temporarily detain and re-route runoff from otherwise directly connected impervious areas to nearby pervious areas or other vegetated areas such as rain gardens, swales, and the like. Assumptions about the modeling process and the extent of implementation are presented in Appendix A. Due to the limited extent of implementation of this program, load reduction values are quite small. Table 3-2 presents the flow and pollutant load reductions associated with the proposed implementation of rain barrels.

Table 3-2. Flow and pollutant load reduction attributed to rain barrels

Condition	Flow Volume (%)	Total Sediment (%)	Total Copper (%)	Total Lead (%)	Total Zinc (%)	Fecal Coliform (%)	Total Phosphorus (%)	Total Nitrogen (%)
Wet weather	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Dry weather	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3.4 Downspout Disconnection Incentive Program

Downspout disconnections provide a similar watershed impact as rain barrels and downspout disconnections are modeled similarly. Assumptions about the modeling process and the extent of implementation are also presented in Appendix A. Implementation of this program is substantially greater than the rain barrel program, although the total load reduction numbers remain small. Table 3-3 presents the flow and pollutant load reductions associated with the proposed implementation of downspout disconnections.

Table 3-3. Flow and pollutant load reduction attributed to downspout disconnections

Condition	Flow Volume (%)	Total Sediment (%)	Total Copper (%)	Total Lead (%)	Total Zinc (%)	Fecal Coliform (%)	Total Phosphorus (%)	Total Nitrogen (%)
Wet weather	0.09	0.04	0.14	0.24	0.19	0.18	0.09	0.09
Dry weather	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3.5 Irrigation Runoff Reduction

Irrigation runoff reduction was modeled as a turf conversion and irrigation efficiency program as documented in Appendix A. Turf conversion transforms area from grasses that require regular irrigation to other, native pervious cover which would not require regular irrigation. The irrigation efficiency program sets the goal of eliminating irrigation overspray practices over the course of the 20-year implementation period. The extent to which each of these programs is assumed to be implemented within the watershed is summarized in Appendix A. Table 3-4 presents annual modeled flow and pollutant load reduction as a percentage of the baseline that is attributed to this irrigation runoff reduction program. It should be noted that the impact of the elimination of irrigation overspray on dry weather pollutant load reductions in the City of San Diego is heavily muted due to the way in which dry weather flows are tabulated for this analysis (as described in Section 2.2).

Table 3-4. Flow and pollutant load reduction attributed to irrigation reduction

Condition	Flow Volume (%)	Total Sediment (%)	Total Copper (%)	Total Lead (%)	Total Zinc (%)	Fecal Coliform (%)	Total Phosphorus (%)	Total Nitrogen (%)
Wet weather	2.86	0.06	0.77	1.53	0.26	0.18	3.04	1.35
Dry weather	34.28	45.02	39.55	44.13	39.72	45.65	44.90	48.60

3.6 Summary of Modeled Nonstructural BMPs

Finally, all nonstructural BMPs were included in the baseline watershed model to determine the aggregate flow and pollutant load reduction. The combined estimates are presented in Table 3-5.

Table 3-5. Flow and pollutant load reduction attributed to all modeled non-structural practices

Condition	Flow Volume (%)	Total Sediment (%)	Total Copper (%)	Total Lead (%)	Total Zinc (%)	Fecal Coliform (%)	Total Phosphorus (%)	Total Nitrogen (%)
Wet weather	2.96	0.10	0.92	1.78	0.46	0.37	3.14	1.45
Dry weather	34.28	45.02	39.55	44.13	39.72	45.65	44.90	48.60

3.7 Non-modeled Nonstructural BMPs

In addition to those BMPs modeled above, the Phase I CLRP also identified a number of additional nonstructural BMPs that, although they have the potential for significant pollutant reduction, lack the data necessary for model representation (Geosyntec Consultants, 2012). These pollution protection measures often seek to change behaviors at residential, commercial, and industrial sites to reduce exposure of pollutants to rainfall. While these practices have been demonstrated to be effective in places where they have been pioneered in western U.S. communities (Caraco and Schueler 1999), quantification of benefits in terms of load reductions attributed to these BMPs are challenging and often require extensive survey and monitoring information to gauge performance (Los Angeles County 2010). With the number of non-modeled, nonstructural BMPs included in the Phase I CLRP, some pollutant load reductions are expected. For the purposes of benefit analyses and justification of funding for these BMPs, the collective load reduction for all non-modeled, nonstructural BMPs are assumed to be 5 percent, for both wet and dry conditions. This assumption represents a conservative estimate that is comparable to the load reductions associated with non-structural BMPs that can be modeled. This assumption will be assessed in the future as BMPs are implemented and focused monitoring studies are performed to attempt to evaluate performance. As the WQIP is developed and updated in the future throughout the implementation period, the modeling system can be updated over time as data become available for quantifying the effectiveness of additional nonstructural BMPs.

4 Quantitative Evaluation of Structural Solutions

Evaluation of structural BMPs requires modeling the re-routing of runoff that would normally drain directly to the drainage network into infiltration or filtration-based BMPs. These structural BMPs can be placed throughout the contributing watershed; their collective ability to filter and infiltrate water improves water quality by removing pollutants from the system. The model simulates the filling, draining, and pollutant removal dynamics of these BMPs. The extent to which these BMPs can be implemented and the BMP modeling assumptions are summarized in Appendix A. These BMPs are broken down into four categories based on the availability of land: (1) centralized BMPs on public land, (2) distributed BMPs on public land, (3) green streets, and (4) centralized BMPs on acquired private land.

Several analyses were run with a series of scenarios to quantify the effectiveness of each of the structural BMPs on public land first using the SUSTAIN model, as described in Section 2. The purpose of this section is to summarize the extent to which structural BMPs contribute to pollutant removal in the watershed. In each of the sub-sections, the effectiveness of the BMP category is presented as a percent reduction relative to the baseline watershed model flow and loads presented in Table 3-1.

4.1 Centralized BMPs on Public Land

The centralized structural BMPs on public parcels incorporated in the model consisted mostly of detention and infiltration facilities. These features were largely located on soils with low infiltration capacities in the San Diego River watershed. The specific sites modeled are presented in Appendix A. Table 4-1 presents the modeled flow and load reductions attributed to these centralized BMPs on public parcels. Appendices E and F present the results of the structural BMP site evaluation memo and the centralized BMP fact sheets.

Table 4-1. Flow and pollutant load reduction attributed to centralized BMPs on public parcels

Condition	Flow Volume (%)	Total Sediment (%)	Total Copper (%)	Total Lead (%)	Total Zinc (%)	Fecal Coliform (%)	Total Phos-phorus (%)	Total Nitrogen (%)
Wet weather	0.01	0.64	0.00	0.04	0.02	2.76	0.29	1.83
Dry weather	2.19	0.57	0.42	0.25	0.15	0.02	1.03	2.03

The City also currently operates five low flow diversion facilities within the San Diego River watershed. These were included in the baseline model of existing conditions and are therefore not included within the flow and pollutant load estimates for dry weather in Table 4-1. Based on review of information on these diversions and communications with City staff, a cumulative diverted flow rate of 2.8 cubic feet per second (cfs) was assumed in the model for these facilities, with individual facility locations and diversion rates represented appropriately.

4.2 Distributed BMPs on Public Land

Both bioretention and permeable pavement were considered for implementation of distributed BMPs on public parcels. Parcels were screened during the Phase I CLRPs to identify the opportunity for implementation, accounting for feasibility constraints such as site slope. Both bioretention and permeable pavement options were configured with and without underdrains depending on the underlying soils. For instance, Hydrologic Soil Group B areas were modeled without underdrains and Hydrologic Soil Group C and D areas were modeled with underdrains. Details on the distributed BMP model representations are presented in Appendix A.

Table 4-2 presents the modeled flow and pollutant load reduction attributed to implementation of distributed BMPs on available public parcels.

Table 4-2. Flow and pollutant load reduction attributed to distributed BMPs on public parcels

Condition	Flow Volume (%)	Total Sediment (%)	Total Copper (%)	Total Lead (%)	Total Zinc (%)	Fecal Coliform (%)	Total Phos-phorus (%)	Total Nitrogen (%)
Wet weather	4.63	0.90	2.66	4.13	4.02	8.29	6.07	5.13
Dry weather	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

4.3 Green Streets

The modeling shows that even the maximum deployment of nonstructural BMPs and centralized and distributed structural BMPs on public land provide only modest pollutant load reductions, well below those needed to meet the WLA reduction requirements. While the above BMPs represent the lowest cost BMPs for pollutant load reduction, more expensive structural solutions will be required to meet these requirements. The two alternatives considered for this study include green streets and centralized structural BMPs on acquired private land (discussed in the following sub-section). Implementing green streets involves constructing structural BMPs, such as bioretention and permeable pavement in the rights of way of various streets. Although they are more expensive than the previously mentioned BMPs, green streets are very efficient at removing pollutant loads in watersheds because of their proximity to pollutant generating surfaces and their location in the existing surface conveyance infrastructure of the stormwater collection system. Additional advantages of green streets include the fact that they are located in the right of way (and therefore have no land acquisition costs) and are more conveniently accessed for maintenance activities.

A detailed desktop analysis was performed throughout the watershed to evaluate the opportunities for retrofitting existing rights-of-way to green streets. The latest information on road coverage, road type, potential drainage area, soil types, and construction infeasibility was combined to identify the number of potential green streets miles in the watershed. The results of this analysis are summarized in Appendix A. The findings of this analysis were then loaded into SUSTAIN, which comprehensively evaluated and optimized the cost and pollutant removal effectiveness for numerous different combinations of green streets. A cost effectiveness curve was generated from this effort and is presented in Section 5 of this report. For the San Diego River watershed, the implementation of green streets provides sufficient load reductions for the critical pollutant to achieve compliance with WLA targets. Table 4-3 summarizes the load reductions for all pollutants that can be attributed to the implementation of green streets. Although green streets are expected to provide dry weather load reductions, nonstructural BMPs (summarized in Section 3) provided 100% load reduction during dry weather so no additional benefits for green streets were quantified in the model.

Table 4-3. Flow and pollutant load reduction attributed to green streets

Condition	Flow Volume (%)	Total Sediment (%)	Total Copper (%)	Total Lead (%)	Total Zinc (%)	Fecal Coliform (%)	Total Phos-phorus (%)	Total Nitrogen (%)
Wet weather	6.54	13.75	16.96	15.21	18.50	19.81	13.95	15.45
Dry weather	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

4.4 Centralized BMPs on Acquired Private Land

Due to the high cost of land acquisition associated with centralized structural BMPs on acquired private land, these BMPs are considered a last resort for implementation to meet necessary load reductions. Therefore, not until other BMP options are exhausted will centralized BMPs on private land be considered for each jurisdiction. Furthermore, based on the schedule determined in the Phase I CLRPs, centralized BMPs on private land will not begin implementation until 2027. This gives much needed time for investigation of other more cost-effective BMP alternatives prior to implementation. For instance, research of nonstructural BMPs not presently modeled may provide definitive results for load reductions that can be later incorporated within the modeling analyses and provide a reduction in lieu of the necessity for centralized structural BMPs on private land. Alternatively, implementation of green streets discussed in the previous section may provide a viable alternative should changes in road redevelopment procedures be achieved prior to 2027 when structural BMPs on private land are set to begin. Therefore, centralized structural BMPs on private land are meant to be a placeholder in the CLRP with an attempt to quantify the costs of meeting the load reduction targets beyond what can be presently quantified with nonstructural BMPs and structural BMPs on public land.

Unlike the green streets optimization, which was based upon a detailed desktop analysis of BMP opportunities, the optimization of centralized BMPs on private land was founded on a higher level planning analysis due to the unknown locations and availability of private land acquisition. Specific spatial and climatic characteristics of each individual subwatershed were loaded into SUSTAIN and hypothetical BMPs were simulated with a fixed drainage area necessary to capture the design storm as detailed in Appendix A. The optimization analysis included numerous combinations of BMP location and size scenarios to develop a cost effectiveness curve, which is presented in Section 5 as an alternative to the green streets approach. For the San Diego River watershed, the implementation of centralized BMPs on private land provides sufficient load reductions for the critical pollutant to achieve compliance with WLA targets. This approach is presented as an alternative compliance strategy to green streets in Section 5 of this report.

5 Optimization Analysis Results

The previous section provided a quantitative analysis of the load reductions achieved for each type of BMP. The focus of the optimization analysis is to consider costs as part of the overall strategy for watershed-wide implementation of these BMPs. This analysis considers implementation of the various BMP levels, while incrementally considering costs for implementation and mapping progress toward achieving the load reduction targets identified for each TMDL pollutant. The method for assessing the optimal strategy was based on cost-effectiveness curves similar to the conceptual diagram presented in Figure 2-1. The cost-effectiveness curve is shown in Figure 5-1, and demonstrates the strategy to meet the 34.7% load reduction for the critical pollutant, fecal coliform.

It is important to note that the optimization process depended on evaluating and comparing the cost-effectiveness of various BMP alternatives. Detailed BMP cost functions consider BMP construction, maintenance, and land acquisition for BMP implementation. Section 6.1 and Appendix B summarize total cost estimates for BMP implementation in 2013 dollars.

As mentioned in the previous section, two alternatives were analyzed for optimization. The first scenario assumed that green streets could be implemented for all areas predetermined as feasible. This scenario demonstrated that green streets (in addition to nonstructural BMPs and structural BMPs on public land), provided sufficient load reductions to meet the target. For comparison purposes, a second scenario was optimized that considered no green streets and relied only on centralized structural BMPs on acquired private land (in addition to nonstructural BMPs and structural BMPs on public land) to meet the load reduction target. The following figures show the results of both scenarios and the overwhelming cost savings if green streets are considered as a major BMP for CLRP implementation. As a result, green streets are the recommended path for cost-effective implementation for the CLRP.

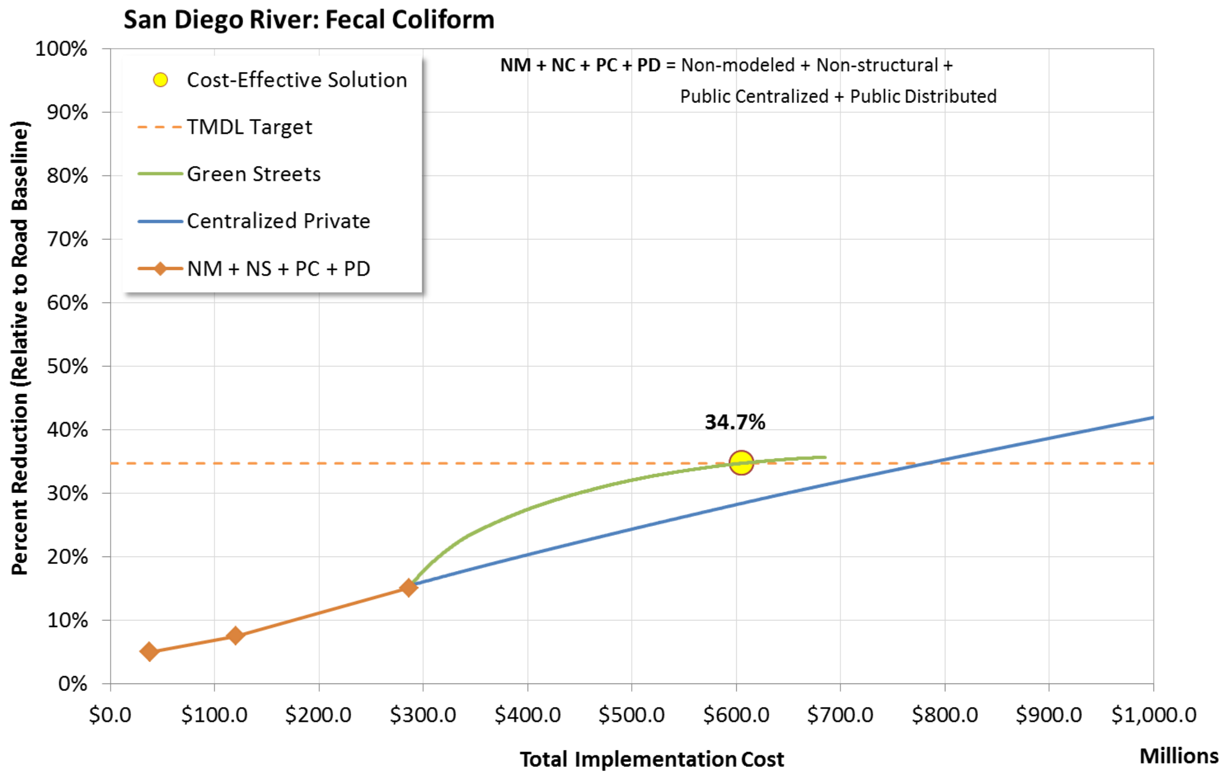

Figure 5-1. Cost-effectiveness curves for wet weather

To determine the maximum cost-effective implementation of green streets, the optimization included a spatial analysis to determine the most cost-effective levels (see Section 4.3) of green streets for each modeled subwatershed. Figure 5-2 shows the optimal maximum cost-effective levels of green streets for each subwatershed (representing the point for meeting the target load reduction in Figure 5-1). Green street management levels (Table 5-1) represent increments of implementation of the maximum feasible green streets implementation opportunity (see Appendix A). The opportunity for feasible green streets is unique to each subwatershed, so management levels represent increases in implementation that are proportional to each subwatershed's maximum available opportunity. Within the optimal subwatersheds for green street implementation, recommended goals for cost-effective implementation of BMPs are listed in Appendix A.

Table 5-1. Management levels for green streets

Management Level	Description
0	No Management
1	20% of available GS opportunity
2	40% of available GS opportunity
3	60% of available GS opportunity
4	80% of available GS opportunity
5	100% of available GS opportunity

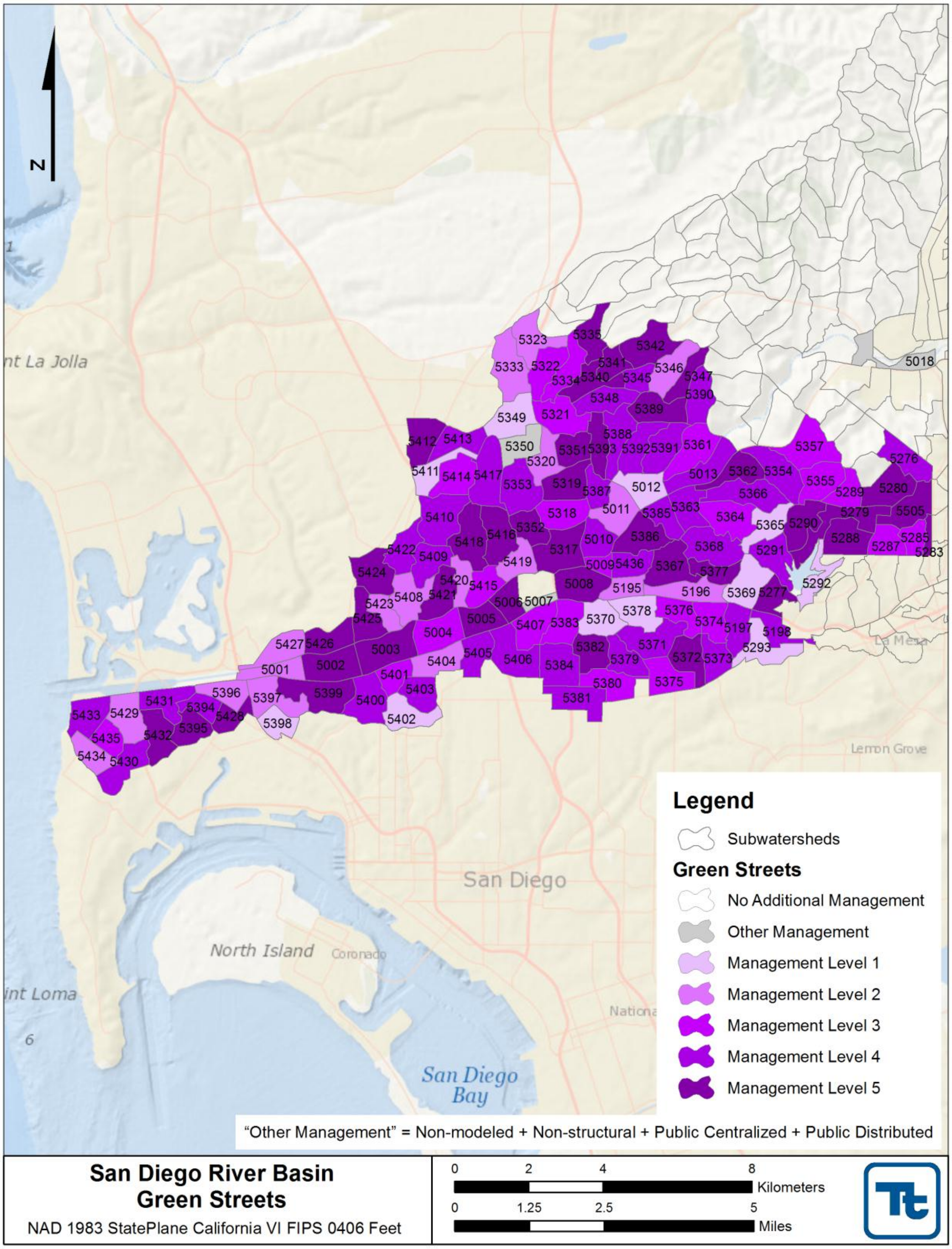

Figure 5-2. Spatially optimized implementation of green streets

The cost effectiveness curves above were only required for evaluation of wet weather results. Once the BMPs were optimized for wet weather, the models were used to simulate associated pollutant reductions for dry weather. Table 5-2 summarizes pollutant load reductions for wet and dry weather conditions for the critical pollutant, fecal coliform. This table illustrate the contribution of each management level BMP commitment to achieving the total pollutant load reduction target.

Table 5-2. Total critical pollutant load reductions (%)

Condition	Non-structural (not modeled)	Non-structural (modeled)	Centralized on Public	Distributed on Public	Green Streets	Centralized on Acquired Private Land	Total[2]
Wet weather	5.00	0.37	2.76	8.29	18.29	n/a	34.7
Dry weather[1]	5.00	95.0	-	-	-	n/a	100.0

[1] Dry weather flow and load reductions reflect only runoff in urban subwatershed.
[2] The load reduction analysis and scheduling of BMPs was performed for final targets only. Interim targets and associated schedules will be further evaluated through an adaptive process as BMPs are implemented and their effectiveness is assessed.

5.1 Other 303(d) Listed Pollutants

Several additional impairments were included on the 303(d) list for the San Diego River watershed. The following waterbodies included additional 303(d) impairment causes:

- Forester Creek: TDS, selenium, pH
- San Diego River, Lower: nitrogen, phosphorus, TDS, manganese, toxicity, dissolved oxygen
- Famosa Slough: eutrophic conditions
- Alvarado Creek: selenium
- Murray Reservoir: nitrogen, pH (note - reservoir modeling was not included in project approach)

Nutrients were included in the modeling framework to estimate the secondary load reduction benefits for total nitrogen and total phosphorus based on the bacteria BMP implementation strategy (Table 5-3). Lower San Diego River and Famosa Slough are listed as impaired due to various symptoms of eutrophication, including excessive nutrient concentrations and low dissolved oxygen. Nutrient reduction benefits were quantified for the San Diego River watershed, which will help resolve observed dissolved problems in the lower portion of the river. Additional modeling would be needed as part of a TMDL development effort (or similar study) to explicitly simulate dissolved oxygen concentrations using a comprehensive modeling approach. A related TMDL effort is currently underway for Famosa Slough, which is being led by the City of San Diego. A detailed modeling system was developed to simulate watershed nutrient load contributions and the resulting impacts on dissolved oxygen and algal growth within the Slough.

Table 5-3. Total watershed wet weather load reductions of additional pollutants (%)

Condition	Flow Volume (%)	Total Sediment (%)	Total Copper (%)	Total Lead (%)	Total Zinc (%)	Fecal Coliform (%)	Total Phos-phorus (%)	Total Nitrogen (%)
Wet weather	16.67	25.00	24.63	24.74	27.22	34.70	25.47	25.34
Dry weather[1]	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

1: Dry weather flow and load reductions reflect only runoff in urban subwatershed.

Nutrient and metals assessments can also provide valuable information that relates to addressing pH impairments. pH was not directly modeled for Forester Creek and Murray Reservoir (Lake Murray) as the causes of the pH impairments have not been fully investigated and additional modeling complexity would be needed to simulate pH conditions, which are dynamically influenced by various biological, chemical, and geologic processes. BMP implementation and associated pollutant load reductions will help address potential pH problems in the watershed. TDS, manganese, and selenium were also not explicitly modeled because the source is likely groundwater in many cases and the pathways are often complex. Stormwater is not expected to be a significant source of selenium, however, implementation activities to address other pollutants will likely reduce possible contributions of selenium from stormwater sources. In addition, elevated TDS concentrations are also related to concentrations in imported water and other factors.

Toxicity cannot be modeled directly; rather, loadings associated with pollutants that cause toxicity can be estimated. The toxicity listing for the Lower San Diego River is likely related to one or more of the pollutants discussed above. These and other possible contaminants (e.g. organic compounds) generally have a high affinity to soil and sediment particles. Because these hydrophilic contaminants are likely to be in stormwater runoff adsorbed to eroded sediment particles, their loadings are relatively proportional to sediment loadings in the San Diego River watershed. Wet- and dry-weather sediment loads are presented in Table 5-3 as a surrogate for the toxicity impairment listing. BMPs that reduce sediment will likely also reduce toxicity, assuming the pollutant(s) that are causing the impairment are sediment-associated.

6 Updated CLRP Implementation Program

Phase 1 of the CLRP provided a foundational cost and schedule framework for compliance with TMDL requirements. It is necessary to update these elements of the plan to incorporate optimization modeling results and new information regarding implementation of nonstructural BMPs. Updates to costs and schedules are presented in this section.

6.1 Updated BMP Implementation Schedule

A new BMP Implementation Schedule was developed for the Phase II CLRP that provided consistency with parallel CLRP planning efforts the City is undertaking in other watersheds for which they are an RP (Appendix C). This consistency enables the City to be strategic in planning and funding of BMPs, particularly since the timelines for TMDL compliance for all watersheds impacted by the overarching Bacteria TMDL are consistent. The Bacteria TMDL Basin Plan Amendment was approved in April 2011, which represents the start date for complying with the WLAs and other TMDL requirements. CLRPs for all watersheds incorporate a 20-year compliance schedule and recognize BMP development and planning efforts that have been completed to date, including development of the CLRP itself. The BMP Implementation Schedule focuses on the BMP actions that may be implemented in future years according to the following overarching strategy: nonstructural BMPs were scheduled to be implemented in years 0–5; currently planned structural BMPs on public land in years 0–10, centralized and distributed structural BMPs on public land in year 3-15, and structural BMPs on acquired private land in years 15-20.

6.2 Updated Costs Estimates

In addition to updating the schedule from Phase 1, costs for individual BMPs were revisited. Nonstructural costs were updated based on interviews with key staff to ensure that the appropriate levels of implementation and resources were accommodated. Costs for structural BMPs were updated based on the modeling results which identified the necessary level of implementation for compliance. Annual maintenance costs were also refined based on interviews with operations and maintenance staff. Based on the updated unit costs and the updated schedule, costs were recalculated for each BMP. Table 6-1 provides a summary of total costs for compliance with the TMDLs. Detailed costs for individual BMPs are presented in Appendix B. Costs are based on 2013 dollars and are not adjusted for present value or inflation. It should be noted that costs presented in the cost effectiveness curves in Section 5 do not correspond directly to costs listed in Table 6-1, since optimization analyses were based on automated cost-functions within the model for comparative analysis, while the costs presented below were based on more rigorous engineering cost analyses utilizing information on BMPs provided by model output.

Table 6-1. Total BMP costs for compliance (millions)

Non-structural (not modeled)	Non-structural (modeled)	Centralized on Public	Distributed on Public	Green Streets	Centralized on Acquired Private Land	Total
$ 12.08	$ 1.04	$ 64.50	$ 74.33	$ 331.00	$ -	$482.94

6.3 Considerations for BMP Implementation

In the coming years, lessons will be learned from projects implemented, conditions will change, new technologies will emerge, and unanticipated challenges will present themselves. Thus, implementation of the CLRP will require continued evaluation and adaptation throughout the 20-year implementation period to ensure that strategies are optimized.

The prioritization process for implementing BMPs must carefully consider many factors, including feasibility, cost effectiveness, and the potential for pollutant load reductions. These factors have been considered and/or analyzed as part of the CLRP development process for each individual management level and the results of these analyses integrated into the scheduling and implementation level decisions presented above. Further prioritization, however, is necessary to ensure that those BMPs with the highest feasibility, highest cost effectiveness, and greatest potential for pollutant load reductions are implemented early in the implementation schedule. This section provides a brief summary of considerations that should be made for each management level as they are implemented.

Nonstructural BMPs

While nonstructural BMPs are known to be the most cost-effective for pollutant load reduction, many of their effects are often difficult to measure or quantify directly in the field. As a result, true cost effectiveness numbers are difficult to obtain. As technical or scientific methods emerge to address such needs, the foundational assumptions for these BMPs should be updated to reflect the most recent understanding. Ultimately, pollutant removal through nonstructural means is likely to continue to be the most cost effective activity due to the absence of construction, land purchase, or maintenance costs. Therefore, with additional studies to quantify the effectiveness of nonstructural BMPs, and with increasing focus on the more successful nonstructural BMPs in terms of pollutant removal, their demonstrated load reductions can potentially offset the need for more costly structural BMPs, particularly those that require land acquisition.

Centralized BMPs on Public Land

Prioritization of centralized structural BMPs on public land may be performed at many stages of the planning process. Early stage prioritization is generally based on regional datasets for soils, topography, and other landscape or land use features. Later stage planning focuses on individual sites and incorporates site-specific information to help determine feasibility, such as drainage area and available space. Both of these efforts were completed as part of the CLRP Phase II and the results were integrated into a prioritized list of BMP opportunities. This list represents the most efficient path for implementing centralized structural BMPs on the publicly owned sites identified.

Distributed BMPs on Public Land

The CLRP Phase II identified a number of publicly owned parcels that were prioritized for implementation of distributed structural BMPs. These prioritizations should be considered during the implementation of distributed BMPs, which account for areas if higher pollutant reduction expected based on physical characteristics, potential for pollutant load reduction (Water Quality Composite Scores shown in Appendix D), and other factors related to feasibility.

Green Streets

The development of green streets represents the largest investment necessary to meet the WLA reduction targets (assuming the City elects to implement green streets instead of centralized structural BMPs on acquired private land). While it is critically important to first implement more cost effective nonstructural BMPs or structural BMPs on public property, a great deal of attention must be directed at appropriately prioritizing the implementation of green streets. Not only does the optimization analysis identify the most cost effective combination of green streets needed to meet the target, but also provides a quantitative measure of how efficient green streets applications would be in individual subwatersheds. Modeling indicates that green streets are more cost effective in certain locations due to key characteristics, such as rainfall patterns, soil types, land uses, and proximity to receiving waters. Figure 5-2 illustrates where green streets are most cost effective. The green streets program should be implemented using this ranking of subwatersheds as a guideline.

Centralized BMPs on Acquired Private Land

Centralized structural BMPs on acquired private land is the most expensive option in terms of construction, O&M, and land acquisition, and is therefore the least attractive for implementation. An analysis was performed that demonstrated the cost-savings if green streets were implemented instead of centralized structural BMPs on acquired private land. However, should green streets or any other management level not be implemented as proposed, centralized structural BMPs on private land are the last alternative to provide the necessary load reductions for WLA attainment.

It is important to note that centralized structural BMPs on private land should be avoided if possible, whether through green streets or other opportunities for nonstructural or structural BMPs on public land. With the adaptive nature of the CLRP and opportunities for revisions in the future, it is advisable to seek other more cost effective BMP opportunities prior to the period needed for structural BMPs on private land. Therefore, centralized structural BMPs on private land are included in the present CLRP as a placeholder for demonstration of the cost savings associated with green streets or investments in other alternative BMPs.

7 Alternative Scenarios

There are several important regulatory considerations currently being evaluated by the City that would affect the calculation of allowable loads and load reductions, but still ensure protection of beneficial uses for San Diego River. These considerations were incorporated into alternative modeling scenarios for evaluation of their sensitivity on cost for CLRP implementation. The resulting information can help guide ongoing discussions regarding prioritization of regulatory decisions on recent and ongoing scientific studies on water quality targets, each of which is aimed at protecting those beneficial uses. For bacteria, these include (1) potential refinements to the allowable exceedance frequency for wet weather conditions based on recent monitoring studies of reference watersheds; and (2) application of a high flow suspension (HFS) provision that suspends recreational beneficial uses during large storm events where recreational activities would be hazardous due to dangerous flow conditions. A HFS exemption would reduce the calculated wet weather load reduction based on the number of wet weather days in the representative year that exceeded a particular flow value (e.g. 0.5 inch of rainfall and the following day). Also, in some cases a low flow suspension (LFS) may be applicable where low or intermittent stream flow would not support recreational uses.

The impacts of the sensitivity of the wet weather bacteria exceedance frequency and a HFS on modeled required load reductions and costs were assessed. Table 7-1 presents the loads attributed to increased exceedance frequencies of 35% and 50% as well as a HFS, and the impact on required load reductions. As shown, increases of the exceedance frequency or inclusion of a HFS results in significant reductions of the required load reductions to comply with the TMDL if these considerations are included in a TMDL re-opener. Table 7-2 presents corresponding cost-savings of each alternative scenario. It should be noted that all scenarios that require a reduction less than 5% (cost of $20.58 million) were limited by the assumption of 5% for all non-modeled nonstructural BMPs, and all BMPs that fit that category are recommended for implementation. It should be noted that for all scenarios with a HFS, only non-modeled nonstructural BMPs or no BMPs are necessary to meet the required load reduction. The decisions to consider alternative exceedance frequencies or a HFS in the TMDL re-opener will result in major cost savings to the City, and every effort should be made to re-open the TMDL and incorporate such modifications based on sufficient scientific justification that an alternative exceedance frequency or HFS is applicable for San Diego River.

Table 7-1. Alternative wet-weather pollutant loads and required reductions

Scenario (HFS and/or Allowable Exceedance Frequency)		Total Load	Non-Exceedence Load	Allowable Exceedence Load	High Flow Suspension (HFS) Load	Exceedance Load	Required Reduction
No HFS	9 days (22% - existing requirement)	1.49E+15	6.46E+13	9.12E+14	0.00E+00	5.18E+14	34.66%
	14 days (35%)	1.49E+15	6.46E+13	1.18E+15	0.00E+00	2.52E+14	16.83%
	21 days (50%)	1.49E+15	6.46E+13	1.36E+15	0.00E+00	6.68E+13	4.47%
With HFS*	6 days (22%)	1.49E+15	1.53E+13	4.73E+14	9.36E+14	7.07E+13	4.73%
	10 days (35%)	1.49E+15	1.53E+13	5.36E+14	9.36E+14	7.84E+12	0.53%
	15 days (50%)	1.49E+15	1.53E+13	5.43E+14	9.36E+14	0.00E+00	0.00%

* wet days that met the HFS criteria were subtracted from the total # of wet days for WY2003, then the allowable exceedance days were calculated based on the remaining # of wet days

Table 7-2. Alternative scenario total costs for compliance (millions)

Scenario (HFS and/or Allowable Exceedance Frequency)		Total Cost (Million $)	Cost Savings From Existing Requirement (Million $)
No HFS	9 days (22% - existing requirement)	482.94	
	14 days (35%)	235.24	247.7
	21 days (50%)	12.08	470.86
With HFS	6 days (22%)	12.08	470.86
	10 days (35%)	12.08	470.86
	15 days (50%)	0	482.94

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