Appendix C: Modeling Approach and Assumptions

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Acronyms and Abbreviations

ac-ft	acre-feet
BMP	best management practice
cfs	cubic feet per second
EPA	U.S. Environmental Protection Agency
GIS	geographic information system
HSG	Hydrologic Soil Group
LACFCD	Los Angeles County Flood Control District
LID	low impact development
LSPC	Loading Simulation Program C++
WMMS	Watershed Management Modeling System

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1. Modeling Overview

1.1. Model Purpose

The purpose of the modeling performed for this study was to determine the amount of stormwater conserved for different project groups and projected weather scenarios.

1.2. Model Platform

The Los Angeles County Department of Public Works Watershed Management Modeling System (WMMS) was used as the primary modeling software for this study. The hydrologic model within this software package is the Loading Simulation Program C++ (LSPC) and is based on the U.S. Environmental Protection Agency (EPA)'s Hydrological Simulation Program - FORTRAN (HSPF) and has been regionally optimized for all major watersheds in Los Angeles County. Although the model is capable of analyzing water quality and sediment, only the water budget portion of the model was used for this study.

1.3. Model Approach

For Task 5 of the LA Basin Stormwater Conservation Study (LA Basin Study), the specific stormwater conservation potential was determined for the 12 conceptual project groups shown in Figure C-1. In order to accomplish this, each project group was developed as a separate database model for input into WMMS. The output stream files were then compared to the baseline stream output files to determine the results for each project type.

1.4. Model Outputs

Using the unique input database for each project group, the models were run using a calculation time step of 1-hour and a yearly output stream summary file. The model output time period was from 2011-2099. However, this was broken into two periods to improve model performance.

For project types covering all seven watersheds in the LA Basin, the models had difficulty running all of the subareas at once. To solve this, the LA River and San Gabriel River watersheds were run as one output file, and the Dominguez Channel, Ballona Creek, Malibu Creek, North Santa Monica Bay, and South Santa Monica Bay watersheds were run in another.

Given 4 climate scenarios, 2 time periods and 1 or 2 runs, depending on the project group, 8 or 16 output stream summary files were generated for each project type. These files were then analyzed and summarized into the results provided in this report.

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2. Detailed Modeling Approach

2.1. Local Solutions – Local Stormwater Capture

2.1.1. Project Description and Modeling Assumptions

Local Stormwater Capture consists of infiltration projects distributed throughout the watershed where there are favorable conditions for recharge. To identify these areas, a geographic information system (GIS) analysis was performed using the screening criteria of aquifer confinement, soil type, and proximity to appropriately sized drainage systems. The area identified in this analysis is shown in Figure C-2. Within this area of favorable conditions, Los Angeles County land use and parcel data was used to identify specific project locations. In general, the categories were government, parks, institutional, golf courses, and small vacant private parcels. Caltrans infiltration projects identified in the District 7 Corridor Stormwater Management Study (Caltrans District 7 2009-2013) were also included in this alternative. Figure C-1 shows the potential projects that were identified.

After all of the candidate parcels were identified, it was assumed that only 25 percent of the identified area could be used for constructing a recharge basin. Based on similar types of projects recently constructed where the tributary area is approximately 10 times the basin area, the surrounding area that would drain into the new basin or gallery was assumed to be 10 times the area of the new basin or To model this effect, the amount of area draining to an infiltration basin was moved into its own land use within the model. This land use was calibrated to model the effect of a small infiltration basin designed to capture and infiltrate the 5-year storm.

2.1.2. Detailed Methodology

The first part in modeling the local stormwater capture alternative was to perform a GIS analysis to target recharge projects only in areas with favorable conditions. To create this search zone, three main criteria were used.

- Areas with unconfined groundwater basins
- Areas with a Hydrologic Soil Group (HSG) of A or B (permeable soils)
- Areas within 1,000 feet of a 36-inch-diameter or greater storm drain or an open channel

GIS coverages for groundwater basins, soil types, and drainage infrastructure were obtained from the Los Angeles County GIS portal (LA County GIS Data Portal). To correlate the GIS data to unconfined aquifers and county soil data to HSG type, a previous groundwater study was used (CH2M HILL 2003).

Once the search area was identified, LA County land type data and parcel data was used to identify specific potential opportunities for small scale infiltration (LA County GIS Data Portal 2014; LA County GIS Data Portal 2015). The target land uses were golf courses; public land; including parks, schools, and government offices; and private open space.

For public land and golf courses, Category 2 of the county land type data was used. Table C-1 below lists which Category 2 land types were selected from the county attribute data and used to screen for potential project types. The data was further filtered using the AIN to verify locations were within a publically owned parcel.

Table C-1. Selected Land Types to Model Potential Projects for Local Stormwater Capture

LA County Land Type Category 2*	Additional Criteria
Golf Courses	Public and Private Land Ownership
Museums & Aquariums	Public Land Ownership Only
Historical Parks	Public Land Ownership Only
Recreation Centers	Public Land Ownership Only
Regional Parks & Gardens	Public Land Ownership Only
Adult Education	Public Land Ownership Only
Colleges & Universities	Public Land Ownership Only
Public Elementary Schools	Public Land Ownership Only
Public High Schools	Public Land Ownership Only
Civic Centers	Public Land Ownership Only
County Offices	Public Land Ownership Only
Government Offices	Public Land Ownership Only
Libraries	Public Land Ownership Only
Courthouses	Public Land Ownership Only

* Source: Los Angeles County GIS Portal (LA County GIS Data Portal 2015)

For private open space, the county parcel data was used along with county building data to identify private parcels without improvements.

Once all of the candidate parcels were identified, a series of post processing steps were performed to prepare the data for input into the model. First, areas less than 0.5 acres were eliminated. It was then assumed that only 25 percent of the acreage identified could actually be used to build recharge infrastructure. To handle very large parcels, it was assumed that no basin, regardless of how large the parcel was, could be larger than 20 acres. For private open space, only parcels between 0.5 acres and 5 acres inclusive were selected.

Because the candidate areas were spread throughout the upper portions of the LA River, San Gabriel River and Dominguez Channel watersheds, it was infeasible to analyze the possible drainage area for each one. Therefore, an assumption was made that 10 times the basin area was tributary to each basin. The data was then cross referenced against the WMMS subbasin data to match a subbasin ID for each shape identified. The areas were then combined for each parcel ID.

For Caltrans projects, the water quality volumes for each infiltration BMP were converted to area using the 5-year capture depth of 3.8 inches. Based on a review of variability of depth across the study area, 6.5 inches was selected as an approximate average of the 50-year 24 hour depth. This depth was then converted to the 5-year depth using the factor in the County Hydrology Manual. A single depth was used so that all project types could be modeled using a consistent methodology.

To apply to results of the GIS analysis and post-processing steps, the land type data was adjusted within the WMMS database. The aggregate area identified for each subbasin ID was assigned to a new land type created in the model to simulate the impact of local infiltration basins. Existing urban land types were then reduced proportionally to avoid adding area to the model.

With the adjusted land type table loaded into the model, the new land type was calibrated to simulate the impacts a small recharge basin would have on stormwater runoff. F-Tables were not used to model these basins because the model runs the entire upstream flow through an F-Table. Infiltration basins in this alternative would not be connected to regional drainage networks. Therefore, F-Tables were not used for this project group.

Instead, to calibrate the land type, a unit F-Table model was developed. The unit model consisted of 10 acres of impervious area draining to an F-Table modeled basin sized to capture the 5-year storm. The assumed diversion structure was an 8-inch flow splitting weir installed in with a 36-inch pipe. The methodology for setting up the unit F-Table was the same used to model the regional stormwater capture.

This unit model was then run using the rainfall and evaporation data from Weather Station 113 for the first 44 years of the Middle 2 projected climate scenario. The volume of runoff generated was then used as a benchmark to adjust the hydrologic characteristics of the BMP land type. Weather Station 113 covers the Hansen/Tujunga Spreading Grounds and was used as a representative weather station for the model calibration.

The actual utilized volume of the unit F-Table was also analyzed to determine the approximate utilization rate of the basin storage. Based on the results, 40% of the 5-year volume was being stored at one time. This was used to quantify the amount of storage used to develop costs estimates.

After testing multiple combinations of parameters, the modeled land type for Urban Grass Non-Irrigated very nearly matched the runoff from the 10-acre calibration model. Therefore, the new land type was given the same characteristics of Urban Grass Non-Irrigated. Although it would have yielded the same results to move the tributary area to Land Use 11, creating a new land type allows future adjustments to be made and prevents the mitigated impervious area from getting confused with actual urban pervious area within the model.

2.2. Local Solutions – Low Impact Development

2.2.1. Project Descriptions and Modeling Assumption

The Local Solutions Low Impact Development (LID) project group consists of small BMPs throughout the residential, commercial, industrial, and institutional portions of the LA Basin. Because this project group will be implemented basin wide the modeling approach used for this scenario was to change the land use breakdown globally within the model.

It is unlikely that all urban areas within the study area will implement LID completely. Instead, only a portion of the area within each land use will likely implement LID, which will vary by land use. For example, institutional land use areas will implement LID to a larger extent under current regulation than will residential areas. The ratio of implementation for each urban land use was taken from Table 4 in the Task 3.2 report (LACFCD 2013). The assumed percentages of LID implementation from Task 3 are shown in Table C-2 below.

Table C-2. Model Assumptions for Local Solutions-Low Impact Development

Land Use Code	Name	LID Ratio*
1	HD_SF_Residential	25%
2	LD_SF_Res_Moderate	20%
3	LD_SF_Res_Steep	5%
4	MF_Res	25%
5	Commercial	35%
6	Institutional	80%
7	Industrial	60%

* Assumed implementation ratios taken from Task 3.2 Report (LACFCD 2013)

Low Impact Development requires that 0.75 inches or the 85th percentile storm is captured or retained, whichever is greater (Los Angeles County 2009). The suitability of the soil, aquifer types, expected performance, and BMP size also differ depending on the location in the study area. To model this difference, two sets of assumptions were used. For the Dominguez Channel, Ballona Creek, Malibu Creek, North Santa Monica Bay, and South Santa Monica Bay watersheds, a rainfall depth of 0.75 inches was used to represent the storm depth that the average BMP would capture and a drawdown time of 3 days was used consistent with NPDES requirements. For the Los Angeles River and San Gabriel River Watersheds, which contain large groundwater aquifers and good soil types, increased stormwater conservation and replenishment of the aquifer is possible. To account for this, a rainfall depth of 1.3 times the 85^{th} percentile storm, 0.96 inches, was used to represent the storm depth the average BMP would capture and a lower drawdown time of 1.5 days was used. Although the 85^{th} percentile storm and expected drawdown time varies throughout the study area, 0.75 inches and 0.97 inches were used as reasonable long-term averages throughout the basin, assuming adequate maintenance of the BMPs will be performed.

2.2.2. Detailed Methodology

To represent LID throughout the watershed, the model was modified in a manner similar to Local Stormwater Capture, which used a unit model to calibrate the land response parameters in the model. Because two different BMP sizes and drawdown times were used, two new land uses were created in the model to model these BMPs. The first modeled a generic BMP with 0.97 inches capture depth and a 1.5 day drawdown time and was used to model areas mitigated with BMPs in the Los Angeles River and San Gabriel River watersheds. The second modeled a 0.75 inch capture depth and a 3 day drawdown time and was used to model areas mitigated by BMPs within Dominguez Channel, Ballona Creek, Malibu Creek, North Santa Monica Bay, and South Santa Monica Bay watersheds. The unit models were built using F-Tables where depth area storage and discharges were set based on the BMP size. Weather Station 113 and the middle climate scenario was used as a representative weather station for the model calibration.

The water budget in the WMMS model uses a parameter called upper-zone nominal storage to model the ponded capacity of different land types, lower-zone nominal storage to model the subsurface storage capacity, and infiltration to control the rate of flow between the upper and lower- zone storage. To simulate the effect of implementing LID BMPs, the lower-zone and infiltration parameters were adjusted iteratively for both new land types so that the long term annual runoff produced from rain falling on the new land types matched the long term annual runoff generated by the F-Table BMP models.

Using the percentages from Table C-2, the land use breakdown table was adjusted to move portions of the modeled area for each urban impervious land use type into the appropriate BMP land use that simulated impervious area mitigated by LID BMPs. For example, if a subbasin in the Los Angeles River watershed had 100 acres of multi-family residential land use defined in the WMMS database, 25 acres was moved into the land use category that simulates implementation of a BMP with a 0.97 inch capture depth and 1.5 day drawdown time.

Although the model calibration was based on a single rain gauge and climate scenario, modeling BMP effects with land use parameters allows the BMPs to be distributed throughout the model and run in real time. The results are, therefore, sensitive to the location based differences in intensity and storm duration, and model the effects of the four climate projections considered.

A key feature of this modeling methodology is that it assumes LID is evenly distributed through the urban areas of the watershed. It is possible that areas with high rates of development would get a concentration of LID. However, over time LID implementation will likely even out. It is also very difficult to predict with any degree of accuracy which areas will experience high levels of development or redevelopment. This model also does not account for development of vacant areas.

2.3. Local Solutions – Complete Streets

2.3.1. Project Descriptions and Modeling Assumption

The Local Solution Complete Streets project group consists of small BMPs throughout the transportation land use portion of the LA Basin. This project group will be implemented basin wide. Therefore, the modeling approach for this scenario matched the methodology described in Section 2.2, except that transportation land types were considered.

The ratio of implementation for transportation land uses were taken from the Table 4 in the Task 3.2 Report (LACFCD). The assumed percentages of LID implementation within roads and streets from Task 3 are shown in Table C-3 below.

Table C-3. Model Assumptions for Local Solutions-Complete Streets

Land Use Code	Name	LID Ratio*
8	Transportation	65%
9	Secondary_Roads	60%

* Assumed implementation ratios taken from Task 3.2 Report (LACFCD 2013)

Similar to LID, a key feature of this modeling methodology is that it assumes LID is evenly distributed through the transportation areas of the watershed. It is possible that areas with high rates of new highway or road construction would get a concentration of LID. However, over time, it was assumed that it will likely even out. This model methodology also does not account for new roads.

2.4. Regional Solutions – Regional Stormwater Capture

2.4.1. Project Descriptions and Modeling Assumption

The Regional Solutions Regional Stormwater Capture project group consists of increasing recharge at existing spreading grounds as well as creating new spreading grounds. During Task 4, many of the basins were remodeled within WMMS to better reflect the actual design and operation of each basin (Reclamation 2014). Modeling methodologies for both the enhanced and new basins were modeled based on the methodology in Task 4.

For existing basins, the recharge rates used in the Task 4 remodel were increased to account for enhanced maintenance and operations. Of the 25 existing spreading grounds analyzed in Task 4, 10 were identified as candidates for increased maintenance to enhance recharge capacity based on Group 1 and Group 3 basins from the 2003 Percolation Optimization Study (MWH 2003). The remaining nine basins were determined to be infeasible to enhance because the depths do not allow for complete drainage. For each enhanced basin, the recharge capacity specified within the spreading ground F-Table in the baseline model was increased by 20 percent.

New spreading grounds were also added to the model as part of the project group. Possible locations for several new spreading grounds were identified in the project evaluation stage. These basins were added to the model using reasonable estimates of available acreage, volume, and recharge rate.

To identify additional recharge opportunity beyond the specific projects identified, a GIS analysis was performed using aquifer confinement, soil type, and proximity to the main channel as screening criteria. This analysis resulted in a large number of potential locations which were then screened on a site-by-site basis using professional judgment. The exercise focused on the San Fernando Valley because that area is underutilized for ground water recharge. The remaining locations were then grouped and modeled as three basins within the LA River Watershed.

Regardless of how the basin was identified, each spreading ground was modeled following the method described in Task 4 (LACFCD 2013). Figure C-3 shows the location of existing, enhanced, and new spreading grounds.

2.4.2. Detailed Methodology

The first step for modeling potential recharge basins was to identify candidate acreages. For new basins without pre-defined locations, areas were measured from aerial images to estimate the size of each new basin. For new basins without pre-defined locations or projects, a GIS analysis was performed. To identify potential projects, the following criteria were used.

- Areas with unconfined groundwater basins
- Areas with a HSG of A or B (permeable soils)
- Areas within 1 mile of a major channel
- Areas without major structures

This analysis was used to identify the Bull Creek Area, Browns Creek Area and LA Forebay Area Spreading Grounds. These basins consist of several open parcels although they are placed in the model as one area. These projects would therefore require additional infrastructure improvements.

For each new basin, the estimated available parcel size was taken and reduced by 0.7 for normal areas and 0.6 for gravel pits. These ratios between gross area and wetted area are consistent with the county's existing basins (Los Angeles County GIS Data Portal 2005) and accounts for access roads, side slopes, and recreation trails. The wetted area was further reduced by 10 percent to account for constructing wetlands or habitat areas with these projects to provide possible water quality treatment and habitat benefits. To estimate the available volume within new basins, a depth of 10 feet was assumed for most new basins. The depth of 10 feet is within the range of depths of existing and planned basins. For new basins within existing gravel pits, a depth of 20 feet was used to account for the increased storage available in these types of basins.

Using the wetted area, depth, and assuming a reasonable percolation rate, F-Tables were developed for each new recharge basin. Percolation rates for most basins were calculated using an assumed drawdown capacity of 1 foot/day. For Miller Pit and United Rock Pit No. 3, the values were based on the Upper San Gabriel Valley Water District Integrated resource Management Plan (CDM SMITH 2013). For the addition of wetted area to the Hansen/Tujunga spreading grounds, the assumed rate was 3.25 feet/day based on the gravelly soils present in this area.

New basins will receive water that is diverted off of the main channel for recharge. For most basins, diversion structures were modeled by copying and adjusting similarly situated and sized existing basins. For the three new basins identified using the GIS analysis, the diversion flow was assumed to be about four times the percolation rate. In general, the diversion structure is much larger than the recharge rate. This is done so more of the peak flows can be diverted and stored in the basin.

The actual model methodology followed Task 4 and matched the way most of the existing basins are modeled. The diversion point is defined in an F-Table which splits flows between downstream and the basin forebay. A second F-Table defined the recharge rate and was designed to bypass excess flow if the basin is full. The bypass works using a third dummy node that uses a point source with drawl and a very high flow rate to almost instantly send the water back into the main channel. This has the effect of closing the basin when it is full which is how the basins will likely be operated if built.

In addition to the new spreading grounds and enhanced maintenance of existing spreading grounds, the model was also updated to include planned modifications to existing spreading grounds. Using the data provided by the Los Angeles County Department of Public Works Water Resources Division (WRD), the volume, percolation, and/or intake values were adjusted in the model. Table C-4 lists the data provided by the county. Because the modeled volumes, percolation rates, and intake rates were calibrated in the model in the Task 4 effort to better match historic volumes and improve model accuracy, the source values provided in Table C-4 were used to proportionally change the calibrated model values. Table C-5 lists the adjusted values used in the model. Three additional pipeline bypass projects were included in the projects provided by the county but were difficult to model in WMMS because they involve pumping water into spread grounds under very specific operational conditions. To resolve this, the results were adjusted in a post processing step using conservation estimates for these three projects provide by LACDPW.

- Peck Road Spreading Basin Pump Station and Pipeline - Estimated Recharge 1,800 AF/Y
- Bull Creek Channel Diversion System to Pacoima Spreading Grounds - Estimated Recharge 2,000 AF/Y
- Devils Gate Bypass Pipeline to Eaton Wash Spreading Grounds - Estimated Recharge- 1,850 AF/Y

For comparison purposes, the historic recharge volume, Task 4 Mid 2 Projected Scenario and Task 5 Mid 2 Projected Scenario recharge results are provided in Table C-6. The difference between the Task 4 and Task 5 results represent the combined effect of all the new basins, expanded basins, and planned projects.

Table C-4. Planned Spreading Ground Improvements - Source Values

Spreading Grounds/ Basin	Storage Capacity (AF)		Percolation Rate (cfs)		Maximum Intake (cfs)	
	Existing	Future (After WRD Planned Modifications)	Existing	Future (After WRD Planned Modifications)	Existing	Future (After WRD Planned Modifications)
Big Dalton Spreading Grounds	12	37	12	-	45	90
Branford Spreading Basin	137	141	1	> 1	1,540	-
Dominguez Gap Spreading Grounds	234	277	1	7	5	15
Eaton Wash Spreading Grounds	525	575	10	-	200	285
Live Oak Spreading Grounds	12	41	13	-	15	20
Lopez Spreading Grounds	25	73	10	-	25	-
Pacoima Spreading Grounds	440	1,197	65	142	600	-
Rio Hondo Coastal Basin Spreading Grounds	3,694	4,644	400	-	1,950	-
Tujunga Spreading Grounds	98.7	1,035	120	-	250	450
Walnut Creek Spreading Basin	170	174	5	8	150	-

Table C-5. Planned Spreading Ground Improvements - Adjusted Values used in WMMS Model

Spreading Grounds/ Basin	Storage Capacity (AF)		Percolation Rate (cfs)		Maximum Intake (cfs)	
	Existing	Future (After WRD Planned Modifications)	Existing	Future (After WRD Planned Modifications)	Existing	Future (After WRD Planned Modifications)
Big Dalton Spreading Grounds	8	24	2	-	45	90
Branford Spreading Basin	137	141	9	18	-	-
Dominguez Gap Spreading Grounds	234	277	1	5	20	60
Eaton Wash Spreading Grounds	526	576	12	-	200	285
Live Oak Spreading Grounds	13	43	1	-	15	20
Lopez Spreading Grounds	24	70	1	-	25	-
Pacoima Spreading Grounds	531	1,445	27	58	600	-
Rio Hondo Coastal Basin Spreading Grounds	3,575	4,495	400	-	1,950	-
Tujunga Spreading Grounds*	103	1,080	139	-	462	832
Walnut Creek Spreading Basin	199	204	3	6	150	-

*Tujunga Spreading Grounds was modeled with Hanson Spreading Grounds in the model and was expanded and enhanced. The values listed represent the contribution of the planned improvement in table C-4 and differ from the actual values found in the model.

Table C-6. Historic Recharge, Task 4 and Task 5 Results – Mid 2 Climate Scenario

Facility Name	Historical Recharge (AFY)	Task 4 Baseline Mid 2 Projected Climate Scenario Recharge (AFY)[b]	Task 5 Mid 2 Projected Climate Scenario Recharge (AFY)
Ben Lomond	2,852	2,470	2,427
Big Dalton	590	599	681
Branford	604	1,194	1,476
Buena Vista and Rock Pit No. 3 Expansion[a]	321	289	1,168
Citrus	1,245	1,299	1,393
Dominguez Gap	499	495	1,948
Eaton Basin	1,284	2,306	2,247
Eaton Wash	1,418	2,471	4,530
Forbes	338	364	353
Hansen/Tujunga and New Tujunga Expansion[a]	21,627	24,173	35,731
Irwindale	10,339	12,180	11,917
Little Dalton	326	338	362
Live Oak	202	189	210
Lopez	629	413	459
Pacoima	6,945	4,631	8,910
Peck Road	8,110	11,170	12,515
Rio Hondo	64,500	66,760	69,997
San Dimas	1,650	1,805	2,019
San Gabriel Canyon	12,048	11,225	11,225
San Gabriel Coastal	20,937	19,916	20,496
Santa Anita	547	357	399
Santa Fe	15,745	17,308	16,790
Sawpit	755	236	254
Sierra Madre	1,500	1,123	1,123
Walnut	1,757	1,833	2,331
Browns Creak Area Spreading Grounds	-	-	1,322
Bull Creak Area Spreading Grounds	-	-	1,382
LA Forebay Spreading Ground	-	-	4,474
New Miller Pit (Santa Fe Dam) Spreading Ground	-	-	4,384
New Sepulveda Dam Spreading Ground	-	-	4,263
New Spadra Spreading Ground (Pomona)	-	-	1,668
Total	**176,768**	**185,144**	**228,454**

[a] Existing Basin is expanded in Task 5 Model.

[b] Small adjustments were made to baseline model after the Task 4 Report was completed.

2.5. Regional Solutions – Stormwater Conveyance Systems

2.5.1. Project Descriptions and Modeling Assumption

The Regional Solution Stormwater Conveyance Systems project group consists of adding channel infiltration within tributaries that are currently concrete lined. This could be accomplished through channel side-ponds where space permits and using in-channel infiltration strips with small berms where space is limited.

To model this alternative, LA County GIS data was used to list all of the concrete lined tributaries within the LA Basin. The tributaries were then screened based on width using aerial photographs of the county. The tributaries identified as candidates for in-channel infiltration are shown in Figure C-4 and listed in Table C-7 below. Table C-7 also lists the width and total length modeled and the breakdown between channel side-ponds and in channel infiltration.

Table C-7. Modeling Assumptions for Regional Solutions-Stormwater Conveyance

Tributary	Modeled Width[a]	Length	% Side Ponds[b]
Aliso Creek	50	15447.6	0.40
Arroyo Seco Channel	50	30278.0	0.05
Bell Creek	50	4590.0	0.00
Browns Creek	50	30032.5	0.05
Bull Creek	60	8034.2	0.01
Burbank Western System	50	3132.1	0.00
Tujunga Wash	70	34987.6	0.00
Verdugo Wash	80	22663.8	0.05
Alhambra Wash	50	2707.2	0.05
Big Dalton Wash	60	16162.4	0.05
Eaton Wash	50	10882.2	0.05
Rio Hondo	75	22320.9	0.05
Rubio Wash	50	11638.4	0.05
San Jose Creek	70	64071.5	0.05
Walnut Creek Channel	50	24415.4	0.05

[a] Width measure from aerial imagery
[b] Ratio of Side Ponds to Total Length

Recharge in the LA River was considered, but given the land constraints and flooding concerns, it was not included in the model. For the San Gabriel River, most of the area within the unconfined ground water basins are already unlined, and therefore, was not included.

2.5.2. Detailed Methodology

For in-channel infiltration strips, a hydraulic analyses was performed assuming a 50-foot-wide channel with 20-foot maintenance easements on either side. It was determined that if the channel was widened to remove the maintenance road on one side, a 25-foot wide gravel strip could be constructed without reducing capacity. This was used as the basis for determining the available wetted area for each channel segment.

In order to slow down low-flows and store water for infiltration, small berms were assumed at 400 feet intervals within portions of in-channel infiltration. The berm size used was a 2-foot-high, 5-foot-wide berm with 3:1 side slopes installed the width of the channel.

For channel side ponds, a 30-foot-wide, 4-foot-deep channel was assumed. Accounting for roads and trails, it was estimated that 74 feet or new right-of-way would need to be purchased. Therefore, this option was limited for most channels.

Using the candidate channels identified, F-Tables were developed form each sub-watershed that the tributary crossed. Within each F-Table, one discharge was for the downstream flow and the second represented the recharge rate. For downstream channel flow, Manning’s equation for rectangular channels using a width measured from GIS, a slope of 0.005, and a Manning’s roughness of 0.02 was assumed. A roughness of 0.02 represents an average between concrete and earthen channel surfaces. Depths were assumed to vary between 0 feet and 10 feet. These assumption are consistent with the current channel model defined in WMMS. The F-Table volume values were further adjusted to account for the volume in side channel ponds and the volume stored behind the in-channel berms.

For recharge capacity, the assumed recharge rate was based on wetted area and an assumed soil drawdown capacity. To estimate the drawdown time, it was assumed that a distributed in-channel infiltration area would perform at about half the rate of a maintained in-channel spreading ground. Using published data from LACDPW for the San Gabriel Costal Spreading Grounds, a drawdown capacity of 3-inches/day was used (WRD 2015).

2.6. Regional Solutions – Alternative Capture

2.6.1. Project Descriptions and Modeling Assumption

The alternative capture project concept consists of recharging channel flows within a shallow ground water basin and the extracting and injecting treated water into deeper aquifers. Although functionally different than a recharge basin, it acts in a similar way from a modeling standpoint. To model this alternative, an F-Table was developed and placed in the model on the LA River. Figure C-5 shows the conceptual location along the LA River for this project.

2.6.2. Detailed Methodology

To model the effects of the Alternative Capture project, an F-Table was developed. Based on the way the project will likely be operated, it was not necessary to set up the forebay, recharge, and bypass dummy nodes that were used to model the spreading grounds in the regional capture option. Instead, the F-Table was developed with two discharges. One discharge represented the downstream flow and the second discharge represented the injection capacity.

Subbasin 6353 was selected to model the Alternative Capture Project. Based on a length of 8,600 feet and a width of 400 feet, an area of 79 acres was calculated for the area column in the design F-Table. The volume column was calculated using varying depths and the area and assumed a rectangular prism. For the downstream discharge, Manning's equation for a rectangular channel was used. Consistent with the LSPC reach model, the value of $n = 0.02$ and $S = 0.005$ were used along with width and depth to create a reasonable discharge table for the downstream flow.

For the injection capacity, it was assumed that injection would only occur when there was a minimum base flow of 150 cubic feet per second (cfs) in the channel. Therefore, when the downstream discharge is 150 cfs, the injection capacity was set to 0.0 cfs and when the downstream discharge is 200 cfs the injection was set to 50 cfs. For discharge between 150 and 200 cfs, the model interpolates between 0.0 and 50 cfs.

2.7. Storage Solutions – LACFCD Dams

2.7.1. Project Descriptions and Modeling Assumption

The LACFCD Dams project group consists of development of structural and nonstructural concepts for major LACFCD dams and assessment of those concepts. The LACFCD Dams project group is comprised of enhancing spillway controls for improved stormwater storage. Concepts include installing operable weirs (e.g., pneumatic gates) and/or gates at the spillway(s) of each dam to allow stormwater to be captured at elevations above the spillway crest.

In Task 4, fourteen (14) major LACFCD dams were modeled and analyzed for climate projections. The results of these analyses were used to assign each of the dams to one of three Performance Levels, which indicated the level of efficiency at which each facility captures stormwater and its resilience to the climate projections.

Task 5 includes developing structural concepts for management of stormwater at major dams under projected future conditions, building upon the analyses and rankings performed in Task 4. Therefore, the results of the Task 4 analyses were reviewed and a statistical analysis was performed to facilitate selection of appropriate criteria for design of potential structural modifications to dams.

2.7.2. Detailed Methodology

Review of Task 4 Analysis Results – LACFCD Dams. In Task 4, three (3) of the 14 major LACFCD dams were identified as Performance Level III, which indicates frequent spillway events in the most extreme climate projections along with low projected capture efficiencies. These dams were considered to have the highest potential for enhancements. Eight (8) of the LACFCD dams were identified as Performance Level II, which indicates somewhat frequent spillway events and somewhat higher capture efficiencies. These dams have a moderate potential for future enhancements. The remaining three (3) LACFCD dams were identified as Performance Level I, which indicates high projected capture efficiencies and low frequencies of spillway events.

The analysis indicated that, though certain facilities may have performed at high efficiency levels under the historical period conditions, increased stormwater runoff under certain climate projections may reduce the overall efficiency of those facilities. For this reason, even the dams identified as Performance Level I were identified in Task 4 as having some potential for future enhancements.

In Task 5, the results of the Task 4 analysis were reviewed and further analyzed for each of the 11 LACFCD dams identified as Performance Levels II or III (i.e., the dams with moderate potential and high potential). All of the Spillway Events for each dam were tallied for each of the six Task 4 projected climate scenarios and sorted by volume of stormwater released. The data was reviewed and analyzed for each dam and each scenario in an effort to identify patterns or trends with a goal of selecting criteria for design of potential structural modifications to the dams to improve the capture and storage of stormwater.

Statistical Analysis of Task 4 Results – LACFCD Dams. A statistical analysis was performed to facilitate the selection of appropriate design criteria for the potential structural modifications to the eleven Performance Level II and III dams. A Log-Pearson III distribution analysis was used to assess Peak Annual Spillway Discharge Volumes during the future period of the study for each of these eleven dams. The results of the hydrologic analyses performed in Task 4 were sorted to identify the discharge volume associated with the largest Spillway Event for each dam for each year of the six projected climate scenarios used in Task 4.

These Log-Pearson III distribution analyses results produced a distinct Peak Annual Spillway Discharge Volume curve for each dam for each projected climate scenario depicting the relationship between Peak Annual Spillway Discharge Volumes and return period. These curves were used to identify the approximate return period for specific discharge volumes.

The Peak Annual Spillway Discharge Volume curves suggested that a reservoir capable of capturing the volume associated with a return period of 2 years would experience very small numbers of Spillway Events and similarly small Spillway

Discharge Volumes. Therefore, the volume associated with a return period of 2 years was selected as the target design criterion for potential structural modifications.

Selection of Design Criteria for Structural Concepts – LACFCD Dams. To improve the future reliability, efficiency, and effectiveness of the LACFCD system's capture of stormwater under future climatic conditions, the design of any potential structural modifications must be sufficiently robust to respond to the entire range of the potential future scenarios.

As economical design requires a selection of specific criteria for projects, designs for the dams must be based on a range of conditions that could be reasonably expected to occur at a facility. For example, structural modifications to a dam based on the wettest projected climate scenario would provide far more storage capacity than could ever be fully utilized if the actual future climate more closely matched the driest climate projection. Similarly, structural modifications based on the driest climate scenarios would not have enough storage capacity to capture the full potential water supply if the actual future climate conditions more closely matched the wettest climate projection. Therefore, the scenarios that represent the mid-range tendencies are the most appropriate basis for a design that would be most responsive to the range of projected conditions.

Similar to Task 4, another review of key metrics for each dam was used in Task 5 to identify which mid-range scenario should guide the design. Five key hydrologic metrics for each dam were used to assess the Mid 1 and Mid 2 scenarios:

- Mean Annual Number of Spillway Events during the 84-year future period (referred to in this report as "Frequency of Spillway Events" or "Mean Annual Frequency of Spillway Events")
- Number of years with Spillway Events during the 84-year future period
- Mean of Annual Peak Spillway Discharge Volumes for the 84-year future period
- 50^{th} Percentile of Annual Peak Spillway Discharge Volume for the 84-year future period
- Peak Spillway Discharge Volume with Return Period of 2 years

The value for each of these metrics for each mid-range scenario was compared with the mean for all six scenarios and the 50^{th} percentile of all six scenarios. The deviation was identified for each and tallied. The results for the Mid 2 scenario correlated more closely with the mean and the 50^{th} percentile than did those of the Mid 1 scenario. Therefore, the Mid 2 scenario was selected as the projected climate scenario design criterion for potential structural modifications.

For the structural LACFCD dam concepts, only ten of the County owned dams were assessed. In Task 4, three facilities that were already performing very efficiently were ranked Performance Level I. These Performance Level I facilities are Puddingstone Dam, Live Oak Dam, and Thompson Creek Dam. Review of the Task 4 results also revealed that capture and storage of stormwater at Big Dalton Dam during the future period of the study was similar to the three Performance Level I dams. The percentages of stormwater captured and stored at all four of these facilities were high and the projected number of Spillway Events and the number of years during which those Spillway Events occur were very low, indicating little potential for improved stormwater capture at these facilities. The total volume of additional stormwater that could potentially be captured by these four dams is essentially a negligible volume – it represents *only* 0.05 percent of the volume that could potentially be captured by the other ten dams. Therefore, Big Dalton Dam and the three Performance Level I dams were not assessed further for potential structural modifications.

Pacoima Dam is noteworthy in that it also had smaller projected numbers of years during which Spillway Events occur than most other LACFCD dams (less than one-third of the 84 years of the future period for most scenarios). However, other conditions at this dam are somewhat more favorable for increased capture of stormwater runoff. Therefore, Pacoima Dam was included among the LACFCD dams for which potential structural modifications were developed and analyzed.

As discussed previously in this section, the volume associated with a return period of 2 years was selected as a target design criterion for potential structural modifications. For each of the ten assessed LACFCD dams, the volume associated with a return period of 2 years for the Mid 2 scenario (or target design volume) was compared with the maximum volume of storage available in the reservoir above the crest elevation of the spillway (or available additional storage). For two of the dams (Devil’s Gate and Pacoima), the target design volume is less than the available additional storage and the return period is 2.0 years. For the other eight dams, the target design volume is greater than the available additional storage and the return periods range from less than 1.0 year to approximately 1.7 years (Table C-8).

Table C-8. Structural Concept Spillway Event Return Periods – LACFCD Dams

Dam Name	Approximate Return Period (years)*
Big Tujunga	< 1.0
Cogswell	1.3
Devil’s Gate	2.0
Eaton Wash	1.7
Morris	< 1.0
Pacoima	2.0
Puddingstone Diversion	1.5
Santa Anita	1.1
San Dimas	1.4
San Gabriel	1.0

Dam Name	Approximate Return Period (years)*

* Return period of the spillway event with discharge volume equal to or greater than the potential storage volume in the reservoir above the Spillway Crest Elevation.

Structural Concepts – LACFCD Dams. The selected design criteria were used to develop structural concepts for the ten LACFCD dams. These structural concepts were developed to enable these dams to capture the maximum volume of stormwater runoff. Operable weirs (pneumatic gates) and/or slide gates would be installed at the spillway(s) of each dam to allow stormwater to be captured at elevations above the spillway crest. During most runoff events that cause the reservoir level to rise above the spillway crest elevation, the operable weirs and/or gates would remain closed. However, in order to maintain the flood control function of the dams, for runoff events during which a rising reservoir level could reach the dam high water elevation, the operable weirs and/or gates could be opened, allowing the facilities to function as mandated for flood control. These changes could affect (and in some cases could increase) the peak rate of flow over a spillway for a particular storm event for the climate scenarios analyzed over the rate that would have otherwise occurred. The structural concepts involve only operable facilities; and operating guidelines for the dams could be developed to ensure that the flood control function of the dams would not be affected. Water stored within flood risk management pool elevations for water conservation is subject to operational releases to the ocean, at any time, if storage capacity within the reservoir is required for flood operations. The capability of the dams to pass the flows of their respective PMF would not be affected. As in Task 4, the PMF flow rate was not exceeded for any of the projected climate scenarios.
Santa Anita Dam was recently modified to allow uncontrolled releases when reservoir elevation is above the seismically safe water elevation. The Task 5 structural concept for Santa Anita Dam does not account for seismic constraints. Buttressing the dam would be necessary to address the seismic issues and allow the structural concept to be implemented in order to store water. Therefore, the structural concept for Santa Anita Dam is excluded from subsequent discussions in this report of structural concepts for the other nine dams. However, the structural concept for Santa Anita Dam is addressed in Appendix E.

Modeling Approach. As in Task 4, the updated WMMS model was used to produce inflow and discharge hydrographs and the volume of stormwater runoff stored at each of the dams for the four Task 5 projected climate scenarios. The analysis of the WMMS results for these structural concepts used the same methodology and the same key stormwater metrics used in Task 4:

- Mean Annual Volume of Stormwater Captured or Retained
- Mean Annual Volume of Stormwater Discharged through Spillway
- Mean Annual Frequency of Spillway Events

The analysis evaluated each of these metrics for each structural concept for each of the four scenarios. For these structural concepts, Spillway Events refer to time periods during which the water surface elevation behind a dam was at or above the spillway crest elevation and the operable spillway weir or gate would be opened. The peak flow rates from all projections were also checked to determine if flows were within the maximum rated discharge capacity of the dams. As in Task 4, the PMF flow rate was not exceeded for any of the dams for any of the climate projections.

Metrics used in Task 4 to rank the dams include the following:

- Average Capture Volume
- Average Spillway Volume
- Capture Efficiency
- Change in Capture Efficiency
- Frequency of Spillway Events

These facility response data were used in Task 5 to assess the performance of the structural concepts. The change of these facility response data from Task 4 for the existing facilities to the respective structural concept was then compiled and analyzed for the four climate projections. The results of these analyses are summarized in the next section.

Development of Nonstructural Concepts – LACFCD Dams. Task 5 includes developing nonstructural concepts for management of stormwater at major dams under future conditions, building upon the analyses performed in Task 4.

For the LACFCD dams, when reservoir stage is below spillway crest elevation, discharges are regulated using valves. The operation guidelines for the dams allow considerable flexibility in operation of the valves to regulate releases to downstream facilities. Day to day operations are influenced by field conditions including immediate and approaching weather conditions, as well as conditions at other facilities located downstream. For reservoir stages above spillway crest elevation, discharges are released through the spillway, which typically has no operational controls.

In Task 3, a generalized F-Table was developed for each of the LACFCD dams from observed historical records to characterize the relationship between the historical average dam discharges versus the reservoir water surface elevation. In Task 4, the operation guidelines and the discharge rating curves for the valves and spillways were reviewed to refine the F-Tables to correlate the actual rated discharge capacity of the valves and spillway.

In Task 5, Rulebased Simulation in Riverware was used to simulate the response of selected LACFCD dams and associated operation guidelines to the four selected climate change scenarios. The Rulebased simulations were developed to correlate releases of captured stormwater from the dams with the rated capacities of the spreading grounds or other facilities located downstream. These Rulebased simulations represent the nonstructural concepts.

The nonstructural concepts were developed with the goal of identifying potential changes to the existing operation guidelines that could facilitate increased capture of stormwater for water conservation and use. The changes might involve optimizing releases of captured stormwater, maximizing utilization of spreading grounds, and optimizing available reservoir storage capacity. Essentially, if changes to the operation guidelines could result in more aggressive release of captured stormwater to spreading grounds, within the limits of the maximum capacity of those facilities, then it may be possible to capture more stormwater for groundwater recharge and use.

Riverware Simulation of Task 4 WMMS Results – LACFCD Dams. The Performance Levels assigned to the dams in Task 4 indicate the level of efficiency at which each facility captures stormwater and its resilience to future climate projections. The flexibility of the existing operation guidelines for the dams suggested to the Study Team that opportunities for improved capture of stormwater would be limited. It was anticipated that it would be neither necessary nor desirable to develop and analyze nonstructural concepts for all of the LACFCD dams identified as Performance Levels II or III. Therefore, priorities were assigned in Task 5 to those dams to guide the Rulebased simulation efforts. To identify priorities, the results of the Task 4 analyses of the dams were reviewed as described for the structural concepts along with the Performance Level rankings.

The priorities were adjusted using institutional knowledge of the functional relationship of the dams with downstream facilities in the system. The highest priority dams were identified as follows:

1. Devil’s Gate Dam
2. Eaton Wash Dam
3. Santa Anita Dam

Rulebased simulation models were developed for these highest priority dams using the inflow hydrograph for the respective reservoir from the Task 4 WMMS results. Like the LACFCD structural concepts, the Mid 2 projected climate scenario was used to develop the models. Rules were developed and refined to mimic the operation guidelines, and discharge was set to the lesser of either the respective F-Table (the actual rated discharge capacity of the valves and spillway) or the combined rated capacity of the spreading grounds or other facilities located downstream.

As discussed previously, the Rulebased simulation models represent the nonstructural concepts and were developed in an effort to optimize releases of captured stormwater, maximize utilization of spreading grounds, and optimize available reservoir storage capacity. The Rulebased simulation models were used to create hydrographs of discharge and volumes of stormwater runoff stored for the respective dam to produce discharge and hydrographs for each dam for all four future period projections. In the case of Devil’s Gate Dam, implementation of these operational changes for increased storage would require that the future planned pipeline be constructed.

Modeling Approach. Metrics used in Task 4 to rank the dams include the following:

- Average Capture Volume
- Average Spillway Volume
- Capture Efficiency
- Change in Capture Efficiency
- Frequency of Spillway Events

As in the analyses of structural concepts, these facility response data were used in Task 5 to assess the performance of the nonstructural concepts. The change of these facility response data from Task 4 for the existing facilities to the respective nonstructural concept was then compiled and analyzed for the four future projections. The results of these analyses are summarized in Section 2.5.3.1 of the report.

2.8. Storage Solutions – USACE Dams

2.8.1. Project Descriptions and Modeling Assumption

The USACE Dams project group consists of development of the structural concept for USACE Hansen Dam and consists of the enhancing the outflow controls for improved stormwater storage. This concept includes modifying Hansen Dam to improve water conservation operations and outlet works.

In Task 4, four (4) USACE dams were modeled and analyzed for climate projections. The results of those analyses indicated full capture of all stormwater runoff. All four of these dams were assigned to Performance Level II, indicating a moderate level of efficiency of stormwater capture and a moderate potential for enhancements.

Task 5 includes developing structural concepts for management of stormwater at major dams under future conditions, building upon the analyses and rankings performed in Task 4. Review of the results of the Task 4 analyses for the four USACE dams in Task 5 suggested that these dams have a somewhat greater potential for enhancements than indicated by the Performance Level II. This finding led to a more detailed review for Hansen Dam in Task 5 to facilitate design of potential structural modifications to the dam. Due to study constraints, Hansen Dam was the only USACE dam assessed and is discussed in the following section.

It should be noted that the Task 4 analyses of the USACE dams and the re-analysis of Hansen Dam in Task 5 were assessments of the potential for capture of stormwater runoff and did not specifically address impacts to flood risk management. The main authorized purpose for the construction of USACE dams is flood risk management and not water conservation or water supply. Therefore, a more in-depth analysis evaluating all of the possible effects of increased stormwater runoff capture would need to be performed before USACE could support increased stormwater runoff capture at USACE dams

2.8.2. Detailed Methodology

Review of Task 4 Analysis Results – USACE Dams. The methodology developed in Task 4 to assess the response of existing dams and reservoirs, under both the historic and projected climate conditions, was based primarily upon the design and operation of the major LACFCD dams. For these facilities, valves are typically used to regulate discharges from the dams when the reservoir water level is below the spillway crest elevation. The operating guidelines for these dams allow considerable flexibility in regulating releases to downstream channels and spreading grounds. For the Task 4 assessment methodology, the volume of water retained or captured in the reservoirs was considered to be available for controlled release to downstream spreading grounds and thus represented available water supply. Conversely, the volume of water released from LACFCD dams during spillway events represented stormwater that was not available for water supply, as these LACFCD dam spillway flows typically surpass the intake capacity of the downstream spreading facilities and would likely flow out to the ocean.

However, when this same assessment methodology was applied to the four USACE dams, the potential for improved performance was not adequately addressed. These dams are designed and operated primarily for flood control with the goal of passing flows downstream as quickly as possible without causing adverse flood damage in the channels and communities downstream. Gated outlets at these dams allow for some control of discharges below the spillway crest elevations, and the Task 4 assessments identified very few instances among the projected climate scenarios when flows from USACE dams surpass the intake capacity of the downstream spreading facilities. However, in addition to the controllable outlets, Sepulveda and Hansen Dams also have ungated outlets that allow for discharge of stormwater impounded behind the dam. The water control plan for a USACE dam is specific to the design of the dam, which limits impoundment and allows for release of stormwater at flow rates that ensure the dam will not overtop in large events. The ungated outlets add to the rapid evacuation of captured stormwater, limiting its capture for water conservation. The temporary impoundment provided by USACE dams does not necessarily contribute to water conservation.

The ungated outlets are just above the “debris pool” elevation. The water control plan for Hansen Dam requires a debris pool to allow debris and sediment to settle out in the reservoir to prevent obstruction of the outlet works during releases from the dam. Currently, the water control plan calls for making flood risk management releases above the debris pool elevation faster than the rate of inflow to drain the pool. Incidental water conservation benefits occur within the debris pool elevations as outlet gates can be operated to accommodate the diversion capacity of downstream spreading grounds.

The discharge capacity of the ungated outlets at Hansen Dam is at times significantly greater than the rated intake capacity of the downstream spreading grounds and the volume of water captured in the Hansen Dam reservoir is not entirely available for water conservation. Hansen Dam has potential to provide improved stormwater capture.

Therefore, the analysis and performance assessment of Hansen Dam for water conservation from Task 4 was investigated further for Task 5. A discussion of additional considerations is presented in the following section.

Re-analysis of Task 4 WMMS Results – USACE Hansen Dam. The F-Table for Hansen Dam was updated to more accurately identify the portion of the volume of water captured in the reservoir and released at rates within the capacity of the downstream spreading grounds. The maximum combined intake capacity was identified for Hansen and Tujunga Spreading Grounds, located directly downstream of Hansen Dam. This maximum rate was identified as the Water Conservation Rate.

The WMMS model was re-run using the updated Hansen Dam F-Table. The analysis of the updated WMMS results used the same methodology and the same key stormwater metrics used in Task 4. Any storm event during which the rate of discharge from the dam was greater than the Water Conservation Rate was considered to be a Water Conservation Rate Exceedance in this re-analysis. The results of the original Task 4 analysis, which indicated full capture of all stormwater runoff for the Mid 2 scenario, are summarized and contrasted with the corresponding results of this re-analysis in Table C-9. These results quantify the influence of the ungated outlets at Hansen Dam on the availability of the stormwater for water supply.

Table C-9. Hansen Dam Re-analysis Results – Mid 2 Scenario

	Original Task 4 Results (Full Capture)		Results of Task 4 Re-analysis	
	Historical	Future	Historical	Future
Mean annual volume captured (ac-ft)	37,181	55,605	18,523	19,518
Mean annual Water Conservation Rate Exceedance discharge volume (ac-ft)	0	0	18,659	36,088
Capture ratio	100%	100%	49.8%	35.1%
Mean annual frequency of Water Conservation Rate Exceedance	0	0	4.12	3.36

The re-analysis results confirm that rates of release of much of the stormwater captured at Hansen Dam exceed the capacity of Hansen and Tujunga Spreading

Grounds and that this dam has significant potential for enhancement of stormwater capture efficiencies.

Development of Structural Concept – USACE Hansen Dam. Because the design and function of the USACE dams are fundamentally different from the LACFCD dams, and because of the locations of these facilities within the water conservation system, development of structural concepts for these facilities presented significant challenges. As discussed previously, limited study resources constrained the Study Team to developing a structural concept for only one USACE dam. And, as also mentioned earlier, the discharge capacity of the ungated outlets at Hansen Dam is at times significantly greater than the rated intake capacity of the Hansen and Tujunga Spreading Grounds directly downstream. So the volume of water captured in the Hansen Dam reservoir is not entirely available for water conservation; and Hansen Dam has potential to provide improved stormwater capture. Therefore, Hansen Dam was selected for development of a structural concept. The following considerations contributed to selection of Hansen Dam:

- There are no major water conservation system facilities or hydrologic features located directly between Hansen Dam and Hansen and Tujunga Spreading Grounds. Thus, discharge rates for release of captured stormwater could be assigned with reasonable confidence.

- Hansen Dam is located directly downstream of LACFCD Big Tujunga Dam with no major facilities or hydrologic features between, so the structural concept for Big Tujunga Dam could be readily adapted to Hansen Dam.

Because the hydrologic conditions at Hansen Dam closely resemble those at LACFCD Big Tujunga Dam upstream, the structural concept developed for Big Tujunga Dam was used as the template for the structural concept for Hansen Dam. Similarly, the F-Table for Big Tujunga Dam (as modified in Task 5 to address the structural concept) was used as the template for development of a new F-Table for Hansen Dam.

Like the structural concepts for LACFCD dams, the structural concept for Hansen Dam would entail both structural and nonstructural modifications. Because the design and function of Hansen Dam is fundamentally different from the LACFCD dams, the structural concept would entail more substantial modifications to existing facilities including the following:

- Addition of gates on existing ungated outlets below the spillway (possibly complemented by installation of valve outlets).

- Operation of gates (and/or valves) below the spillway to mimic the operation of the valves at LACFCD dams.

- Modification of existing spillway to increase the length from 284 feet to approximately 322 feet to offset diminished discharge capacity for flood control due to changes to operational guidelines for increased stormwater capture.

- Installation of operable weirs (e.g., pneumatic gates) and/or gates at the spillway to allow stormwater to be captured at elevations above the spillway crest.

- Any other modifications necessary to maintain the structural and seismic stability of Hansen Dam in response to storage of stormwater runoff for more prolonged periods of time.

Like the LACFCD dams, if an extreme runoff event caused the reservoir level to rise above the spillway crest elevation, the operable weirs and/or gates at the spillway would remain closed. However, for the most extreme runoff events during which a rising reservoir level could reach the dam high water elevation, the operable weirs and/or gates would be opened, allowing the facility to function as mandated for flood control. Further studies would be required to analyze potential operational changes to the dams and to evaluate potential impacts to other uses such as recreation.

Modeling Approach. The F-Table for Hansen Dam was developed by modifying the F-Table for Big Tujunga Dam, which was updated for Task 5, to represent the structural concept. For reservoir stages below the spillway crest elevation, the discharge rates for Big Tujunga Dam were distributed proportionally to account for the differences between the two dams of the depth and the volume of storage below the spillway crest. Because the height of the High Water Level above the spillway crest is approximately the same for both dams, the discharge rates for Big Tujunga Dam were unchanged and were used for the Hansen Dam F-Table for reservoir stages above the spillway crest elevation.

Like the LACFCD dams, the updated WMMS model was used to produce inflow and discharge hydrographs and the volume of stormwater runoff stored for Hansen Dam for the four climate projections. The analysis of the WMMS results for this structural concept used the same methodology and the same key stormwater metrics used in Task 4:

- Average Capture Volume
- Average Conservation Release Exceedance Volume
- Capture Efficiency
- Change in Capture Efficiency
- Frequency of Water Conservation Rate Exceedances

The change in stormwater storage capture for Hansen dam from the re-analysis of the Task 4 results is shown in Table C-9.

2.9. Storage Solutions – Debris Basins

2.9.1. Project Descriptions and Modeling Assumption

The Storage Solution Debris Basins project group consists of taking existing infrastructure used for storing debris flows and adding a stormwater storage use to them. Although these basins do not recharge groundwater themselves, this may increase recharge and at downstream spreading grounds.

To find basins beneficial for this use, a screening process was conducted. Using the LA County GIS point data of all the debris basin in the county (Los Angeles County GIS Data Portal 2010), the following criteria was used:

- Within the study area
- Upstream of a spreading ground
- Strong hydraulic connection to downstream spreading ground
- 75 percent of volume greater than 5 acre-feet (ac-ft)

After eliminating basins that did not meet the above criteria, 20 basins were identified as candidates for this project type. The 20 basins modeled are shown in Figure C-6. It was important to only include basins upstream of a spreading ground and with a strong hydraulic connection because metering flow would have no or little effect on recharge quantities where there was no hydraulic response. A strong hydraulic connection was determined on a case-by-case basis using professional judgment. Debris basins behind dams were eliminated, for example, because metering flow behind a dam would have little impact on facilities downstream of the dam outflow.

For each of the 20 debris basins identified, an F-Table was then created to meter the flow beneath the spillways over 3 days to allow the downstream spreading grounds to empty some after a large storm. Metering flow over a longer period would likely result in more recharge at downstream basins but would also cause odor and vector issues.

2.9.2. Detailed Methodology

For each debris basin modeled, an F-Table was developed using the volumes provided by LA County Department of Public Works and using reasonable assumptions about debris basin geometry and hydraulics. To determine the basin invert and basin spillway elevations, a maintenance report was used that provided 5 and 25 percent capacity elevations (LACDPW 2000). These numbers were used to estimate a reasonable invert and spillway elevation. Given the volume and estimated depths, the area for the F-Table was calculated assuming a rectangular prism. For discharges at elevations below the spillway, the discharge was set to vary linearly with depth and to drain the basin in 3 days. For discharges above the spillway, the weir flow equation was used using an assumed weir length of 30 feet and a weir coefficient of 3.5. Table C-10 below shows the volume and depth used to create the F-Table for each basin.

Table C-10. Modeled Debris Basin Volumes and Depths

Facility Name	Volume[a] (ac-ft)	Estimated Depth[b] (feet)
Little Dalton	182.5	10.3
Sawpit	77.8	22.7
Sierra Madre villa	59.8	6.5
Wilson	49.4	14.7
Sierra Madre dam	35.7	21.4
Schoolhouse	16.4	2.9
Morgan (e)	13.9	11.8
Englewild	13.8	9.2
Sombrero	11.6	16.0
West Ravine	11.3	1.1
Lincoln	11.0	11.4
Harrow	10.3	4.1
Fern (e)	10.2	16.0
Fair Oaks	9.1	7.1
Hook West (e)	7.6	6.8
Gordon (e)	7.4	10.7
Hog	7.2	6.1
Crescent Glen	6.2	8.0
Fullerton (pd2202-u2)	5.4	8.0
Lannan	5.3	8.3
Total	**551.9**	

[a] This value is the level storage volume reduced by 25 percent to account for sediment
[b] Estimated depth measured from assumed sediment surface to invert of spillway.

2.10. Management Solutions – Stormwater Policies

Management Solutions Stormwater Polices project group are non-structural management and policy measures to encourage stormwater conservation. Stormwater polices could impact both the Local Solutions, LID and Complete Streets models. Therefore those models were combined and used as the basis for this project type.

To model the stormwater conservation that this project may yield, both the depths and the implementation rates were increased above the values used in the Local Solutions models. Policies that encourage better maintenance may result in increased performance for land use types that likely have dedicated maintenance staff. To model this, the depths for institutional, commercial, industrial, and transportation were increased by 20 percent from 0.75 to 0.9 inch. A stormwater policy that offers financial incentives to implement LID in the form of feed-in-tariffs could increase the implementation rates beyond the base rates used from Task 3. This was modeled by increasing all of the implementation rates proportionally by 50 percent for base rates below 40 percent, by 25 percent for base rates below 80 percent and by 10 percent for the base rate at 80 percent. A tiered approach was used because the barriers to LID implementation will increase significantly as implementation approaches 100 percent. Table C-11 describes the specific rates used to model the project group. All other methodologies match those described above in the Local Solutions LID except that four calibrated land types were used instead of two. This was necessary because a 20% depth increase was modeled for some of the land uses. The four land types were:

- 0.97 inch capture depth, 1.5 day drawdown time (Same as LID Model)
- 0.75 inch capture depth, 3 day drawdown time (Same as LID Model)
- 1.17 inch capture depth, 1.5 day drawdown time (Enhanced Maintenance)
- 0.9 inch capture depth, 3 day drawdown time (Enhanced Maintenance)

The same calibration procedure described in Section 2.2 was used to create the additional land types for this project group.

Table C-11. Modeled Capture Depths for Management Solutions-Stormwater Policies

Land Use Code	Name	LID Ratio*
1	HD_SF_Residential	38%
2	LD_SF_Res_Moderate	30%
3	LD_SF_Res_Steep	08%
4	MF_Res	38%
5	Commercial	44%
6	Institutional	88%
7	Industrial	75%
8	Transportation	81%
9	Secondary_Roads	75%

* Assume implementation ratios taken from Task 3.2 Report (LACFCD 2013)

2.11. Management Solutions – Green Infrastructure

The Management Solutions Green Infrastructure Programs project group is a set of programs to encourage green infrastructure across the watershed. Because it is based on LID, the Local Solutions LID model was used as a base to model this project.

Many of the programs identified may reduce the time it takes to reach the implementation ratio from Task 3, but may not increase the final value. Therefore, no model changes were needed. However, programs focused on residential implementation may encourage more homeowners to willingly implement LID. Therefore, this project was modeled by increasing the base rates from Task 3 for each residential land use type to 50% implementation. The model was then modified in the same way as the base LID model Table C-12 below describes the LID ratios used to model the project group. All other methodologies match those described above in the Local Solutions LID.

Table C-12. Modeled LID Rates for Management Solutions-Green Infrastructure

Land Use Code	Name	LID Ratio*
1	HD_SF_Residential	50%
2	LD_SF_Res_Moderate	50%
3	LD_SF_Res_Steep	50%
4	MF_Res	50%
5	Commercial	35%
6	Institutional	80%
7	Industrial	60%

* Assume implementation ratios taken from Task 3.2 Report (LACFCD 2013)

2.12. Management Solutions – Regional Impact Programs

2.12.1. Project Description and Modeling Assumptions

The Management Solution Regional Impact Programs project group could encourage local capture and floodplain reclamation across the watershed. Local capture is encouraged through increased small scale infiltration projects and storm water retention in open channel facilities that receive large volumes of storm water runoff. Floodplain reclamation would be to restore the floodplain throughout the watershed.

For small scale infiltration projects throughout the watershed, the GIS analysis and land use screening performed for the Local Stormwater Capture was used for this model (Refer to Section 2.1 for details).

The post processing step for the golf courses, public projects, and Caltrans projects were also used from Sections 2.1 except that 50 percent of the parcel areas were used for recharge to account for the increased focus a regional program may have on infiltration.

For private open space, one of the programs identified as favorable was to emphasize open space as recharge. This was already modeled in Local Stormwater Capture. However, the greater focus of a special program may increase the number of projects. To model this, it was assumed that a larger portion of the identified private open space would be used. Therefore, 50 percent of the identified open space parcels were assumed to be an infiltration BMP versus 25 percent assumed in the Local Stormwater Capture model.

The remaining post processing and modeling steps followed are the same as those described in Section 2.1.

Open channel facilities floodplain reclamation improvements that are included in this program were modeled using a vegetated or earth channel lining instead of the reinforced concrete channel that is present now. Through the replacement of the channel bottom to a more permeable material, local capture of storm water could be increased.

2.12.2. Detailed Methodology

The first step in modeling the open channel facilities floodplain reclamation improvements was to perform a GIS analysis of the study area, inclusive of Dominguez Channel, Ballona Creek, Malibu Creek, Los Angeles River, and the San Gabriel River. Using the open channel data obtained from the Los Angeles County GIS Data Portal, 2010, facilities were selected using the following criteria:

- Within the defined study area
- Open Channel Facilities
- Material Type of Reinforced Concrete
- Channel width greater than 20 feet
- Excluding isolated open channels within the network

Using the provided data source, open channel facilities with a material type of reinforced concrete cement were selected within the defined study area. Isolated open channels were then manually removed from the selected open channel facilities. The channel width of the remaining Open Channel Facilities were approximated and grouped into width categories using aerial imagery and channels with a width less than 20 feet were removed. Figure C-7 shows all the channels that passed the screening and were modeled.

The final widths of the remaining channels were then scaled up by a factor of three to account for the increased roughness of the proposed channel bottom. The width factor of three was determined using hydraulic calculations to match the capacity of a widened vegetated channel to concrete lined channel with the same depth. Several sizes and depths were checked using a Manning's Roughness of 0.015 for concrete and 0.050 for a more naturalized channel lining.

Because the open channel facilities were distributed throughout the study area, two general cases were applied. The first general case included areas within permeable soils while the second general case included areas outside of permeable soils. For permeable soils of Hydrologic Soil Group (HSG) A or B, an F-table was used with a recharge rate of 0.13 cfs per acre. For impermeable soils with HSG C or D, significant infiltration is unlikely. Instead, the channel area was moved to a pervious land type within the model to account for the benefit of less impervious area. The design of the channel would likely be a terraced section with an earthen low-flow channel that could convey the typical storm with a vegetated floodway to convey the high flow events. Because of this, about half the channel section would not typically be wetted. Since recharge only occurs within the wetted area of a channel, the model results were scaled down by 50% to account for the portions of the channel that would not typically receive flow. Additionally, an assumed long term implementation ratio of 0.75 was used to scale the results to account for some areas along the river that could likely not be widened.

3. Comparison of Modeling Approaches between LA Basin Stormwater Conservation Study and LADWP Stormwater Capture Master Plan

Outlined below are some of the key differences between the Storm Water Capture Master Plan (SCMP) prepared for the City of Los Angeles and the LA Basin Stormwater Conservation Study (LA Basin Study) prepared for the Los Angeles County Department of Public Works (LACDPW).

Although many of the approaches and strategies considered in each study are similar, there were some key differences in the modeling approach and the respective study methodologies which resulted in differences in the total amount of stormwater conservation and subsequently, the cost per acre foot.

Item	SCMP Modeling and Cost Approach	LA Basin Model and Cost Approach	Significance of the Difference in Approach
1.	Stormwater Conservation quantities are calculated as a percentage of rainfall based on a unit model and rain gauge depths scaled by area (see item 5) and estimated LID rates (see item 2).	Stormwater Conservation quantities are calculated based on a calibrated loss model, land use area (see item 5), and LID rates, and is based on reduction in runoff.	The results yielded lower conservation estimates in the LA Basin model which increases the Cost /acre-foot when compared with the SCMP.
2.	Estimated future LID implementation rates and capture depths were developed and then modified based on a geophysical category A, B, or C.	Estimated future LID rates and capture depths were developed and then modified for different project groups based on the impact different policies or programs would have.	Estimated LID rates and capture depths differ between the two studies as well as the methodologies for modifying them. This results in differences in total conservation and cost.
3.	Weather data is based on the historical weather set and did not include climate change impacts. The cost range reported reflects ranges in project difficulty.	The Basin Study considered the impacts of climate change. The weather data is based on future climate projections. The cost range reflects ranges in future rainfall variability and facility performance.	The historical weather set compares with the Low 2 projected climate scenario (see Task 3 report), which is just below the middle of the range of costs noted in the LA Basin report.
4.	The study area is the City of Los Angeles and	The study area is the entire LA Basin and includes	The inclusion of other areas that are less conducive to

	includes large amounts of area that is well suited for infiltration (referred to as geophysical categories A and B in the SCMP). Based on the results, the majority of conservation comes from these high efficiency areas.	large portions of area less conducive to infiltration. While it is possible that areas less conducive to infiltration may require less mitigation to retrofit existing impervious areas, particularly in watersheds with a lower percentage of overall impervious area, the study costs were based on the same unit costs for BMP types throughout the study area.	infiltration means that the LA Basin study BMPs are on average less efficient compared to the BMPs modeled in the SCMP. This increases the overall cost/acre-foot in comparing the LA Basin Study with the SCMP.
5.	Estimated LID implementation rates (see item 2) were applied to the SCAG Land Use data to determine the amount of area over which conservation would occur.	Estimated LID implementation rates (see item 2) used were applied to the impervious urban areas based on the nine urban impervious land uses within the County LSPC model. The model has 21 land uses defined where nine are urban impervious land uses, two are urban pervious land uses, and the remaining ten are non-urban land uses. Although the entire LA Basin is part of the model, the conservation modeled represent improvements of the impervious portions of urban land uses. Future studies may wish to also include improvements of pervious areas that could increase storm water conservation.	The exclusion of urban pervious area from the LA Basin model yielded lower conservation estimates for the LA Basin model after accounting for the study area size. The different land use data sources may also yield some differences depending on how consistent the sources are with each other.
6.	Total costs were based on developing a representative BMP for a representative parcel size and then scaling up based on an assumed mix of BMP types.	Total costs were based on calculating a BMP capture volume by multiplying the assumed capture depth by the implementation area.	Depending on the details of the SCMP's cost approach, the estimated efficiency of the Unit BMP approach is likely greater on a per parcel basis than using a volume

			calculation. There is also likely a difference in efficiency on a per parcel basis depending on how the pervious area was treated.
7	Conservation estimates were derived from rainfall directly.	Conservation estimates were derived from the County LSPC model, which is a semi-distributed model with the operation of existing infrastructure included. This allowed the conservation results to be adjusted to account for the loss of volume available for recharg at the downstream spreading grounds.	Because the LA Basin Study accounted for reduced infiltration of runoff at regional facilities, the modeled conservation estimates are lower and the cost/acre-foot are higher compared to the SCMP.

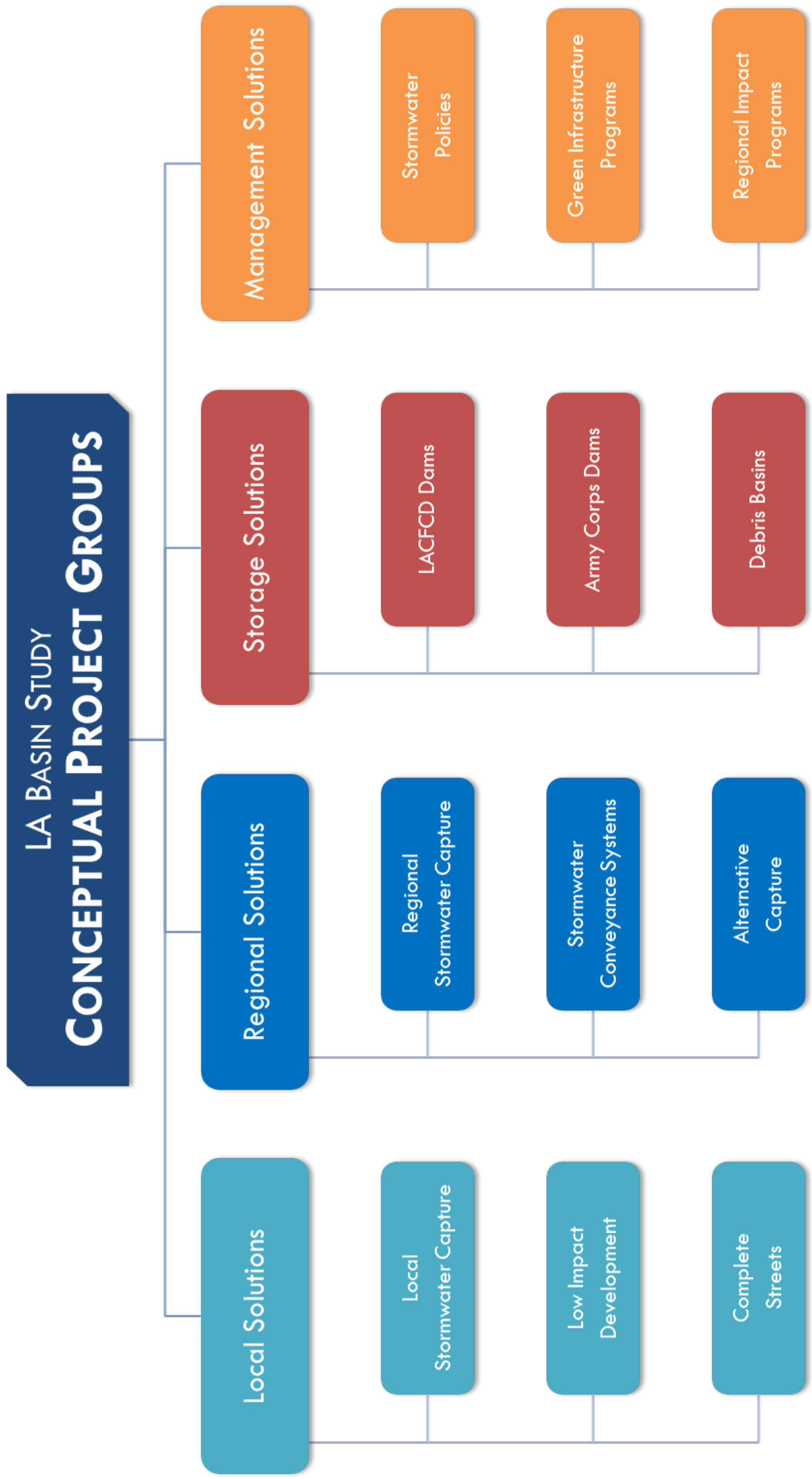

Figure C-1. Los Angeles Basin Stormwater Conservation Study Conceptual Project Groups

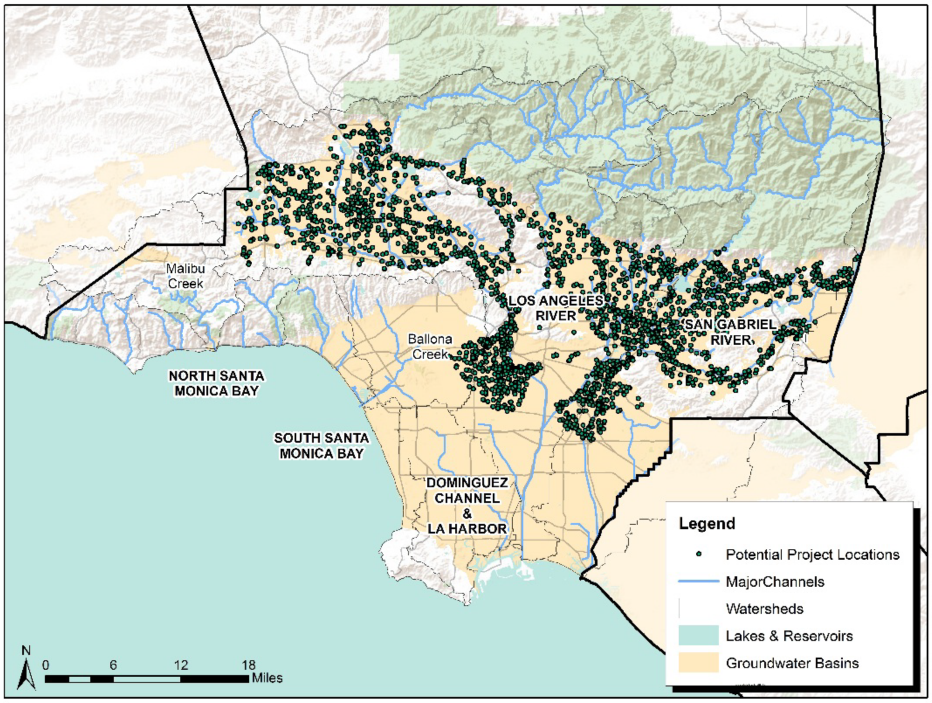

Figure C-2. Local Stormwater Potential Project Locations

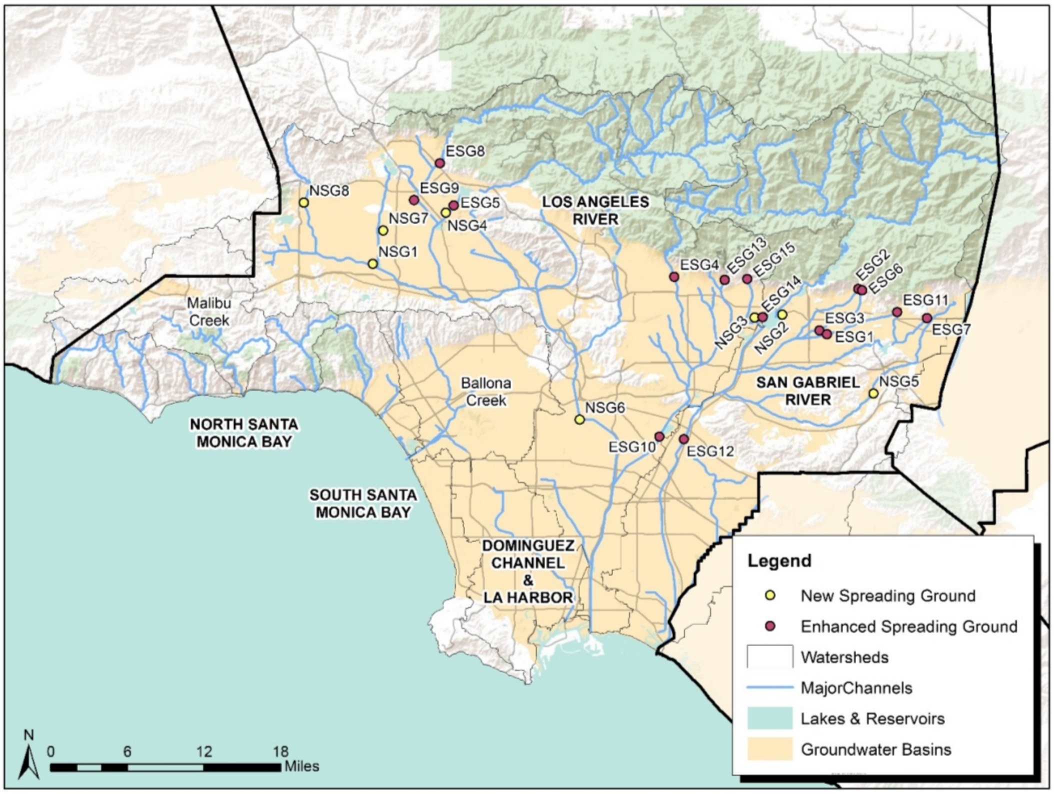

Figure C-3. Regional Stormwater Capture

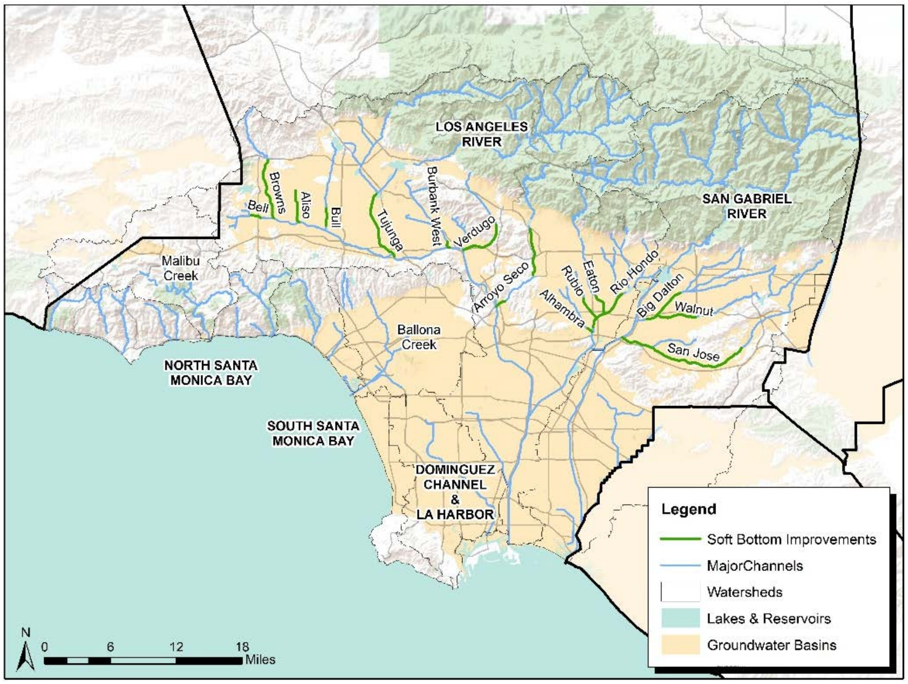

Figure C-4. Stormwater Conveyance Systems

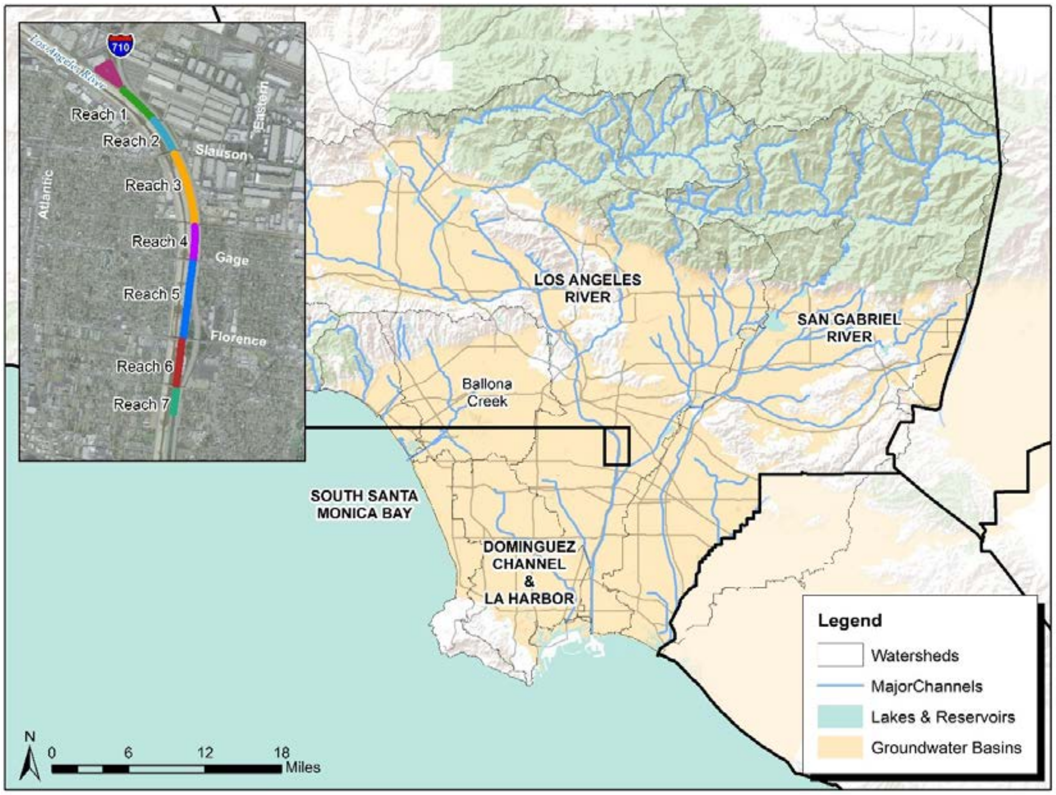

Figure C-5. Alternative Capture

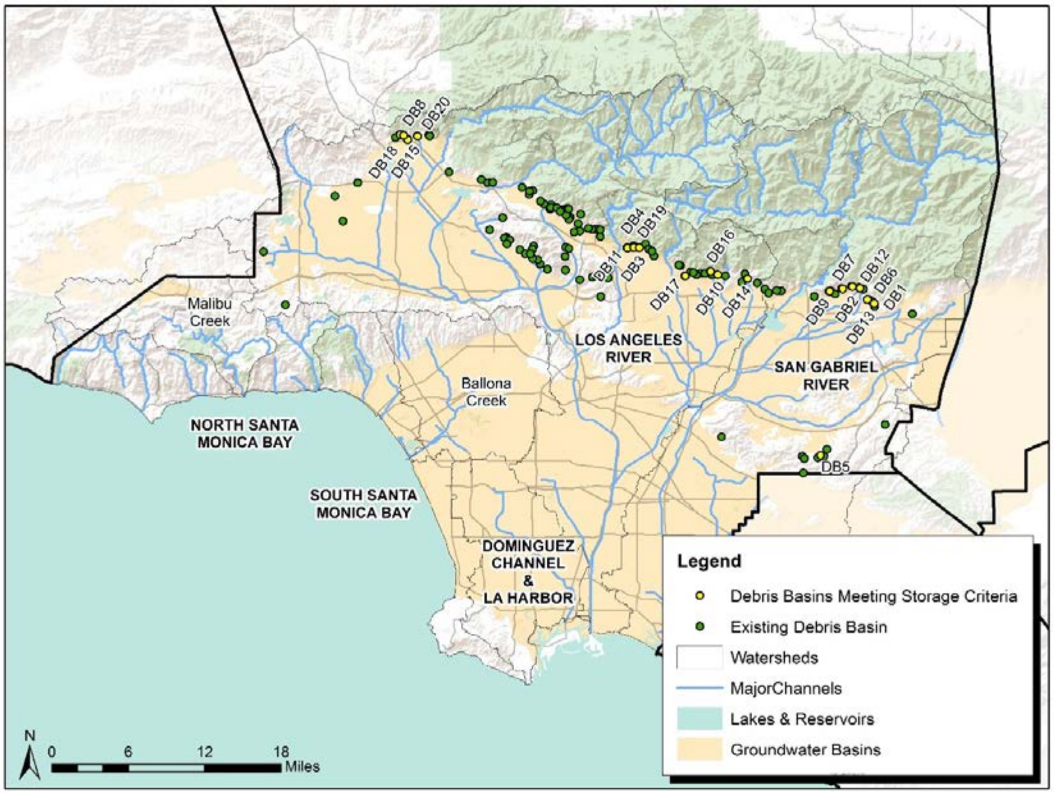

Figure C-6. Debris Basins

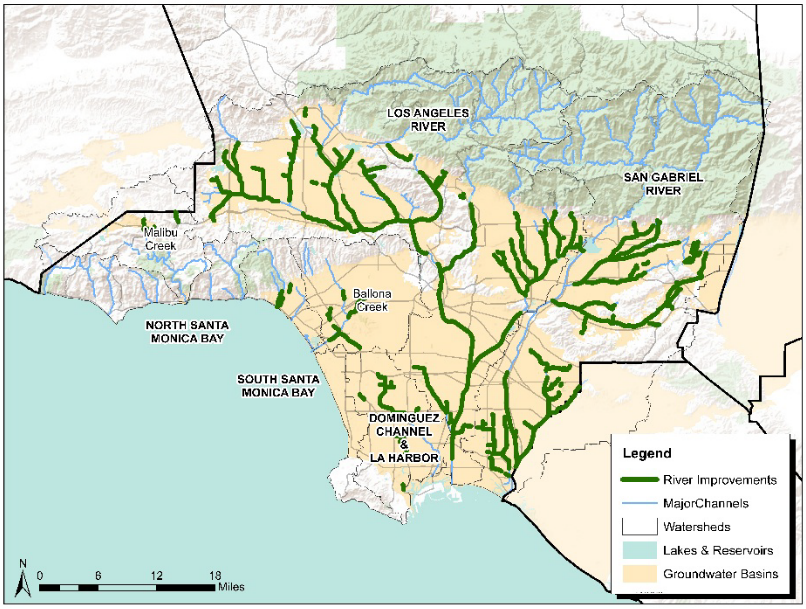

Figure C-7. Potential Open Channel Floodplain Reclamation Improvements

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