RECLAMATION

Managing Water in the West

Los Angeles Basin Stormwater Conservation Study

Task 5 Infrastructure & Operations Concepts Report

U.S. Department of the Interior
Bureau of Reclamation

County of Los Angeles
Department of Public Works

Los Angeles County
Flood Control District

October 2015

Mission Statements

The mission of the County of Los Angeles Department of Public Works is to provide public infrastructure and municipal services to protect and enrich the daily lives of over 10 million people in Los Angeles County.

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover Photo: Morris Dam along the San Gabriel River, Los Angeles County, California.

Los Angeles Basin Stormwater Conservation Study

Task 5. Infrastructure & Operations Concepts Report

October 2015

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Foothill Municipal Water District Incorporated FMWD January 7, 1952 California

Heal the Bay

Las Virgenes Municipal Water District

California Water Boards State Water Resources Control Board Regional Water Quality Control Boards

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The River Project

Three Valleys MWD

TreePeople

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Acronyms and Abbreviations

ac-ft	acre-foot (1 ac-ft = 43,560 ft^3)
AFY	acre-feet per year
BMP	Best Management Practices
cfs	cubic feet per second
DSAC	Dam Safety Action Classification
ESG	enhanced spreading ground
EWMP	Enhanced Watershed Management Plan
F-Table	Hydrologic Function Table
GIS	geographic information system
LA Basin Study	Los Angeles Basin Stormwater Conservation Study
LACDPW	Los Angeles County Department of Public Works
LACFCD	Los Angeles County Flood Control District
LID	low impact development
MWD	Metropolitan Water District of Southern California
NSG	new spreading ground
O&M	operations and maintenance
PMF	Probable Maximum Flood
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
ROW	right-of-way
STAC	Stakeholder Technical Advisory Committee
Study Team	LACFCD and Reclamation
USACE	United States Army Corps of Engineers
WMMS	Watershed Management Modeling System

Glossary

Adaptation Strategies: Strategies to increase stormwater conservation while adapting for climate change projections.

Aquitard: Layers of low permeability soil or rock that retard the vertical movement of groundwater flow.

Basin Study Watersheds (Study Area): The Los Angeles River, San Gabriel River, Ballona Creek, South Santa Monica Bay, North Santa Monica Bay, Malibu Creek, and Dominguez Channel/Los Angeles Harbor watersheds.

Biofiltration: Vegetated BMPs designed to capture and filter stormwater runoff through a soil layer. Following filtration, treated runoff exits through an underdrain to the downstream conveyance network.

Bioretention: Vegetated BMPs designed to capture and filter stormwater runoff through a soil layer. Following filtration, treated runoff infiltrates through underlying soils.

Capture Efficiency: The ratio of total recharge captured versus the total stormwater potential at a specific facility. Potential combines both what was captured and what bypassed, representing the total possible amount of stormwater moving through a facility.

Climate Projection: Climate conditions and meteorological parameters (e.g., temperature and precipitation) corresponding to a single global climate model simulation of future climate conditions under a given emissions scenario and initial condition.

Complete Streets: Transportation routes that are designed to accommodate the accessibility and convenience of all transportation users, including pedestrians, bicyclists, transit riders, and motorists. Complete streets also incorporate the key design elements of green streets, providing stormwater treatment and management.

F-Table: Hydrologic function table. Used to simulate operations guidelines for stormwater facilities and is a generalized volume versus discharge curve. Watershed Management Modeling System (WMMS) F-Tables control the discharge rate at specific volumes within the model.

Future Period: Projected water years 2012 through 2095.

Historic Hydrology: Period of historic record encompassing water years 1987 through 2000.

Historic Period: Equivalent to Historic Hydrology (used interchangeably).

Land Use: A specific use assigned to a particular land area with a known impervious surface area.

LSPC: (Loading Simulation Program in C++) Calculates and produces hydrologic output time series data for a specific set of subwatersheds and based on a specific dataset of weather files. LSPC is the hydrologic simulation program under the Watershed Management Modeling System (WMMS).

Meteorological Inputs: Observed historic records or computer-generated projections of precipitation and evapotranspiration.

Nonstructural concept: A concept that does not involve construction or physical alteration to a facility such as changes in operation or maintenance activities.

Operation Guidelines: A set of recommended instructions that provide guidance on how to efficiently and safely operate a water conservation or flood control facility based on different stream or reservoir conditions.

Probable Maximum Flood (PMF): A flooding event that results from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the region.

Projected Hydrology: Future period encompassing water years 2012 through 2095.

Rating Curve: Relationship between a reservoir water surface elevation or storage volume and the outflow or discharge from a dam.

Rulebased Simulation: Operating policies, called rules in Riverware, that contain logic for operating a modelled system based on hydrologic conditions, time of year, demands, and other considerations.

Run: Performance of a single hydrologic modeling setup using an individual climate change scenario.

Simulation: Equivalent to Run (used interchangeably).

Spillway Event: A storm event during which the reservoir water surface elevation behind a LACFCD dam is at or above the spillway crest elevation and is discharging flows.

Stormwater (Available): The amount stormwater runoff that passes out of a subwatershed which can potentially be captured within itself at upstream locations (reported in acre-feet [af]).

Stormwater (Recharge): The total amount of stormwater infiltrated within a subwatershed with contributions from all water conservation facilities (reported in acre-feet [af]).

Stormwater (Total): The total amount of stormwater within a subwatershed system. It is the sum of Recharge and Available (reported in acre-feet [af]).

Stormwater Capture (% Capture): The ratio of Recharge to Total Stormwater for the subwatershed.

Structural Concept: A concept that involves construction or physical changes to a facility.

Subwatershed: A sub-division of a larger watershed. Smallest area unit in WMMS.

Unconfined Aquifer: An aquifer that has the water table as its upper boundary.

Water Conservation Rate: The maximum combined intake capacity for spreading grounds located directly downstream of a USACE dam.

Water Conservation Rate Exceedance: A storm event during which the rate of discharge from a USACE dam is greater than the Water Conservation Rate.

Water Control Manual: USACE equivalent of dam operation guidelines.

Water Year: The 12-month period from October 1 through September 30 for any given year. Water years are written as the ending year (i.e., water year 1986-87 is written as 1987).

Watershed (Drainage Area): Surface drainage area upstream of a specified point on a watercourse. A geographical portion of the Earth's surface from which water drains or runs off to a single point.

Executive Summary

The Los Angeles County Flood Control District (LACFCD) partnered with the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) to collaborate on the Los Angeles Basin Stormwater Conservation Study (LA Basin Study). The purpose of the LA Basin Study is to investigate long-range water conservation and flood risk management impacts caused by projected changes in climate conditions and population in the Los Angeles region. The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve future water supply and flood control issues. These recommendations will be developed from the alternatives developed in Task 5 and through a trade-off analysis being conducting as part of the next and final task of the LA Basin Study.

The objective of Task 5, Infrastructure and Operations Concepts, is to identify and develop both structural and nonstructural (i.e., plans, policies, etc.) concepts to manage stormwater under projected conditions for the Los Angeles River, San Gabriel River, South Santa Monica Bay, North Santa Monica Bay, Ballona Creek, Malibu Creek, and Dominguez Channel/Los Angeles Harbor watersheds (Basin Study Watersheds). The efforts and results previously completed for Task 2 – Water Supply and Water Demand Projections, Task 3 – Downscaled Climate Change and Hydrologic Modeling, and Task 4 – Existing Infrastructure Response and Operations Guidelines Analysis serve as the basis for Task 5. The major tasks and subtasks of Task 5 include:

- Develop Concepts
  - Identify a range of opportunities and options using stakeholder input
  - Determine preliminary concepts for further evaluation
- Evaluate and Refine Concepts for Technical Analysis
  - Assess structural and nonstructural concepts pertaining to dams, spreading grounds, flood control channels, decentralized storage, infiltration, reuse facilities, debris basins, or other new concepts
  - Apply minimum stormwater conservation selection criteria
- Appraisal-Level Facility Concept Planning
  - Evaluate selected concepts for future system reliability, efficiency, and effectiveness

In addition to any new stormwater conservation concepts that are developed, the existing facilities from the Task 4 analysis were considered for enhancement.

The Watershed Management Modeling System (WMMS), which was used for the historic and projected hydrologic modeling for Task 4, was also used for Task 5. Hydrologic simulations were conducted for the LA Basin Study with the purpose of analyzing the potential impacts that climate change may have on stormwater conservation and flood flows. WMMS used observed meteorological inputs to produce the simulated Historic Hydrology for water years 1987 through 2000. For the future period of water years 2012 through 2095, four climate projection scenarios (Low 1, Low 2, Mid 2, and High 1) from the Task 4 analysis were modeled in WMMS.

Concept Development

Concept development consisted of identifying and developing various stormwater capture options, including enhancements to the existing water conservation and flood risk management system, in a collaborative manner with stakeholders and the public. The concepts developed include both structural and nonstructural concepts in response to identifying various adaptation strategies to extend water supply and address impacts from climate change.

The LACFCD and Reclamation (Study Team) hosted two charrettes to solicit stormwater capture concepts for potential projects. The charrettes were held in November 2014 in downtown Los Angeles. The first charrette included attendees from the LA Basin Study's Stakeholder Technical Advisory Committee (STAC) and the second charrette welcomed members of the public. The STAC and public identified a wide-range and comprehensive list of stormwater capture concepts. Additionally, the Study Team reached out to other LACFCD staff to gather potential concepts. After the charrettes and internal outreach efforts, nearly 500 stormwater capture concepts were collected. After a screening process, 126 of the concepts were targeted for more detailed evaluations based on their potential to enhance stormwater capture.

Technical Analysis of Concepts

As part of the technical analysis, the 126 concepts were subdivided into three separate categories based on the characteristics and scale of each concept:

- **Centralized Projects –** Structural concepts related to large recharge and storage solutions (e.g., recharge basins, dams, channels, and debris basins)

- **Decentralized Projects & Distributed Programs –** Structural and nonstructural concepts related to smaller distributed recharge or direct use solutions (e.g., sub-regional infiltration, green streets, and cisterns)

- **Plans, Policies, & Partnerships –** Nonstructural concepts that incentivize or facilitate stormwater conservation

After separate scoring criteria were developed for each category based upon input from the STAC, the concepts were then scored and ranked to identify favorable concepts that could be incorporated into projects for appraisal-level analysis.

The technical criteria for Centralized Projects included the expected stormwater conservation benefit, expected unit cost of stormwater conserved, multiple benefits and partnerships, property ownership, and implementability. Additional factors for Decentralized Projects & Distributed Programs included opportunity application area and legal/institutional challenges. Additional factors for Plans, Policies, & Partnerships included expected enhancement in stormwater conservation benefit and innovation. For all categories, the greatest emphasis was assigned to the stormwater conservation benefit, unit cost of stormwater conserved, and multiple benefits categories to reflect the importance of these factors.

Appraisal-Level Analysis

During the appraisal-level analysis the 126 concepts were further investigated and alternative features of the highest scoring concepts were compared and combined to develop a final set of 12 project groups (see Figure ES-1). An appraisal-level evaluation was then performed to aid in selecting the most beneficial concepts. Each project group was categorized in one of the four main project categories shown below:

- **Local Solutions –** Decentralized projects distributed across the watershed that promote infiltration via stormwater best management practices (BMPs).
- **Regional Solutions –** Centralized projects that provide for additional infiltration via existing and new spreading grounds and channel modifications.
- **Storage Solutions –** Centralized projects that provide additional storage via modifications to the existing LACFCD and U.S. Army Corps of Engineers (USACE) dams and at the LACFCD debris basins.
- **Management Solutions –** Plans, programs, and policies that promote increased infiltration by providing incentives to implement the Local, Regional and Storage solutions sooner.

Each of the 12 project groups within the four project categories is discussed in the following section.

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

Local Solutions

The Local Solutions category is comprised of three project groups:

- **Local Stormwater Capture –** This project group consists of facilities that receive large volumes of runoff from upstream areas for infiltration and stormwater retention. Local stormwater capture facilities may be in the form of surface infiltration basins or underground infiltration chambers. The Local Stormwater Capture project group is comprised of the following elements:
    - Infiltration at parks and schools
    - New park space for infiltration
    - Golf course stormwater improvements for infiltration
    - Infiltration in Caltrans right-of-ways
    - Underground infiltration chambers (sub-regional infiltration)
    - Recapture of right-of-ways for stormwater capture
- **Low Impact Development –** Low impact development (LID) concepts are distributed structural BMPs that capture and infiltrate runoff close to the source, at the parcel scale. LID BMPs include bioretention, permeable pavement, and other infiltration BMPs. The LID project group is comprised of the following elements:
    - Distributed BMPs upstream of lower efficiency spreading grounds
    - "Urban acupuncture" (many small projects over the basin)
    - Rain gardens
    - Parking lot storage and connectivity
    - Green roofs
- **Complete Streets –** Complete Streets ensure the safety, accessibility, and convenience of all transportation users such as pedestrians, bicyclists, transit riders, and motorists. Complete Streets promote the treatment and management of onsite retention, filtration, and infiltration. These BMPs are typically implemented as linear bioretention/biofiltration BMPs. The Complete Streets project group is comprised of the following elements:
    - Green street stream tributaries upstream of waterways
    - Prioritized green streets based upon capture potential
    - Use parkways and road medians to capture stormwater
    - Multiple green infrastructure strategies
    - Under street infiltration using underground infiltration galleries

Regional Solutions

The Regional Solutions category is comprised of the following project groups:

- **Regional Stormwater Capture –** The concepts related to the construction of new spreading basins and enhancement of existing basins scored highly during the concept development phase. Accordingly, the Regional Stormwater Capture project group assumes the construction of new spreading grounds and enhanced maintenance of existing spreading grounds to increase groundwater recharge.

- **Stormwater Conveyance Systems –** This project group includes potential stormwater conservation from a suite of channel modification concepts. A preliminary screening of areas favorable for converting portions of concrete channels to soft bottom channels, focusing on tributary reaches overlying unconfined groundwater basins, was performed. Two approaches were evaluated to enhance short-term stormwater detention within existing or converted soft bottom channels areas: "River speed bumps," which are small in-channel earthen detention structures, and channel side ponds where easements are wide enough or land appears available for their installation.

- **Alternative Capture –** This project consists of groundwater recharge adjacent to the Los Angeles River in the Central Basin. Due to limited land availability in the Los Angles Forebay area for spreading basins, the Water Replenishment District of Southern California Groundwater Basin Master Plan identified a concept where flows would be diverted from the Los Angeles River and conveyed to shallow recharge ponds for soil aquifer treatment constructed along power line easements (CH2M HILL, 2012). Because the area has limited potential for direct recharge, shallow extraction wells along the perimeter of the basins would extract the treated groundwater, which would then be injected into the production aquifer.

Storage Solutions

Storage Solutions include modification or reoperation of existing USACE and LACFCD dams and debris basins to enhance surface storage, which would eventually be released to downstream spreading basins to recharge groundwater. The Storage Solutions category consist of three project groups:

- **LACFCD Dams –** Concepts were developed for nine LACFCD dams to enable them to capture an increased volume of stormwater runoff, which would entail both structural and nonstructural modifications to the dams. Operable weirs (e.g., pneumatic gates) and/or 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 properly for flood risk mitigation. 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.

- **USACE Dams –** Similar to the LACFCD dams, a structural concept was developed for Hansen Dam in an effort to maximize capture of stormwater runoff. The structural concept for Big Tujunga Dam was used as the template for the structural concept for Hansen Dam.

- **Debris Basins –** This project group assumes select debris basins could be modified with controlled outflow works to temporarily store and release stormwater to downstream spreading basins to increase groundwater recharge. A preliminary screening of the LACFCD debris basins was performed to identify candidate basins for modification. Debris basins with the largest storage capacities and located upstream of spreading grounds were identified for modification.

Management Solutions

Management Solutions represent improvements, or more aggressive enhancements, to the Local Solutions discussed previously. The general assumption is that the implementation of Local Solutions will not be achieved quickly and that widespread installation would likely occur over a longer period of time without the benefit of these Management Solutions. Management Solutions are made up of the following:

- **Stormwater Policies –** Stormwater policies are control measures that encourage stormwater conservation. The Stormwater Policies project group is comprised of the following elements:

  - Enhanced Watershed Management Programs (EWMPs) for stormwater conservation
  - Align regulatory and environmental plans with water conservation/supply goals
  - Rainfall-hydrology modeling to quantify pre-storm capture
  - Streamline regulatory requirements for maintenance of existing and urbanized stormwater infrastructure
  - Remove invasive plants in system

  - Feed-in-tariff for groundwater infiltration

- **Green Infrastructure Programs –** Green infrastructure programs encourage implementation of LID across the watershed. The Green Infrastructure Programs project group is comprised of the following elements:

  - LID/BMPs
  - Increase permeable space to balance water conservation goals
  - Increase urban permeability
  - Emphasize residential infiltration in high-density locations
  - Encourage residential land changes for promoting infiltration

- **Regional Impact Programs –** Regional impact programs encourage local stormwater capture solutions across the watershed. The Regional Impact Programs project group is comprised of the following elements:

  - Implement open space stormwater improvements
  - Utilize government parcels first for stormwater capture, storage, and infiltration
  - Investigate recharge along river embankments
  - Develop county-wide parcel fee with mitigation rebate
  - Implement school stormwater improvements
  - Implement regional projects (e.g., public parks and schools to infiltrate flows)
  - Depress all sports fields for stormwater capture
  - Consider all open areas as a stormwater facility

Stormwater Capture Findings

Stormwater Conservation

Enhancing the Study Area's stormwater capture is an adaptation strategy that the region can undertake to provide more locally sourced water in the face of climate change. The WMMS Model was run for four different projected climate scenarios. The modeled hydrology results for the projected climate scenarios were used to compare the potential stormwater storage or conservation for the different conceptual project groups. As shown in Figure ES-2, implementation of the various project groups results in a wide range of stormwater conservation and increased storage. Table ES-1 presents the range of values of the stormwater conservation and increased storage and also lists other features of each project group. On the low end, the Debris Basins project group provides 90 to 230 acre-feet per year (AFY) of additional storage for potential conservation, while the LACFCD Dams provides the highest potential for additional storage with range of

57,400 to 264,100 AFY from the low to high climate projection scenario. It is important to note that this additional storage would need to be released in such a way that the downstream spreading facilities can infiltrate the flows for recharge.

The next highest project groups for stormwater conservation include two management solutions: Stormwater Policies and Green Infrastructure Programs. Management Solutions represent improvements, or more aggressive enhancements, to local solutions. The Stormwater Policies project group uses a combination of LID and Complete Streets as a model baseline, and increases the stormwater conservation through changes in stormwater policy. This Management Solution provides approximately 155,300 to 235,000 AFY of stormwater conservation. The Green Infrastructure Programs project group builds on the LID model, and provides approximately 106,400 to 171,800 AFY of stormwater conservation. The Regional Stormwater Capture project group provides 26,100 to 59,900 AFY of stormwater conservation.

The maximum potential for stormwater conservation and storage would be achieved by combining all the Regional Solutions and Storage Solutions with the Stormwater Policies and Regional Impact Programs. The maximum potential for conservation and storage would range from 244,000 to 481,000 AFY for the low to high projected climate scenarios.

Additional stormwater capture related to the various solutions analyzed will not negate or reduce the need for maintaining existing capacities at flood management facilities. The capacity of the flood risk management facilities must be maintained to ensure public safety due to the challenges of climate change.

Capital and Operational Costs

Capital and operations and maintenance (O&M) costs were developed for each project group, and the costs were annualized over a 50-year analysis period. The resulting annual cost per acre of stormwater conserved could be used as an estimate of the cost effectiveness of each project group. A comparison of the conservation costs for each projected group is shown in Figure ES-3 below. Table ES-1 lists the costs for each project group along with additional details.

Although the LACFCD Dams storage solution provides the most stormwater storage and appears to be the most cost effective, it should be noted that this is only increased storage and would need to be released in such a way that it could be infiltrated at the downstream spreading grounds. Two of the regional solutions, Regional Stormwater Capture and Alternative Capture, are cost effective. Regional Stormwater Capture provides approximately 26,100 to 59,900 AFY of stormwater conservation, with a low cost compared to other project groups. While Alternative Capture represents one of the lowest volumes of stormwater conservation, this option is still favorable due to its cost effectiveness.

The Stormwater Policies and Green Infrastructure Programs project high volumes of stormwater conservation because of the potential widespread implementation of LID and Complete Streets, but both options are more costly to implement than the Regional Stormwater, Alternative Capture, and LACFCD Dam concepts.

Other Project Characteristics and Benefits

Some of the project groups provide multiple benefits beside the capture of stormwater. In addition to stormwater conservation, complementary benefits may include, but are not limited to, flood risk management, water quality, recreation, habitat/connectivity, ecosystem function, and climate resilient actions. These other benefits could help to identify project partners as projects with multiple benefits can help to leverage funding. When adding multiple benefit components to a project group, it is important to note that flood risk management cannot be compromised. The additional benefits are summarized in Table ES-2.

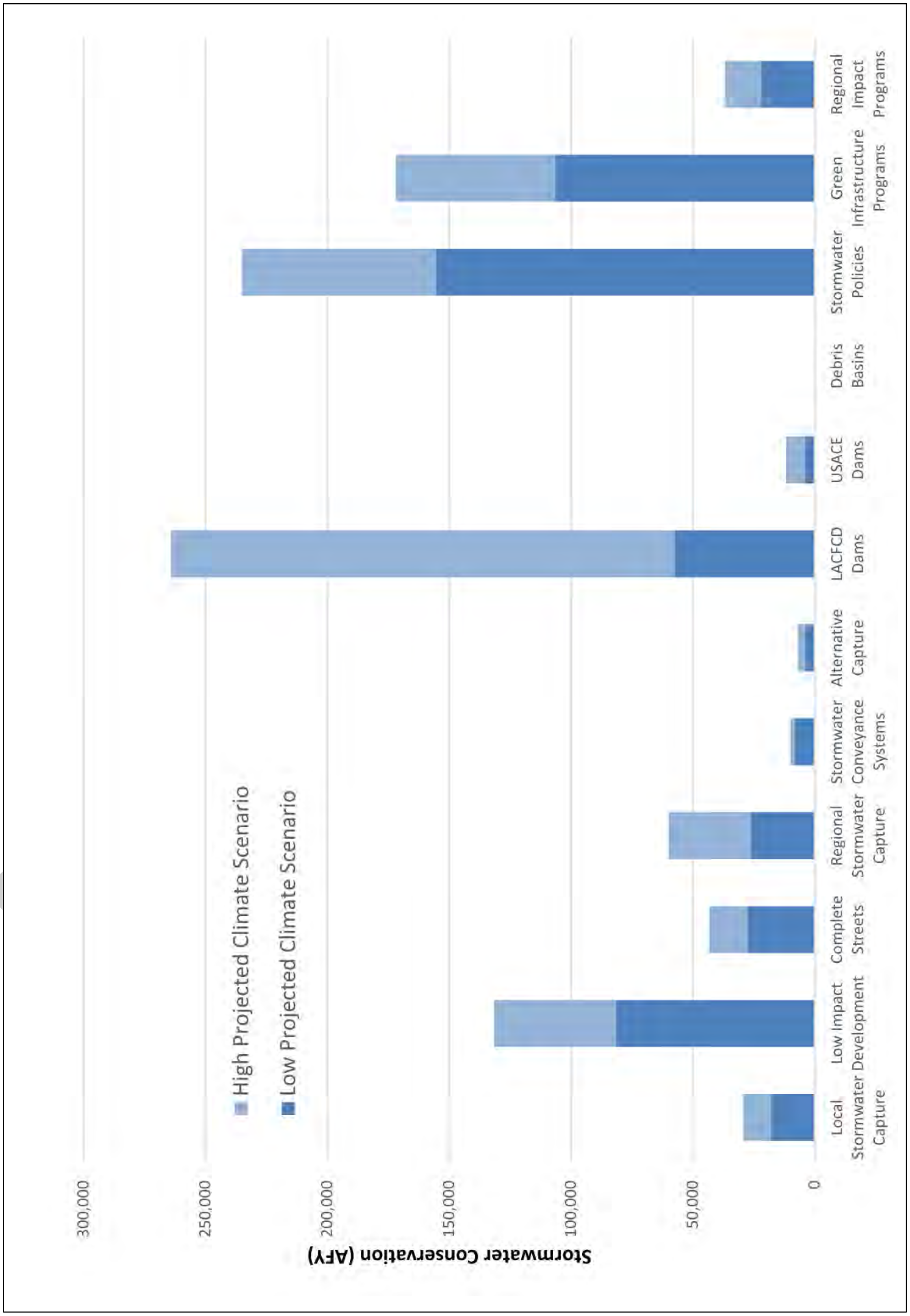


Figure ES-2. Stormwater Conservation Comparison by Conceptual Project Groups

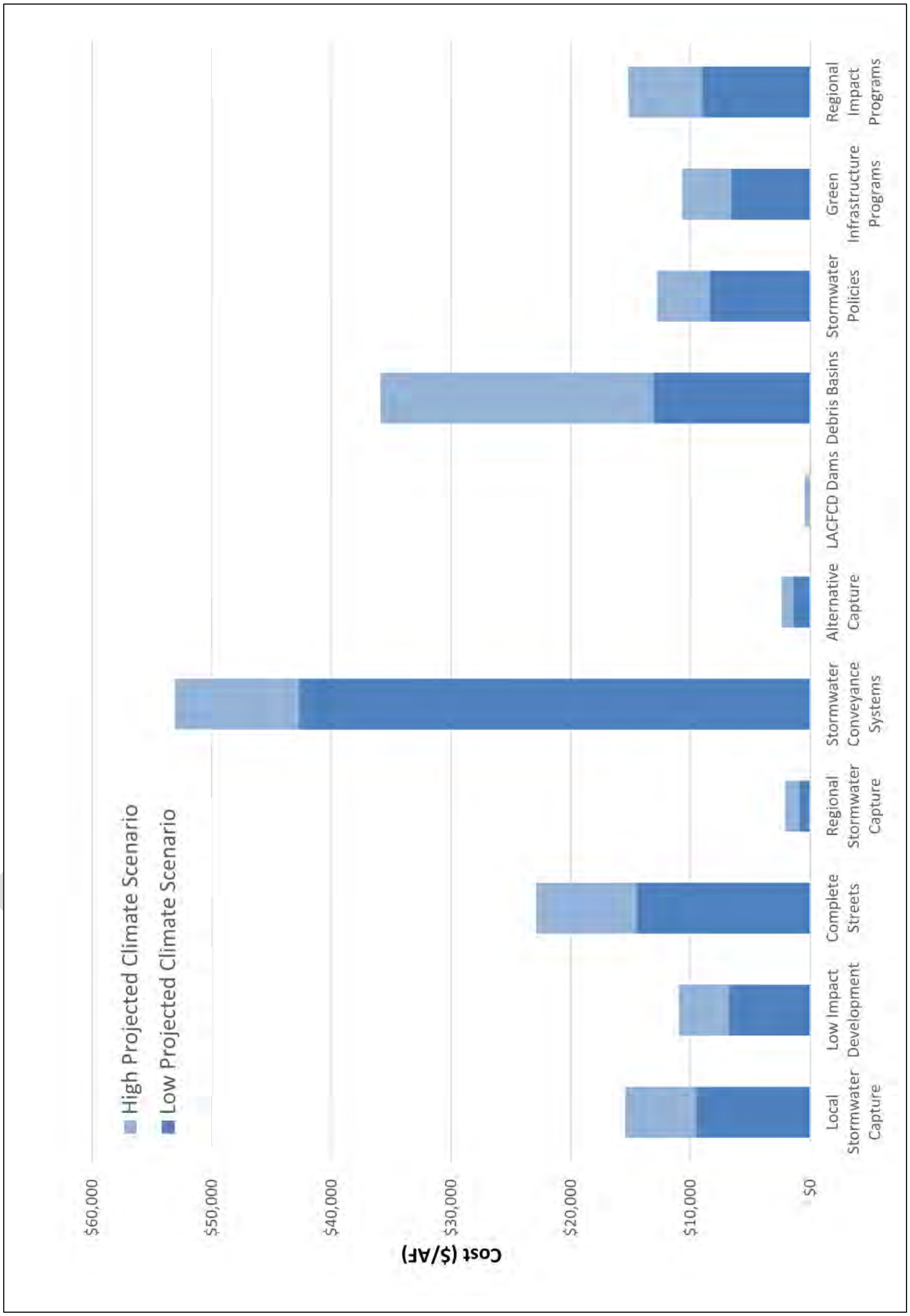


Figure ES-3. Cost per Acre Foot Conserved Comparison by Conceptual Project Groups

Table ES-1. Summary of Project Group Benefits and Costs

Project Group	Stormwater Conserved/ Storage Capacity (AFY)	Recreation (miles of trail)	Habitat (acres)	ROW (acres)	Range of Costs ($/AF)
Local Solutions					
Local Stormwater Capture[a]	17,900 to 29,300	204	266	2,655	$9,500 to $15,500
Low Impact Development[b]	81,400 to 131,600	0	0	0	$6,800 to $11,000
Complete Streets[b]	27,300 to 43,300	0	0	0	$12,100 to $19,200
Regional Solutions					
Regional Stormwater Capture[a]	26,100 to 59,900	12	42	682	$900 to $2,100
Stormwater Conveyance Systems[a]	8,000 to 10,000	3	8	31	$42,700 to $53,100
Alternative Capture[a]	3,800 to 6,900	2	2	34	$1,400 to $2,400
Storage Solutions					
LACFCD Dams[c]	57,400 to 264,100	0	0	0	$100 to $480
USACE Dams[c, d]	3,800 to 11,800	0	0	0	-
Debris Basins[a]	90 to 230	1	0	0	$13,100 to $35,900
Management Solutions					
Stormwater Policies[b]	155,300 to 235,000	0	0	0	$7,900 to $11,900
Green Infrastructure Programs[b]	106,400 to 171,800	0	0	0	$6,600 to $10,700
Regional Impact Programs[a]	21,800 to 36,900	204	266	2,655	$9,000 to $15,200

[a] Conservation through groundwater recharge
[b] Conservation through groundwater recharge or stormwater retention for potential reuse
[c] Increased storage capacity or stormwater retention for potential reuse or recharge; costs exclude estimates for Santa Anita Dam
[d] Cost Information for USACE dams not determined for this study.

Table ES-2. Summary of Project Group Additional Benefits

Project Group	Flood	Water Quality	Recreation	Habitat	Aesthetics	Heat Island Mitigation	Climate Resilient
Local Solutions							
Local Stormwater Capture	X	X	X	X	X	X	X
Low Impact Development		X			X	X	X
Complete Streets		X	X		X	X	X
Regional Solutions							
Regional Stormwater Capture	X	X	X	X	X	X	X
Stormwater Conveyance Systems	X	X	X	X	X	X	X
Alternative Capture	X	X	X	X	X	X	X
Storage Solutions							
LACFCD Dams	X	X					X
USACE Dams	X						X
Debris Basins	X	X					X
Management Solutions							
Stormwater Policies		X	X		X	X	X
Green Infrastructure Programs		X			X	X	X
Regional Impact Programs	X	X	X	X	X	X	X

1. Introduction

1.1. Study Purpose

The purpose of the Los Angeles Basin Stormwater Conservation Study (LA Basin Study) is to study long-term water conservation and flood control impacts from projected climate conditions and population changes in the Los Angeles Basin. The LA Basin Study will recommend potential changes to the operation of stormwater capture systems, modifications to existing facilities, and development of new facilities that could help resolve future water supply and flood control issues. The recommendations will be developed through identifying alternatives and conducting trade-off analyses as part of the next task, Task 6.

1.2. Study Background

The Los Angeles County Flood Control District (LACFCD) has been considering the possibility of large-scale enhancement of the LACFCD's water conservation capabilities through the study of long-term projected needs and projected climate conditions. Informal discussions occurred between LACFCD and several major water agencies on the same subject. As a result, this interest was the driving force for creating a partnership between the LACFCD and U.S. Department of the Interior, Bureau of Reclamation (Reclamation) under the Basin Studies Program (Reclamation 2009).

The LA Basin Study utilizes the latest climate science and hydrologic modeling tools to create a vision of the near-term and long-term future of stormwater capture in Los Angeles County. The LA Basin Study provides the opportunity for multiple water management agencies to participate in a collaborative process to plan for future local water supply scenarios. The LA Basin Study examines opportunities to enhance existing LACFCD and LA Basin Study partner facilities and operations and develop new facilities to demonstrate direct benefits to water agencies and local communities.

The LA Basin Study utilizes, to the greatest extent practicable, existing information on the availability and suitability of various open space and underdeveloped parcel opportunities as infiltration sites. The LA Basin Study evaluates potential infiltration sites for soil characteristics, groundwater basin condition, conveyance/diversion/outlet requirements, site remediation requirements, property valuation and availability, environmental impact, regulatory requirements, community impact, multiuse potential, and other factors deemed necessary to assess a potential site.

The LA Basin Study considers the technical viability of implementing innovative facility concepts that show a prospective for increasing infiltration capacity to recharge groundwater. The trade-off analysis, Task 6, will later be conducted to evaluate not just the economic costs and benefits of the various stormwater capture alternatives but also various other regional effects such as increased habitat, recreation, and environmental benefits as well. The final outcome and recommendations of the LA Basin Study concept development and trade-off analyses will serve as a guiding document for further local water supply development planning, financing strategy, and policy adoption for LACFCD and other LA Basin Study partners.

The efforts and results previously completed for Task 2 – Water Supply and Water Demand Projections, Task 3 – Downscaled Climate Change and Hydrologic Modeling, and Task 4 – Existing Infrastructure Response and Operations Guidelines Analysis serve as the basis for Task 5. Task 2 developed an understanding of the future population and its water demand on various water resources. The Task 2 analysis also assessed the various sources of water supply and examined, if they were to be sufficiently leveraged, how they might satisfy the potential demand. Within Task 3, the climate change scenarios downscaled by Reclamation's Technical Service Center were used to develop 47 future projections of precipitation and evaporation. These future weather projections—or projected meteorological inputs—were then used by the LACFCD to perform hydrology simulations in the Watershed Management Modeling System (WMMS). A historical meteorological data set represented the baseline conditions in WMMS and then the climate projections were used for analysis of future conditions. For Task 4, a subset of six climate projections was used to capture the lower, average, and upper hydrologic regimes for the modeling of the LACFCD and U.S. Army Corps of Engineers (USACE) dams and the regional spreading grounds. Task 4 provided a foundation for understanding the potential future needs of the flood control and water conservation system with the purpose of developing infrastructure and operations concepts during this Task 5. Task 6 – Trade-off Analysis will be completed next and then Task 7- Final Report will be completed to finish the study.

1.3. Description of Study Area

The Los Angeles River, San Gabriel River, South Santa Monica Bay, North Santa Monica Bay, Ballona Creek, Malibu Creek, and Dominguez Channel/Los Angeles Harbor watersheds (Basin Study Watersheds) are the focus of this LA Basin Study, and are shown in Figure 1. This study incorporates the entire watershed boundaries, including where they extend beyond the County of Los Angeles.

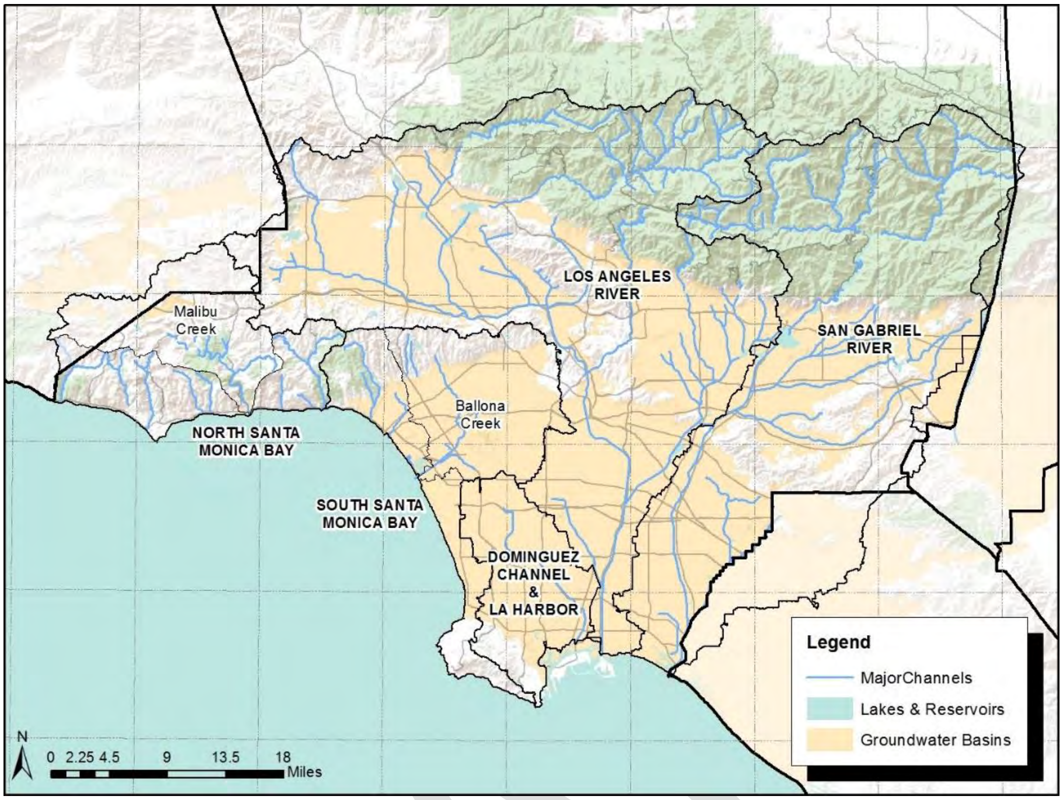


Figure 1. Los Angeles Basin Stormwater Conservation Study Watersheds

The LA Basin Study area includes several large groundwater basins, including the Central Basin, Main San Gabriel Basin, Raymond Basin, San Fernando Valley Basin, Six Basins, and West Coast Basin (Figure 2). The LACFCD's 14 major dams and reservoirs (Figure 3) are located in the front range of the San Gabriel Mountains stretching more than 40 miles from the San Fernando Valley on the west to the eastern edge of the San Gabriel Valley (LACDPW, 2013). The largely undeveloped watershed area upstream of the LACFCD dams is approximately 400 square miles and the majority of it is within the Angeles National Forest. Spreading grounds—which serve to infiltrate stormwater runoff—are located in areas of high permeability downstream from the LACFCD dams. Rubber dams are located within the natural bottom portions of a river and help to retain and percolate stormwater through the river bottom.

The Basin Study Watersheds include more than 9 million people and cover approximately 1,900 square miles. More than 95 percent of Los Angeles County's population resides within the LA Basin Study area. This population concentration also accounts for more than one-fourth of the State of California's population. Presently, California's population is 38.8 million people and the County of Los Angeles' population is just over 10 million. By 2050, the populations of California and the County of Los Angeles are projected to reach approximately 50.3 million and 11.4 million, respectively.

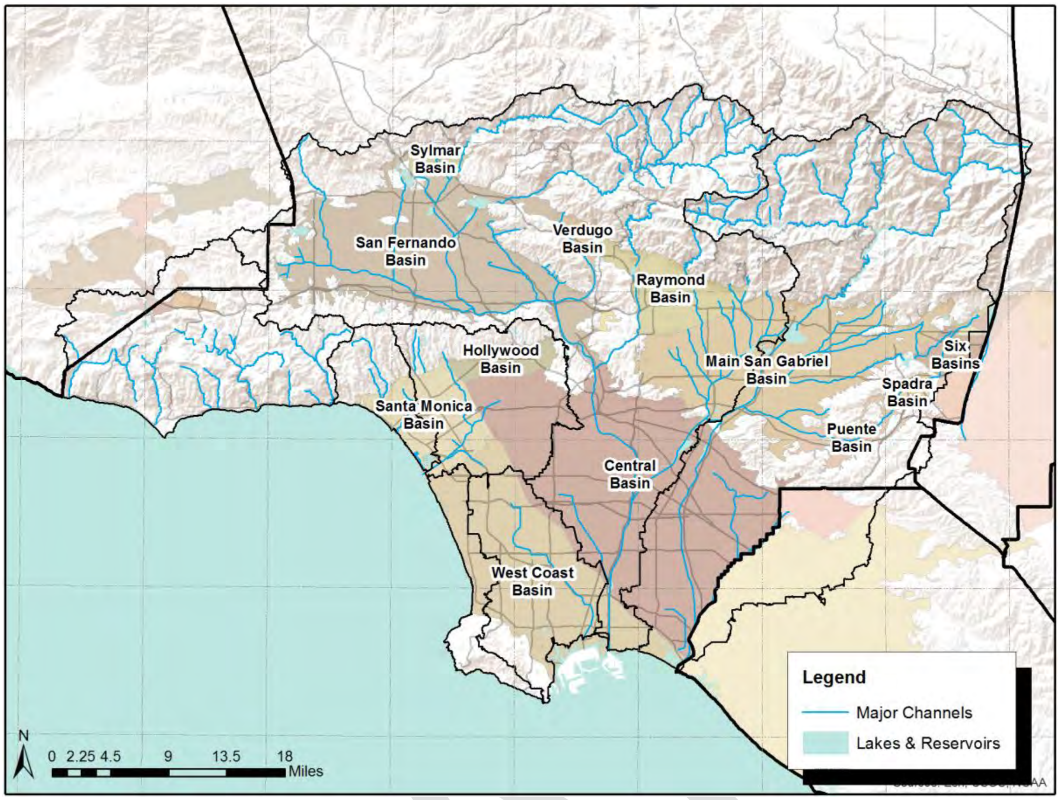


Figure 2. LA Basin Study Major Groundwater Basins

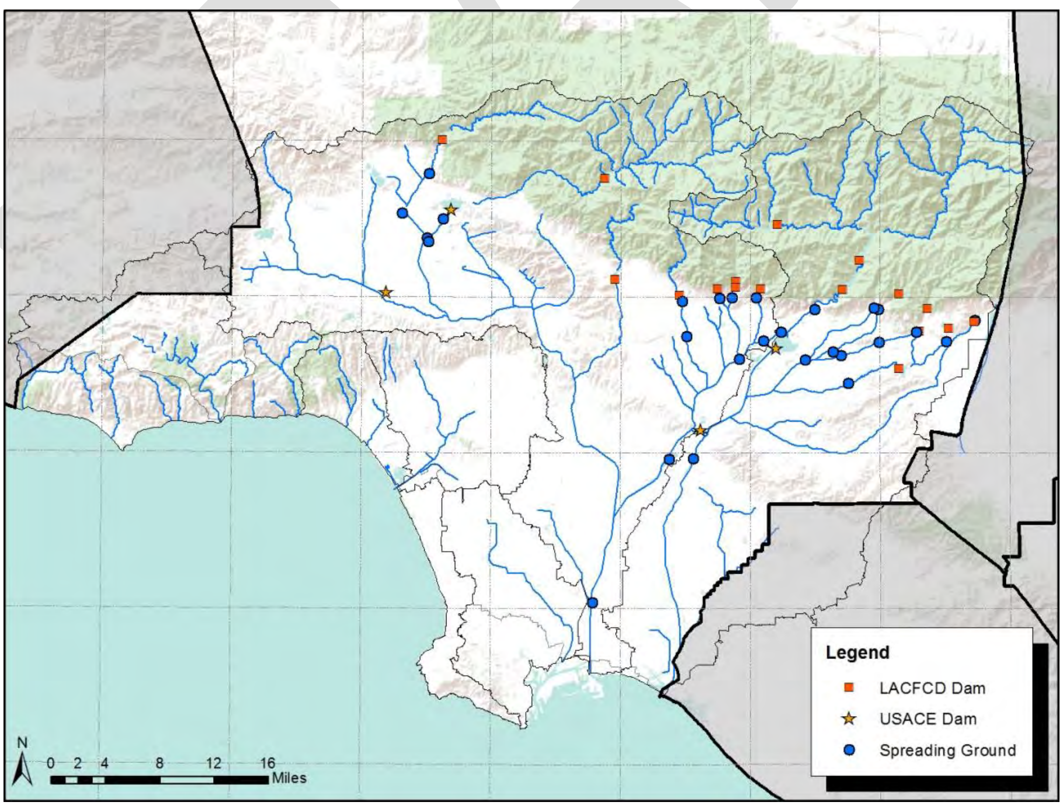


Figure 3. LACFCD Flood Control and Water Conservation Facilities

According to the California Department of Finance, the state's population as a whole is projected to increase by more than 34 percent, while Los Angeles County's is projected to increase by approximately 16 percent (Department of Finance, 2013). Projected larger population growth rates outside of Los Angeles County indicate there will be enormous pressure and competition for imported sources of water and the need for increased development of local water supply sources. At present, Los Angeles County accounts for the largest amount of water demand of any urbanized county in California. Total water usage within the Los Angeles County portion of the Metropolitan Water District of Southern California (MWD) service area—an area wholly served by the LACFCD—exceeded 1.54 million acre-feet in fiscal year 2011-12 (MWD, 2012).

1.4. Objectives and Outcomes of Task 5

The objective of Task 5 is to identify and develop structural and nonstructural concepts to manage stormwater under future conditions. These concepts build upon the selected climate change projection subset and the findings from the analysis of the existing water conservation and flood risk management facilities in *Task 4 – Existing Infrastructure Response & Operations Guidelines Analysis*. The major tasks and subtasks of Task 5 include:

- **Develop Concepts**
  - Identify a range of opportunities and options using stakeholder input
  - Determine preliminary concepts for further evaluation
- **Evaluate and Refine Concepts for Technical Analysis**
  - Assess structural and nonstructural concepts pertaining to dams, spreading grounds, flood control channels, decentralized storage, infiltration, reuse facilities, debris basins, or other new concepts
  - Apply minimum stormwater conservation selection criteria
- **Appraisal-Level Facility Concept Planning**
  - Evaluate selected concepts for future system reliability, efficiency, and effectiveness

In addition to any new stormwater conservation concepts that are developed, the existing facilities from the Task 4 analysis were considered for enhancement. Task 4 assessed the following LACFCD and USACE existing flood control and water conservation facilities (Figure 3):

- 18 major dams and reservoirs
- 26 spreading facilities

1.5. Hydrology Models Used for Study

The WMMS which was used for the historic and projected hydrologic modeling for Task 4 was also used for Task 5. The Loading Simulation Program in C++ (LSPC) is the underlying hydrologic program within WMMS that performs the simulations. LSPC was used to simulate the hydrologic runoff and volume outputs for all reservoirs, spreading facilities, and major channel outlets within the LACFCD system. For simplicity, LSPC is referred to as either WMMS or the model in this report.

The structural concepts developed for the selected LACFCD and USACE dams were simulated using WMMS. The nonstructural concepts developed for the selected LACFCD dams were simulated in Task 5 using Rulebased simulation in Riverware. Riverware is a river system modeling tool, developed for use as a platform for operational decision-making, responsive forecasting, operational policy evaluation, system optimization, water accounting, water rights administration, and long-term resource planning. Rulebased simulation in Riverware is driven by logical policy statements rather than explicitly specified input values for operations such as reservoir releases, storages, diversions, etc. In general, the operating policies, called rules, contain logic for operating the system based on hydrologic conditions, time of year, demands, and other considerations.

The structural concepts developed for the spreading grounds, debris basins, channels, local solutions and management solutions were also simulated using WMMS.

1.5.1. Bounding and Future Climate Projections

Hydrologic simulations were conducted for the LA Basin Study with the purpose of analyzing the potential impacts that climate change may have on stormwater conservation and flood flows. WMMS used observed meteorological inputs to produce the simulated Historic Hydrology for water years 1987 through 2000. For the future period of water years 2012 through 2095, WMMS produced hydrologic outputs corresponding to the various climate projections assessed in Task 3.

Task 4 analyzed 47 climate projections and chose six of these to be representative scenarios of the possible future climate. Two scenarios, High 1 and High 2, were selected to represent projected climates that resulted in the most precipitation; another two scenarios, Middle 1 (Mid 1) and Middle 2 (Mid 2), were selected to represent the mean and median of the projected future climates; and lastly two scenarios, Low 1 and Low 2, were selected to represent projected climates with the least amount of precipitation.

For the Task 5 modeling, four out of these six climate scenarios were chosen to decrease the overall time required for model simulations. The selected scenarios were High 1, Middle 2, Low 1, and Low 2. High 1 was chosen to represent the high tendency hydrology because it more consistently represented the high event throughout the study period. Although High 2 is slightly higher in the middle of the century, it is comparatively very dry for the first portion. For the central climate tendency, Middle 2 was chosen because it more consistently represented the average in range of variability of projected climates. For the Low tendency hydrology, Low 1 was selected because it more consistently represented the low tendency hydrology through the study period. Low 2 was also used in Task 5 modeling because it most closely resembled the Historical Hydrology. Figure 4 from the Task 4 report (LACDPW, 2014) shows the range of variability in stormwater runoff volume and how the chosen climate scenarios relate to each other.

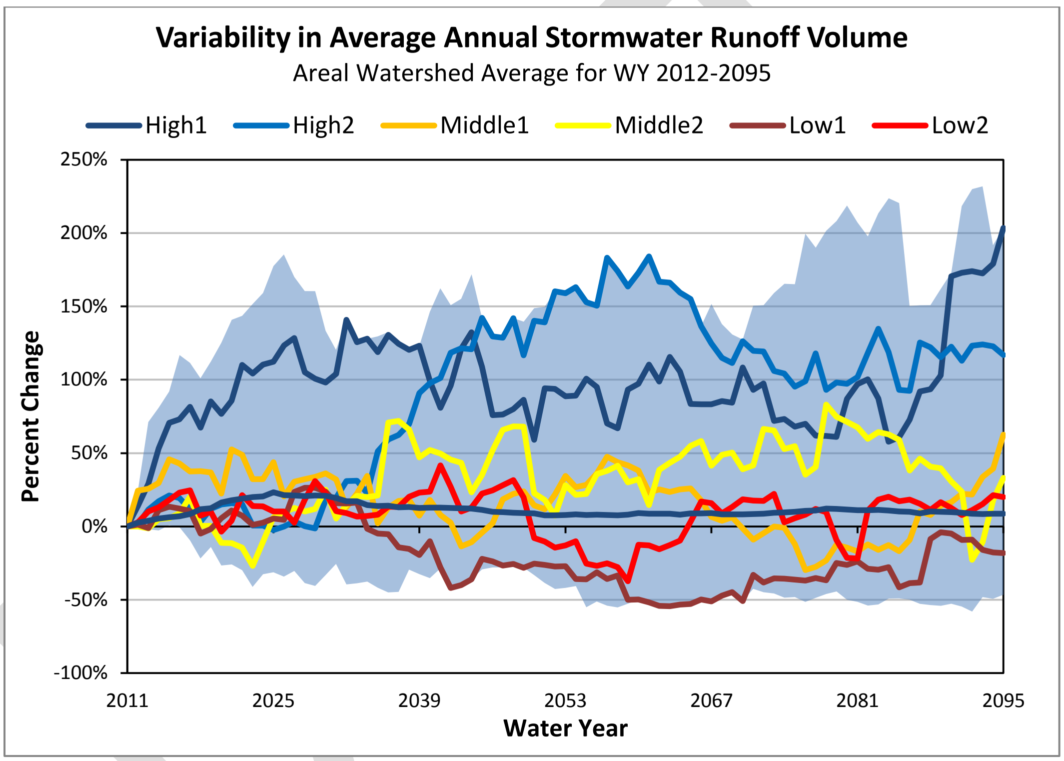


Figure 4. Projected Climate Scenario Subset – Annual Stormwater Runoff

2. Methods

This section describes the Task 5 methodology for the three main subtasks: concept development, technical analysis of the concepts, and appraisal-level analysis of the concepts.

2.1. Concept Development

Concept development consisted of identifying and developing stormwater conservation options, including enhancements to the existing water conservation and flood risk management system, in a collaborative manner with stakeholders and the public.

The LACFCD and Reclamation (Study Team) hosted two charrettes to solicit stormwater capture concepts for potential projects. The two charrettes were held on November 12, 2014, in downtown Los Angeles. The first charrette included attendees from the Stakeholder Technical Advisory Committee (STAC) and the second charrette included members of the general public. The STAC and public identified a wide-range and comprehensive list of stormwater capture concepts. Additionally, the Study Team reached out to other LACFCD staff to gather potential ideas. After the charrettes and internal outreach efforts, a total of 484 stormwater capture concepts were collected. The concepts were compiled and categorized based on the following characteristics to develop the Stormwater Capture Opportunities and Options List:

- Concept Implementation Lead
- Concept Type
- Category
- Scale
- Technique
- Implementation Form

Appendix A includes the complete Stormwater Capture Opportunities and Options List.

An initial evaluation of the 484 concepts in the Stormwater Capture Opportunities and Options List was performed to identify similar or duplicate concepts. Similar and duplicate concepts were combined and cross referenced to a representative concept for subsequent screening and evaluation; 242 similar or duplicate concepts were identified. Appendix A also includes the consolidated Stormwater Capture Opportunities and Options List of 242 concepts.

An initial screening of the 242 consolidated Stormwater Capture Opportunities and Options was performed to identify concepts emphasizing stormwater capture. Each concept was screened based on the following general criteria: Stormwater Conservation Focus and potential Stormwater Capture. Stormwater Conservation Focus characterized and scored concepts as having a low, moderate, or high focus on stormwater conservation based upon their description (Low = 1, Moderate = 3, High = 5). Stormwater Capture characterized the general degree of capture potential that the concept has as low, moderate, or high via its infiltration ability and/or storage capacity (Low = 1, Moderate = 3, High = 5). This was based upon the implementation form, scale of the proposed concept, and best professional judgment. Next, the Stormwater Conservation Focus and Stormwater Capture scores were multiplied to establish a combined Stormwater Score (maximum of 25 points) for each concept to produce the Stormwater Conservation Matrix. Concepts with scores of 15 or greater were retained for further technical analysis. Based upon these criteria, a total of 126 concepts were carried forward to the next step, Technical Analysis of Concepts. Table 1 lists the concepts alphabetically based on the SW Score. The concept shown in Table 1 is the unedited name of the concept idea generated during the charrettes and discussions. Appendix A includes the consolidated Stormwater Conservation Matrix.

Table 1. Stormwater Conservation Concepts

Item No.	Concept	SW Score
1	Abandoned Quarry Pits for storage	25
2	Alternative streams in unconfined aquifers (e.g., Tujunga Wash Greenway)	25
3	Arroyo Seco Confluence with Los Angeles River	25
4	Bring the Headworks Spreading Grounds back on line	25
5	Channel side-ponds	25
6	Construct more retention dams (rubber)	25
7	Construct the San Jose Spreading Grounds (adjacent to Cal Poly Pomona)	25
8	Deepen existing spreading grounds	25
9	Depress all sports fields for stormwater capture	25
10	EWMPs for water conservation	25
11	Golf course stormwater improvements	25
12	Improve stormwater capture and habitat along Tujunga Wash corridor	25
13	Increase soft-bottom channels	25
14	Increase urban permeability	25
15	Increased and enhanced maintenance at existing spreading grounds (e.g., remove top soil)	25
16	Infiltration at parks	25
17	Investigate Little Tujunga Dam concept	25
18	Investigate more stormwater capture facilities near Santa Anita and Sierra Madre Dams	25
19	Investigate potential recharge sites around Sepulveda Dam	25
20	Investigate recharge along river embankments	25

Table 1. Stormwater Conservation Concepts

Item No.	Concept	SW Score
21	Make a regional stormwater capture plan to create projects on a watershed level	25
22	Modify Operation Guidelines at Santa Anita Dam	25
23	New basins	25
24	New centralized facility approach	25
25	New reservoirs	25
26	Offline wetland restoration with infiltration	25
27	Old Pacoima Wash	25
28	Olive Pit	25
29	Percolation ponds along Los Angeles River	25
30	Raise dams	25
31	Regional projects (e.g., public parks, schools to infiltrate flows)	25
32	Reoperate existing basins	25
33	Reoperation of USACE dams	25
34	Restore capacities at LACFCD reservoirs by performing sediment removal	25
35	Retrofit USACE dams for water conservation	25
36	River speed bumps	25
37	Santa Anita Mall and Racetrack Stormwater Capture Project	25
38	The Los Angeles Forebay – Big infiltration basins under everything	25
39	Verdugo Wash Confluence with Los Angeles River	25
40	"Re-plumb" individual basins within the spreading grounds for increased flexibility	15
41	“Urban Acupuncture” (many small projects over the basin)	15
42	Adjust safe yield during wet and dry periods to allow more storage	15
43	Advanced rainfall-hydrology modeling to quantify pre-storm capture	15
44	Align regulatory and environmental plans with water conservation/supply goals	15
45	Aquifer Storage and Recovery wells	15
46	Centralized stormwater capture at Brackett Airport	15
47	Centralized stormwater capture at La Verne University	15
48	Check spreading grounds for stormwater linkages	15
49	Cistern use mandatory where infiltration is not suitable	15
50	Cisterns in homes	15
51	Collect stormwater from large, flat roofs in industrial areas	15
52	Commercial incentive program to capture stormwater	15
53	Conjunctive Use	15
54	Consider all open areas as a stormwater facility	15
55	Consolidate conservation programs with more efficient programs	15
56	Consolidate less efficient systems (dams/watershed)	15
57	Construct berms in the back of debris basins to help percolate water	15
58	Construct distributed BMPs upstream of lower efficiency spreading grounds	15
59	Construct large-scale of low impact developments (LIDs) in Compton Creek Watershed	15

Table 1. Stormwater Conservation Concepts

Item No.	Concept	SW Score
60	Construct permeable sidewalks and tree wells for infiltration	15
61	County roads sub-surface (ala Elmer Avenue)	15
62	County-wide parcel fee w/ mitigation rebate	15
63	Debris basin reoperation with forebay pre-treatment	15
64	Debris basin retrofit	15
65	Debris basins – Install French drains to recharge groundwater table	15
66	Detain stormwater on industrial land for eventual release into LACFCD channels for capture	15
67	Distributed storage tanks	15
68	Emphasize residential infiltration in high-density locations	15
69	Encourage cisterns/rain barrels	15
70	Encourage rain gardens	15
71	Encourage residential land changes for promoting infiltration	15
72	Enhanced storage in groundwater basins to reduce evapotranspiration losses	15
73	Feed-in-tariff for groundwater infiltration	15
74	Find options for cost effective stormwater treatment options	15
75	Flood plain reclamation	15
76	Freshwater reservoir at mouth of the Los Angeles River	15
77	Generate stormwater standards for high permeability soils	15
78	Green alleys	15
79	Green roofs	15
80	Green street mandate (driven by CA building code)	15
81	Green street stream tributaries	15
82	Implement a long-term floodplain buy-back study/program	15
83	Improve in-river drop structures with water conservation design emphasis	15
84	Improve, avoid duplication of roles, and expedite the regulatory environment to enable stormwater projects	15
85	Increase permeable space to balance water conservation goals	15
86	Increase perviousness (meaning esp. exposed soil!)	15
87	Increase residential land use infiltration	15
88	Infiltration in Caltrans highway cloverleaf exchange open areas	15
89	Infiltration wells in-channels	15
90	Los Angeles River at Taylor Yard	15
91	Los Angeles River at the Cornfields/LA State Historic Park	15
92	Los Angeles River at the Piggyback Yard	15
93	LID/BMPs	15
94	New park space (as green infrastructure)	15
95	Open space stormwater improvements	15
96	Parking lot storage and connectivity	15
97	Perform groundwater cleanup	15

Table 1. Stormwater Conservation Concepts

Item No.	Concept	SW Score
98	Pomona Fairplex Parking Lot Multipurpose Redesign (similar to Santa Anita Park)	15
99	Porous pavement parking lots	15
100	Prioritize infiltration over storage	15
101	Prioritize these upstream areas for action because the areas are so large	15
102	Prioritized green streets based upon capture potential	15
103	Private parking lot retrofit	15
104	Rain gardens	15
105	Recapture rights-of-way as small scale infiltration areas	15
106	Relocate Irwindale racetrack or store stormwater beneath it	15
107	Remove invasive plants in system	15
108	Reoperate pump stations to capture, detain, and pump stormwater to a storage facility	15
109	School stormwater improvements	15
110	Start at top of watershed to capture more water upstream	15
111	Stormwater smart grid	15
112	Plan stormwater treatment facility to collect, treat, and use runoff	15
113	Streamline regulatory requirements for maintenance of existing and urbanize stormwater infrastructure	15
114	Stronger LID ordinances to target existing properties and not just new development	15
115	T-ditches at Rio Hondo spreading grounds (west basin)	15
116	Transfer USACE dams to Reclamation	15
117	True smart streets as permeable, filtering and conveyance systems	15
118	Under street infiltration	15
119	Underground infiltration chambers	15
120	Underground storage under airport runways	15
121	Underground storm drains connecting to groundwater	15
122	Use geology maps to target best areas to infiltrate to the water table – avoid perched water	15
123	Use or pool municipal dollars for basin study every 5 years to ensure reliability	15
124	Use parkways and road medians to capture stormwater	15
125	Utilize Bull Creek Retention Basin to help store and transport water to Pacoima Wash for recharge	15
126	Utilize government parcels first for stormwater capture, storage, and infiltration	15

2.2. Technical Analysis of Concepts

As part of the technical analysis, the 126 concepts in the Stormwater Conservation Matrix were subdivided into three separate categories based on the characteristics and scale of each concept:

- **Centralized Projects –** Structural concepts related to centralized recharge and storage solutions (e.g., recharge basins, dams, channels, and debris basins). 51 total concepts.

- **Decentralized Projects & Distributed Programs** – Structural and nonstructural concepts related to distributed recharge or direct use solutions (e.g., sub-regional infiltration, green streets, and cisterns). 39 total concepts.

- **Plans, Policies, & Partnerships –** Nonstructural concepts that incentivize or facilitate stormwater conservation. 36 total concepts.

Separate technical (scoring) criteria were developed for each category and the concepts were scored and ranked to identify favorable concepts that could be incorporated into projects for appraisal-level analysis. Technical scoring criteria were developed to prioritize concepts with a high stormwater conservation benefit as well as other project benefits.

2.2.1. Technical Criteria Development

Separate technical criteria were developed for: (1) Centralized Projects, (2) Decentralized Projects and Distributed Programs, and (3) Plans, Policies, and Partnerships based on valuable suggestions from the STAC. Each criterion had a maximum score of 5, which was multiplied by a weighting factor to provide a total score for that criterion. These scores were then summed to develop an overall concept score. Weighting factors ranged from 1 to 5. The maximum possible score was 100 for all concept categories. Tables 2 through 4 summarize technical criteria for these concept groups.

For Centralized Projects, the technical criteria included the following:

- Expected Annual Stormwater Conservation Benefit
- Expected Unit Cost of Stormwater Conserved
- Multiple Benefits and Partnerships
- Property Ownership
- Implementability/Permitting/Site Modification Requirements
- Legal and Institutional Challenges

The highest weights, based upon input from the STAC, were assigned to the expected annual stormwater conservation benefit, unit cost of stormwater conserved, and multiple benefits and partnerships categories to reflect the importance of these factors (Table 2). Collectively, these three categories represent 70 percent of the maximum possible score for the centralized concepts.

The technical criteria for Decentralized Projects & Distributed Programs used a similar criteria, scoring, and weighting scheme (Table 3). For decentralized projects and programs, the technical criteria included the following:

- Expected Unit Stormwater Conservation Benefit
- Expected Unit Cost of Stormwater Conserved
- Multiple Benefits and Partnerships
- Potential Opportunity Application Area
- Implementability/Permitting/Site Modification Requirements
- Legal and Institutional Challenges

To reflect the distributed nature of these concepts, however, land availability was scored in terms of potential opportunity application area, with higher scores assigned for concepts with widespread application areas. Like the centralized concepts, the stormwater conservation benefit, unit cost of stormwater conserved, and multiple benefits categories were assigned the highest weights.

The technical criteria for Plans, Policies, and Partnerships included the following:

- Expected Enhancement in Stormwater Conservation Benefit
- Innovation
- Multiple Benefits
- Partnerships
- Implementability/Jurisdictional Complexity
- Legal and Institutional Challenges

The criteria placed emphasis on the expected enhancement in stormwater conservation, innovation, and multiple benefits categories (Table 4). These criteria accounted for 70 percent of the maximum possible score for these concepts.

Table 2. Technical Criteria – Centralized Projects

Criteria	Description	Scoring Criteria	Weight
Expected Annual Stormwater Conservation Benefit	Potential annual stormwater capture, storage, groundwater recharge, or direct-use quantity. Higher scores for larger stormwater conservation benefits.	5 = > 5,000 AFY 4 = 1,500 to 5,000 AFY 3 = 1,000 to 1,500 AFY 2 = 500 to 1,000 AFY 1 = 200 to 500 AFY 0= < 200 AFY	5
Expected Cost per Unit Stormwater Conserved	Total lifecycle cost for each acre-foot of stormwater captured. Capital cost inclusive of design, permitting, and construction; plus O&M costs (20 year amortization). Higher scores for lower unit cost projects.	5 = < $250/ac-ft 4 = $250 to $500/ac-ft 3 = $500 to $1,000/ac-ft 2 = $1,000 to $1,500/ac-ft 1 = $1,500 to $2,500/ac-ft 0 => $2,500/ac-ft	5
Multiple Benefits/Partnerships	In addition to stormwater conservation, complementary benefits may include, but are not limited to, flood risk management, water quality, recreation, habitat/connectivity, ecosystem function, and climate resilient actions. These added benefits promote inter-agency partnerships that help to leverage resources. Higher scores for greater benefits.	5 = Five or More Additional Benefits 4 = Four Additional Benefits 3 = Three Additional Benefits 2 = Two Additional Benefits 1 = One Additional Benefit 0 = Stormwater Conservation Benefit Only	4
Property Ownership	Based on availability and relative ease of obtaining necessary land rights. Higher scores for available properties.	5 = Public Property, Available 3 = Private Property, Available 0 = Property Not Available	3
Implementability, Permitting, Site Modification Requirements	The relative physical difficulty associated with implementing a project and overcoming its challenges, both anticipated and unexpected. Higher scores for concepts adapting existing infrastructure.	5 = Reoperation of Existing Facility 3 = Enhancement of Existing Facility 1 = New Project	2
Legal and Institutional Challenges	The relative systematic difficulty associated with implementing a project and overcoming its legal and institutional obstacles. Higher scores for concepts with no major barriers.	5 = No Significant Barriers 4 = Some Difficulty; Multiparty Agreements, Change in Current Practices 1 = Significant Challenges	1

Table 3. Technical Criteria – Decentralized Projects & Distributed Programs

Criteria	Description	Scoring Criteria	Weight
Expected Unit Stormwater Conservation Benefit	Potential annual stormwater capture, storage, groundwater recharge, or direct-use quantity evaluated per acre of area. Higher scores for larger stormwater conservation benefits.	5 = > 1.0 AFY/ac 3 = 0.5 to 1.0 AFY/ac 0 = < 0.5 AFY/ac	5
Expected Cost per Unit of Stormwater Conserved	Total lifecycle cost for each acre-foot of stormwater captured. Projects consist of capital and O&M costs (20 year amortization), while programs include all reasonable implementation costs Higher scores for lower unit cost projects.	5 = < $1,000/ac-ft 4 = $1,000 to $2,000/ac-ft 3 = $2,000 to $5,000/ac-ft 2 = $5,000 to $10,000/ac-ft 1 = $10,000 to 15,000/ac-ft 0 = > $15,000/ac-ft	5
Multiple Benefits, Partnerships	In addition to stormwater conservation, complementary benefits may include, but are not limited to, flood risk management, water quality, recreation, habitat/connectivity, ecosystem function, and climate resilient actions. These added benefits promote inter-agency partnerships that help to leverage resources. Higher scores for greater benefits.	5 = Five or More Additional Benefits 4 = Four Additional Benefits 3 = Three Additional Benefits 2 = Two Additional Benefits 1 = One Additional Benefit 0 = Stormwater Conservation Benefit Only	4
Potential Opportunity Application Area	Assigned based on relative spatial scale of implementation and considering land availability. Higher scores for larger areas and greater availability.	5 = Large-scale and/or Ample Property Available 3 = Medium-scale and/or Property Available 0 = Small-scale and/or Limited/No Property Available	3
Implementability, Permitting, Site Modification Requirements	The relative physical difficulty associated with implementing a concept and overcoming its challenges, both anticipated and unexpected. Higher scores for concepts with fewer challenges.	5 = No Significant Challenges 3 = Some Difficulty 0 = Difficult to Implement	2
Legal and Institutional Challenges	The relative systematic difficulty associated with implementing a concept and overcoming its legal and institutional obstacles. Higher scores for concepts with no major barriers.	5 = No Significant Barriers 4 = Some Difficulty; Multiparty Agreements, Change in Current Practices 1 = Significant Challenges	1

Table 4. Technical Criteria – Plans, Partnerships, & Policies

Expected Enhancement in Stormwater Conservation Benefit	Potential for enhancements in stormwater conservation. Higher scores for larger stormwater conservation benefits.	5= High 3= Moderate 0= Low	5
Innovation	Relative degree of innovation and natural systems integration. Higher scores for greater innovation.	5= High 3= Moderate 0= Low	5
Multiple Benefits	In addition to stormwater conservation, complementary benefits may include, but are not limited to, flood risk management, water quality, recreation, habitat/connectivity, ecosystem function, and climate resilient actions. Higher scores for greater benefits.	5 = Five or More Additional Benefits 4 = Four Additional Benefits 3 = Three Additional Benefits 2 = Two Additional Benefits 1 = One Additional Benefit 0 = Stormwater Conservation Benefit Only	4
Partnerships	Potential for beneficial partnerships between various entities with respect to collaboration, integration, and funding. Higher scores for greater partnership opportunities.	5= High 3= Moderate 0= Low	3
Implementability, Jurisdictional Complexity	Based on the jurisdictional complexity associated with implementing a concept. Higher scores for concepts within fewer jurisdictions.	5 = Implementable within a Single Jurisdiction (e.g., Single City) 4 = Requires Implementation across Two Jurisdictions (e.g., City and County) 1= Requires Implementation across Multiple Jurisdictions (e.g., Multiple Cities)	2
Legal and Institutional Challenges	The relative systematic difficulty associated with implementing a concept and overcoming its legal and institutional obstacles. Higher scores for concepts with no major barriers.	5 = No Significant Barriers 4 = Some Difficulty; Multiparty Agreements, Change in Current Practices 1 = Significant Challenges	1

2.2.2. Technical Analysis

For the 126 concepts that had a SW Score of 15 or greater in the Stormwater Conservation Matrix, a technical analysis was performed in accordance with the criteria developed for each concept category as outlined in Table 4. The resulting scores were compared and ranked within categories. Importantly, scores were not compared across categories in order to ensure a diverse portfolio of stormwater capture options.

Scores for individual concepts were assigned based on published estimates, previous studies, readily available information (e.g., project descriptions and planning documents), and best professional judgment. The results for each category were placed into an Appraisal-Level Stormwater Conservation Matrix.

2.2.2.1 Centralized Projects

The Centralized Projects included 51 concepts relegated to the construction, reoperation, or rehabilitation of the LACFCD and USACE dams, and the LACFCD spreading grounds, debris basins, and channels. As shown in Table 5, scores for the 51 concepts ranged from 30 to 83 (out of a possible 100) based on the weighted criteria. The highest scoring concepts included reoperation and modification of existing dams to enhance storage of stormwater for eventual recharge in downstream recharge basins, the construction of new or reoperation of existing spreading grounds, retrofitting debris basins for stormwater conservation, and channel modifications.

Table 5. Technical Analysis – Centralized Project Scores

Item No.	Concept Description	Score
1	Reoperation of USACE dams	83
2	Retrofit USACE dams for water conservation	79
3	Investigate potential recharge sites around Sepulveda Dam	77
4	New basins	77
5	Olive Pit	76
6	Debris basin retrofit	73
7	Channel side-ponds	70
8	Increased and enhanced maintenance at existing spreading grounds (e.g., remove top soil)	68
9	Restore capacities at LACFCD reservoirs by performing sediment removal	68
10	Construct the San Jose Spreading Grounds (adjacent to Cal Poly Pomona)	67
11	Old Pacoima Wash	67
12	Improve stormwater capture and habitat along Tujunga Wash corridor	66
13	Increase soft-bottom channels	66
14	Modify Operation Guidelines at Santa Anita Dam	64
15	Utilize Bull Creek Retention Basin to help store and transport water to Pacoima Wash for recharge	63

Table 5. Technical Analysis – Centralized Project Scores

Item No.	Concept Description	Score
16	Deepen existing spreading grounds	63
17	The Los Angeles Forebay – Big infiltration basins under everything	62
18	Abandoned Quarry Pits for storage	61
19	Raise dams	60
20	Alternative streams in unconfined aquifers (e.g., Tujunga Wash Greenway)	60
21	T-ditches at Rio Hondo spreading grounds (west basin)	59
22	Percolation ponds along Los Angeles River	58
23	"Re-plumb" individual basins within the spreading grounds for increased flexibility	58
24	Construct more retention dams (rubber)	58
25	Reoperate existing basins	55
26	Consolidate less efficient systems (dams/watershed)	54
27	Check spreading grounds for stormwater linkages	54
28	Bring the Headworks Spreading Grounds back on line	52
29	Start at top of watershed to capture more water upstream	52
30	Offline wetland restoration with infiltration	50
31	Improve in-river drop structures with water conservation design emphasis	49
32	Make a regional stormwater capture plan to create projects on a watershed level	49
33	Debris basin reoperation with forebay pre-treatment	48
34	Reoperate pump stations to capture, detain, and pump stormwater to a storage facility	48
35	Investigate Little Tujunga Dam concept	45
36	Arroyo Seco Confluence with Los Angeles River	45
37	Verdugo Wash Confluence with Los Angeles River	45
38	Los Angeles River at Taylor Yard	45
39	Los Angeles River at the Cornfields/LA State Historic Park	45
40	Los Angeles River at the Piggyback Yard	45
41	New reservoirs	45
42	Debris basins – Install French drains to recharge groundwater table	44
43	Santa Anita Mall and Racetrack Stormwater Capture Project	43
44	River speed bumps	43
45	Pomona Fairplex Parking Lot Multipurpose Redesign (similar to Santa Anita Park)	43
46	Freshwater reservoir at mouth of the Los Angeles River	41
47	Construct berms in the back of debris basins to help percolate water	40
48	Infiltration wells in channels	38
49	Relocate Irwindale racetrack or store stormwater beneath it	35
50	Centralized stormwater capture at Brackett Airport	30
51	Centralized stormwater capture at La Verne University	30

2.2.2.2 Decentralized Projects and Distributed Programs

The Decentralized and Distributed Programs concepts included 39 concepts related to the implementation of distributed recharge and direct use projects; the implementation of distributed LID water conservation elements; and decreasing the imperviousness of the watershed. As shown in Table 6, scores for the concepts ranged from 49 to 96 based on the weighted criteria. The highest scoring concepts included new park space (green infrastructure), infiltration in public spaces, right-of-ways, transportation easements, and "green street" improvements.

Table 6. Technical Analysis – Decentralized Projects & Distributed Programs Scores

Item No.	Concept Description	Score
1	New park space (as green infrastructure)	96
2	Golf Course Stormwater Improvements	91
3	Infiltration at parks	91
4	Infiltration in Caltrans highway cloverleaf exchange open areas	91
5	County-wide parcel fee w/ mitigation rebate	88
6	Underground infiltration chambers	88
7	Recapture right-of-ways as small scale infiltration areas	87
8	Construct distributed BMPs upstream of lower efficiency spreading grounds	85
9	"Urban Acupuncture" (many small projects over the basin)	84
10	Rain gardens	84
11	Conjunctive Use	81
12	Construct large-scale of LIDs in Compton Creek Watershed	81
13	Green street stream tributaries	76
14	Parking lot storage and connectivity	76
15	Prioritized green streets based upon capture potential	76
16	Use parkways and road medians to capture stormwater	76
17	County roads sub-surface (ala Elmer Avenue)	75
18	Flood plain reclamation	75
19	Implement a long-term floodplain buy-back study/program	75
20	Under street infiltration	75
21	Increase residential land use Infiltration	71
22	Enhanced storage in groundwater basins to reduce evapotranspiration losses	70
23	Increase perviousness (meaning esp. exposed soil!)	70
24	Underground storm drains connecting to groundwater	67
25	Commercial incentive program to capture stormwater	66
26	Porous pavement parking lots	66
27	Construct permeable sidewalks and tree wells for infiltration	65
28	Underground storage under airport runways	63
29	Detain stormwater on industrial land for eventual release into LACFCD channels for capture	62
30	Green street mandate (driven by CA building code)	62

Table 6. Technical Analysis – Decentralized Projects & Distributed Programs Scores

Item No.	Concept Description	Score
31	Green alleys	59
32	Cisterns in homes	56
33	Collect stormwater from large, flat roofs in industrial areas	56
34	Distributed storage tanks	56
35	Private parking lot retrofit	56
36	True smart streets as permeable, filtering and conveyance systems	56
37	Perform groundwater cleanup	53
38	Green roofs	51
39	Consolidate conservation programs with more efficient programs	49

2.2.2.3 Plans, Policies, and Partnerships

The Plans, Policies, and Partnerships concepts included 36 stormwater conservation concepts. As shown in Table 7, scores for the concepts ranged from 29 to 93 based on the weighted criteria. The highest scoring concepts were related to incentivizing or requiring LID ordinances, the use of public land (e.g., schools, parks, and government property) for water conservation projects, and streamlining regulatory structures.

Table 7. Technical Analysis – Plans, Partnerships, & Policies Scores

Item No.	Concept Description	Score
1	LID/BMPs	93
2	Open Space Stormwater Improvements	91
3	Utilize government parcels first for stormwater capture, storage, and infiltration	91
4	Investigate recharge along river embankments	88
5	Align regulatory and environmental plans with water conservation/supply goals	81
6	School Stormwater Improvements	81
7	EWMPs for water conservation	81
8	Advanced rainfall-hydrology modeling to quantify pre-storm capture	80
9	Increase permeable space to balance water conservation goals	77
10	Regional projects (e.g., public parks and schools to infiltrate flows)	77
11	Plan stormwater treatment facility to collect, treat, and use runoff	77
12	Streamline regulatory requirements for maintenance of existing and urbanize stormwater infrastructure	77
13	Improve, avoid duplication of roles, and expedite the regulatory environment to enable stormwater projects	75
14	Cistern use mandatory where infiltration is not suitable	74
15	Remove invasive plants in system	71
16	Depress all sports fields for stormwater capture	71

Table 7. Technical Analysis – Plans, Partnerships, & Policies Scores

Item No.	Concept Description	Score
17	Emphasize residential infiltration in high-density locations	71
18	Feed-in-tariff for groundwater infiltration	71
19	Increase urban permeability	71
20	Stormwater Smart Grid	71
21	Adjust safe yield during wet and dry periods to allow more storage	66
22	Generate stormwater standards for high permeability soils	62
23	New centralized facility approach	62
24	Transfer USACE dams to Reclamation	62
25	Use geology maps to target best areas to infiltrate to the water table- avoid perched water	62
26	Consider all open areas as a stormwater facility	61
27	Encourage cisterns/rain barrels	61
28	Encourage rain gardens	61
29	Encourage residential land changes for promoting infiltration	61
30	Investigate more stormwater capture facilities near Santa Anita and Sierra Madre Dams	58
31	Stronger LID ordinances to target existing properties and not just new development	58
32	Use or pool municipal dollars for basin study every 5 years to ensure reliability	55
33	Find options for cost effective stormwater treatment options	45
34	Aquifer Storage and Recovery wells	40
35	Prioritize these upstream areas for action because the areas are so large	30
36	Prioritize infiltration over storage	29

2.3. Appraisal-Level Analysis

The objective of the appraisal-level analysis was to further investigate the 126 concepts and compare alternative features to aid in selecting the most beneficial plan. The analysis consisted of the following steps.

1. Analysis criteria were developed to evaluate the preferred concepts.

2. Concept planning was performed to develop projects for further analysis using the ranked concepts in the Appraisal-Level Stormwater Conservation Matrix.

3. Finally, conceptual design criteria for the projects and other characteristics (e.g., recreational and habitat opportunities) were developed, the WMMS Model was modified to reflect the new concepts, and the output was evaluated.

The following sections describe the analysis criteria and concept planning for the appraisal-level analysis. The conceptual design criteria for the projects and the results of the appraisal-level analysis are presented in Section 3.

2.3.1. Analysis Criteria

Reclamation criteria for Appraisal-Level Analyses are described in Reclamation Manual Directives and Standards FAC 09-01 and CMP 09-02. In CMP 09-02, "Appraisal-Level" is defined as "the level of analysis and data collection needed to initially determine the nature of water and related resource problems and needs in a particular area, formulate and assess preliminary alternatives, determine Reclamation interest, and recommend subsequent actions."

Under FAC 09-01, Appraisal-Level Analyses "are intended to be used as an aid in selecting the most economical plan by comparing alternative features" and are to be prepared "using the available site-specific data." FAC 09-01 also states that "appraisal cost estimates are used in appraisal reports to determine whether more detailed investigations of a potential project are justified. These estimates may be prepared from cost graphs, simple sketches, or rough general designs which use the available site-specific design data." Appraisal cost estimates are included in this report for selected concepts.

The Study Team collaborated to identify evaluation criteria to be used in the appraisal-level analyses. These criteria, or evaluation outputs, will be used to facilitate the economic and trade-off analysis of the projects in the final study task. The appraisal-level evaluation criteria are as follows:

- Annual Amount of Stormwater Conserved
- Climate Resiliency
- Capital Costs
- Operations and Maintenance Costs
- Habitat Improvements
- Recreation Opportunities
- Water Quality Benefits
- Flood Risk Management
- Energy Consumption

2.3.2. Concept Planning

In general, the highest scoring concepts from the Appraisal-Level Stormwater Conservation Matrix were integrated into 12 project groups. Within each group, the various concepts served as general elements in developing the projects for the appraisal-level analysis. These 12 project groups were categorized into four project categories:

- **Local Solutions –**Decentralized projects distributed across the watershed that promote infiltration via stormwater BMPs.

- **Regional Solutions –** Centralized projects that provide for additional infiltration via existing and new spreading grounds and channel modifications.

- **Storage Solutions –** Centralized projects that provide additional storage via modifications to the existing LACFCD and USACE dams and at the LACFCD debris basins.

- **Management Solutions –** Plans, programs and policies that promote increased infiltration by providing incentives to implement the Local, Regional and Storage solutions sooner.

The Local Solutions project group incorporates concepts from the Appraisal-Level Stormwater Conservation Matrix for Decentralized Projects & Distributed Programs (Table 6); the Regional Solutions and Storage Solutions project groups incorporate concepts from the Appraisal-Level Stormwater Conservation Matrix for Centralized Projects (Table 5); and the Management Solutions project group incorporates concepts from the Appraisal-Level Stormwater Conservation Matrix for Plans, Partnerships, & Policies (Table 7).

Figure 5 summarizes each of the 12 project groups within the four project categories. Table 8 outlines the concepts within each project group.

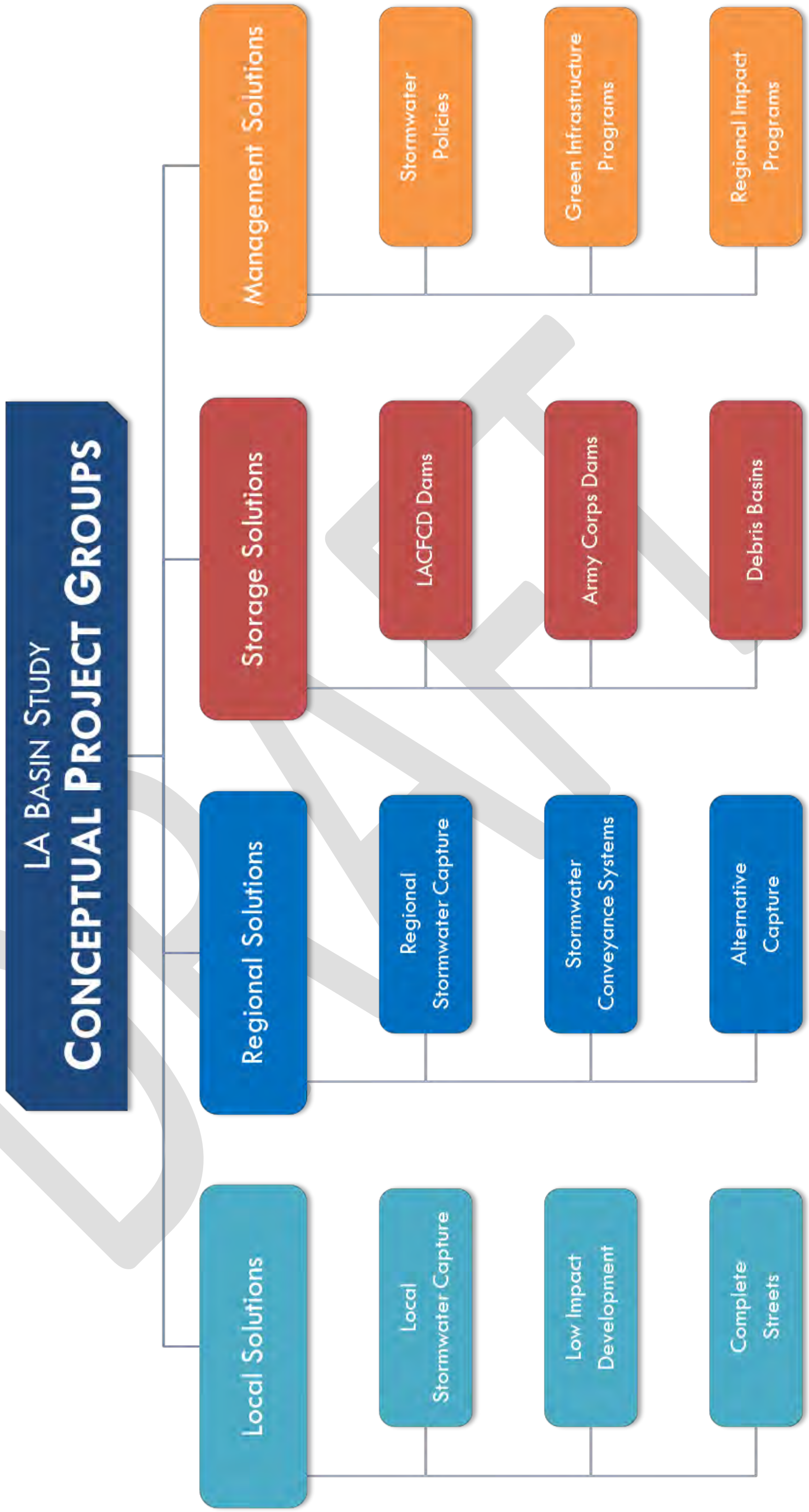


Figure 5. LA Basin Study – Conceptual Project Groups

Table 8. Conceptual Project Groups

Local Solutions	Score
1.Local Stormwater Capture	
New park space (as green infrastructure)	96
Golf Course Stormwater Improvements	91
Infiltration at parks	91
Infiltration in Caltrans highway cloverleaf exchange open areas	91
Underground infiltration chambers	88
Recapture rights-of-way as small scale infiltration areas	87
2. Low-Impact Development	
Construct distributed BMPs upstream of lower efficiency spreading grounds	85
"Urban Acupuncture" (many small projects over the basin)	84
Rain gardens	84
Parking lot storage and connectivity	76
Green roofs	51
3. Complete Streets	
Green street stream tributaries	76
Prioritized green streets based upon capture potential	76
Use parkways and road medians to capture stormwater	76
County roads sub-surface (ala Elmer Avenue)	75
Under street infiltration	75
Regional Solutions	**Score**
4. Regional Stormwater Capture	
Investigate potential recharge sites around Sepulveda Dam	77
New basins	77
Increased and enhanced maintenance at existing spreading grounds (e.g., remove top soil)	68
Construct the San Jose Spreading Grounds (adjacent to Cal Poly Pomona)	67
Abandoned Quarry Pits for storage	61
5. Stormwater Conveyance Systems	
Channel side-ponds	70
Improve stormwater capture and habitat along Tujunga Wash corridor	66
Increase soft-bottom channels	66
Alternative streams in unconfined aquifers (e.g., Tujunga Wash Greenway)	60
River speed bumps	43
6. Alternative Capture	
The Los Angeles Forebay – Big infiltration basins under everything	62
Consolidate less efficient systems (dams/watershed)	54

Table 8. Conceptual Project Groups

Storage Solutions	Score
7. LACFCD Dams	
Restore capacities at LACFCD reservoirs by performing sediment removal	68
Raise dams	60
8. USACE Dams	
Reoperation of USACE Dams	83
Retrofit USACE dams for water conservation	79
9. Debris Basins	
Debris basin retrofit	73
Debris basin reoperation with forebay pre-treatment	48
Construct berms in the back of debris basins to help percolate water	40
Management Solutions	**Score**
10. Stormwater Policies	
EWMPs for water conservation	81
Align regulatory and environmental plans with water conservation/supply goals	81
Advanced rainfall-hydrology modeling to quantify pre-storm capture	80
Streamline regulatory requirements for maintenance of existing and urbanize stormwater infrastructure	77
Remove invasive plants in system	71
Feed-in-tariff for groundwater infiltration	71
11. Green Infrastructure Programs	
LID/BMPs	93
Increase permeable space to balance water conservation goals	77
Increase urban permeability	71
Emphasize residential infiltration in high-density locations	71
Encourage residential land changes for promoting infiltration	61
12. Regional Impact Programs	
Open Space Stormwater Improvements	91
Utilize government parcels first for stormwater capture, storage, and infiltration	91
Investigate recharge along river embankments	88
County-wide parcel fee w/ mitigation rebate*	88
School Stormwater Improvements	81
Regional projects (e.g., public parks and schools to infiltrate flows)	77
Depress all sports fields for stormwater capture	71
Consider all open areas as a stormwater facility	61

*Concept originally scored as Decentralized and moved to Regional Impact Program category for appraisal-level analysis.

To determine the amount of stormwater conserved for each project group the WMMS hydrology program was used. Although the model is capable of analyzing water quality and sediment, only the water budget portion of the model was used for this study. 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.

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 Water Year 2011-2095. Each model was run for the four climate scenarios previously discussed.

Outlined in the following sections are specifics of the modeling assumptions for each project group.

2.3.3. Local Solutions

2.3.3.1 Local Stormwater Capture Modeling

Local Stormwater Capture concepts consist of facilities that receive runoff from upstream areas for infiltration and stormwater retention. Runoff is typically diverted to local stormwater facilities after it has already entered storm drains. Local stormwater capture facilities may be in the form of surface infiltration basins or underground infiltration chambers.

The Local Stormwater Capture project group consisted of the following elements:

- Infiltration at parks
- New park space for infiltration
- Golf course stormwater improvements for infiltration
- Infiltration in Caltrans right-of-ways
- Underground infiltration chambers (sub-regional infiltration)
- Recapture of right-of-ways for stormwater infiltration

Modeling Approach. A geographic information system (GIS) analysis was performed to identify land where these projects could be potentially implemented. Favorable areas in the watershed were identified based on: unconfined aquifer conditions, permeable soil types, and proximity to appropriately sized drainage systems.

Figure 6 shows the potential application areas for local stormwater capture projects. Within this area, land use and parcel data were evaluated to identify specific project locations. In general, government properties including schools, parks, institutional land, golf courses, and vacant parcels were identified as potential locations for these projects. Caltrans stormwater infiltration projects proposed as part of the Caltrans District 7 Corridor Stormwater Management Studies were also included in this alternative.

A total of 2,888 target parcels were identified, comprising approximately 26,498 acres. Table 9 summarizes the number of projects and target parcel acreages by watershed. Parcels greater than 0.5 acre, within 1,000 feet of a 36-inch storm drain (or larger) with an average slope less than 20 percent, within Hydrologic Soil Group A and B, and within an unconfined aquifer are considered potential locations for local stormwater capture. A portion (25 percent) of each target parcel was assumed to be available for construction of an infiltration basin or gallery. 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 gallery. To model this effect, the amount of area draining to an infiltration or gallery basin was moved into its own land use designation within the WMMS model, and that land use was calibrated to simulate the effect of capture and infiltration for the 5-year storm.

Appendix C provides a more detailed discussion of the assumptions used to model this project group.

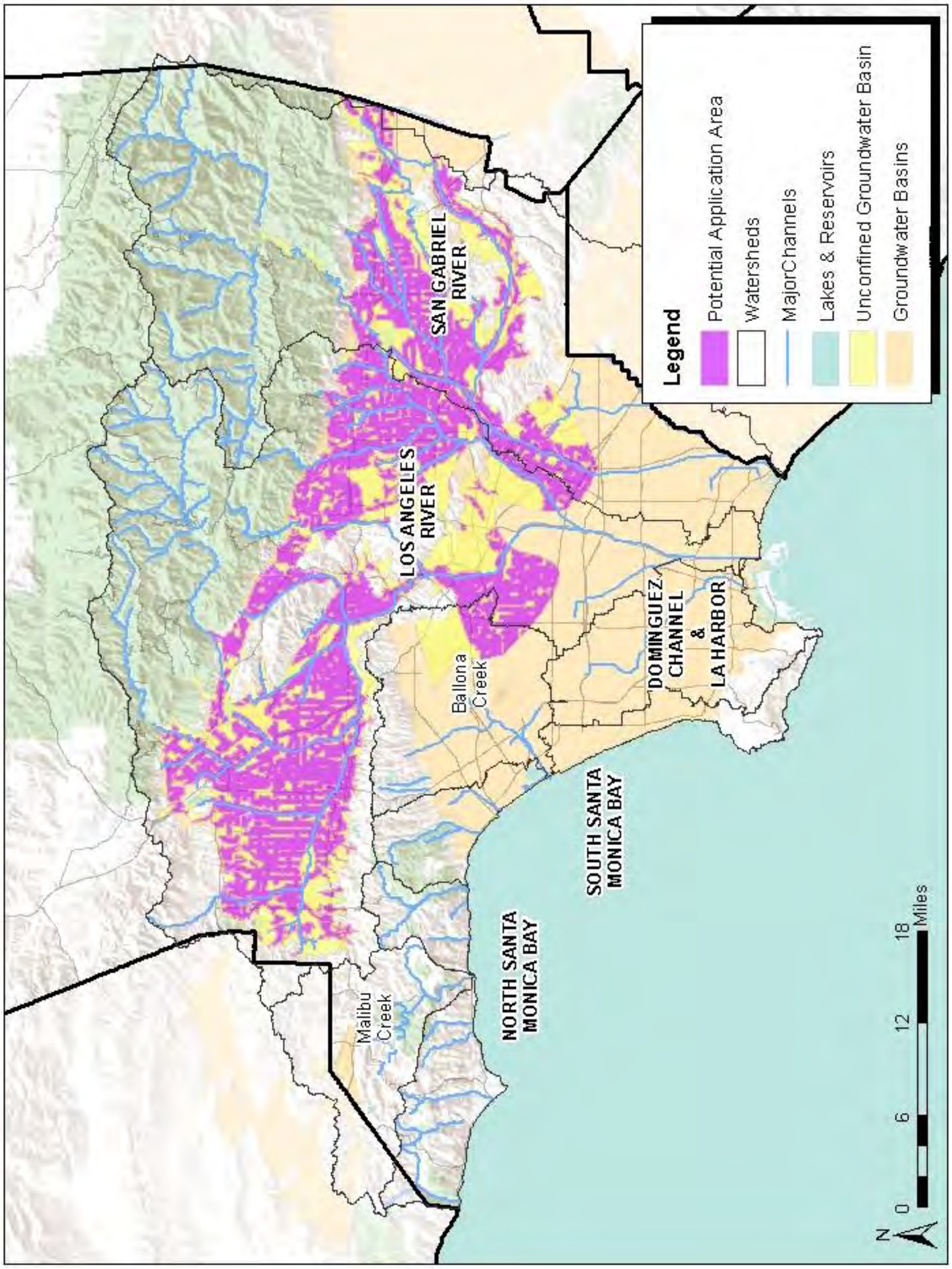


Figure 6. Local Stormwater Capture Concept Area

Table 9. Summary of Local Stormwater Capture

Watershed	Watershed Area (acres)	Number of Projects	Implementation Area		ROW (acres)	Habitat (acres)	Recreation Trails (feet)
			(acres)	(%)*			
Ballona Creek	135,090	73	612.6	0.5	53.4	5.3	12,265
Dominguez Channel	70,428	2	3.6	0.0	-	-	-
Los Angeles River	533,840	1,676	15,923.6	3.0	1,426.6	142.7	644,841
Malibu Creek	129,825	0	0.0	0.0	-	-	-
San Gabriel River	434,475	1,137	9,957.9	2.3	1,175.4	117.5	419,592
Total	**1,303,657**	**2,888**	**26,497.7**	**2.0**	**2,655.4**	**265.5**	**1,076,698**

* Percent of watershed area

2.3.3.2 Low Impact Development Modeling

Low impact development (LID) concepts are distributed structural BMPs that capture and infiltrate runoff close to the source, at the parcel scale. The tributary area for LID BMPs are generally smaller than the local stormwater capture projects, and include bioretention, permeable pavement, and other infiltration BMPs that prevent runoff from leaving a parcel. LID can be incorporated throughout the watersheds by the LID ordinances, residential participation of LID, and LID retrofits of public parcels.

The high-scoring LID opportunities in the Appraisal-Level Stormwater Conservation Matrix included:

- Distributed BMPs upstream of lower efficiency spreading grounds
- “Urban acupuncture” (many small projects over the basin)
- Rain gardens
- Parking lot storage and connectivity
- Green roofs

Modeling Approach. Similar to the Local Stormwater Capture projects, GIS analysis was performed to identify land where these LID projects could be potentially implemented. The analysis assumed a portion of the area within each land use will be likely to implement LID, and this portion will vary by land use. For example, highly regulated land uses (e.g., institutional and industrial) are more likely to implement LID to a larger extent than land uses that are not closely regulated (e.g., residential). LID implementation values developed as part of Task 3.2 of the LA Basin Study (LACFCD, 2014) were used as the basis to simulate the effects of future LID. LID implementation percentages were estimated for different land uses for the year 2095, as shown in Table 10.

Where LID is implemented, regardless of implementation form (e.g., rain garden or permeable pavement), it was assumed to retain the 85th percentile storm, represented by a rainfall depth of 0.75 inches for the Malibu Creek, Ballona Creek, and Dominguez Channel watersheds. For modeling, it was also assumed that BMPs would drain within 3 days in these watersheds. A rainfall depth of 0.97 inches and a draw down time of 1.5 days was assumed for the Los Angeles River and San Gabriel River watersheds. This increase in these two watersheds accounts for the increased suitability and performance of infiltration BMPs within unconfined aquifers, which cover large areas of the Los Angeles River and San Gabriel River watersheds. These values were used as approximate averages over the watershed and possible BMP types. A portion of the impervious area within the parcel was assumed to implement LID, depending on the land use. Unlike local stormwater capture projects, which was limited to areas within Hydrologic Soil Groups A and B and within an unconfined aquifer, LID projects are proposed across the study area. Table 11 summarizes the application of LID throughout the watersheds.

Table 10. Estimated LID Implementation Values

WMMS Land Use Description (applied only to urban uses)	LID Implementation Value for 2095 (% Land Area)
High-Density Single-Family Residential	25%
Low-Density Single-Family Residential, Moderate Slope	20%
Low-Density Single-Family Residential, High Slope	5%
Multi-family Residential	25%
Commercial	35%
Institutional	80%
Industrial	60%
Transportation	65%
Secondary Roads	60%

Source: *Los Angeles Basin Study, Task 3.2 Hydrologic Modeling Report* (LACFCD, 2013) Table 10. Estimated LID Implementation Values

Table 11. Summary of Low Impact Development

Watershed	Watershed Area (acres)	Total Urban Impervious Area Excluding Streets (acres)	Institutional Land Use (acres)	Industrial Land Use (acres)	Commercial Land Use (acres)	Residential Land Use (acres)	Implementation Area (acres)	Implementation Ratio of Impervious Area (%)
Ballona Creek	135,090	37,585	3,872	3,314	7,371	23,029	13,368	36
Dominguez Channel	70,428	29,825	2,670	10,412	5,854	10,889	13,136	44
Los Angeles River	533,840	119,149	11,440	29,180	19,149	59,379	48,063	40
Malibu Creek	129,825	5,092	532	405	1,327	2,829	1,761	35
San Gabriel River	434,475	94,778	11,695	21,455	16,705	44,922	39,181	41
Total	**1,303,657**	**286,430**	**30,210**	**64,767**	**50,404**	**141,048**	**115,509**	**40**

The actual model changes were accomplishes by moving the portions of mitigated areas into new land uses that were calibrated to mimic the effect LID BMPs have on rainfall runoff. Appendix C provides more detail on data and assumptions used to model this project type.

2.3.3.3 Complete Streets Modeling

The goal of Complete Streets is to ensure that the safety, accessibility, and convenience of all transportation users—pedestrians, bicyclists, transit riders, and motorists—is accommodated. One aspect of Complete Streets is stormwater treatment and management providing onsite retention, filtration, and infiltration to reduce urban runoff from the roadway, driveways, and sidewalk area similar to green streets.

The high-scoring green street opportunities in the Appraisal-Level Stormwater Conservation Matrix included:

- Green street stream tributaries (green streets upstream of waterways)
- Prioritized green streets based upon capture potential
- Use parkways and road medians to capture stormwater
- County roads retrofit (multiple green infrastructure strategies)
- Under street infiltration (underground infiltration galleries)

The Complete Streets project group consists of small BMPs throughout the transportation land use portion of the LA Basin. This is very similar in model methodology to the Low Impact Development project group model except that transportation land uses were modeled instead. For this alternative, the implementation rates for the transportation urban land uses were taken from the Task 3 report and are listed in Table 10. Table 12 summarizes the application of these concepts throughout the watersheds.

Table 12. Summary of Complete Streets

Watershed	Watershed Area (acres)	Total Urban Impervious Street Area (acres)	Implementation Area (acres)	Implementation Ratio of Impervious Area (%)
Ballona Creek	135,090	17,942	10,945	61
Dominguez Channel	70,428	10,258	6,309	62
Los Angeles River	533,840	46,295	28,371	61
Malibu Creek	129,825	986	609	62
San Gabriel River	434,475	23,064	14,192	62
Total	**1,303,657**	**98,546**	**60,427**	**61**

Appendix C provides more detail on data and assumptions used to model this project type.

2.3.4. Regional Solutions

2.3.4.1 Regional Stormwater Capture Modeling

The 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 (LACFCD, 2014). Modeling methodologies for both the enhanced and new basins were modeled based on the methodology in Task 4.

Task 4 of the study ranked the existing spreading grounds based on performance levels. Of the 26 existing spreading grounds analyzed in Task 4, 16 are shallow basins. Potential enhanced management processes that could be implemented in the target basins as described in the 2003 *Percolation Optimization Study* (MWH, 2003). These activities included frequent (annual) removal of the clogging layer by scraping, less frequent ripping of the basins, further break up clogging layers, the construction of furrows, and use of equipment and techniques that minimize soil compaction. For the purpose of this study, these efforts are assumed to increase the recharge capacity of the basins by 20 percent. For each enhanced basin, the recharge capacity specified within the spreading ground F-Table in the baseline model was increased by 20 percent. Nine of the 16 basins analyzed in Task 4 are deep pit basins. These basins were excluded from the project group because they do not that do not allow for complete drainage, which is required to perform the enhanced maintenance describe above.

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.

Potential locations for new spreading basins were identified based on previous reports (CDM, 2013; Geosyntec, 2014) and a GIS search of vacant properties near main channel features that overlay unconfined groundwater basins. This analysis resulted in a large number of potential locations which were then screened on a site-by-site basis. The analysis focused on the San Fernando Valley because that area is underutilized for groundwater recharge. The remaining locations were then grouped and modeled as three basins within the Los Angeles River watershed.

Existing gravel pits in favorable areas were assumed to be repurposed as spreading basins where appropriate. The existing gravel pits are very deep and would be difficult to maintain if the entire depth was used as a recharge basin, therefore, this alternative assumes the construction of 20 foot deep basins at these locations (e.g., on the floor of the gravel pit). Representative diversion capacities and infiltration capacities were assigned based on nearby spreading basins or other published estimates.

For each new spreading basin, an F-Table was created to model the diversion capacity from off the main channel connected to a second F-Table that modeled the recharge capacity. For the purpose of simulations, nearby basins were grouped and modeled as a single (large) basin.

Regardless of how the basin was identified, each spreading ground was modeled following the method described in Task 4 (LACFCD, 2013). Refer to Appendix C for additional assumptions used to model this project type.

2.3.4.2 Stormwater Conveyance System Modeling

The Stormwater Conveyance System project group consists of in-channel infiltration within tributaries that are currently concrete lined. This would 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, GIS data was used to identify all of the concrete lined tributaries within the watershed that overlie an unconfined aquifer. The tributaries were then screened based on width using aerial photography. Channel widths of 50 feet or more were identified as potential targets for modification.

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 groundwater basins are already unlined, and therefore, was not included.

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.

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 of 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 subwatershed that the tributary crossed. Within each F-Table, one discharge was for the downstream flow and the second represented the recharge rate. Depths were assumed to vary between 0 feet and 10 feet. These assumptions 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.

Refer to Appendix C for additional assumptions used to model this project type.

2.3.4.3 Alternative Capture Modeling

The Alternative Capture project group consists of injecting groundwater in eight reaches in shallow basins beside the LA River and then extracting for use as local water supply. Although functionally different than a recharge basin it acts in a similar way from a modeling standpoint.

To model the Alternative Capture project, an F-Table was developed and placed in the model on the Los Angeles River. 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.

For the injection rate, 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 rate was set to 0.0 cfs and when the downstream discharge is 200 cfs the injection rate was set to 50 cfs. For discharge between 150 and 200 cfs, the model interpolates between 0.0 and 50 cfs. Refer to Appendix C for additional assumptions used to model this project type.

2.3.5. Storage Solutions

2.3.5.1 LACFCD Dams Modeling

This section describes the methods used for development of structural and nonstructural concepts for major LACFCD dams and assessment of those concepts.

Structural Concepts. 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 as discussed in the next section.

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 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
- 50th 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 50th 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 50th 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 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 13).

Table 13. 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

* 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 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. 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. The F-Tables that were developed in Task 4 for each of the nine dams were modified in Task 5 to incorporate the structural concept described. Discharges from LACFCD dams are regulated using valves for reservoir stages below spillway crest elevations. For reservoir stages below spillway crest elevation, the F-Tables were unchanged from Task 4. For reservoir stages above spillway crest elevation, the rate of discharge was limited to the capacity of the valves, until the reservoir stage reaches the dam high water elevation (crest of dam, in most cases). For the modeling, for reservoir stages at or above the dam high water elevation, the operable weirs and/or gates were treated as closed and the rates of discharge from spillways were adjusted the F-Tables from Task 4 on that basis. For a given dam, this model approximated the addition of a pneumatic gate at the crest of the spillway up to the dam high water elevation, which could be lowered during major runoff events as necessary to maintain flood protection.

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 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 dam 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.

Nonstructural Concepts. This section describes the methods used for development of nonstructural concepts (i.e., management techniques) for selected major LACFCD dams and assessment of those concepts, building upon the analyses and rankings performed in Task 4.

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 water conservation 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.

Modeling Approach. The analyses of the Rulebased simulation model results for the nonstructural concepts used the same methodology and the same key stormwater metrics used in Task 4 and in the Task 5 analysis of the structural concepts:

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

The analyses evaluated each of these metrics for each nonstructural concept for each of the four future projections. For these structural concepts, Spillway Events refer to time periods during which the water surface elevation behind a dam was at or above the dam crest elevation and the operable spillway weir or gate would be opened.

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 the next section.

2.3.5.2 USACE Dams Modeling

This section describes the methods used for development of the structural concept for USACE Hansen Dam and assessment of that concept.

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.

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 14. These results quantify the influence of the ungated outlets at Hansen Dam on the availability of the stormwater for water supply.

Table 14. 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 discussed previously, 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 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, during most runoff events that cause the reservoir level to rise above the spillway crest elevation, the operable weirs and/or gates at the spillway would remain closed. However, for runoff events during which a rising reservoir level could reach the dam high water elevation, those operable weirs and/or gates could be opened, allowing the facility to function as mandated for flood control.

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 for Hansen Dam 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 14

Additional Considerations of USACE Dam Concepts. Four USACE dams are located within the LACFCD system of water conservation and flood risk management infrastructure. As discussed above, study resources permitted an appraisal-level analysis of only one USACE facility; Hansen Dam was selected. The remaining three USACE facilities for which an appraisal-level analysis was not conducted are Santa Fe, Sepulveda, and Whittier Narrows Dams.

The USACE dams within the Study Watersheds are managed primarily for flood protection. However, this LA Basin Study is investigating options for capturing additional stormwater across the region; and the USACE dams present an opportunity to repurpose existing infrastructure to achieve multiple goals. To develop high-level recommendations for enhancing stormwater capture at these dams, the Study Team reviewed publicly available USACE documents such as Water Control Manuals and Storage Allocation Diagrams for each of the dams. The review identified general constraints and challenges associated with repurposing the USACE dams to place a greater emphasis on stormwater capture. These constraints and challenges are deemed realistic limitations that must undergo additional and in depth study if the region wishes to pursue reoperation of the USACE dams to include water conservation in addition to their current mission of flood protection. These considerations include the following:

1. **Structural Considerations** – Generally, dams are designed with an emphasis on flood protection, water conservation, or both. For the USACE

dams, the emphasis is on flood protection. To repurpose these dams to include water conservation would require an in-depth study of their physical characteristics.

- Increasing water conservation pools at USACE dams will increase the loading time on the dams over the design, which would need to be analyzed. The dams were all originally designed to provide temporary impoundment of flood waters and not long-term water conservation storage. There would be increased potential for seepage when water is stored behind the dams for longer than originally intended; and the dams would likely require structural modifications to accommodate long-term water conservation storage. Any proposed physical alterations to the dams to accommodate water conservation would need to be analyzed for increased risk to the dam and evaluated.

- The safety of USACE dams is rated through the Dam Safety Action Classification (DSAC) Ratings. DSAC ratings are based on a combination of the probability of failure and the risk associated with the dam (USACE, 2012). The current ratings for the USACE dams, where a rating of DSAC I is considered "unsafe" and DSAC V is "adequately safe", are: Hansen = III, Santa Fe = II, Sepulveda = III, and Whittier Narrows = II (USACE, 2015). For each USACE dam, the DSAC rating would need to be further assessed prior to repurposing to include water conservation.

2. **Flood Protection Considerations** – Repurposing the USACE dams to include water conservation must consider any associated changes to their existing function within the LACFCD system of water conservation and flood risk management infrastructure, which would require in-depth study.

    - Modification of USACE dams could impact their flood protection performance within the regional system and potentially propagate negative flood protection effects to other parts of the regional flood risk management system. These effects would have to be mitigated for any new project.

    - Upstream inundations due to the increased water conservation activities would have to be investigated and mitigated. Additional land easements upstream of the USACE dams may be required.

3. **Operational Considerations** – Repurposing the USACE dams to include water conservation must consider their existing operation capabilities and evaluate potential challenges under climate change.

    - The re-analysis of the Task 4 results for Hansen Dam suggests that all four of the USACE dams have a potential for increased water conservation under the different projected climate scenarios. It is unknown to what extent operational enhancements at Santa Fe Dam, Sepulveda, and Whittier Narrows Dam could produce in terms of increased stormwater conservation.

- Repurposing of USACE dams would necessitate revising the associated Water Control Plans. This potentially could prompt California Environmental Quality Act and National Environmental Policy Act.

- Since the primary purpose of the USACE dams is flood protection, 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.

- Potential maintenance and operational costs due to the additional water conservation operations should be evaluated. Current O&M funding is only for flood protection and additional funding would likely be required.

4. **Legal Considerations** – The USACE dams are operated under very specific guidelines set by the United States Congress. Any proposed structural enhancements or operational changes would likely require a lengthy process to repurpose the USACE dams to include water conservation.

    - Any modifications would need to be reauthorized through Congress to include water conservation as one of the authorized purposes of the dam.

    - To repurpose USACE dams to hold water conservation pools, agreements between the USACE and a local sponsor may be required. Since the USACE's primary mission is flood protection, there needs to be operational flexibility for USACE to release stored water to retain runoff as necessary, compatible with providing flood protection to the downstream communities.

2.3.5.3 Debris Basins Modeling

This Storage Solution Debris Basins project group assumes select debris basins will be modified with controlled outflow works to temporarily store and then release stormwater to downstream spreading basins to increase groundwater recharge.

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. 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.

Because the debris basins still need to serve their primary purpose of flood risk management, it was assumed that 25 percent of the volume would be full of sediment when a storm occurs and therefore would be unavailable for stormwater storage. Using the volume and spillway elevation and assuming a rectangular geometry, a stage-storage-discharge table (F-Table) was developed and added to the model. The F-Table was created to meter the flow below the spillway elevation over 3 days to allow the downstream spreading grounds to recharge some of the flow after a large storm.

Refer to Appendix C for more detailed information on the assumptions in the model.

2.3.6. Management Solutions

2.3.6.1 Stormwater Policies Modeling

Stormwater Policies are non-constructed control measures that encourage stormwater conservation. The high-scoring stormwater policies in the Appraisal-Level Stormwater Conservation Matrix include the following:

- EWMPs for water conservation
- Align regulatory and environmental plans with water conservation/supply goals
- Advanced rainfall-hydrology modeling to quantify pre-storm capture
- Streamline regulatory requirements for maintenance of existing and urbanize stormwater infrastructure
- Remove invasive plants in system
- Feed-in-tariff for groundwater infiltration

Stormwater Polices would impact two of the Local Solutions models, Low Impact Development and Complete Streets. Therefore those models were combined and used as the basis for this project group. To model the increase in stormwater conservation through changes in stormwater policy, both the efficiency 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 effective capture depths for institutional, commercial, industrial, and transportation were increased by 20 percent from 0.75 to 0.9 inches for the Malibu Creek, Ballona Creek, and Dominguez Channel Watersheds and from 0.97 to 1.17 inches for Los Angeles River and San Gabriel River watersheds.

Policies that offer financial incentives to implement LID in the form of feed-in-tariffs would increase the implementation rates beyond the base rates assumed in 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. Appendix C describes the specific rates and capture depths used to model the project group. All other methodologies match those described above in the Low Impact Development project group.

Table 15 summarizes the application of these concepts throughout the watersheds.

Table 15. Summary of Stormwater Policies

Watershed	Watershed Area (acres)	Total Urban Impervious Area(acres)	Institutional Land Use (acres)	Industrial Land Use (acres)	Commercial Land Use (acres)	Residential Land Use (acres)	Trans. (acres)	Implementation Area (acres)	Implementation Ratio of Impervious Area (%)
Ballona Creek	135,090	55,528	3,872	3,314	7,371	23,029	17,942	31,997	58
Dominguez Channel	70,428	40,083	2,670	10,412	5,854	10,889	10,258	25,175	63
Los Angeles River	533,840	165,444	11,440	29,180	19,149	59,379	46,295	99,519	60
Malibu Creek	129,825	6,079	532	405	1,327	2,829	956	3,171	52
San Gabriel River	434,475	117,842	11,695	21,455	16,705	44,922	23,064	69,552	59
Total	**1,303,657**	**384,975**	**30,210**	**64,767**	**50,404**	**141,048**	**63,236**	**229,414**	**60**

2.3.6.2 Green Infrastructure Programs Modeling

The Green Infrastructure Programs project group is a set of programs to encourage green infrastructure across the watershed. The high-scoring Green Infrastructure Program concepts in the Appraisal-Level Stormwater Conservation Matrix included the following:

- LID/BMPs
- Increase permeable space to balance water conservation goals
- Increase urban permeability
- Emphasize residential infiltration in high-density locations
- Encourage residential land changes for promoting infiltration

This Management Solution uses the Low Impact Development model as a baseline, and increases the stormwater conservation through green infrastructure programs. Many of the programs identified may reduce the time it takes to reach full-scale implementation by encouraging and providing incentives for implementation. One area would be programs focused on residential implementation that 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 percent implementation. Table C-9 in Appendix C describes the specific rates and model changes used to model the project group. All other methodologies match those described above in the Low Impact Development project group.

Table 16 summarizes the application of these concepts throughout the watersheds.

Table 16. Summary of Green Infrastructure Programs

Watershed	Watershed Area (acres)	Total Urban Impervious Area Excluding Streets (acres)	Institutional Land Use (acres)	Industrial Land Use (acres)	Commercial Land Use (acres)	Residential Land Use (acres)	Implementation Area (acres)	Implementation Ratio of Impervious Area (%)
Ballona Creek	135,090	37,585	3,872	3,314	7,371	23,029	19,180	51
Dominguez Channel	70,428	29,825	2,670	10,412	5,854	10,889	15,877	53
Los Angeles River	533,840	119,149	11,440	29,180	19,149	59,379	63,052	53
Malibu Creek	129,825	5,092	532	405	1,327	2,829	2,547	50
San Gabriel River	434,475	94,778	11,695	21,455	16,705	44,922	50,537	53
Total	**1,303,657**	**286,430**	**30,210**	**64,767**	**50,404**	**141,048**	**151,194**	**53**

2.3.6.3 Regional Impact Programs Modeling

Regional Impact Programs encourage local stormwater capture solutions across the watershed. Local stormwater capture concepts are comprised of facilities that receive stormwater runoff from upstream areas for infiltration and stormwater retention. This management solution assumes a model baseline for local stormwater capture, and increases the stormwater conservation through regional impact programs.

The high-scoring Regional Impact Program concepts in the Appraisal-Level Stormwater Conservation Matrix included:

- Open space stormwater improvements
- Utilize government parcels first for stormwater capture, storage, and infiltration
- Investigate recharge along river embankments
- County-wide parcel fee with mitigation rebate
- School stormwater improvements
- Regional projects (e.g., public parks and schools to infiltrate flows)
- Depress all sports fields for stormwater capture
- Consider all open areas as a stormwater facility

To model the Regional Impact Programs, the GIS analysis and land use screening from Local Stormwater Capture was used. 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 vacant parcels would be used. Therefore, 50 percent of the identified vacant parcels were assumed to be an infiltration BMP versus 25 percent assumed in the Local Stormwater Capture model. Using the same method as the Local Stormwater Capture model, the surrounding area that would drain into the new infiltration basin or gallery was assumed to be ten times the area of the new basin or gallery. Table 17 summarizes the application of these concepts throughout the watersheds.

Table 17. Summary of Regional Impact Programs

Watershed	Watershed Area (acres)	Number of Projects	Implementation Area		ROW (acres)	Habitat (acres)	Recreation Trails (feet)
			(acres)	(%)			
Ballona Creek	135,090	73	768	0.6	53.4	5.3	12,265
Dominguez Channel	70,428	2	4	0.0	0.0	0.0	-
Los Angeles River	533,840	1,676	19,870	3.7	1,426.6	142.7	644,841
Malibu Creek	129,825	0	0	0.0	0.0	0.0	-
San Gabriel River	434,475	1,137	12,685	2.9	1,175.4	117.5	419,592
Total	**1,303,657**	**2,888**	**33,327**	**2.6**	**2,655.4**	**265.5**	**1,076,698**

3. Appraisal-Level Analysis Results and Discussion

This section presents the appraisal-level analysis for each of the 12 project groups and categorized by the four broad categories: Local Solutions, Regional Solutions, Storage Solutions, and Management Solutions. Additional information for each of the 12 project groups is presented in the following appendices:

- Appendix B includes factsheets for each of the Local Solutions, Regional Solutions, Storage Solutions, and the Management Solutions project groups that summarize their characteristics, stormwater conservation and other benefits, capital and O&M costs, and other information.

- Appendix C includes a detailed discussion of the hydrologic modeling of each project group included in Appendix B.

- Appendix D includes estimated capital and operational costs for each project group included in Appendix B.

- Appendix E includes detailed results and costs for the LACFCD and USACE dams.

3.1. Local Solutions

Local solutions are decentralized infiltration concepts that are distributed across the watershed. The Local Solutions category is comprised of three project groups:

- Local Stormwater Capture
- Low Impact Development
- Complete Streets

The results of the appraisal-level analysis for each of these project groups is presented in Section 3.1.

3.1.1. Local Stormwater Capture

As previously discussed, local stormwater capture concepts consist of facilities that receive larger volumes of runoff from upstream areas for infiltration and stormwater retention compared to concepts that manage stormwater at the source. Runoff is typically diverted to local stormwater facilities after it has already entered storm drains and engineered channels. Local stormwater capture facilities may be in the form of surface infiltration basins or underground infiltration chambers as shown in Figure 7.

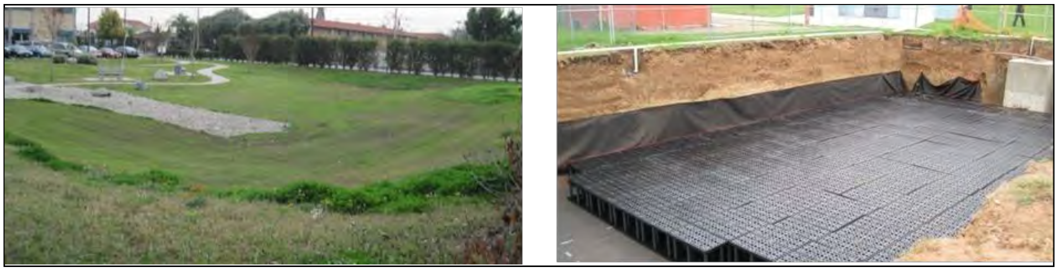


Figure 7. Surface Infiltration Basin and Underground Infiltration Chambers

In addition to stormwater conservation, some of the additional benefits of local stormwater capture projects are recreational, community enhancement, and habitat restoration. Naturalized surface systems like infiltration basins can enhance plant and bird habitat and provide educational opportunities. Underground systems can allow the beneficial use of a site to be maintained while simultaneously managing stormwater for recharge and water quality.

Appendix B includes a factsheet for the Local Stormwater Capture concepts that summarizes important features of this project group.

3.1.1.1 Results

Using the WMMS model, the Local Stormwater Capture project group was modeled to determine the amount of stormwater conserved for four projected climate scenarios. For the Mid 2 projected climate scenario, implementation of local stormwater capture projects will provide approximately 23,265 acre-feet of stormwater conservation per year. Table 18 summarizes the stormwater conserved per year in each watershed for each climate scenario. The values listed are the net results and have been adjusted to account for any reduction in conservation at regional facilities.

Table 18. Stormwater Conserved for Local Stormwater Capture

Watershed	Watershed Area (acres)	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Ballona Creek	135,090	466	541	619	753
Dominguez Channel	70,428	2	3	3	4
Los Angeles River	533,840	10,734	12,445	13,988	17,768
Malibu Creek	129,825	-	-	-	-
San Gabriel River	434,475	6,739	7,705	8,655	10,762
Total	**1,303,657**	**17,941**	**20,963**	**23,265**	**29,287**

The Los Angeles River watershed represents the largest volume of stormwater conservation based on total volume and also as a percentage of watershed area. This is due to the relatively favorable soil and aquifer conditions for stormwater capture in the Los Angeles River watershed compared to other watersheds.

Compared to other Local Solution projects, the Local Stormwater Capture concepts provide a moderate level of resiliency for stormwater conservation where the aquifer is unconfined. This is because they are sized to contain the 5-year storm which is a larger storm than the other Local Solution projects.

3.1.1.2 Capital and Operational Costs

Capital costs were developed based on a line item unit cost approach. Quantities of each line item were calculated based on the BMP storage volume and typical design configurations. The unit costs were derived from the Los Angeles Department of Water and Power (LADWP) Stormwater Capture Master Plan (Geosyntec, 2014). Capital Costs include construction costs, engineering, project management, legal and permitting, and contingency. An additional property acquisition cost was assumed for purchase of private open space parcels for the use of local stormwater capture projects, totaling approximately 2,655 acres.
An O&M cost was calculated using BMP storage volumes and unit costs derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014) and annualized over a 50-year analysis period. A summary of the local stormwater capture costs are presented below.

- **Capital Cost:** $2,393,000,000
- **O&M Cost:** $122,000,000/yr
- **Land Acquisition:** $1,328,000,000
- **Cost per Acre-foot:** $9,500 to $15,500

These cost estimates presented are considered to be planning level only (order of magnitude), and costs may be refined as projects are implemented. The financial strategy to fund these projects will require a coordinated, regional approach to ensure that costs are split by multiple partners across the region.

3.1.1.3 Other Project Characteristics and Benefits

Local Stormwater Capture concepts provide multiple benefits beside the retention of stormwater. In addition to stormwater conservation, complementary benefits may include, but are not limited to, flood risk management, water quality, recreation, habitat/connectivity, ecosystem function, and climate resilient actions. These other benefits could help to identify project partners as projects with multiple benefits can help to leverage funding. It should be noted that while local stormwater capture projects may provide some flood risk benefit, it will not negate or reduce the need for maintaining existing capacities at flood control facilities.

It was assumed that when implementing local stormwater capture on vacant parcels, 10 percent of the parcel could be used for wetland habitat, and recreational trails could be constructed on the perimeter of the parcel. This results in 266 acres of habitat and approximately 204 miles of recreational trails.

3.1.2. Low Impact Development

Low Impact Development (LID) concepts are distributed structural BMPs that capture and infiltrate runoff close to the source, at the parcel scale as shown in Figure 8. The tributary area for LID BMPs are generally smaller than the local stormwater capture projects, and include bioretention, permeable pavement, and other infiltration BMPs that prevent runoff from leaving a parcel. LID can be incorporated throughout the watersheds by the LID ordinances, residential participation of LID, and LID retrofits of public parcels.

Figure 8. Schematic Concept of LID at the Parcel Scale

Appendix B includes a factsheet for the LID project that summarizes important features of this project group.

3.1.2.1 Results

The LID concepts were analyzed for four projected climate scenarios using the WMMS model. As an example, for the Mid 2 projected climate scenario, implementation of local stormwater capture projects will provide approximately 115,240 acre-feet of stormwater conservation per year. Table 19 summarizes for each climate scenario the stormwater conserved per year in each watershed. The values listed are the net results and have been adjusted to account for any reduction in conservation at regional facilities.

Table 19. Stormwater Conserved for Low Impact Development

Watershed	Watershed Area (acres)	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Ballona Creek	135,090	8,047	8,648	9,287	10,157
Dominguez Channel	70,428	6,947	7,483	8,157	9,007
Los Angeles River	533,840	34,499	41,081	51,659	60,711
Malibu Creek	129,825	1,177	1,257	1,283	1,401
San Gabriel River	434,475	30,766	35,596	44,854	50,286
Total	**1,303,657**	**81,437**	**94,067**	**115,240**	**131,562**

The Los Angeles River watershed represents the largest volume of stormwater conservation due to the large size of the watershed. However, the Dominguez Channel has the highest percentage of stormwater conservation relative to watershed area because the watershed is highly impervious with a larger percentage of institutional and industrial land uses compared to other watersheds These land uses, because they are highly regulated, are assumed to have a higher LID implementation rate than land uses that are not closely regulated (e.g., residential). Watersheds that are less impervious (e.g., Malibu Creek) have a lower percentage of stormwater conservation relative to watershed area.

LID projects provide a large volume of stormwater conservation because of widespread implementation across the study area. But compared to other project groups, LID projects provide a lower level of resiliency in stormwater conservation. While LID BMPs provide some resiliency through infiltration into the groundwater aquifer where the aquifer is unconfined, they are only sized to retain the 85th percentile storm. A rainfall depth of 0.75 to 0.97 inches was used to represent the 85th percentile storm, and runoff from larger storms are bypassed. Therefore, the LID BMPs are not able to provide storage in larger storms compared to local stormwater capture.

3.1.2.2 Capital and Operational Costs

Capital costs were developed based on a line item unit cost approach. Quantities of each line item were calculated based on the BMP storage volume and typical design configurations. The unit costs were derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014). A breakdown of BMP types was assumed for each land use to determine unit costs. No property acquisition was assumed for this concept. An O&M cost was calculated using BMP storage volumes and unit costs derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014) and annualized over a 50-year analysis period.

A summary of the Low Impact Development costs are presented below.

- **Capital Cost:** $10,177,000,000
- **O&M Cost:** $474,000,000/yr
- **Land Acquisition:** $0
- **Cost per Acre-foot:** $6,800 to $11,000

These cost estimates presented are considered to be planning level only (order of magnitude), and costs may be refined as projects are implemented. The financial strategy to fund these projects will require a coordinated, regional approach to ensure that costs are split by multiple partners across the region. Some of the costs will be funded by private developers to incorporate LID concepts into their site design for significant development and redevelopment projects.

3.1.2.3 Other Project Characteristics and Benefits

In addition to stormwater conservation, complementary benefits may include, but are not limited to, water quality, recreation, aesthetics, habitat/connectivity, mitigation of urban heat island effect, and climate resilient actions. These other benefits could help to identify project partners as projects with multiple benefits can help to leverage funding.

3.1.3. Complete Streets

The goal of Complete Streets is to ensure that the safety, accessibility, and convenience of all transportation users—pedestrians, bicyclists, transit riders, and motorists—is accommodated. Complete Streets serve a much larger purpose than just moving cars. They encourage healthy recreational activities such as walking, running, and bicycling. The Complete Streets Design Guide (City of Los Angeles, 2015) provides a compilation of design concepts and BMPs for streets as a companion to the Mobility Plan 2035, an update to the Mobility Element of the City of Los Angeles General Plan.

One aspect of Complete Streets is stormwater treatment and management providing onsite retention, filtration, and infiltration to reduce urban runoff from the roadway, driveways, and sidewalk area as shown in Figure 9. These stormwater management facilities in the public right-of-way are typically implemented as linear bioretention/biofiltration BMPs installed parallel to roadways to supplement or replace existing parkway landscaping. Systems receive runoff from the gutter via curb cuts or curb extensions and infiltrate through native or engineered soil media. Permeable pavement can also be implemented as part of Complete Streets.

Appendix B includes a factsheet for the Complete Street concepts that summarizes important features of this project group.

Figure 9. Schematic Concept of Complete Streets

3.1.3.1 Results

The WMMS model was run for four projected climate scenarios. For the Mid 2 projected climate scenario, implementation of Complete Street concepts will provide approximately 35,230 acre-feet of stormwater conservation per year. Table 20 summarizes the stormwater conserved per year in each watershed. The values listed are the net results and have been adjusted to account for any reduction in conservation at regional facilities.

Table 20. Stormwater Conserved for Complete Streets

Watershed	Watershed Area (acres)	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Ballona Creek	135,090	4,180	4,490	4,835	5,283
Dominguez Channel	70,428	2,127	2,271	2,482	2,738
Los Angeles River	533,840	13,975	16,266	18,540	23,684
Malibu Creek	129,825	252	268	273	300
San Gabriel River	434,475	6,808	7,922	9,100	11,264
Total	**1,303,657**	**27,342**	**31,217**	**35,230**	**43,269**

The Los Angeles River watershed represents the largest volume of stormwater conservation due to the large size of the watershed. However, the Ballona Creek and Dominguez Channel watersheds have the highest percentage of stormwater conservation relative to watershed area because of their large percentage of impervious transportation areas. Malibu Creek has the least transportation land use areas, and correspondingly, the lowest amount of stormwater conservation for Complete Street implementation.

Complete Streets provide a large volume of stormwater conservation because of widespread implementation across the study area. But compared to other project groups, Complete Streets provide a lower level of resiliency in stormwater conservation. While Complete Streets provide some resiliency through infiltration into the groundwater aquifer where the aquifer is unconfined, stormwater management facilities in Complete Streets are only sized to retain the 85^{th} percentile storm. A rainfall depth of 0.75 to 0.97 inches was used to represent the 85^{th} percentile storm, and runoff from larger storms are bypassed. Therefore, Complete Streets are not able to provide storage in larger storms compared to the Local Stormwater Capture project group.

3.1.3.2 Capital and Operational Costs

Capital costs were developed based on a line item unit cost approach. Quantities of each line item were calculated based on the BMP storage volume and typical design configurations. The unit costs were derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014). A breakdown of BMP types was assumed for each land use to determine unit costs. No property acquisition was assumed for this concept. An O&M cost was calculated using BMP storage volumes and unit costs derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014) and annualized over a 50-year analysis period.

A summary of the Complete Streets costs are presented below.

- **Capital Cost:** $6,297,000,000
- **O&M Cost:** $263,000,000/yr
- **Land Acquisition:** $0
- **Cost per Acre-foot:** $12,100 to $19,200

These cost estimates presented are considered to be planning level only (order of magnitude), and costs may be refined as projects are implemented. As a note, the large conservation costs for complete streets in this section is attributed to the full cost of the improvement being linked only to the stormwater conservation benefit, whereas there are many other primary benefits provided by complete streets, such as increased modal transportation, a vehicle transportation corridor, roadway lighting, and utilities. A more in depth cost analysis should indicate a much lower conservation cost for this type of impermanent. The financial strategy to fund these projects will require a coordinated, regional approach to ensure that costs are split by multiple partners across the region.

3.1.3.3 Other Project Characteristics and Benefits

Green streets have been demonstrated to provide “complete streets” benefits in addition to stormwater management, including pedestrian safety and traffic calming, street tree canopy and heat island effect mitigation, increased property values, and a boost in economic activity and visibility of storefront businesses.

3.2. Regional Solutions

Regional solution projects recharge groundwater by infiltrating stormwater in spreading grounds and soft bottom channels. The Regional Solutions category is comprised of three project groups:

- Regional Stormwater Capture
- Stormwater Conveyance Systems
- Alternative Capture

The results of the appraisal-level analysis for each of these project groups is presented in Section 3.2.1.

3.2.1. Regional Stormwater Capture

The concepts related to the construction of new spreading basins and enhancement of existing basins are high-scoring concepts in the Appraisal-Level Stormwater Conservation Matrix (Appendix A). The high-scoring Regional Stormwater Capture opportunities in the Appraisal-Level Stormwater Conservation Matrix included:

- Investigate potential recharge sites around Sepulveda Dam
- New basins
- Increased and enhanced maintenance at existing spreading grounds (e.g., remove top soil)
- Construct the San Jose Spreading Grounds (adjacent to Cal Poly Pomona)
- Abandoned Quarry Pits for storage

The Regional Stormwater Capture project group considers the construction of eight new spreading grounds and enhancements at existing spreading grounds to increase groundwater recharge. The project group also includes two recently constructed projects and 11 planned modifications to existing spreading grounds. More details on these projects are included in Appendix C. Appendix B includes a factsheet that summarizes important features of this project group.

Potential recreation and habitat enhancements for the new basins include trails or parkways and wetland forebay areas. For this Regional Solution type, 10 percent of the area of all new basins were assumed to be dedicated to habitat. In total, the group of projects would include 42 acres of habitat and over 12 miles of recreational trail.

Figure 10 shows a schematic of a new spreading ground (NSG) and Figure 11 shows the location of the NSGs and the enhanced spreading grounds (ESG) where enhanced soil management actives would be performed. Tables 21 and 22 summarize their characteristics.

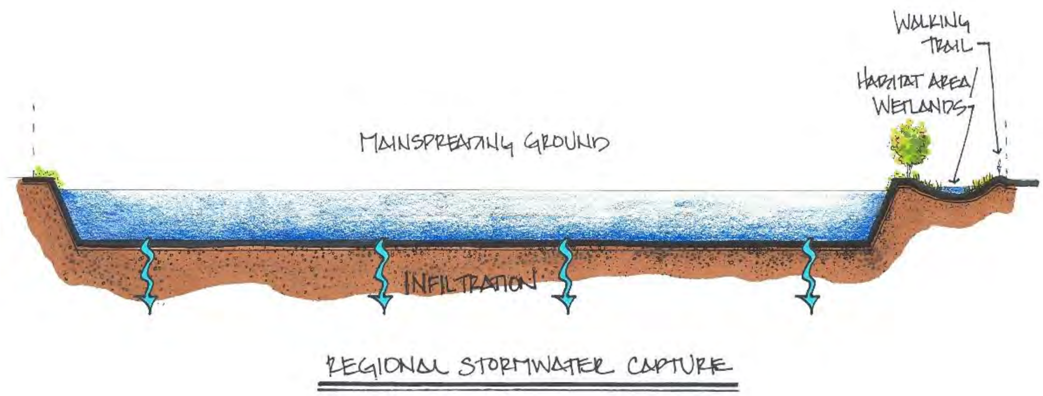


Figure 10. Schematic Concept of a New Spreading Ground

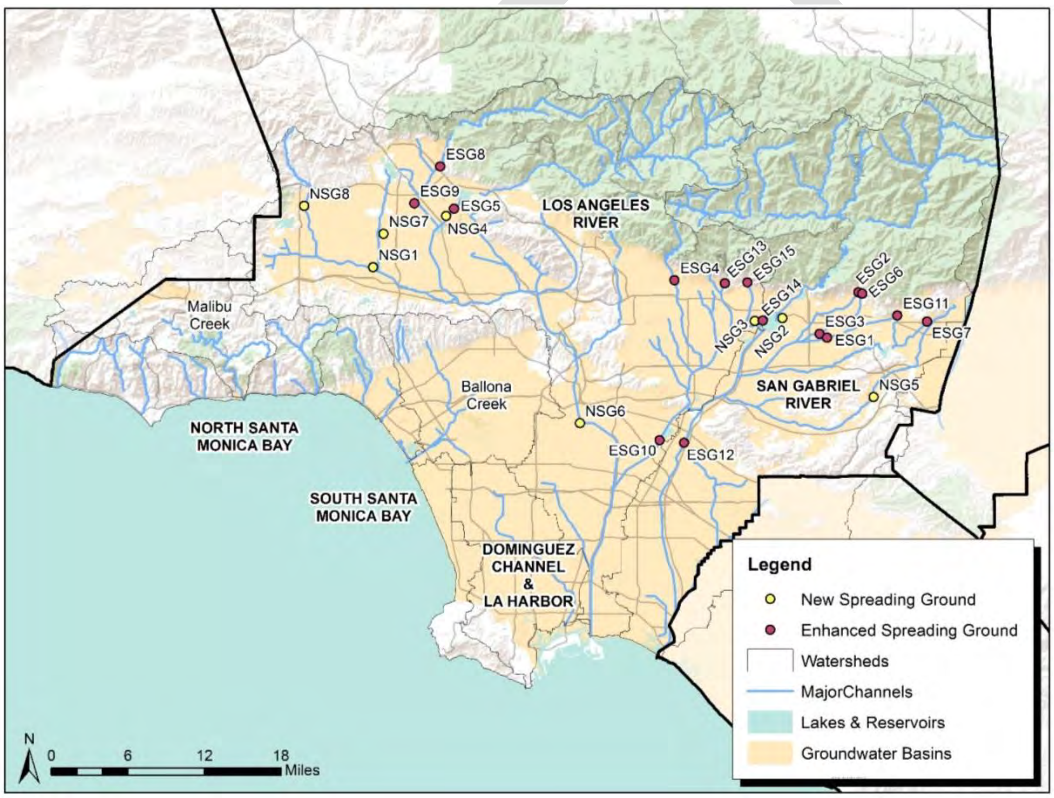


Figure 11. Regional Stormwater Capture Projects

Table 21. New Spreading Grounds

ID	Location	Wetted Area (acres)	Storage (ac-ft)	Intake (cfs)	Estimated Recharge Capacity (cfs)	ROW (acres)	Habitat[a] (acres)	Recreation Trails (feet)
NSG1	Sepulveda Dam	40.6	405.9	200.0	18.6	58.3	4.1	7,431
NSG2	Miller Pit	33.8	612.0	120.0	30.9	56.7	3.4	6,128
NSG3	Rock Pit No. 3	53.4	477	240[c]	25.0	89.2	5.3	7,807
NSG4	New Tujunga Spreading Grounds	219.3	4292.1	1,200[b]	338.7	365.7	21.9	11,307
NSG5	Spadra Basin	12.3	122.8	45.0	10.0	17.5	1.2	3,673
NSG6	LA River Spreading Ground	23.9	26.6	48	12.1	40.0	2.7	7,666
NSG7	Bull Creek Area Spreading Grounds	16.5	11.5	21	5.2	18.2	1.2	5,454
NSG8	Browns Creek Area Spreading Grounds	35.3	24.7	45	11.2	36.1	2.5	13,993
Total		**435**	**5,973**	**479**	**452**	**682**	**42**	**63,459**

[a] Assume 10 percent of wetted area
[b] Total intake for new and enhanced Tujunga Spreading Grounds
[c] Expansion of Buena Vista Spreading Grounds

Table 22. Enhanced Spreading Grounds

ID	Location	Wetted Area (acres)	Storage (ac-ft)	Intake (cfs)	Existing Percolation Rate (cfs)	Enhanced Percolation Rate (cfs)
ESG1	Ben Lomond	17	168	400	30	36
ESG2	Big Dalton	6.7	8	45	15	18
ESG3	Citrus	14.6	77	245	28	34
ESG4	Eaton Wash	25.2	526	200	14	17
ESG5	Hansen/Tujunga	190.3	1,572	650	570	684
ESG6	Little Dalton	4.7	5	20	12	14
ESG7	Live Oak	3	13	15	12	14
ESG8	Lopez	12	24	25	12	14
ESG9	Pacoima	107.3	440	600	65	78
ESG10	Rio Hondo	429	3,575	1,950	400	480
ESG11	San Dimas	9.5	30	25	8	10
ESG12	San Gabriel Coastal	95.9	550	350	75	90
ESG13	Santa Anita	8.5	25	20	5	6
ESG14	Santa Fe	95	635	600	400	480
ESG15	Sawpit	4	13	30	12	14

3.2.1.1 Results

Implementation of the Regional Stormwater Capture projects will provide approximately 43,311 acre-feet of additional stormwater conservation per year based on the Mid 2 projected climate scenario. Table 23 summarizes the modeled change in stormwater conservation associated with the Regional Stormwater Capture project group. The historic, Task 4 baseline, and modeled stormwater conservation is provided in Appendix C

Climate resilient stormwater capture improvements conserve more stormwater when it is available. As shown in Table 23, larger amounts of stormwater conservation are projected to occur under the wet scenario verses the dryer climate scenarios. The increased stormwater conserved associated with the new and expanded basins ranges from approximately 20,000 AFY for the Low 1 climate scenario to approximately 40,000 AFY for the High 1 climate scenario. The increases associated with the existing basins ranges from approximately 7,000 to 20,000 AFY for the same climate scenarios.

Table 23. Stormwater Conserved for Regional Stormwater Capture

Recharge Basin	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Existing Basins	**6,777**	**12,330**	**13,381**	**20,086**
Ben Lomond[a, c]	-80	-76	-43	-30
Big Dalton[a, b]	62	78	82	102
Branford[b]	175	265	282	361
Citrus[a]	53	98	94	119
Dominguez Gap[b]	1,239	1,406	1,454	1,554
Eaton Basin[c]	-60	-73	-59	-65
Eaton Wash[b]	1,171	1,904	2,059	2,843
Forbes[c]	-10	-11	-12	-15
Irwindale[c]	-178	-284	-263	-330
Little Dalton[a]	18	24	24	32
Live Oaka	16	20	22	26
Lopez[a, b]	41	44	46	52
Pacoima[a, b]	2,406	4,118	4,279	5,939
Peck Road	626	1,197	1,345	2,069
Rio Hondo[a]	1,359	2,793	3,238	5,763
San Dimasa	173	237	214	293
San Gabriel Canyon	0	0	0	0
San Gabriel Coastal[a]	71	579	580	1,087
Santa Anita[a]	36	40	41	50
Santa Fe[a, c]	-766	-512	-519	-360
Sawpit[a]	8	16	19	26
Sierra Madre	0	0	0	0
Walnut[b]	417	467	498	568
Expanded Basins	**5,505**	**10,724**	**12,437**	**19,466**
Buena Vista and New Rock Pit No. 3	503	786	878	1,164

Table 23. Stormwater Conserved for Regional Stormwater Capture

Recharge Basin	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Hansen/Tujunga and New Tujunga Expansion[b]	5,002	9,938	11,559	18,301
New Basins	**13,854**	**16,809**	**17,493**	**20,326**
Browns Creek Area Spreading Grounds	825	1,229	1,322	1,766
Bull Creek Area Spreading Grounds	1,175	1,348	1,382	1,569
LA River Spreading Grounds	3,976	4,317	4,474	4,825
Miller Pit (Santa Fe Dam) Spreading Ground	2,809	4,175	4,384	5,593
Sepulveda Dam Spreading Ground	3,702	4,143	4,263	4,680
Spadra Spreading Ground (Pomona)	1,367	1,596	1,668	1892
Net Change	**26,136**	**39,863**	**43,311**	**59,878**

[a] Recharge rate enhanced 20 percent through improved maintenance

[b] Includes planned modifications to existing basin volume, recharge rate, and/or intake rate.

[c] Negative numbers represents a reduction in recharge compared to the baseline condition, and results from reduction in available water due to increased capture upstream.

3.2.1.2 Capital and Operational Costs

Capital costs were developed based on a line item unit cost approach. Quantities of each line item were calculated based on the sizing of the basins, habitat and recreational improvements, and other associated infrastructure. The unit costs were derived from previous CH2M cost estimates for similar project work. Approximately 682 acres would be required for the recharge basins, including the private open space parcels that could be purchased are existing gravel pits that could be repurposed as recharge basins. Land acquisition cost is a significant portion of the estimated capital cost for this project group. An O&M cost of 5 percent of the construction costs was calculated, added to power consumptions costs, and annualized over a 50-year analysis period for the new basins. The additional O&M costs for the enhanced basins were inflated from 2000 unit rates costs per acre for the Rio Hondo Spreading grounds (MWH, 2003). A summary of the Regional Stormwater Capture project costs are presented below.

- **Capital Cost:** $652,000,000
- **O&M Cost:** $13,000,000/yr
- **Land Acquisition:** $341,000,000
- **Cost per Acre-foot:** $900 to $2,100

Refer to Appendix D for a more detailed summary of capital and operational costs.

3.2.1.3 Other Project Characteristics and Benefits

Implementation of Regional Stormwater Capture projects will provide approximately 42 acres of wetland habitat, and over 12 miles of recreational trails. In addition, the new and enhanced basins provide water quality benefits though soil aquifer treatment and an associated reduction in pollutant loading to receiving waters.

3.2.2. Stormwater Conveyance Systems

This project group provides stormwater conservation benefits through a suite of channel modification concepts. A preliminary screening of areas favorable for conversion to soft bottom channels was performed focusing on tributary reaches overlying unconfined groundwater basins. The main channel reaches were eliminated for evaluation of potential streambed modification because of the greater potential for impacts to flood risk management. Potential recreation and habitat opportunities include trail networks, parkways, and riparian habitat corridors along the naturalized channel easements. Figure 12 shows the locations of tributaries identified for streambed modification.

The high-scoring channel modification concepts in the Appraisal-Level Stormwater Conservation Matrix included:

- Channel side-ponds
- Improve stormwater capture and habitat along Tujunga Wash corridor
- Increase soft-bottom channels
- Alternative streams in unconfined aquifers (e.g., Tujunga Wash Greenway)
- River speed bumps

Two approaches were evaluated to enhance short-term stormwater detention within existing or converted soft bottom channels areas. “River speed bumps”, small in-channel earthen detention structures, were assumed for all modified channel reaches. Channel side ponds which are narrow recharge basins built along existing channels as shown in Figure 13, were considered where easements are wide enough or land appears available for their installation. Table 24 summarizes the characteristics of the channel modifications. Appendix B includes a factsheet that summarizes important features of this project group.

The potential for adverse impacts to capacity, freeboard and flood protection associated with naturalizing the channels and potential strategies to mitigate these issues would need to be evaluated during subsequent studies.

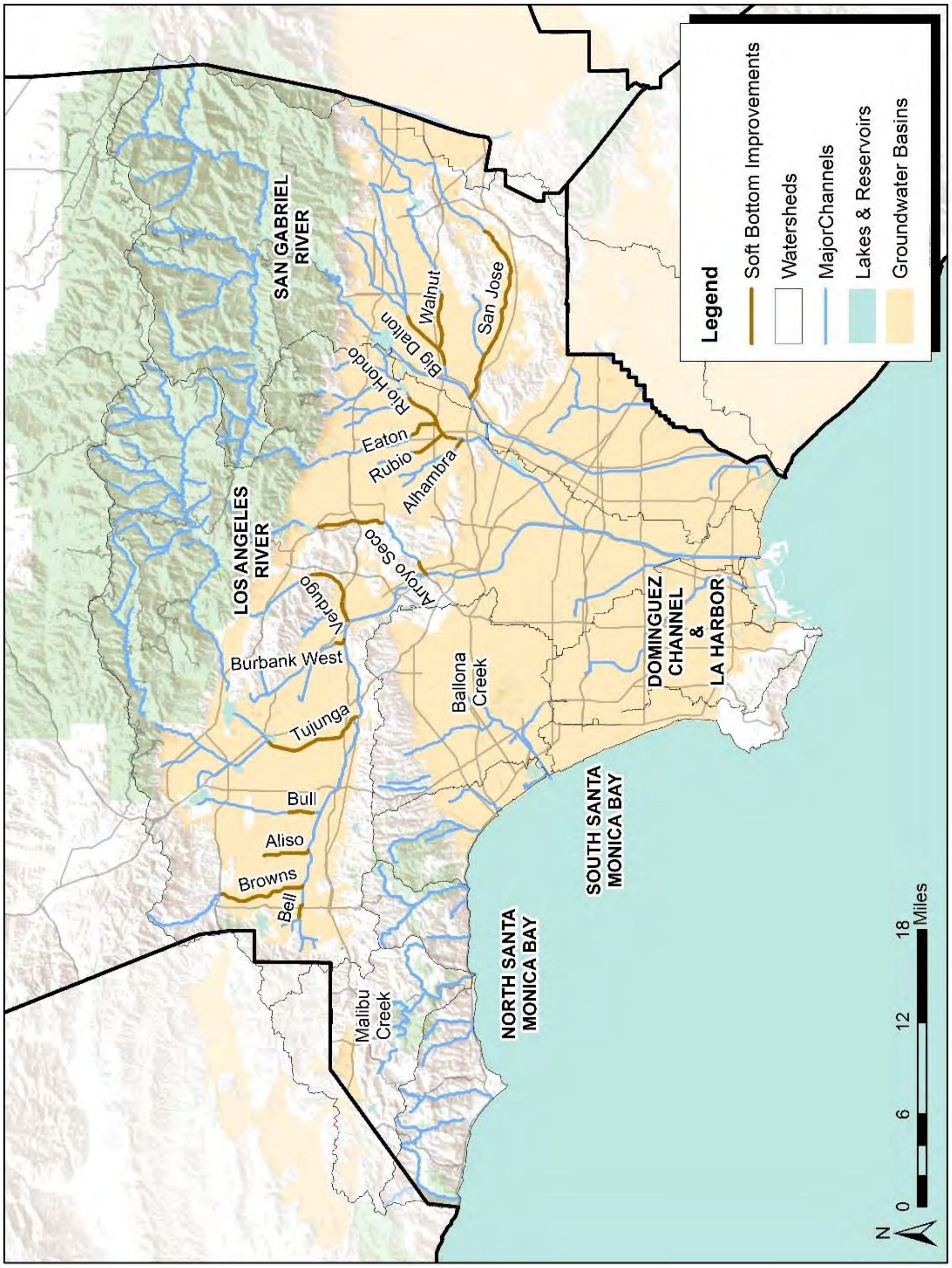


Figure 12. Stormwater Conveyance Systems

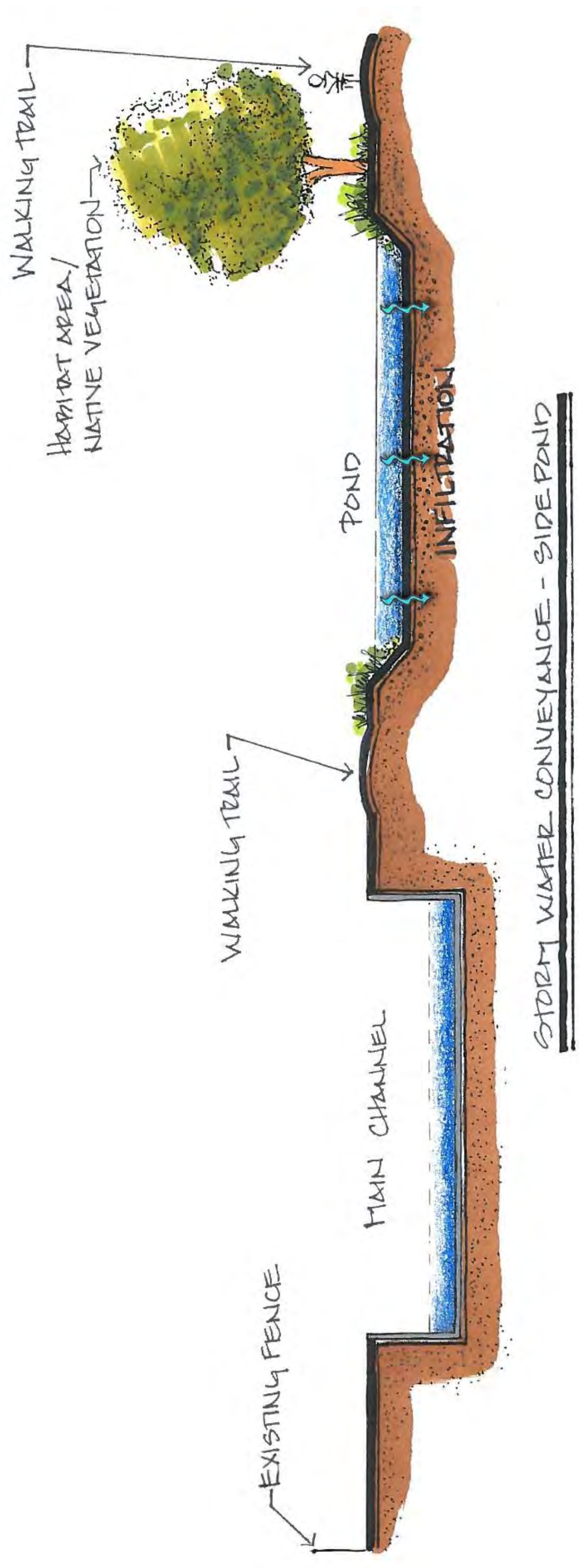


Figure 13. Schematic of Stormwater Conveyance Systems

Table 24. Channel Modifications

Channel	Width (feet)	Modification Length (feet)	Length of Side Pond (feet)	Percolation Rate (cfs)	ROW (acres)	Habitat (acres)	Recreation Trails (feet)
Alhambra Wash	50	2,572	135	0.2	0.2	0.1	135
Aliso Creek	50	9,269	6,179	1.3	10.5	2.8	6,179
Arroyo Seco Channel	50	28,764	1,514	2.7	2.6	0.7	1,514
Bell Creek	50	4,590	-	0.3	-	-	-
Big Dalton Wash	60	15,354	808	1.9	1.4	0.4	808
Browns Creek	50	28,531	1,502	2.3	2.6	0.7	1,502
Bull Creek	60	7,954	80	0.7	0.1	0.0	80
Burbank Western System	50	3,132	-	0.2	-	-	-
Eaton Wash	50	10,338	544	2.2	0.9	0.2	544
Rio Hondo	75	21,205	1,116	2.6	1.9	0.5	1,116
Rubio Wash	50	11,056	582	1.4	1.0	0.3	582
San Jose Creek	70	60,868	3,204	6.8	5.4	1.5	3,204
Tujunga Wash	70	34,988	-	3.7	-	-	-
Verdugo Wash	80	21,531	1,133	2.7	1.9	0.5	1,133
Walnut Creek Channel	50	23,195	1,221	2.8	2.1	0.6	1,221
Total		**283,346**	**18,018**	**31.7**	**30.6**	**8.3**	**18,018**

3.2.2.1 Results

Implementation of the Stormwater Conveyance Systems project group will provide approximately 9,188 acre-feet of stormwater conservation per year based on the Mid 2 projected climate scenario. Table 25 summarizes the modeled increase in stormwater conservation relative to baseline conditions.

Table 25. Stormwater Conserved for Stormwater Conveyance Systems

Channel	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Alhambra Wash	66	71	73	77
Aliso Creek	337	393	401	428
Arroyo Seco Channel	863	908	932	1012
Bell Creek	104	115	118	129
Big Dalton Wash	429	489	487	532
Browns Creek	497	578	601	669
Bull Creek	227	251	257	275
Burbank Western System	73	78	81	87
Eaton Wash	195	218	220	241
Rio Hondo	635	725	740	812
Rubio Wash	255	285	291	320
San Jose Creek	2,052	2,346	2,389	2,566
Tujunga Wash	911	1048	1076	1160
Verdugo Wash	849	914	947	1033
Walnut Creek Channel	522	566	575	627
Total	**8,014**	**8,987**	**9,188**	**9,968**

The modeled stormwater conservation ranges from approximately 8,000 to 10,000 AFY for the dry Low 1 and wet High 1 climate scenarios shown in Table 25. The increase in conservation under wet conditions illustrates the resilient nature of these improvements. The adaptive capacity of these modifications, however, is limited by the finite capacity the modified channels to recharge groundwater and to convey food stage flows. The channel modification projects appear to be less resilient than the regional stormwater capture projects.

3.2.2.2 Capital and Operational Costs

Capital costs were developed based on a line item unit cost approach. Quantities of each line item were calculated based on width of channel improvements, habitat and recreational improvements, and other associated infrastructure. The unit costs were derived from previous CH2M cost estimates for similar project work. Approximately 31 acres of land acquisition would be needed where the existing easement is not wide enough to accommodate channel side ponds. An O&M cost of 5 percent of the construction costs was calculated and annualized over a 50-year analysis period. A summary of the Stormwater Conveyance System project costs are presented below.

- **Capital Cost:** $7,139,000,000
- **O&M Cost:** $127,000,000/yr
- **Land Acquisition:** $15,000,000
- **Cost per Acre-foot:** $42,700 to $53,100

Refer to Appendix D for a more detailed summary of capital and operational costs.

3.2.2.3 Other Project Characteristics and Benefits

Additional benefits associated with the new Stormwater Conveyance Systems include habitat space and recreational opportunities. Implementation of the Stormwater Conveyance Systems project group will provide 8 acres of habitat and over 3 miles of recreational trail, as well as urban heat island mitigation and water quality benefits.

3.2.3. Alternative Capture

The high-scoring Alternative Capture concepts in the Appraisal-Level Stormwater Conservation Matrix included:

- The Los Angeles Forebay – Big infiltration basins under everything
- Consolidate less efficient systems (dams/watershed)

Although significant recharge of stormwater derived from the Rio Hondo and San Gabriel River occur within the Central Basin, there are no managed groundwater recharge facilities on the Los Angeles River in the Central Basin, with the exception of the Dominguez Gap spreading grounds. One reason for this is the limited land available within the Los Angeles Forebay area for spreading basins. The *Ground Water Basins Master Plan Water Replenishment District of Southern California* identified a concept where flows would be diverted from the Los Angeles River and conveyed to shallow recharge ponds constructed along power line easements (CH2M HILL, 2012). The infiltration provides soil aquifer treatment of the diverted flows. The area is underlain by a shallow aquitard, which limits the potential for direct recharge of the unconfined aquifer system. Shallow extraction wells along the perimeter of the basins would extract the treated groundwater, which would then be injected below the shallow aquitard into the production aquifer. Groundwater in the shallow aquifer system would need to be evaluated to confirm it is of suffice quality for deep injection before proceeding with the project. Figure 14 shows the assumed location of this facility and Figure 15 shows a schematic. Table 26 summarizes its characteristics. Appendix B includes a factsheet that summarizes important features of this project.

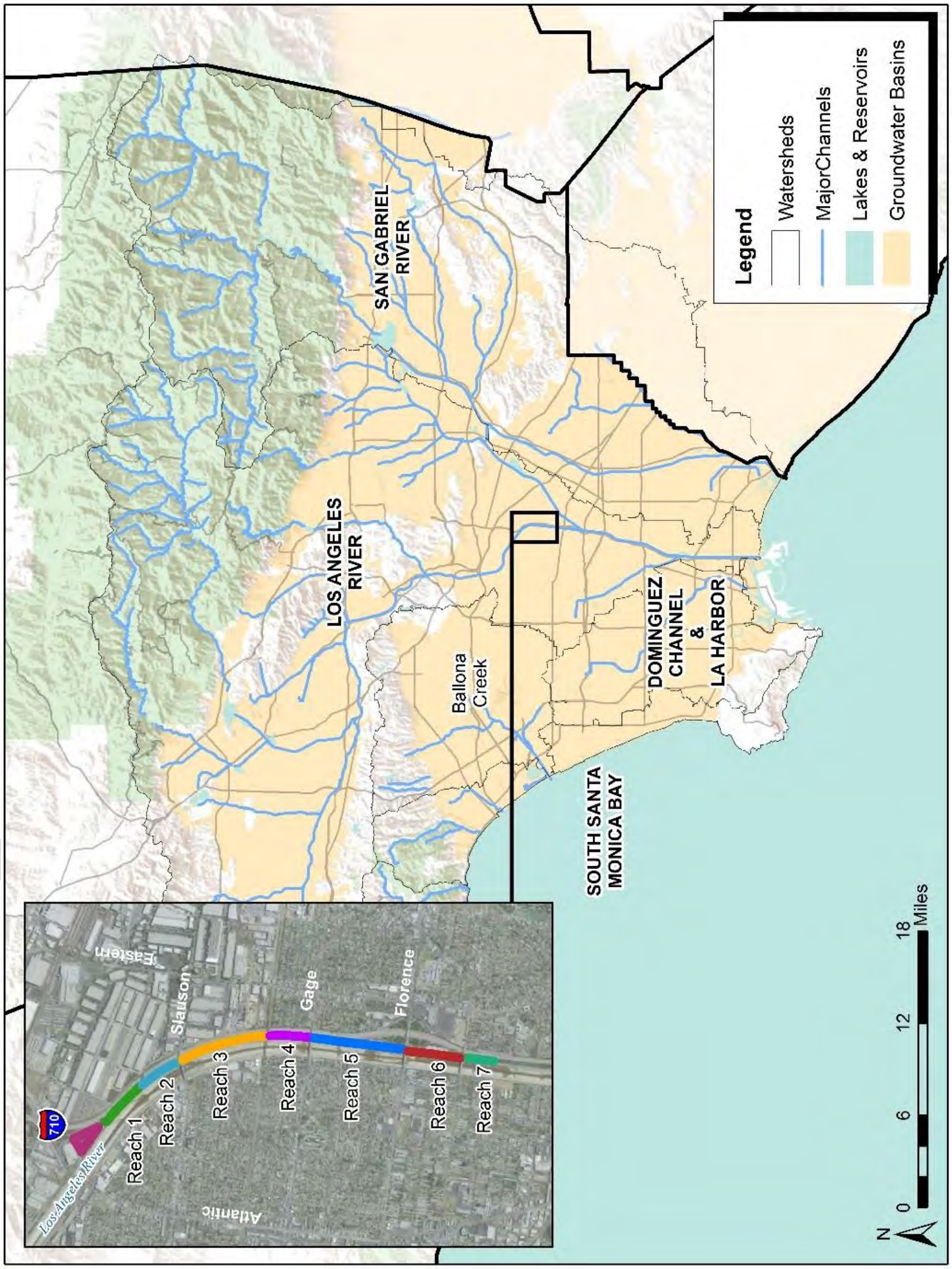


Figure 14. Alternative Capture

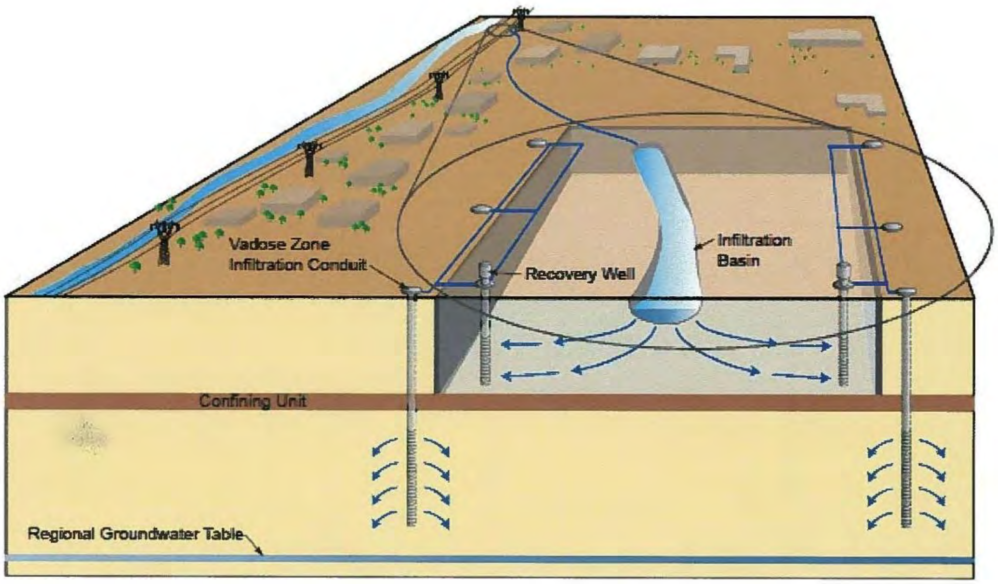


Figure 15 Alternative Capture Schematic

Table 26. Alternative Capture

Reach No.	Infiltration Area (acres)	No. of Extraction Wells	No. of Injection Wells	Reach Length (feet)	ROW (acres)	Habitat (acres)	Recreation Trails (feet)
0	3.8	4	8	1,300	6.3	0.4	1,300
1	1.5	2	4	1,255	2.5	0.2	1,255
2	2.4	2	4	1,230	4.0	0.2	1,230
3	5.1	6	12	2,530	8.5	0.5	2,530
4	2.7	4	8	1,170	4.5	0.3	1,170
5	2.5	2	4	2,600	4.2	0.3	2,600
6	1.4	2	4	1,355	2.3	0.1	1,355
7	0.7		4	1,355	1.2	0.1	1,355
Total	**20.1**	**24**	**48**	**12,795**	**33.5**	**2.0**	**12,795**

3.2.3.1 Results

Implementation of the Alternative Capture project will provide approximately 5,587 acre-feet of stormwater conservation per year based on the Mid 2 projected climate scenario. Table 27 summarizes the additional stormwater conservation relative to baseline conditions.

Table 27. Stormwater Conserved for Alternative Capture

Channel	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Los Angeles River	3,847	5,324	5,587	6,884

The modeled stormwater conservation ranges from 3,847 to 6,884 AFY for the dry Low 1 and wet High 1 climate scenarios shown in Table 27. The increase in conservation under wet conditions illustrates the resilient nature of these improvements. The adaptive capacity of these modifications, however, is limited by the capacity of the recharge basins and diversion structure.

3.2.3.2 Capital and Operational Costs

Capital costs were developed based on a line item unit cost approach. Quantities of each line item were calculated based on the size of the basin segments, recreational improvements, and other associated infrastructure. The unit costs were derived from previous estimates. Approximately 34 acres of land acquisition would be required where the existing easement is not wide enough to accommodate channel side ponds. An O&M cost of 5 percent of the construction costs was calculated and added to power consumption costs. The resulting O&M costs were annualized over a 50-year analysis period. A summary of the Alternative Capture project costs are presented below.

- **Capital Cost:** $135,000,000
- **O&M Cost:** $3,000,000/yr
- **Land Acquisition:** $16,750,0000
- **Cost per Acre-foot:** $1,400 to $2,400

Refer to Appendix D for a more detailed summary of capital and operational costs.

3.2.3.3 Other Project Characteristics and Benefits

Implementation of Alternative Capture concepts will provide 2 miles of recreational trails and 2 acres of habitat area. In addition, the alternative capture basins provide water quality benefits though soil aquifer treatment and an associated reduction in pollutant loading to receiving waters.

3.3. Storage Solutions

Storage Solution projects include modification or reoperation of existing dams and debris basins to enhance surface water storage, which would eventually be released to downstream spreading basins to recharge groundwater. The storage solutions category consists of three project groups:

- LACFCD Dams
- USACE Dams
- Debris Basins

The results of the appraisal-level analysis for each of these project groups are presented below. It is *important to recognize* that for all structural and nonstructural improvements in this section, the volume of increased stormwater capture is only an increase in the total or operational storage capacity at each facility. This volume is potentially available for groundwater recharge at a later point in time and does not represent an actual increase in total stormwater recharged.

3.3.1. LACFCD Dams

3.3.1.1 Structural Concepts

As previously discussed in Section 2.4.3.1, structural concepts were developed for the nine remaining 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 under certain conditions.

3.3.1.2 Results

A summary of the results for the nine LACFCD dams considered for each of the four scenarios analyzed in Task 5 is presented in Tables 28 through 32 on the following pages. The Task 5 results for the Structural Concepts for the key metrics are presented for comparison alongside the corresponding Task 4 results. Selected results are also provided for the Historical period for comparison. (A separate summary of these results for each dam is presented in Tables E-1 through E-10 in Appendix E of this report.)

For seven of the nine dams, Capture Ratios are generally near 100 percent for all of the scenarios. For the other two dams (Big Tujunga and Morris), Capture Ratios are much lower, but higher for the Task 5 Structural Concepts than for either the Historic period or the corresponding Task 4 projected climate scenarios.

It is noteworthy that Capture Ratios are typically higher for the drier projected climate scenarios. Because the volumes captured are generally smaller for drier periods, the reservoirs can be drawn down more quickly after a runoff event, making storage capacity more readily available for capture of runoff during subsequent events.

Table 28. LACFCD Dams Structural Concept Results – High 1 Scenario

Dam Name	Mean Annual Volume Captured* (ac-ft)			Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio			Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Event	
	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
Big Tujunga	12,845	19,299	40,753	34,289	12,846	64.2%	35.9%	75.9%	-28.2%	11.7%	1.85	3.61
Cogswell	19,282	27,397	51,680	25,898	1,624	75.5%	51.4%	96.9%	-24.2%	21.3%	1.82	0.36
Devil's Gate	9,570	12,925	32,204	19,277	0	66.9%	40.1%	100.0%	-26.8%	33.1%	2.94	0.00
Eaton Wash	3,681	6,426	9,105	2,739	61	86.6%	70.1%	99.3%	-16.5%	12.7%	5.46	0.10
Morris	44,980	53,120	156,526	189,341	86,017	39.8%	21.9%	64.5%	-17.9%	24.7%	0.96	1.49
Pacoima	6,219	14,354	18,009	4,123	468	87.0%	77.6%	97.3%	-9.5%	10.3%	1.70	0.49
Puddingstone Diversion	6,452	12,106	14,053	1,975	29	94.9%	86.0%	99.8%	-8.9%	4.9%	3.54	0.02
San Dimas	4,474	6,798	10,771	4,066	93	82.1%	62.5%	99.0%	-19.6%	16.9%	2.00	0.15
San Gabriel	90,825	140,764	224,166	94,785	11,438	82.1%	59.8%	95.1%	-22.3%	13.1%	1.89	0.88
Totals	**198,329**	**293,188**	**557,267**	**376,492**	**112,576**	**64.6%**	**43.8%**	**83.2%**	**-20.8%**	**18.6%**	**NA**	**NA**

* Volume captured does not indicate volume of water used for stormwater recharge. Volume captured indicates total increased volume of storage available for potential water conservation use.

Table 29. LACFCD Dams Structural Concept Results – Mid 2 Scenario

Dam Name	Mean Annual Volume Captured* (ac-ft)			Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio			Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Event	
	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
Big Tujunga	12,845	14,699	26,485	16,277	4,496	64.2%	47.3%	85.2%	-16.9%	21.1%	1.24	1.48
Cogswell	19,282	22,187	33,949	12,477	721	75.5%	63.9%	97.8%	-11.6%	22.3%	1.06	0.18
Devil's Gate	9,570	10,324	20,071	9,774	28	66.9%	51.4%	99.9%	-15.6%	32.9%	2.04	0.02
Eaton Wash	3,681	4,780	6,057	1,291	15	86.6%	78.7%	99.8%	-7.9%	13.1%	3.14	0.04
Morris	44,980	46,560	118,413	109,910	38,094	39.8%	29.7%	75.6%	-10.0%	35.9%	0.76	0.83
Pacoima	6,219	9,419	10,678	1,404	145	87.0%	86.8%	98.4%	-0.3%	11.3%	0.57	0.08
Puddingstone Diversion	6,452	8,011	8,898	895	8	94.9%	90.0%	99.9%	-4.9%	5.1%	1.77	0.01
San Dimas	4,474	4,823	6,864	2,095	53	82.1%	69.5%	99.0%	-12.6%	16.9%	1.45	0.08
San Gabriel	90,825	108,576	147,980	44,152	4,770	82.1%	71.1%	96.9%	-11.0%	14.8%	1.18	0.25
Totals	**198,329**	**229,379**	**379,394**	**198,274**	**48,330**	**64.6%**	**53.6%**	**88.6%**	**-10.9%**	**24.1%**	**NA**	**NA**

* Volume captured does not indicate volume of water used for stormwater recharge. Volume captured indicates total increased volume of storage available for potential water conservation use.

Table 30. LACFCD Dams Structural Concept Results – Low 1 Scenario

Dam Name	Mean Annual Volume Captured* (ac-ft)			Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio			Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Event	
	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
Big Tujunga	12,845	8,910	12,509	5,425	1,827	64.2%	61.7%	86.6%	-2.5%	22.5%	0.50	0.45
Cogswell	19,282	14,593	18,630	4,404	370	75.5%	76.7%	97.9%	1.1%	22.3%	0.43	0.10
Devil's Gate	9,570	6,879	10,649	3,770	0	66.9%	64.6%	100.0%	-2.3%	33.1%	0.93	0.00
Eaton Wash	3,681	2,867	3,351	500	15	86.6%	85.2%	99.5%	-1.5%	12.9%	1.12	0.02
Morris	44,980	42,070	72,169	43,516	13,435	39.8%	49.1%	84.2%	9.3%	44.4%	0.46	0.32
Pacoima	6,219	4,387	4,977	613	23	87.0%	87.1%	98.9%	0.1%	11.8%	0.20	0.01
Puddingstone Diversion	6,452	4,323	4,686	371	8	94.9%	92.1%	99.8%	-2.8%	5.0%	0.62	0.01
San Dimas	4,474	2,883	3,592	740	31	82.1%	79.1%	98.5%	-3.0%	16.4%	0.49	0.05
San Gabriel	90,825	68,813	82,523	15,302	1,603	82.1%	81.8%	98.1%	-0.3%	16.0%	0.42	0.13
Totals	**198,329**	**155,724**	**213,086**	**74,641**	**17,313**	**64.6%**	**67.5%**	**92.4%**	**3.0%**	**27.8%**	**NA**	**NA**

* Volume captured does not indicate volume of water used for stormwater recharge. Volume captured indicates total increased volume of storage available for potential water conservation use.

Table 31. LACFCD Dams Structural Concept Results – Low 2 Scenario

Dam Name	Mean Annual Volume Captured[a] (ac-ft)			Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio			Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Event	
	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
Big Tujunga	12,845	14,160	22,480	10,841	2,523	64.2%	56.4%	89.5%	-7.8%	25.4%	1.15	1.06
Cogswell	19,282	21,199	29,000	8,158	359	75.5%	72.1%	98.6%	-3.4%	23.1%	0.90	0.11
Devil's Gate	9,570	10,103	16,230	6,127	0	66.9%	62.2%	100.0%	-4.7%	33.1%	1.85	0.00
Eaton Wash	3,681	4,226	5,064	854	16	86.6%	83.2%	99.7%	-3.4%	13.0%	2.20	0.06
Morris	44,980	46,067	109,524	84,465	21,026	39.8%	35.3%	83.8%	-4.5%	44.1%	0.76	0.56
Pacoima	6,219	7,927	8,546	651	31	87.0%	92.1%	99.3%	5.0%	12.2%	0.44	0.02
Puddingstone Diversion	6,452	6,783	7,298	533	19	94.9%	92.7%	99.7%	-2.2%	4.9%	0.94	0.02
San Dimas	4,474	4,471	5,564	1,144	50	82.1%	79.3%	98.7%	-2.8%	16.7%	0.94	0.08
San Gabriel	90,825	102,910	125,292	24,640	2,270	82.1%	80.7%	98.2%	-1.4%	16.1%	0.88	0.15
Totals	**198,329**	**217,846**	**328,999**	**137,412**	**26,296**	**64.6%**	**61.3%**	**92.5%**	**-3.3%**	**28.0%**	**NA**	**NA**

* Volume captured does not indicate volume of water used for stormwater recharge. Volume captured indicates total increased volume of storage available for potential water conservation use.

Figure 16 and Figure 17 show the Annual Volume Captured Volume (blue) and Annual Spillway Discharge Volume (red) for the Mid 2 projected climate scenario for both the existing and proposed structural enhancements to Devil's Gate Dam. The prominence of the plot for Annual Volume Captured emphasizes the high Capture Ratios of the structural concept for this dam; and comparison of the chart of the Task 4 results provides a graphic depiction of the significant improvement of Capture Ratios resulting from the structural concept for this dam. Corresponding charts for the structural concepts for six of the other LACFCD dams are graphically similar to the charts for Devil's Gate Dam below.

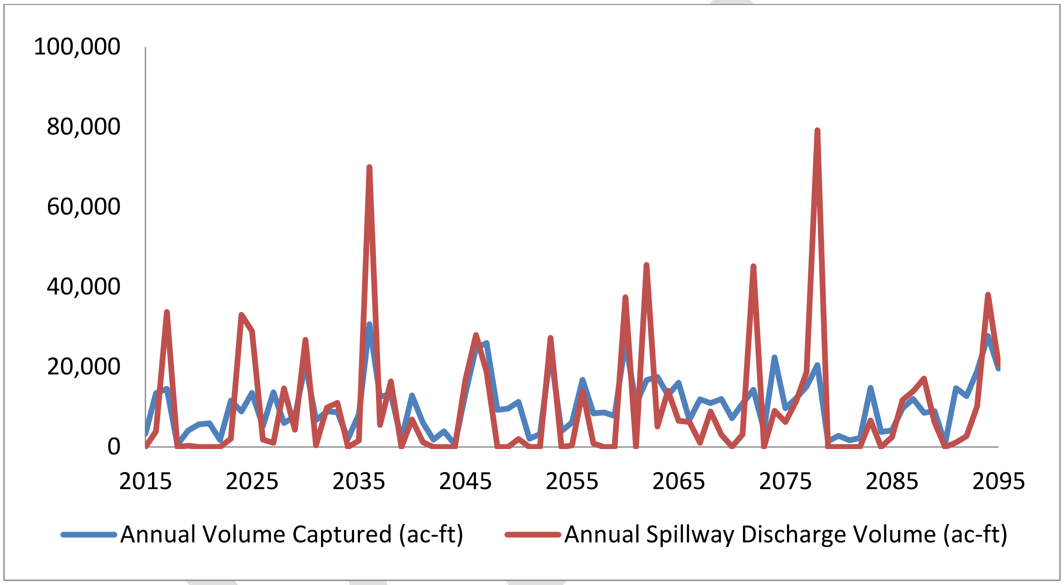


Figure 16. Existing Devil's Gate Dam Results (Task 4) – Mid 2 Scenario

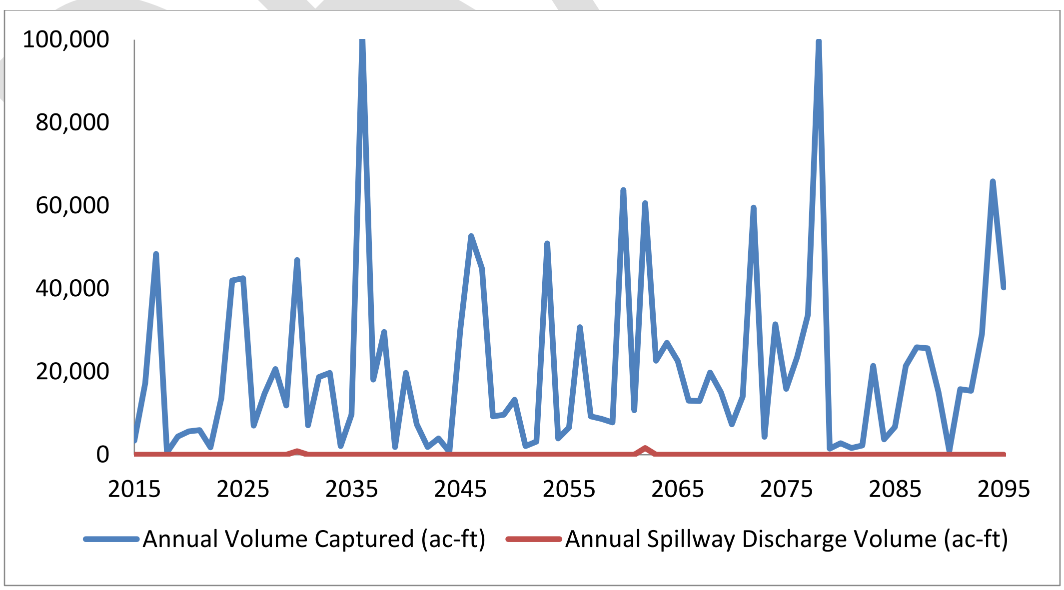


Figure 17. Devil's Gate Dam Structural Concept Results – Mid 2 Scenario

Corresponding charts for the structural concepts for Big Tujunga Dam and Morris Dam exhibit much more prominent Annual Spillway Discharge Volume plots, which emphasize the lower Capture Ratios of these two dams. As an example, the corresponding charts for Morris Dam (Figures 18 and 19) are presented below. Corresponding charts for Big Tujunga Dam are graphically similar to the charts for Morris Dam below.

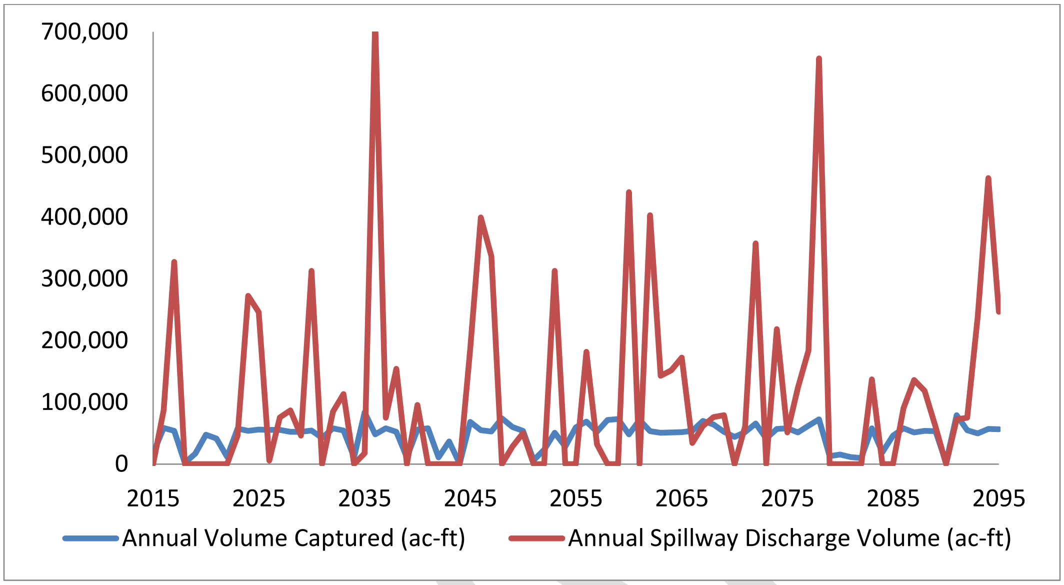


Figure 18. Existing Morris Dam Results (Task 4) – Mid 2 Scenario

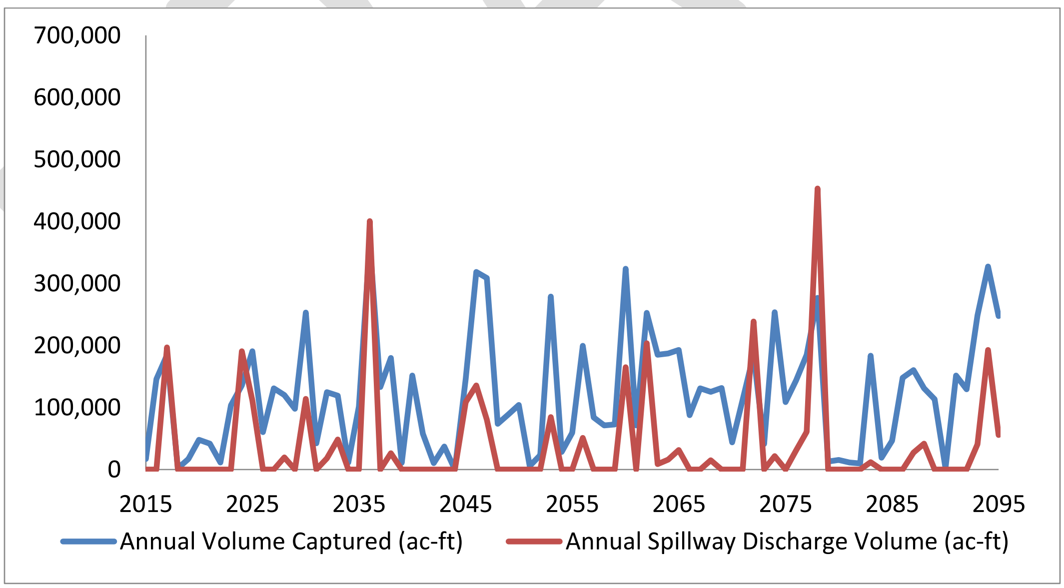


Figure 19. Morris Dam Structural Concept Results – Mid 2 Scenario

3.3.1.3 Capital and Operational Costs

A summary of the appraisal-level cost estimates for the structural concepts for each of the nine LACFCD dams considered in Task 5 is presented in Table 32. Included in this table are the estimated costs per acre-foot of water captured at each dam for the Middle 2 projected climate scenario, which was used as the design criterion for the structural concepts, as discussed in Section 2.4.1. A more extensive summary of the results for each of the projected climate scenarios for each dam is also presented in Appendix E in Table E-14 and in Figures E-7 through E-16.

Table 32. LACFCD Dams Summary of Estimated Costs of Structural Concepts (Mid 2 Scenario)

Dam Name	Estimated Total Annual Cost	Change of Mean Annual Volume Captured* (Mid 2 Scenario) (ac-ft)	Estimated Annual Cost per ac-ft of Additional Volume Captured (Mid 2 Scenario)
Big Tujunga	$1,099,474	11,786	$93
Cogswell	$1,145,670	11,762	$97
Devil's Gate	$4,634,504	9,747	$475
Eaton Wash	$1,351,402	1,277	$1,059
Morris	$3,798,384	71,853	$53
Pacoima	$3,029,836	1,259	$2,407
Puddingstone Diversion	$466,349	888	$525
San Dimas	$1,366,958	2,041	$670
San Gabriel	$10,550,903	39,404	$268
Totals	**$27,443,480**	**150,015**	**$183**

* Volume captured represents the additional stormwater available for conservation releases. It does not represent increased volume of increased recharge.

Detailed appraisal-level cost estimates for the structural concepts for the ten selected LACFCD dams are included in the Appendix E of this report.

As discussed previously, the structural concepts for the nine LACFCD dams involved structural modifications to the dams and nonstructural modifications to the operating guidelines. The costs of developing and implementing modifications to operating guidelines are treated as incidental to the costs of structural modifications in the cost estimates for the structural concepts.

Operable weirs (e.g., 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. Each cost estimate was developed by identifying major characteristics of the spillway facilities at each of the nine dams, including spillway types, dimensions and any operational controls, such as gates. Potential of spillway modifications were identified for each dam, such as pneumatic gates, slide gates, etc.

Pneumatic gates were selected for seven dams: Big Tujunga, Cogswell, Devil's Gate, Eaton Wash, Puddingstone Diversion, San Dimas, and San Gabriel. Slide gates were selected for Pacoima Dam, which has tunnel spillways. Slide gates were also included in the concept for Devil's Gate at eleven port openings in the base of the ogee spillway headworks. Existing drum gates at the Morris Dam spillway could be used to control water up to approximately five feet below the high water elevation. These drum gates would need to be modified or replaced to enable capture of the full volume of stormwater proposed in the structural concept for this dam.

As discussed previously, capture ratios are lower for the nonstructural concepts considered in Task 5 than for either the Historic or the corresponding Task 4 projected climate scenarios for those three LACFCD dams. In addition, the nonstructural concepts considered would involve only operational changes at the dams with no significant capital improvements identified. And, since the nonstructural concepts would offer no increased benefits, no cost estimates were prepared for the nonstructural concepts.

3.3.1.4 Other Project Characteristics and Benefits

The structural concepts for LACFCD dams are climate resilient. By increasing the capture and storage of stormwater, these concepts offer opportunities for increased flood risk management. These concepts may also provide a water quality benefit.

3.3.1.5 Nonstructural Concepts

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 projected period projections.

3.3.1.6 Results

A summary of the results for the three LACFCD dams considered for Nonstructural Concepts in Task 5 for the Mid 2 projected climate scenario is presented in Table 33. Summaries of the corresponding results for these dams considered for the other three climate scenarios analyzed in Task 5 are presented in Tables E-11 through E-13 in Appendix E. The Task 5 results for the Nonstructural Concepts for the key metrics are presented alongside the corresponding Task 4 results for comparison. Selected results are also provided for the Historical period for comparison.

Table 33. LACFCD Dams Nonstructural Concept Results – Mid 2 Scenario

Dam Name	Mean Annual Volume Captured* (ac-ft)			Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio			Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Event	
	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
Devil's Gate	9,570	10,324	9,241	9,774	10,335	66.9%	51.4%	46.0%	-15.6%	-21.0%	2.04	2.82
Eaton Wash	3,681	4,780	2,264	1,291	3,166	86.6%	78.7%	37.3%	-7.9%	-49.3%	3.14	17.43
Santa Anita	3,312	4,589	4,377	644	806	92.9%	87.6%	83.6%	-5.3%	-9.3%	1.15	1.80
Totals	**16,564**	**19,693**	**15,882**	**11,709**	**14,307**	**74.9%**	**62.7%**	**50.6%**	**-12.2%**	**-24.3%**	**NA**	**NA**

* Volume captured does not indicate volume of water used for stormwater recharge. Volume captured indicates total increased volume of storage available for potential water conservation use.

The results for the Capture Ratio metric are lower for the Task 5 Nonstructural Concepts than those for either the Historic period or for the corresponding projected climate scenarios from the Task 4 analyses. These results indicate that the flexibility of the existing operation guidelines has allowed for highly efficient operation of the dams. These results suggest that captured stormwater is released at high rates, making reservoir capacity available as quickly as the system will allow, resulting in high stormwater runoff capture ratios.

Therefore, the Nonstructural Concepts developed and analyzed for this study did not serve to identify any operational efficiency improvements at the three LACFCD dams considered. While there may be opportunities to improve the operational efficiency of the dams, these results suggest that it would be necessary to undertake a more intensive and detailed modelling effort to identify any such improvements.

3.3.1.7 Capital and Operational Costs

As discussed in the previous section, capture ratios are lower for the nonstructural concepts considered in Task 5 than for either the Historic or the corresponding Task 4 projected climate scenarios for those three LACFCD dams. In addition, the nonstructural concepts considered would involve only operational changes at the dams with no significant capital improvements identified. And, since the nonstructural concepts would offer no increased benefits, no cost estimates were prepared for the nonstructural concepts.

3.3.1.8 Other Project Characteristics and Benefits

Since no increased benefits were identified for the nonstructural concepts, no other project characteristics or benefits were identified. However, if a more intensive and detailed effort were undertaken to model the nonstructural concepts, and if that effort did identify opportunities to improve the operational efficiency of the dams, then project characteristics and benefits would be the same as those discussed in the LACFCD Dams Structural Concepts section.

3.3.2. USACE Dams

Like the LACFCD dams, a structural concept was developed for Hansen Dam in an effort to maximize capture of stormwater runoff. Because the hydrologic conditions at Hansen Dam closely resemble those at LACFCD Big Tujunga Dam upstream, the structural concept for Big Tujunga Dam was used as the template for the structural concept for Hansen Dam. To do this, the Task 5 F-Table for Big Tujunga Dam was scaled and modified for development of a new F-Table for Hansen Dam.

3.3.2.1 Results

A summary of the results for Hansen Dam for each of the four climate scenarios analyzed in Task 5 is presented in Table 34. The Task 5 results for the key metrics are presented for comparison alongside the corresponding updated Task 4 results. Selected results are also provided for the Historical period.

As with the LACFCD dams, the Capture Ratios for the Structural Concept are typically higher for the drier scenarios. Additionally, Capture Ratios were found to be higher for the Task 5 Structural Concepts than for either the Historic or the corresponding Task 4 projected climate scenarios.

3.3.2.2 Capital and Operational Costs

Limited study resources constrained the investigation by the Study Team of USACE dams. Estimates of capital and operational costs were not developed for Hansen Dam.

3.3.2.3 Other Project Characteristics and Benefits

Project characteristics and benefits would be the same as those discussed in the LACFCD Dams Structural Concepts section.

3.3.2.4 Concepts at Other USACE Dams

Due to limited resources, a detailed concept could only be developed for Hansen dam; however, a number of high-level recommendations were identified for possible future efforts into improving the water conservation of the other USACE dams. Santa Fe, Sepulveda, and Whittier Narrows Dams require a more in-depth analysis, but the following are a number of opportunities that could be explored further in future studies.

- Conduct a more in-depth feasibility study to increase water conservation
- Increasing the storage capacity behind the dam through sediment removal
- Increasing the dam and spillway heights to provide additional storage
- Improving downstream spreading grounds intake capacity
- Constructing levees to protect existing facilities or parks within the dams
- Developing a seasonal water conservation pool similar to Prado Dam

Although the LA Basin Study is investigating stormwater conservation and places a great emphasis on capturing stormwater for recharge, the USACE dams will need to continue to address flood control. The USACE dams' primary purpose, which is flood risk management, must not be compromised by proposed changes for water conservation. Therefore, any stormwater conservation concepts will need to work within the flood control mandate that the USACE adheres to. However, a balanced approach of stormwater conservation and flood control should be able to be balanced to help the region become more resilient to climate change. Future study of these USACE dams and enhanced partnerships with agencies interested in increase stormwater capture should be pursued.

Table 34. Hansen Dam Structural Concept Results

Scenario	Mean Annual Inflow (ac-ft)		Mean Annual Volume Captured[a] (ac-ft)		Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio		Capture Ratio Change from Historical		Mean Annual Frequency of Water Conservation Rate Exceedances	
	Task 4 (Updated)	Task 5 (Structural Concept)	Task 4 (Updated)	Task 5 (Structural Concept)	Task 4 (Updated)	Task 5 (Structural Concept)	Task 4 (Updated)	Task 5 (Structural Concept)	Task 4 (Updated)	Task 5 (Structural Concept)	Task 4 (Updated)	Task 5 (Structural Concept)
Historical	37,181	NA	18,523	NA	18,659	NA	49.8%	NA	NA	NA	4.12	NA
High 1	96,128	96,099	24,633	36,448	71,495	59,650	25.6%	37.9%	-24.2%	-11.9%	3.99	1.56
Middle 2	55,605	55,588	19,518	27,555	36,088	28,033	35.1%	49.6%	-14.7%	-0.2%	3.36	1.01
Low 1	27,019	27,012	13,610	17,379	13,410	9,633	50.4%	64.3%	0.6%	14.5%	2.86	0.50
Low 2	44,773	44,760	19,494	27,230	25,278	17,530	43.5%	60.8%	-6.3%	11.0%	3.75	0.92

Note:
[a] Volume captured does not indicate volume of water used for stormwater recharge. Volume captured indicates total increased volume of storage available for potential water conservation use.

3.3.3. Debris Basins

This project category assumes select debris basins will be modified with controlled outflow works to temporarily store and then release stormwater to downstream spreading basins to increase groundwater recharge. A preliminary screening of the LACFCD debris basins was performed to identify candidate basins for modification. Debris basins with the largest storage capacities and located upstream of spreading grounds were identified for modification.

Regular maintenance to remove sediment and other debris is needed to maintain the flood control and debris function. For this alternative, maintenance after storm events is critical to restore the basin storage capacity for flood risk management. In addition, more frequent sediment removal will be required to maintain storage capacity for stormwater conservation

Figure 20 shows a typical section of the debris basin and Figure 21 shows the location of the selected debris basins. Table 35 summarizes their characteristics. Appendix B includes a factsheet that summarizes features of the debris basin project.

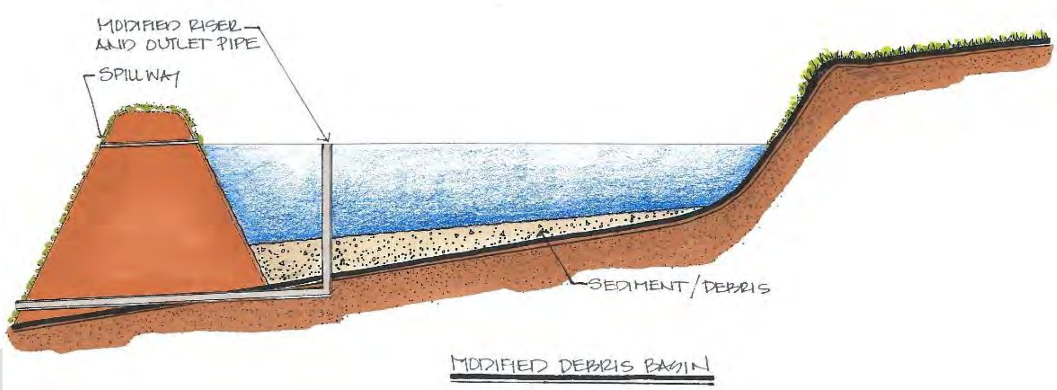


Figure 20. Schematic of Debris Basin Modification

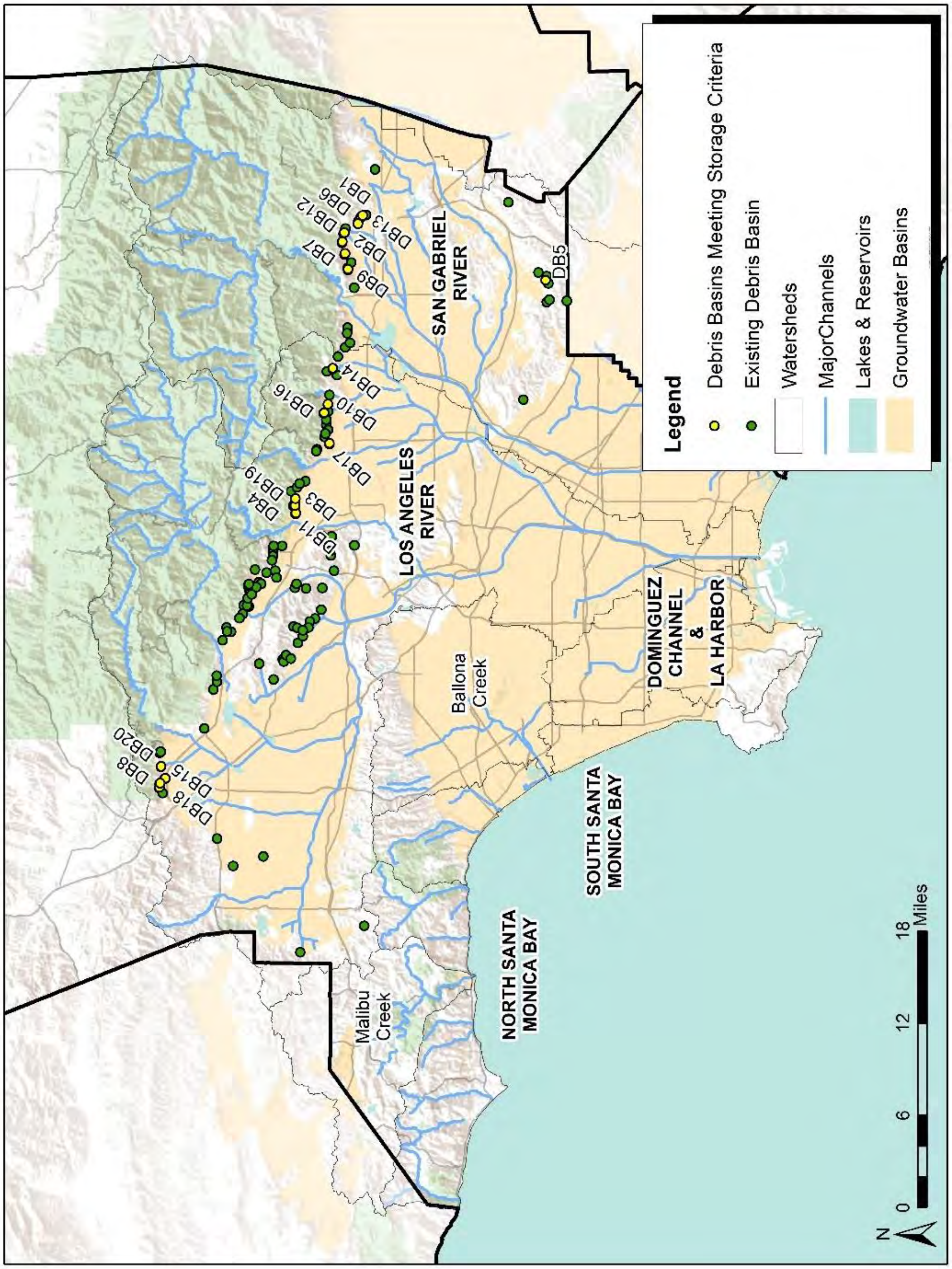


Figure 21. Debris Basins

Table 35. Debris Basins

ID	Facility	Storage (ac-ft)	ROW (acres)	Habitat (acres)	Recreation Trails (feet)
DB1	Crescent Glen	6.2	-	-	92.9
DB2	Englewild	13.8	-	-	129.1
DB3	Fair Oaks	9.1	-	-	119.5
DB4	Fern	10.2	-	-	84.1
DB5	Fullerton (PD2202-U2)	5.4	-	-	86.1
DB6	Gordon	7.4	-	-	87.8
DB7	Harrow	10.3	-	-	167.7
DB8	Hog	7.2	-	-	114.8
DB9	Hook West	7.6	-	-	112.0
DB10	Lannan	5.3	-	-	84.5
DB11	Lincoln	11.0	-	-	103.5
DB12	Little Dalton	182.5	-	-	443.9
DB13	Morgan	13.9	-	-	114.6
DB14	Sawpit	77.8	-	-	195.5
DB15	Schoolhouse	16.4	-	-	253.4
DB16	Sierra Madre Dam	35.7	-	-	136.6
DB17	Sierra Madre Villa	59.8	-	-	319.6
DB18	Sombrero	11.6	-	-	89.7
DB19	West Ravine	11.3	-	-	340.9
DB20	Wilson	49.4	-	-	193.6
Total		**551.9**			**3,270**

3.3.3.1 Results

Installation of outlet structures at the 20 debris basins will provide a storage capacity of approximately 552 acre-feet which can be infiltrated at the downstream spreading grounds. Implementation of the Debris Basins project group will provide approximately 145 acre-feet of stormwater conservation per year based on the Mid 2 projected climate scenario. Table 36 summarizes the modeled change in stormwater conservation by watershed relative to baseline conditions.

Table 36. Stormwater Conserved for Debris Basins

Watershed	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Los Angeles River	34	34	48	63
San Gabriel River	52	69	97	167
Total	**86**	**104**	**145**	**230**

The amount of stormwater conserved, shown in Table 36, is low relative to other stormwater capture alternatives investigated for this study. Sediment loading to the basins under the climate scenarios was not evaluated explicitly, but sediment loading is expected to increase under wet climate scenarios and increase wildfire risks with a warmer climate, which may limit the surface water storage capacity and climate resiliency of this project group.

3.3.3.2 Other Project Characteristics and Benefits

This project offers limited opportunities for habitat benefits because it does not include new right-of-way designated for this purpose. The storage and ultimate capture of stormwater in downstream spreading grounds does provide a water quality benefit. It was assumed that recreational trails would be built around a portion of the perimeter of the 20 modified basins providing approximately 3,270 linear feet of trail.

3.3.3.3 Capital and Operational Costs

Capital costs were developed based on a line item unit cost approach. Unit rates for riser and basin modification were derived from previous estimates. O&M costs include costs for more frequent sediment removal. The resulting O&M costs were annualized over a 50-year analysis period. A summary of the Debris Basin concept costs are presented below.

- **Capital Cost:** $41,000,000
- **O&M Cost:** $1,300,000/yr
- **Land Acquisition:** $0
- **Cost per Acre-foot:** $13,100 to $35,900

Refer to Appendix D for a more detailed summary of capital and operational costs.

3.4. Management Solutions

Management Solutions represent improvements or slight enhancements to the Local Solutions discussed in Section 3.1. In most cases, the Management Solutions represent the same stormwater opportunities already modeled for the ultimate value achieved in water year 2095. The general assumption is that the implementation of Local Solutions will not be achieved quickly and that widespread installation would likely occur over a long period of time. Some of the management solutions may speed up the incremental increase of stormwater for each year until 2095.

Management Solutions consists of three main project groups:

- Stormwater Policies
- Green Infrastructure Programs
- Regional Impact Programs

The results of the appraisal-level analysis for each of these project groups is presented below.

3.4.1. Stormwater Policies

Stormwater Policies are non-constructed control measures that encourage stormwater conservation. The high-scoring stormwater policies in the Appraisal-Level Stormwater Conservation Matrix include the following:

- EWMPs for water conservation
- Align regulatory and environmental plans with water conservation/supply goals
- Advanced rainfall-hydrology modeling to quantify pre-storm capture
- Streamline regulatory requirements for maintenance of existing and urbanize stormwater infrastructure
- Remove invasive plants in system
- Feed-in-tariff for groundwater infiltration

Using the methodology described in Section 2, the additional implementation area that could be added to the LID implementation area is shown in Figure 22.

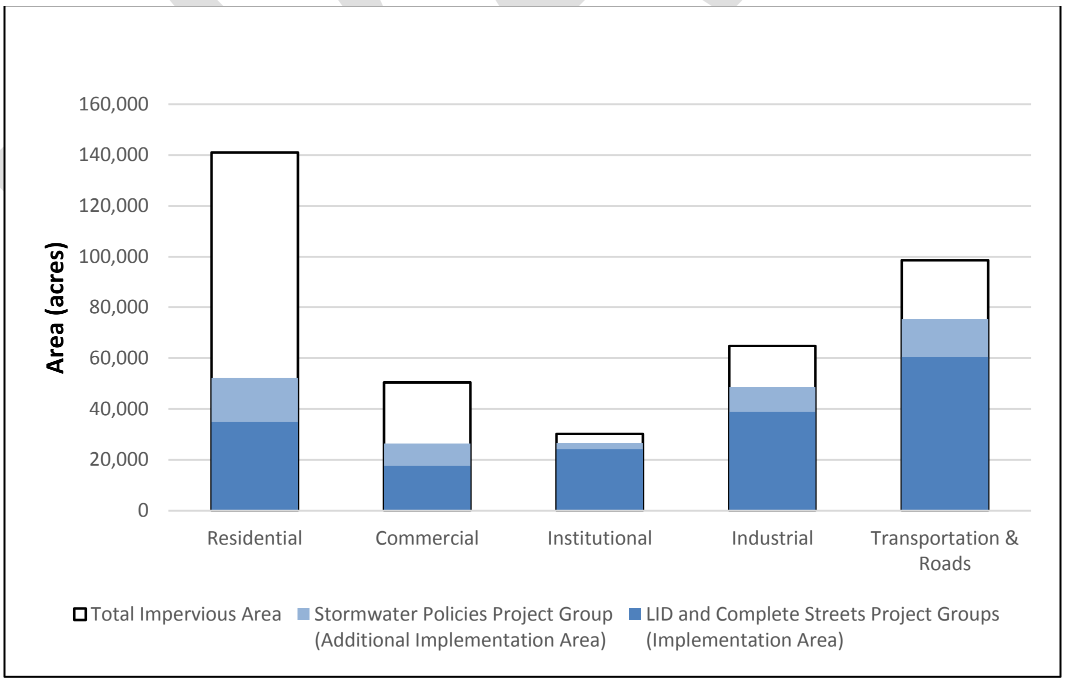


Figure 22. Implementation Area – Stormwater Policies Project Group

3.4.1.1 Results

The WMMS model was run for four climate projections. For the Mid 2 projected climate scenario, implementation of stormwater policies will provide approximately 193,181 acre-feet of stormwater conservation per year. Table 37 summarizes the stormwater conserved per year in each watershed. The values listed are the net results and have been adjusted to account for any reduction in conservation at regional facilities.

Table 37. Stormwater Conserved for Stormwater Policies

Watershed	Watershed Area (acres)	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Ballona Creek	135,090	20,743	22,117	24,378	26,879
Dominguez Channel	70,428	14,469	15,380	17,353	19,353
Los Angeles River	533,840	67,282	78,282	86,201	108,711
Malibu Creek	129,825	2,130	2,454	2,536	2,791
San Gabriel River	434,475	50,722	57,508	62,713	77,239
Total	**1,303,657**	**155,346**	**175,742**	**193,181**	**234,972**

The Los Angeles River watershed represents the largest volume of stormwater conserved due to the large size of the watershed. However, the Dominguez Channel has the highest percentage of stormwater conserved relative to watershed area because the watershed is highly impervious with a large percentage of institutional and industrial land uses. These land uses, because they are highly regulated, are assumed to have a higher LID implementation rate than land uses that are not closely regulated (e.g., residential). Watersheds that are less impervious (e.g., Malibu Creek) have a lower highest percentage of stormwater conserved relative to watershed area.

LID and Complete Streets provide a large volume of stormwater conservation because of widespread implementation across the study area. But compared to other project groups, stormwater policies provide a lower level of resiliency in stormwater conservation. LID and Complete Streets provide some resiliency through infiltration into the groundwater aquifer where the aquifer is unconfined, but they are sized to retain the 85th percentile storm. A rainfall depth of 0.75 inch was used to represent the 85th percentile storm, and runoff from larger storms are bypassed. Stormwater Policies increase the amount of stormwater conserved by increasing the implementation of LID projects.

3.4.1.2 Capital and Operational Costs

Capital costs were developed based on a line item unit cost approach. Quantities of each line item were calculated based on the BMP storage volume and typical design configurations. The unit costs were derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014). A breakdown of BMP types were assumed for each land use to determine unit costs. No property acquisition was assumed for this concept. An O&M cost was calculated using BMP storage volumes and unit costs derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014) and annualized over a 50-year analysis period. A summary of the stormwater policies costs are presented below.

- **Capital Cost:** $21,490,000,000
- **O&M Cost:** $959,000,000/yr
- **Land Acquisition:** $0
- **Cost per Acre-foot:** $7,900 to $11,900

3.4.1.3 Other Project Characteristics and Benefits

Project characteristics and benefits are the same as those discussed in Section 3.1.2, Low Impact Development, and Section 3.1.3, Complete Streets.

3.4.2. Green Infrastructure Programs

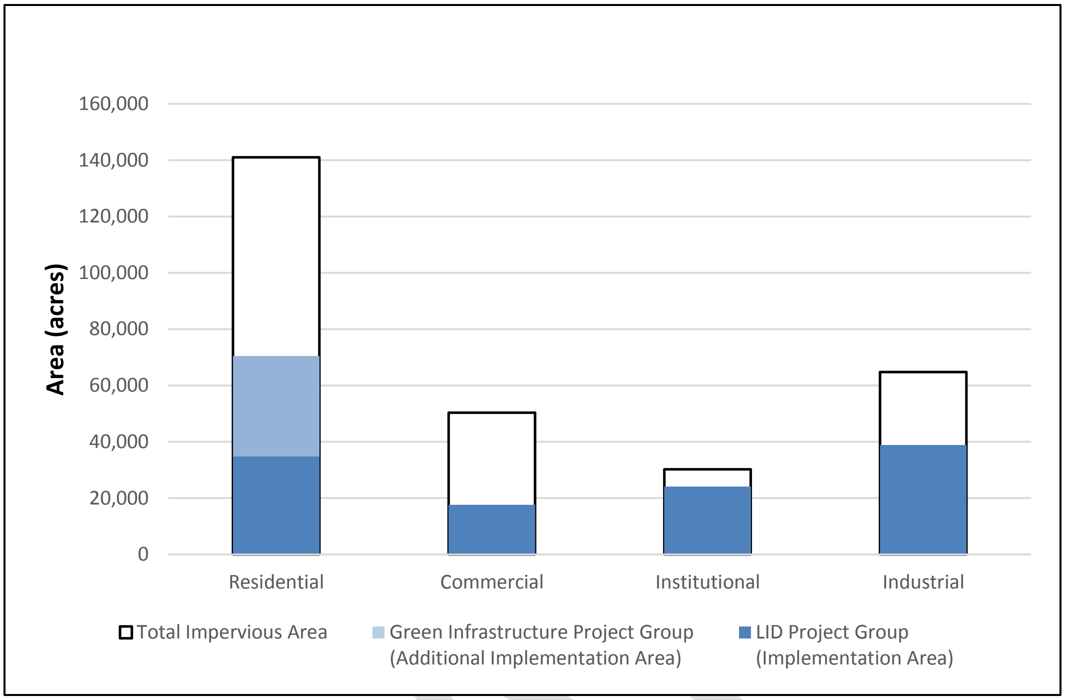
Green Infrastructure Programs encourage implementation of LID across the watershed. When deployed across numerous parcels throughout the watershed, LID projects can collectively make a significant impact on stormwater capture. LID can retain the water at the source before it runs off from the parcel and travels downstream.

The MS4 Permit and local ordinances require significant development and redevelopment projects to incorporate LID concepts into their site design. Existing residential parcels also provide an important opportunity for LID implementation. Runoff from residential parcels often flow directly to a curb and gutter or other conveyance system on the street. A well-designed residential LID program can engage individual homeowners to reduce their contribution to stormwater runoff.

The high-scoring Green Infrastructure Program concepts in the Appraisal-Level Stormwater Conservation Matrix included the following:

- LID/BMPs
- Increase permeable space to balance water conservation goals
- Increase urban permeability
- Emphasize residential infiltration in high-density locations
- Encourage residential land changes for promoting infiltration

Using the methodology described in Section 2, the additional implementation area



that could be added to the LID implementation area is shown in Figure 23.

Figure 23. Implementation Area – Green Infrastructure Project Group

3.4.2.1 Results

The WMMS model was run for four climate projections. For the Mid 2 projected climate scenario, implementation of stormwater policies will provide approximately 139,407 acre-feet of stormwater conservation per year. Table 38 summarizes the stormwater conserved per year in each watershed. The values listed are the net results and have been adjusted to account for any reduction in conservation at regional facilities.

Table 38. Stormwater Conserved for Green Infrastructure Programs

Watershed	Watershed Area (acres)	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Ballona Creek	135,090	11,540	12,404	13,320	14,566
Dominguez Channel	70,428	8,434	9,067	9,886	10,917
Los Angeles River	533,840	45,212	53,900	61,707	79,650
Malibu Creek	129,825	1,706	1,822	1,859	2,030
San Gabriel River	434,475	39,490	45,695	52,635	64,641
Total	**1,303,657**	**106,383**	**122,889**	**139,407**	**171,803**

The Los Angeles River watershed represents the largest volume of stormwater conservation due to the large size of the watershed. However, the Dominguez Channel has the highest percentage of stormwater conservation relative to watershed area because the watershed is highly impervious with a large percentage of institutional and industrial land uses. These land uses, because they are highly regulated, are assumed to have a higher LID implementation rate than land uses that are not closely regulated (e.g., residential). Watersheds that are less impervious (e.g., Malibu Creek) have a lower implementation rate of LID.

LID projects provide a large volume of stormwater conservation because of widespread implementation across the study area. But compared to other project groups, Green Infrastructure Programs provide a lower level of resiliency in stormwater conservation. LID BMPs provide some resiliency through infiltration into the groundwater aquifer where the aquifer is unconfined, but they are sized to retain the 85^{th} percentile storm. A rainfall depth of 0.75 to 0.97 inches was used to represent the 85^{th} percentile storm, and runoff from larger storms are bypassed. Therefore, compared to Local Stormwater Capture, LID BMPs are not able to provide as much resiliency in larger storms.

3.4.2.2 Capital and Operational Costs

Capital costs were developed based on a line item unit cost approach. Quantities of each line item were calculated based on the BMP storage volume and typical design configurations. The unit costs were derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014). A breakdown of BMP types were assumed for each land use to determine unit costs. No property acquisition was assumed for this concept. An O&M cost was calculated using BMP storage volumes and unit costs derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014) and annualized over a 50-year analysis period. A summary of the Green Infrastructure Programs costs are presented below.

- **Capital Cost:** $13,115,000,000
- **O&M Cost:** $592,000,000/yr
- **Land Acquisition:** $0
- **Cost per Acre-foot:** $6,600 to $10,700

3.4.2.3 Other Project Characteristics and Benefits

Project characteristics and benefits are the same as those discussed in Section 3.1.2, Low Impact Development.

3.4.3. Regional Impact Programs

Regional Impact Programs encourage local stormwater capture solutions across the watershed. Local Stormwater Capture concepts are comprised of facilities that receive large volumes of stormwater runoff from upstream areas for infiltration and stormwater retention. This management solution assumes a model baseline for Local Stormwater Capture, and increases the stormwater conservation through Regional Impact Programs.

The high-scoring Regional Impact Program concepts in the Appraisal-Level Stormwater Conservation Matrix included the following:

- Open space stormwater improvements
- Utilize government parcels first for stormwater capture, storage, and infiltration
- Investigate recharge along river embankments
- County-wide parcel fee with mitigation rebate
- School stormwater improvements
- Regional projects (e.g., public parks, schools to infiltrate flows)
- Depress all sports fields for stormwater capture
- Consider all open areas as a stormwater facility

3.4.3.1 Results

The WMMS model was run for four climate projections. For the Mid 2 p climate scenario, implementation of local stormwater capture projects will provide approximately 28,984 acre-feet of stormwater conservation per year. Table 39 summarizes the stormwater conserved per year in each watershed. The values listed are the net results and have been adjusted to account for any reduction in conservation at regional facilities.

Table 39. Stormwater Conserved for Regional Impact Programs

Watershed	Watershed Area (acres)	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Ballona Creek	135,090	176	523	776	1,250
Dominguez Channel	70,428	2	3	3	4
Los Angeles River	533,840	13,111	15,254	17,221	21,939
Malibu Creek	129,825	-	-	-	-
San Gabriel River	434,475	8,554	9,782	10,983	13,659
Total	**1,303,657**	**21,844**	**25,562**	**28,984**	**36,853**

The Los Angeles River watershed represents the largest volume of stormwater conservation based on total volume and also as a percentage of watershed area. This is due to the relative favorable soil and aquifer conditions for stormwater capture in the Los Angeles River watershed compared to other watersheds.

Local stormwater capture projects are modeled to capture and infiltrate runoff from larger storms (i.e., 5-year storm), which will help promote groundwater recharge and provide resiliency in stormwater conservation when more water is available. Regional Impact Programs would help increase stormwater conservation by increasing the size of Local Stormwater Capture concepts.

3.4.3.2 Capital and Operational Costs

Capital costs were developed based on a line item unit cost approach. Quantities of each line item were calculated based on the BMP storage volume and typical design configurations. The unit costs were derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014). An additional property acquisition cost was assumed for purchase of private open space parcels for the use of local stormwater capture projects, totaling approximately 2,655 acres. An O&M cost was calculated using BMP storage volumes and unit costs derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014) and annualized over a 50-year analysis period. A summary of the Regional Impact Programs costs are presented below.

- **Capital Cost:** $2,975,000,000
- **O&M Cost:** $119,000,000/yr
- **Land Acquisition:** $1,328,000,000
- **Cost per Acre-foot:** $9,000 to $15,200

3.4.3.3 Other Project Characteristics and Benefits

Project characteristics and benefits are the same as those discussed in Section 3.1.1, Local Stormwater Capture.

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4. Stormwater Capture Findings

The key objectives of Task 5 were to identify and develop long-term structural and nonstructural (i.e., management techniques) concepts to manage stormwater under future conditions. These concepts built upon projected climate conditions and population changes in the Los Angeles Basin. Potential changes to the operation of stormwater capture systems, modifications to existing facilities, and development of new facilities were analyzed to help resolve future water supply and flood risk management issues. Alternatives were identified and analyses were conducted to determine the potential for stormwater conservation, the benefits and costs. A summary of the benefits and costs for each alternative is presented in Table 40.

4.1. Stormwater Conservation

Stormwater is an invaluable local resource that can help provide resiliency to future water supply and flood risk issues in the Los Angeles region.
The LACFCD already recharges a significant amount of stormwater at regional spreading basins, but there is potential for modification or changes in the operation of the existing stormwater capture systems, and the development of new facilities that could help provide greater resiliency to emerging climate change impacts.

The projected hydrology results for the range of climate scenarios were used to compare the stormwater conservation for the 12 different project groups.
As shown in Figure 24 and Table 40, implementation of structural concepts for the LACFCD Dams would achieve the highest volume of annual stormwater storage ranging from 57,400 to 264,100 AFY. It should be noted that this is storage and would need to be released in such a way that it could be infiltrated at the downstream spreading grounds. Operable weirs and/or gates would be installed at the spillway(s) of ten LACFCD dams to allow stormwater to be captured at elevations above the spillway crest.

The next highest project groups for stormwater conservation include two Management Solutions: Stormwater Policies and Green Infrastructure Programs. Management Solutions represent improvements, or more aggressive enhancements, to Local Solutions. The Stormwater Policies project group uses a combination of LID and Complete Streets as a model baseline, and increases the stormwater conservation through improvements to stormwater policy. This project group provides approximately 155,300 to 235,000 AFY of stormwater conservation. The Green Infrastructure Programs project group builds on the LID model, and provides approximately 106,400 to 171,800 AFY of stormwater conservation. The Regional Stormwater Capture project group provides 26,100 to 59,900 AFY of stormwater conservation.

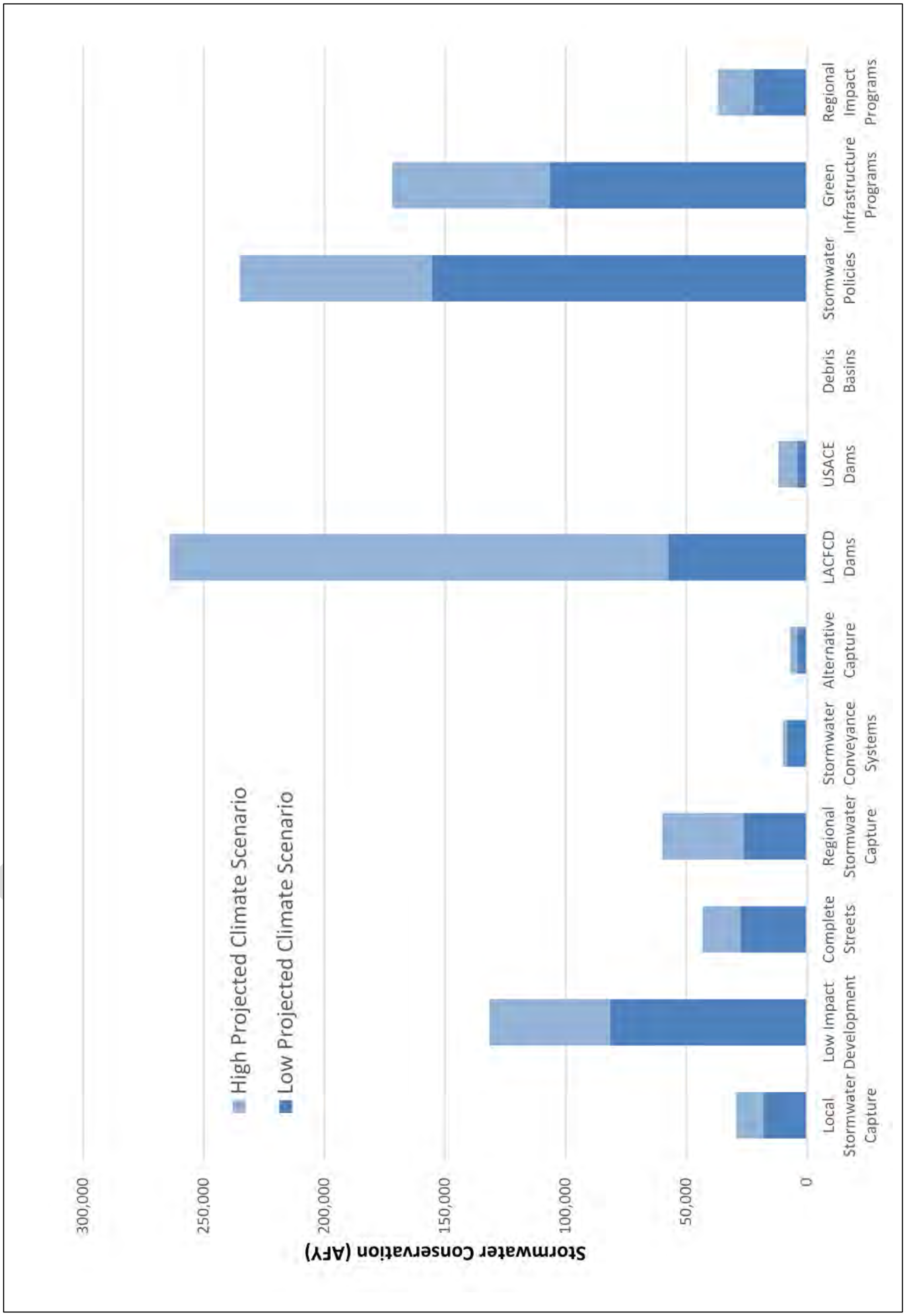

Figure 24. Stormwater Conservation Comparison by Conceptual Project Groups

Table 40. Summary of Project Group Benefits and Costs

Project Group	Stormwater Conserved/ Storage Capacity (AFY)	Recreation (miles of trail)	Habitat (acres)	ROW (acres)	Range of Costs ($/AF)
Local Solutions					
Local Stormwater Capture[a]	17,900 to 29,300	204	266	2,655	$9,500 to $15,500
Low Impact Development[b]	81,400 to 131,600	0	0	0	$6,800 to $11,000
Complete Streets[b]	27,300 to 43,300	0	0	0	$12,100 to $19,200
Regional Solutions					
Regional Stormwater Capture[a]	26,100 to 59,900	12	42	682	$900 to $2,100
Stormwater Conveyance Systems[a]	8,000 to 10,000	3	8	31	$42,700 to $53,100
Alternative Capture[a]	3,800 to 6,900	2	2	34	$1,400 to $2,400
Storage Solutions					
LACFCD Dams[c]	57,400 to 264,100	0	0	0	$100 to $480
USACE Dams[c, d]	3,800 to 11,800	0	0	0	-
Debris Basins[a]	90 to 230	1	0	0	$13,100 to $35,900
Management Solutions					
Stormwater Policies[b]	155,300 to 235,000	0	0	0	$7,900 to $11,900
Green Infrastructure Programs[b]	106,400 to 171,800	0	0	0	$6,600 to $10,700
Regional Impact Programs[a]	21,800 to 36,900	204	266	2,655	$9,000 to $15,200

[d] Cost Information for USACE dams not determined for this study.
[c] Increased storage capacity or stormwater retention for potential reuse or recharge; costs exclude estimates for Santa Anita Dam
[a] Conservation through groundwater recharge
[b] Conservation through groundwater recharge or stormwater retention for potential reuse

The maximum potential for stormwater conservation and storage would be achieved by combining all the Regional Solutions and Storage Solutions with the Stormwater Policies and Regional Impact Programs. The maximum potential for conservation and storage would range from 244,000 to 481,000 AFY for the low to high projected climate scenarios.

Additional stormwater capture related to the various solutions analyzed will not negate or reduce the need for maintaining existing capacities at flood management facilities. The capacity of the flood management facilities must be maintained.

4.2. Capital and Operational Costs

Capital and O&M costs were developed for each project group, and the costs were annualized over a 50-year analysis period. The resulting annual cost per acre of stormwater conserved could be used as an estimate of the cost effectiveness of each project group. Figure 25 below shows a comparison of the cost per acre foot of stormwater for the various project groups.

Although the LACFCD Dams project group provides the most stormwater storage and appears to be the most cost effective, it should be noted that this is storage and would need to be released in such a way that it could be infiltrated at the downstream spreading grounds. Two of the Regional Solutions, Regional Stormwater Capture and Alternative Capture, are cost effective. Regional Stormwater Capture provides approximately 26,100 to 59.900 AFY of stormwater conservation, with a low cost compared to other project groups. While Alternative Capture represents one of the lowest volumes of stormwater conservation, this option is still favorable due to its cost effectiveness.

The Stormwater Policies and Green Infrastructure Programs project high volumes of stormwater conservation because of the potential widespread implementation of LID and Complete Streets, but both options are more costly to implement than the Regional Stormwater, Alternative Capture, and LACFCD Dam concepts.

The financial strategy to fund these projects will require a coordinated, regional approach to ensure that costs are split by multiple partners across the region. For example, the LACFCD, LADWP, and USACE can share project capital and operational costs for those facilities that they operate together. Some of the costs for LID implementation will be funded by private developers to incorporate LID concepts into their site design for new/redevelopment. Other costs for residential LID may be paid for by homeowners to retrofit their properties with LID features such as rain tanks. Incentive programs can potentially be aligned with existing water conservation programs such as turf replacement or xeriscaping incentives.

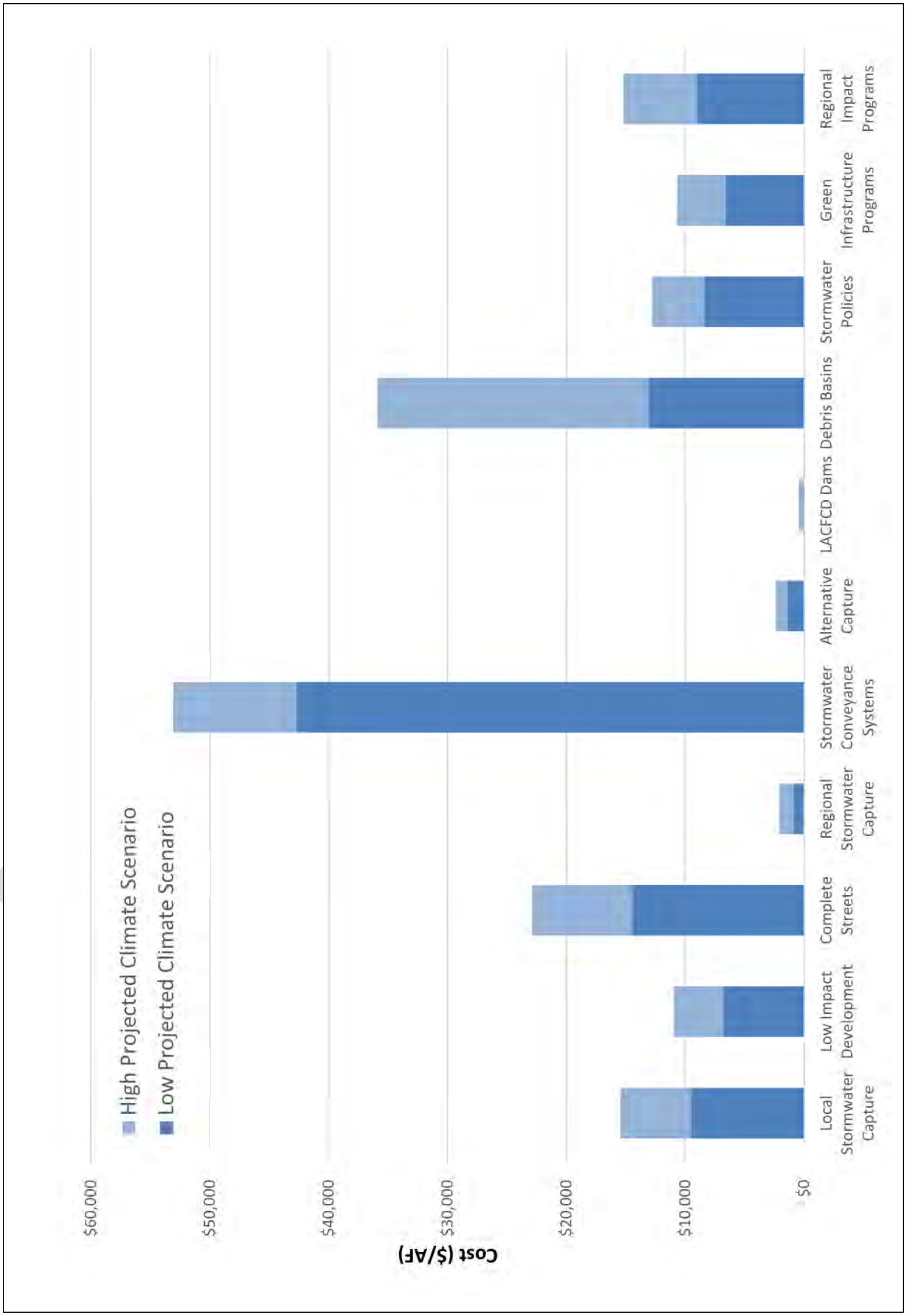

Figure 25. Cost per Acre Foot Conserved Comparison by Conceptual Project Groups

4.3. Other Project Characteristics and Benefits

Some of the project groups provide multiple benefits beside the retention of stormwater. In addition to stormwater conservation, complementary benefits may include, but are not limited to, flood risk management, water quality, recreation, habitat/connectivity, ecosystem function, and climate resilient actions. These other benefits could help to identify project partners as projects with multiple benefits can help to leverage funding. The additional benefits are summarized in Table 41.

Local Stormwater Capture and the Regional Solutions project groups can provide community enhancement through bikeways or passive walking and hiking trails, in addition to habitat restoration. Naturalized infiltration basins can enhance plant and bird habitat and provide educational opportunities. Underground systems can allow the beneficial use of a site to be maintained and used as a park or ballfield while simultaneously managing stormwater.

Green streets have been demonstrated to provide "complete streets" benefits in addition to stormwater management, including pedestrian safety and traffic calming, street tree canopy and heat island effect mitigation, increased property values, and a boost in economic activity and visibility of storefront businesses. The additional benefit of climate resiliency helps to prepare the region for climate change by providing projects that increase water supply and reduces vulnerability to adverse climate change impacts.

Table 41. Summary of Project Group Additional Benefits

Project Group	Flood	Water Quality	Recreation	Habitat	Aesthetics	Heat Island Mitigation	Climate Resilient
Local Solutions							
Local Stormwater Capture	X	X	X	X	X	X	X
Low Impact Development		X			X	X	X
Complete Streets		X	X		X	X	X
Regional Solutions							
Regional Stormwater Capture	X	X	X	X	X	X	X
Stormwater Conveyance Systems	X	X	X	X	X	X	X
Alternative Capture	X	X	X	X	X	X	X
Storage Solutions							
LACFCD Dams	X						X
USACE Dams	X						X
Debris Basins	X	X					X
Management Solutions							
Stormwater Policies		X	X		X	X	X
Green Infrastructure Programs		X			X	X	X
Regional Impact Programs	X	X	X	X	X	X	X

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RECLAMATION
Managing Water in the West

Los Angeles Basin Stormwater Conservation Study

Task 5 Infrastructure and Operations Concepts Appendices

U.S. Department of the Interior
Bureau of Reclamation

County of Los Angeles
Department of Public Works

Los Angeles County
Flood Control District

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Appendix A: Concept Development and Technical Analysis Spreadsheets

See separate excel file:

- *"Appendix A.xlsx"*

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Appendix B: Project Group Fact Sheets

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Los Angeles Basin
Stormwater Conservation Study

Local Solutions

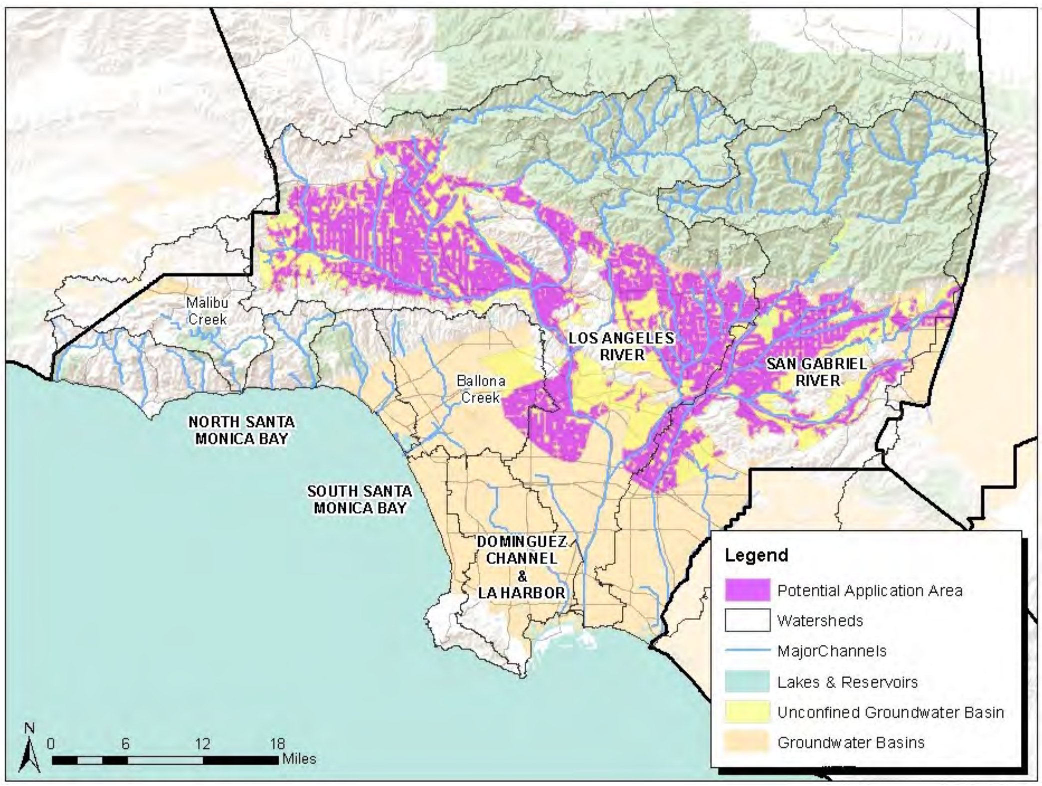
Local Stormwater Capture

KEY FEATURES

- **2,888 local stormwater capture projects**
- **23,300 AFY stormwater captured**
- **266 acres of habitat**
- **204 miles of recreational trails**
- **Project Cost: $11,900/acre-feet**

Overview

The LA Basin Study is assessing the region's major water conservation and flood risk mitigation infrastructure to prepare for future drivers that may impact water supply, such as changes to climate and population. The study is a long-range planning effort that is evaluating the potential of the existing facilities and additional new stormwater capture concepts to increase the resiliency of local water supplies under an uncertain future. The Local Stormwater Capture Project Group improves stormwater conservation at the community level through capture and infiltration projects in favorable areas. Stormwater runoff is collected by storm drains and channels and is diverted to local stormwater facilities for infiltration and retention to help increase recharge, improve water quality, enhance the community, and facilitate habitat restoration. Favorable areas were identified based on: unconfined aquifer conditions, permeable soil types, and proximity to drains and channels. Potential project sites include government properties, parks, schools, golf courses, vacant parcels, and Caltrans right-of-way.



Local Stormwater Capture Projects

A total of 2,888 potential project locations were identified. The Los Angeles River and San Gabriel River Watersheds offer the greatest potential to implement local stormwater capture projects. These stormwater capture projects could include green infrastructure such as infiltration chambers at parks, golf courses, and other public right-of-way.

Surface Infiltration Basin

Subsurface Infiltration Basin

Visit the Study at **tiny.cc/LABasinStudy**

Summary of Local Stormwater Capture Projects

Watershed	Watershed Area (acres)	No. of Projects	Right-of-Way (acres)
Ballona Creek	135,090	73	53.4
Dominguez Channel	70,428	2	-
Los Angeles River	533,840	1,676	1,426.6
Malibu Creek	129,825	0	-
San Gabriel River	434,475	1,137	1,175.4
TOTAL	**1,303,657**	**2,888**	**2,655.4**

Multiple-Benefits & Partner Opportunities

In addition to stormwater conservation, complementary benefits of local stormwater capture projects include flood risk management, water quality, recreation, habitat/connectivity, and climate resilient actions. These other benefits could help to identify project partners as projects with multiple benefits can help to leverage funding. There are opportunities for collaboration and partnering between the County of Los Angeles and other cities within the watershed area. For example, the Municipal Separate Storm Sewer System (MS4) Permit for Los Angeles provides a compliance pathway through the development of Enhanced Watershed Management Programs (EWMPs) to evaluate opportunities within the participating Permittees' collective jurisdictional area in a watershed management area for collaboration among Permittees and other partners

Implementation Challenges

Local stormwater capture projects would be individually planned and designed specifically for available parcels and constructed on public parcels. The local improvements require the acquisition of approximately 2,655 acres of right-of-way. This acquisition is based on private open space parcels that could be purchased for local stormwater capture and used as small scale infiltration areas. None of the local stormwater capture opportunities have any onerous permitting requirements which would preclude their implementation.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is ensure a reliable future water supply. The Los Angeles County Flood Control District is investigating solutions to adapt to climate change and continue to further enhance its stormwater capture efforts. Resiliency to projected climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it for later within deep groundwater reserves. Local stormwater capture solutions can enhance the resiliency of the region and help manage projected climate risks. Increased infiltration and stormwater retention from these projects can both replenish local groundwater reserves to provide a more reliable water supply and help mitigate some potential flooding impacts.

Findings

Implementation of local stormwater capture projects could provide approximately 23,300 acre-feet of stormwater conservation per year (AFY) for the middle climate scenario, 26,498 acres of mitigation, 266 acres of habitat, and approximately 204 miles of recreational trails.

Stormwater Conserved for
Local Stormwater Capture

Watershed	Middle Projected Climate Scenario (AFY)
Ballona Creek	619
Dominguez Channel	3
Los Angeles River	13,988
Malibu Creek	-
San Gabriel River	8,655
TOTAL	**23,265**

Local Solutions

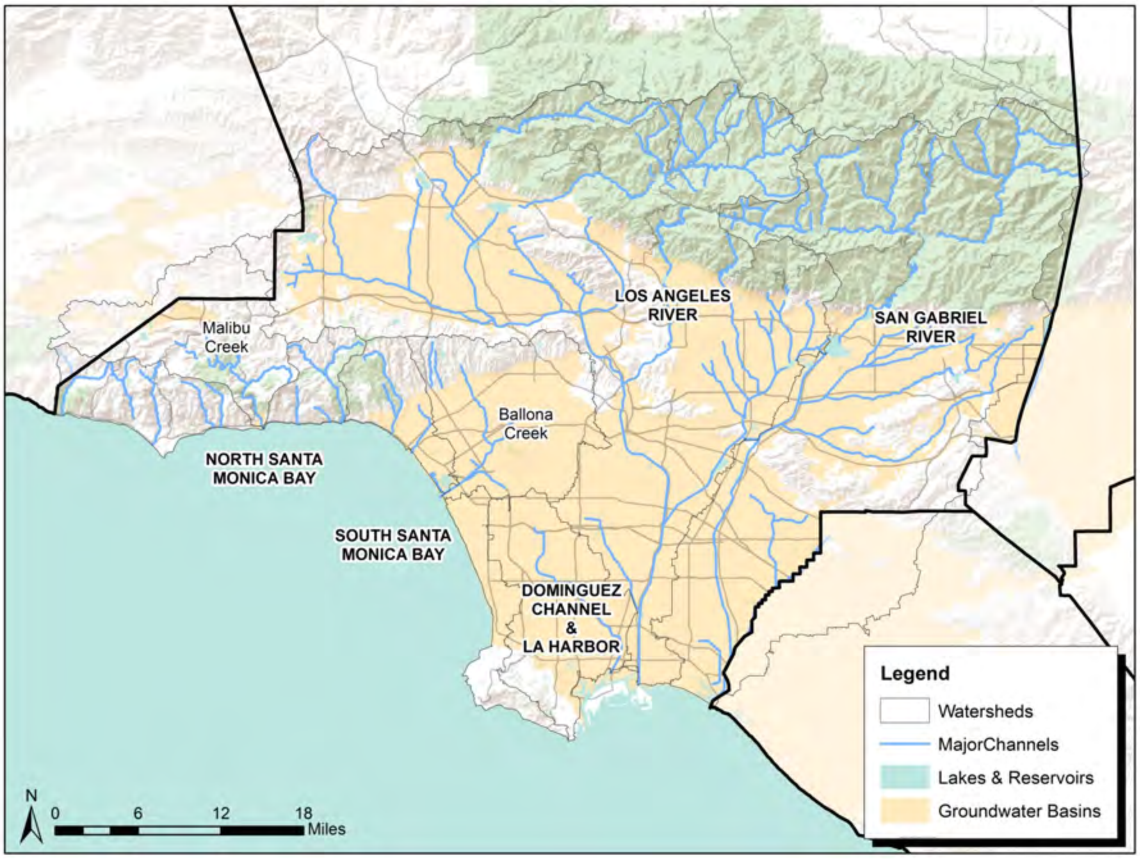
Low Impact Development

KEY FEATURES

- 115,509 acres (40%) of mitigated impervious area
- 115,200 AFY stormwater captured
- Project Cost: $7,800/acre-feet

Overview

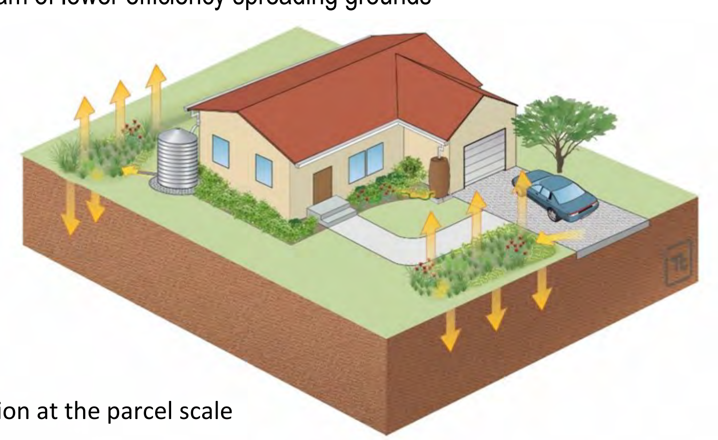
The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The Low Impact Develop Project Group provides stormwater capture through low impact development (LID) measures in residential, commercial, industrial, and institutional areas. Projects include bioretention, permeable pavement, and other infiltration and direct use Best Management Practices (BMPs). For this project group, 115,509 acres of land was modeled as implementing LID.



Low Impact Development

Implementation of LID projects help mitigate the increase of impervious surface resulting from development on both private and public parcels. The most likely LID projects to be built are listed below.

- Construct distributed BMPs upstream of lower efficiency spreading grounds
- Many small projects over the basin ("Urban acupuncture")
- Rain gardens
- Parking lot storage and connectivity
- Green roofs



LID Implementation at the parcel scale

PUBLIC WORKS
COUNTY OF LOS ANGELES
Public Service That Works

LOS ANGELES COUNTY FLOOD CONTROL DISTRICT
100 YEARS 1915–2015

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Local Solution – Low Impact Development

Summary of Low Impact Development Projects

Watershed	Watershed Area	Total Impervious Area Excluding Streets (acres)	Implementation Area	Implementation Ratio of
Ballona Creek	135,090	37,585	13,368	36%
Dominguez Channel	70,428	29,825	13,136	44%
Los Angeles River	533,840	119,149	48,063	40%
Malibu Creek	129,825	5,092	1,761	35%
San Gabriel River	434,475	94,778	39,181	41%
Total	**1,303,657**	**286,430**	**115,509**	**40%**

Multiple-Benefits & Partner Opportunities

In addition to stormwater conservation, complementary benefits of local stormwater capture projects include water quality, aesthetics, and heat island mitigation. Compared to local stormwater capture projects that are larger and provide multi-benefits for various stakeholders, LID projects would be implemented in vast numbers at a distributed scale. The LID projects would either be the responsibility of private homeowners, or each individual jurisdiction where the LID project is located. There may be opportunities for collaboration on the development of a residential LID program that incentivizes homeowners to install LID BMPs on residential land (e.g., rain tanks, hardscape removal, etc.).

Implementation Challenges

LID implementation is driven by ordinances in individual cities. To achieve the project level of LID implementation, a framework will have to be in place to promote widespread implementation over the next century, and significant development and redevelopment would be required. None of the low impact development opportunities have any onerous permitting requirements which would preclude their implementation.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is ensure a reliable future water supply. The Los Angeles County Flood Control District is investigating solutions to adapt to climate change and continue to further enhance its stormwater capture efforts. Resiliency to projected climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it for later within deep groundwater reserves. Low Impact Development solutions can enhance the resiliency of the region and help manage projected climate risks. Increased infiltration and stormwater retention from these projects can replenish local groundwater reserves to provide a more reliable water supply.

Findings

Implementation of LID projects could result in approximately 115,200 acre-feet of stormwater conservation per year (AFY) for the middle climate scenario, and 115,509 acres of mitigated impervious surface, representing 40 percent of the overall impervious land use.

Stormwater Conserved for Low Impact Development

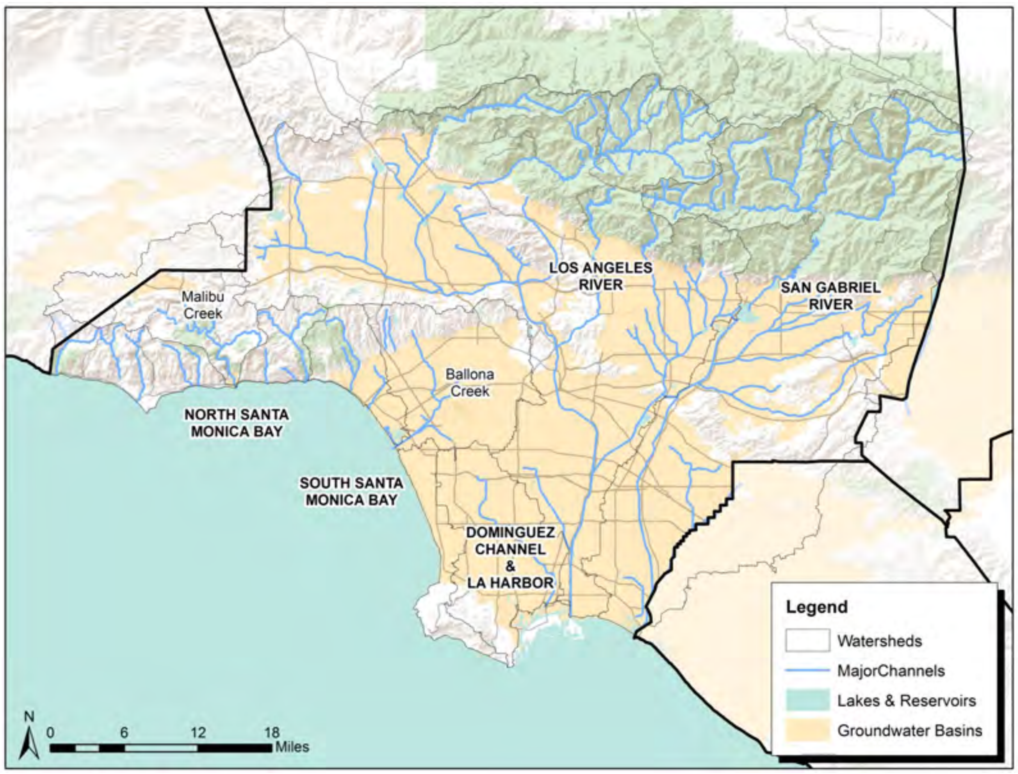
Watershed	Middle Projected Climate Scenario (AFY)
Ballona Creek	9,287
Dominguez Channel	8,157
Los Angeles River	51,659
Malibu Creek	1,283
San Gabriel River	44,854
Total	**115,240**

KEY FEATURES

- 60,400 acres (61%) of mitigated impervious area
- 35,200 AFY stormwater captured
- Project Cost: $14,900/acre-feet

Overview

The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The Complete Streets Project Group utilizes the complete streets initiative to implement stormwater treatment and management. Complete Streets could provide a plan to ensure the safety, accessibility, and convenience of all transportation users, including pedestrians, bicyclists, transit riders, and motorists. This alternative implements stormwater capture and infiltration practices on transportation related land uses, resulting in approximately 60,400 acres of mitigation.



Complete Streets Projects

There is approximately 100,000 acres of transportation related impervious area within the Los Angeles Basin. Complete Streets could provide opportunities for stormwater treatment and management by providing on-site retention, filtration, and infiltration. These projects are typically implemented as bioretention/biofiltration Best Management Practices (BMPs) installed parallel to roadways to supplement parkway landscaping. These BMP systems receive runoff from the gutter via curb cuts. Permeable pavement could also be implemented as part of Complete Streets. Complete Streets projects could include:

- Green streets and stream tributaries stormwater capture
- Parkways and road medians stormwater capture

Complete Streets Schematic

Visit the Study at **tiny.cc/LABasinStudy**

Summary of Complete Streets Projects

Watershed	Watershed Area (acres)	Total Impervious Street Area (acres)	Implementation Area (acres)	Implementation Ratio of Impervious Area
Ballona Creek	135,090	17,942	10,945	61%
Dominguez Channel	70,428	10,258	6,309	62%
Los Angeles River	533,840	46,295	28,371	61%
Malibu Creek	129,825	986	609	62%
San Gabriel River	434,475	23,064	14,192	62%
Total	**1,303,657**	**98,546**	**60,427**	**61%**

Multiple-Benefits & Partner Opportunities

In addition to stormwater management, Complete Streets also provide pedestrian safety and traffic calming, street tree canopy and heat island effect mitigation, increased property values, and a boost in economic activity and visibility of storefront businesses. There are opportunities for the various cities, organizations, and other agencies within the study area to collaborate on a green infrastructure-related streets program. Other street programs could be considered to include other cities, universities, and non-governmental organizations.

Implementation Challenges

Municipalities within the region have adopted ordinances to incorporate green infrastructure requirements for streets projects. These types of programs and ordinances represent the initial stages of developing a comprehensive program. The Complete Streets concept does not have any onerous permitting requirements that could prevent their implementation.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is ensure a reliable future water supply. The Los Angeles County Flood Control District is investigating solutions to adapt to climate change and ways to further enhance its stormwater capture efforts. Resiliency to future climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it for later within deep groundwater reserves. Complete Streets solutions could enhance the resiliency of the region and help manage projected climate risks. Increased infiltration and stormwater retention from these projects could replenish local groundwater reserves to provide a more reliable water supply.

Findings

Implementation of Complete Streets projects could result in approximately 35,200 acre-feet of stormwater conservation per year (AFY) for the middle climate scenario, and 60,427 acres of mitigated impervious surface, representing 61 percent of the overall impervious street area.

Stormwater Conserved for Complete Streets

Watershed	Middle Projected Climate Scenario (AFY)
Ballona Creek	4,835
Dominguez Channel	2,482
Los Angeles River	18,540
Malibu Creek	273
San Gabriel River	9,100
Total	**35,230**

Los Angeles Basin
Stormwater Conservation Study

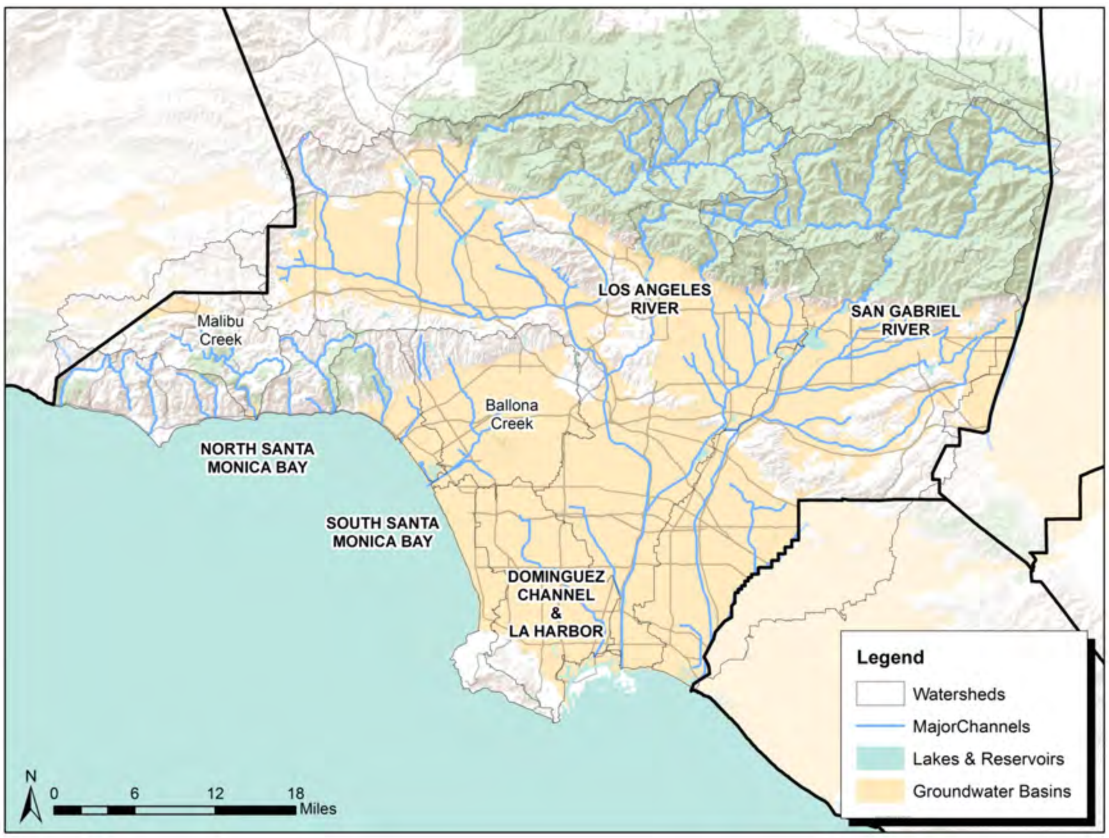
Management Solutions
Stormwater Policies

KEY FEATURES

- 229,414 acres (60%) of mitigated impervious area
- 193,200 AFY stormwater captured
- Project Cost: $9,600/acre-feet

Overview

The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The Stormwater Polices Project Group encourages stormwater conservation through policy and improved regulations. Policies could include incentives or requirements for greater implementation rates and enhanced maintenance to increase performance. Stormwater Polices assume a combination of the Low Impact Development (LID) and Complete Streets local solutions, and increases the stormwater conservation through various changes in stormwater policy. This management solution is estimated to implement decentralized projects over approximately 229,414 acres of impervious area.



Stormwater Policies Projects

Several different changes to policy and regulations can be improved upon such as:

- Utilizing EWMPs for the dual-purpose of water conservation
- Align regulatory and environmental plans with water conservation/supply goals
- Use advanced rainfall-hydrology modeling to quantify pre-storm capture
- Streamline requirements for maintenance of existing infrastructure
- Remove invasive "water thirsty" plants in water conservation system
- Develop "feed in tariff" for groundwater infiltration

COUNTY OF LOS ANGELES PUBLIC WORKS Public Service That Works

LOS ANGELES COUNTY FLOOD CONTROL DISTRICT 100 YEARS 1915–2015

U.S. DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

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Management Solutions – Stormwater Policies

Summary of Stormwater Policies Projects

Watershed	Watershed Area (acres)	Total Impervious Area (acres)	Implementation Area (acres)	Implementation Ratio of Impervious Area
Ballona Creek	135,090	55,528	31,997	58%
Dominguez Channel	70,428	40,083	25,175	63%
Los Angeles River	533,840	165,444	99,519	60%
Malibu Creek	129,825	6,079	3,171	52%
San Gabriel River	434,475	117,842	69,552	59%
Total	**1,303,657**	**384,975**	**229,414**	**60%**

Multiple-Benefits & Partner Opportunities

In addition to stormwater conservation, complementary benefits of LID and Complete Streets include water quality, aesthetics, and heat island mitigation. The strategy of Enhanced Watershed Management Programs (EWMPs) has been to take a collaborative approach to comply with the Los Angeles County Municipal Separate Storm Sewer System (MS4) permit through a watershed management group. A similar collaborative approach could be taken for stormwater conservation to involve multiple stakeholders within a watershed.

Implementation Challenges

Potential implementation challenges and permitting requirements for Low Impact Development and Complete Streets local solutions would apply. LID implementation is driven by ordinances in individual cities. To achieve the project level of LID implementation, a framework will have be in place to promote widespread implementation over the next century, and significant development and redevelopment would be required. Cities within the region have adopted ordinances to incorporate green infrastructure requirements for streets projects. These types of programs and ordinances represent the initial stages of developing a comprehensive program.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is ensure a reliable future water supply. The Los Angeles County Flood Control District is investigating solutions to adapt to climate change and continue to further enhance its stormwater capture efforts. Resiliency to projected climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it for later within deep groundwater reserves. Stormwater policies that increase LID and Complete Streets implementation could enhance the resiliency of the region and help manage future climate risks. Increased infiltration and stormwater retention from these projects could replenish local groundwater reserves to provide a more reliable water supply.

Stormwater Conserved for Stormwater Policies

Watershed	Middle Projected Climate Scenario (AFY)
Ballona Creek	24,378
Dominguez Channel	17,353
Los Angeles River	86,201
Malibu Creek	2,536
San Gabriel River	62,713
Total	**193,181**

Findings

Implementation of stormwater policies could result in approximately 193,200 acre-feet of stormwater conservation per year (AFY) for the middle climate scenario, and 229,400 acres of mitigated impervious surface, representing 60 percent of the overall impervious land use.

Management Solutions

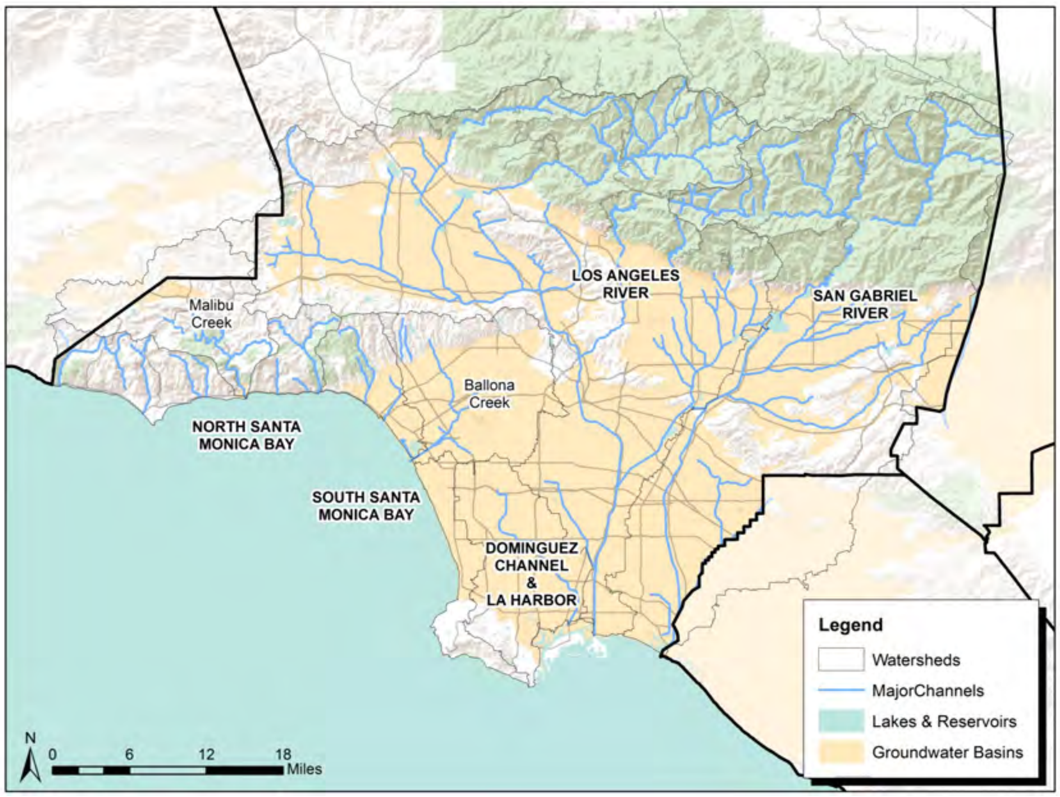
Green Infrastructure Programs

KEY FEATURES

- ► 151,194 acres (53%) of mitigated impervious area
- ► 139,400 AFY stormwater captured
- ► Project Cost: $8,200/acre-feet

Overview

The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The Green Infrastructure Programs Project Group encourages implementation of LID through green infrastructure programs. When deployed across the basin, LID projects could make significant impact on stormwater capture. Green Infrastructure Programs assume increases in stormwater conservation through green infrastructure.



Green Infrastructure Programs Projects

The MS4 Permit and local ordinances require significant development and redevelopment projects to incorporate LID concepts into their site design. Existing residential parcels could also provide an important opportunity for LID implementation. Runoff from residential parcels often flow directly to a curb and gutter or other conveyance system on the street. A well-designed residential LID program can engage individual homeowners to reduce their contribution to stormwater runoff. Potential solutions to implement additional green infrastructure could include:

- ► Low Impact Development/Best Management Practices for Stormwater
- ► Increase permeable space to balance water conservation goals
- ► Increase urban permeability
- ► Emphasize residential infiltration in high-density locations
- ► Encourage residential land changes for promoting infiltration

Many of the programs could reduce the time it takes to reach full-scale implementation, but may not increase the final value. However, programs focused on residential land uses may encourage homeowners to willingly participate in LID implementation.

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Management Solutions – Green Infrastructure Programs

Summary of Green Infrastructure Programs Projects

Watershed	Watershed Area (acres)	Total Impervious Area Excluding Streets (acres)	Implementation Area (acres)	Implementation Ratio of Impervious Area
Ballona Creek	135,090	37,585	19,180	51%
Dominguez Channel	70,428	29,825	15,877	53%
Los Angeles River	533,840	119,149	63,052	53%
Malibu Creek	129,825	5,092	2,547	50%
San Gabriel River	434,475	94,778	50,537	53%
Total	**1,303,657**	**286,430**	**151,194**	**53%**

Multiple-Benefits & Partner Opportunities

In addition to stormwater conservation, complementary benefits of LID projects include water quality, aesthetics, and heat island mitigation. Compared to local stormwater capture projects that are larger and provide multi-benefits for various stakeholders, LID projects could be implemented wide-scale. The LID projects would be the responsibility of land owners, or the LID jurisdiction. There could be opportunities for collaboration on the development of a residential LID program that incentivizes homeowners to install LID BMPs on residential land (rain tanks, hardscape removal, etc.).

Implementation Challenges

LID implementation is driven by individual cities. To achieve widespread LID implementation, an LID framework would have be in place. In addition to the County requirements, owners/developers of some project sites may be subject to the Industrial General Permit and/or the Construction General Permit. None of the LID opportunities have any onerous permitting requirements which would preclude their implementation.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is ensure a reliable future water supply. The Los Angeles County Flood Control District is investigating solutions to adapt to climate change and continue to further enhance its stormwater capture efforts. Resiliency to future climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it for later within deep groundwater reserves. Green infrastructure programs could enhance the resiliency of the region and help manage projected climate risks.
Increased infiltration and stormwater retention from these projects could replenish local groundwater reserves to provide a more reliable water supply.

Findings

Implementation of green infrastructure programs could result in approximately 139,400 acre-feet of stormwater conservation per year (AFY) for the middle climate scenario, and 151,194 acres of mitigated impervious surface, representing 53 percent of the overall impervious land use.

Stormwater Conserved for Green Infrastructure Programs

Watershed	Middle Projected Climate Scenario (AFY)
Ballona Creek	13,320
Dominguez Channel	9,886
Los Angeles River	61,707
Malibu Creek	1,859
San Gabriel River	52,635
Total	**139,407**

Los Angeles Basin
Stormwater Conservation Study

Management Solutions

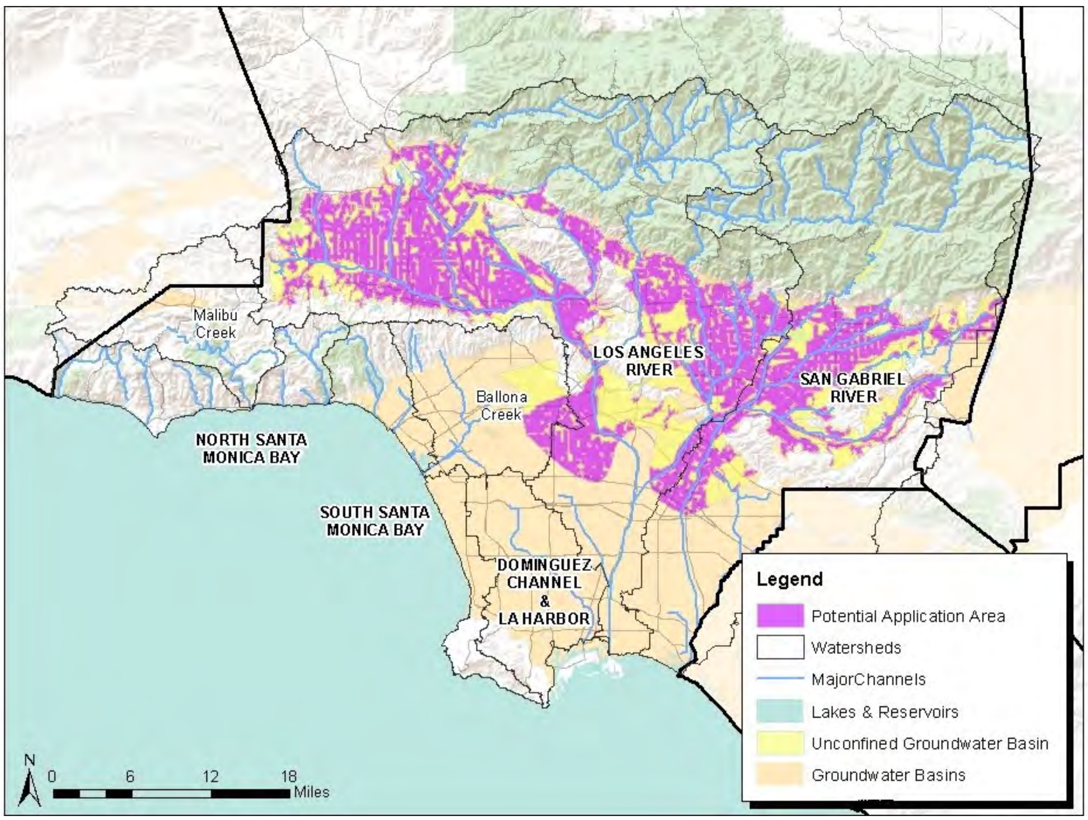
Regional Impact Programs

KEY FEATURES

- **2,888 Regional Impact Programs Projects**
- **29,000 AFY stormwater captured**
- **266 acres of habitat**
- **204 miles of recreational trails**
- **Project Cost: $10,300/acre-feet**

Overview

The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The Regional Impact Programs Project Group encourages local stormwater capture solutions through regional programs that will have a large-scale impact. Local stormwater capture concepts are comprised of facilities that receive large volumes of stormwater runoff from upstream areas for infiltration and stormwater retention. Aside from increasing recharge, local stormwater capture projects can improve water quality, enhance the community, and facilitate habitat restoration. Management Solution 3 assumes a model baseline of implementing local stormwater capture solutions, and increases the stormwater conservation through regional impact programs.



Regional Impact Programs Projects

Regional Impact Programs could include the following strategies:

- Promote and value open space for its stormwater benefits
- Utilize government parcels first for stormwater capture, storage, and infiltration
- Investigate recharge along river embankments
- County-wide parcel fee with mitigation rebate
- School stormwater improvements
- Programs to implement stormwater projects at public parks and schools
- Depress all sports fields for stormwater capture

Regional impact programs would encourage local stormwater capture across the watershed. Most of the programs may reduce the time it takes to reach full-scale implementation, but may not increase the total conservation. However, for open space areas, the percentage of the parcel used for infiltration was increased to account for regional impact programs.

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Management Solutions – Regional Impact Programs

Summary of Regional Impact Programs Projects

Watershed	Watershed Area (acres)	No. of Projects	Right-of-Way (acres)
Ballona Creek	135,090	73	53.4
Dominguez Channel	70,428	2	0.0
Los Angeles River	533,840	1,676	1,426.6
Malibu Creek	129,825	0	0.0
San Gabriel River	434,475	1,137	1,175.4
Total	**1,303,657**	**2,888**	**2,655.4**

Multiple-Benefits & Partner Opportunities

In addition to stormwater conservation, complementary benefits of local stormwater capture projects include flood risk management, water quality, recreation, habitat/connectivity, and climate resilient actions. These other benefits could help to identify project partners as projects with multiple benefits can help to leverage funding. There are opportunities for collaboration and partnering between the County of Los Angeles and other cities within the watershed area. For example, the Municipal Separate Storm Sewer System (MS4) Permit for Los Angeles provides a compliance pathway through the development of Enhanced Watershed Management Programs (EWMP) to evaluate opportunities within the participating Permittees' collective jurisdictional area for collaboration among Permittees and other partners on multi-

Implementation Challenges

The local improvements could require the purchase of approximately 2,655 acres of right-of-way. This acquisition is based on private open space parcels that could be purchased for local stormwater capture and used as small scale infiltration areas. Local stormwater capture projects would likely be individually planned and designed specifically for available parcels and constructed on public parcels. None of the local storwmwater capture opportunities or regional impact programs have any onerous permitting requirements which would preclude their implementation.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is ensure a reliable future water supply. The Los Angeles County Flood Control District is investigating solutions to adapt to climate change and continue to further enhance its stormwater capture efforts. Resiliency to projected climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it for later within deep groundwater reserves. Local stormwater capture projects and regional impact programs can enhance the resiliency of the region and help manage future climate risks. Increased infiltration and stormwater retention from these projects can both replenish local groundwater reserves to provide a more reliable water supply and help mitigate some potential flooding impacts.

Stormwater Conserved for Regional Impact Programs

Watershed	Middle Projected Climate Scenario (AFY)
Ballona Creek	776
Dominguez Channel	3
Los Angeles River	17,221
Malibu Creek	-
San Gabriel River	10,983
Total	**28,984**

Findings

Regional impact programs could result in approximately 29,900 acre-feet of stormwater conservation per year (AFY) for the middle climate scenario, 33,327 acres of mitigation, 266 acres of habitat, and 204 miles of recreational trails.

Los Angeles Basin
Stormwater Conservation Study

Regional Stormwater Capture

KEY FEATURES

- Eight new spreading grounds with 10 percent dedicated habitat and trails
- 15 enhanced spreading grounds using soil management practices
- Average 43,300 AFY stormwater captured
- 42 acres of new habitat
- Over 12 miles of recreational trails
- Project Cost: $1,300/acre-feet

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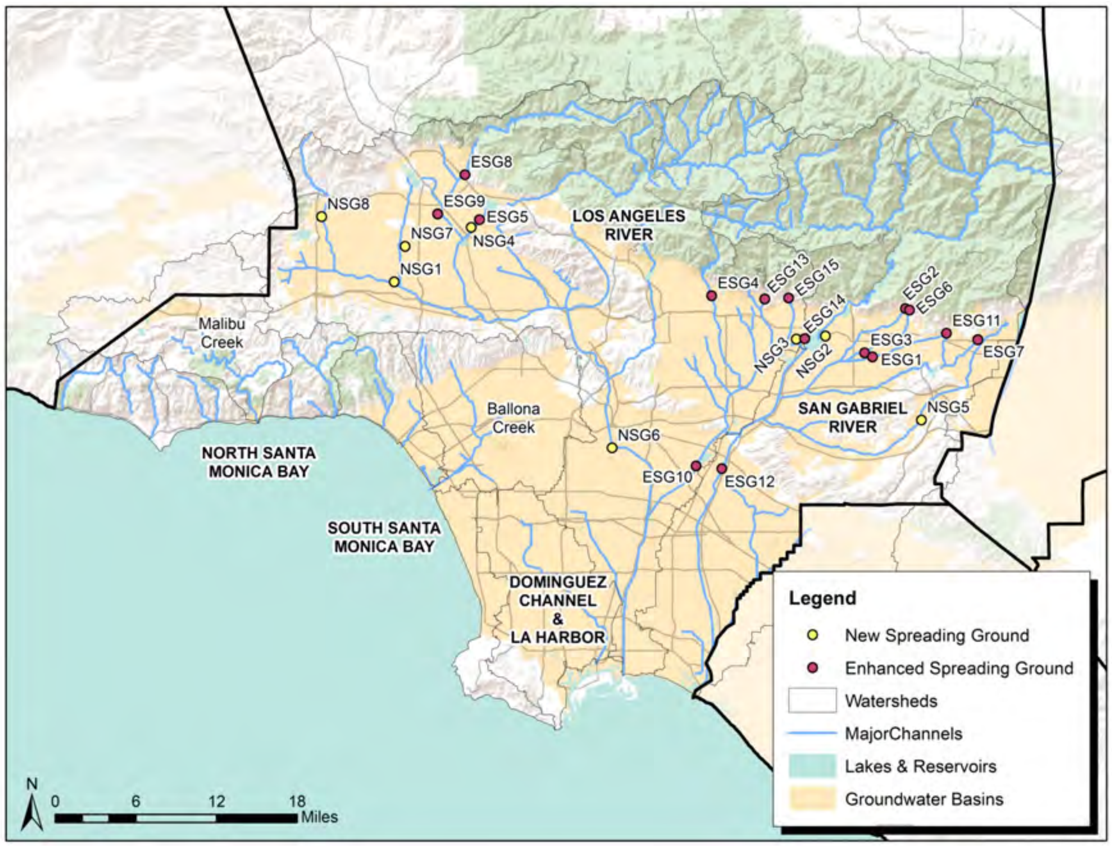
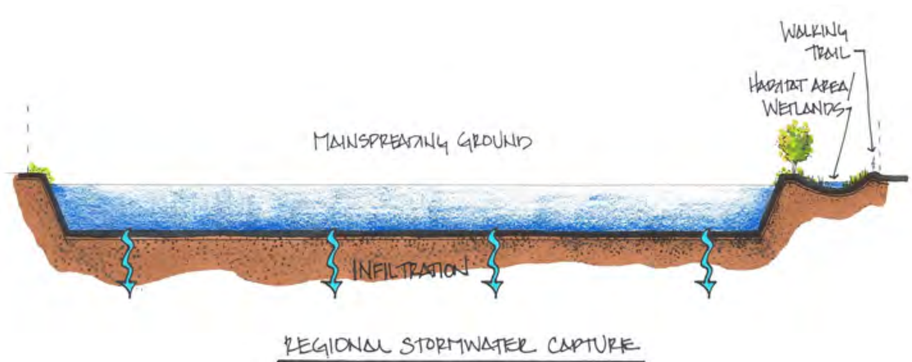
Overview

The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The Regional Stormwater Capture Project Group could improve groundwater recharge through construction of 8 new spreading grounds and enhanced maintenance at 15 existing spreading grounds. Aside from increasing stormwater recharge, spreading grounds also offer recreational opportunities and potential wildlife habitat improvements.



Regional Stormwater Capture Projects

Potential locations for new spreading basins were identified based on previous reports and a search of vacant properties near main channel features in recharge areas. Existing gravel pits in favorable areas were assumed to be repurposed as spreading basins where appropriate. Task 4 of the study ranked the existing spreading grounds based on performance levels. Of the 25 Existing spreading grounds analyzed in Task 4, 16 were identified as candidates for increasing maintenance to enhance recharge capacity.



Multiple-Benefits & Partner Opportunities

Given the regional benefits of these stormwater capture projects, there could be potential opportunities for collaboration and partnering among the County of Los Angeles, groundwater water management agencies, and water purveyors, as well as Los Angeles County Sanitation District for recycled water projects. In addition, other parties with interests related to the multi-benefit components of the project could be other potential project partners. 10-percent of new basins were assumed dedicated to habitat.

Implementation Challenges

Significant land acquisition would be required to construct the eight new recharge basins. Construction of the new basins would require acquisition of 682 acres of right-of-way.

Additional permitting requirements would be required for new basins located downstream of waste water treatment plant outfalls. Flow in the Los Angeles River below Sepulveda Dam contains tertiary treated effluent, and basins located downstream of Sepulveda Dam would need to comply with the latest Regulations for Groundwater Replenishment Using Recycled Water.

None of the other basins are expected to have permitting requirements that would preclude their implementation.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is ensure a reliable future water supply. The Los Angeles County Flood Control District is investigating solutions to adapt to climate change and continue to further enhance its stormwater capture efforts. Resiliency to future climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it for later within deep groundwater reserves. Regional stormwater capture solutions could enhance the resiliency of the region and help manage future climate risks. Increased infiltration and stormwater retention from these projects could both replenish local groundwater reserves to provide a more reliable water supply and help mitigate some potential flooding impacts. The Regional Stormwater Capture Projects are intended to capture and infiltrate stormwater which will help promote groundwater recharge and provide resiliency when more water is available .

New and Enhanced Basins

ID	Location
New Basins	
NSG1	Miller Pit
NSG2	New Tujunga Spreading Grounds
NSG3	Rock Pit No. 3
NSG4	Sepulveda Dam
NSG5	Spadra Basin
NSG6	LA Forbay Spreading Ground
NSG7	Bull Creak Area Spreading Grounds
NSG8	Browns Creak Area Spreading Grounds
Enhanced Basins	
ESG1	Ben Lomond
ESG2	Big Dalton
ESG3	Citrus
ESG4	Eaton Wash
ESG5	Hansen/Tujunga
ESG6	Little Dalton
ESG7	Live Oak
ESG8	Lopez
ESG9	Pacoima
ESG10	Rio Hondo
ESG11	San Dimas
ESG12	San Gabriel Coastal
ESG13	Santa Anita
ESG14	Santa Fe
ESG15	Sawpit

Findings

Implementation of Regional Stormwater Capture projects could provide approximately 43,300 acre-feet of stormwater conservation per year (AFY) based on average for the results from the middle climate scenario, 42 acres of wetland habitat, and over 12 miles of recreational trails.

Stormwater Conserved for Regional Stormwater Capture

Recharge Basin	Middle Projected Climate Scenario (AFY)
Existing and Enhanced Basins	13,381
Expanded and New Basins	29,930
Net Change	**43,311**

Regional Solutions

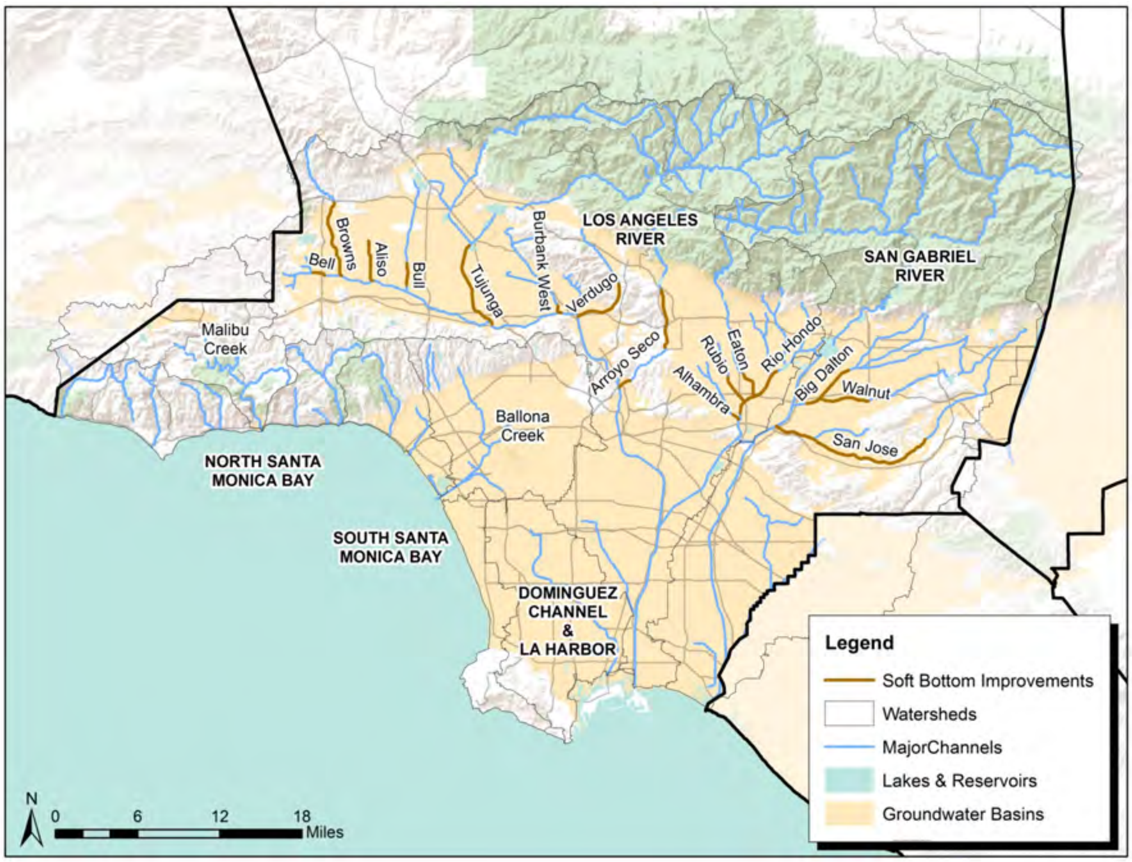
Stormwater Conveyance Systems

KEY FEATURES

- Over 57 miles of soft bottom or side pond improvements along 15 different channels
- Average 9,200 AFY stormwater captured
- Over 3 miles of recreational trails
- Over 8 acres of habitat
- Project Cost: $46,300/acre-feet

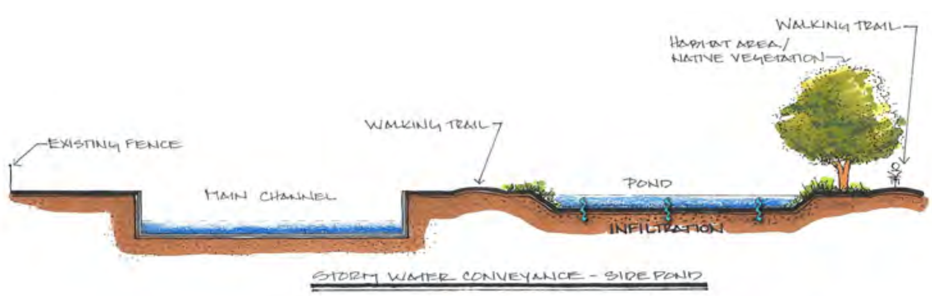
Overview

The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The Stormwater Conveyance Systems Project Group could improve stormwater conservation through soft bottom channel modifications. There are many concrete lined channels in Los Angeles County, and converting some to soft bottom could improve groundwater recharge, improve water quality, and provide opportunities for recreational trails, parkways, and riparian habitat corridors. However, the region's need for increased stormwater capture must still balance the dual goal of flood risk management.



Stormwater Conveyance Systems Projects

The proposed projects targeted for soft bottom conversion focus on tributary reaches with larger channels that have favorable soil conditions for recharging stormwater. Two approaches were evaluated to enhance short term stormwater detention within existing or converted soft bottom channels areas. "River speed bumps", small in-channel earthen detention structures, were assumed for all modified channel reaches. Channel side ponds were considered where easements or land appears available for their installation.



Regional Solutions – Stormwater Conveyance Systems

Multiple-Benefits & Partner Opportunities

Potential opportunities for collaboration and partnering could be with the County of Los Angeles, groundwater water management agencies, and water purveyors, as well as Los Angeles County Snatiation District for recycled water projects. In addition, other parties with interests related to the multi-benefit components of the project (local city departments for example) are other potential project partners. Multiple-benefit opportunities including habitat and recreational improvements could be incorporated into these projects.

Implementation Challenges

The region's need for increased stormwater capture must still balance the dual goal of flood risk management. The channel modifications would need to preserve existing flood protection and flow capacity. Significant permitting challenges are associated with the proposed channel modifications. Detailed hydrology and hydraulics studies would need to be performed to confirm the modified channels provide adequate flood mitigation, and coordination among local governments, the Army Corps of Engineers, and the Los Angeles County Flood Control District (LACFCD) would be required.

Additionally, most of the land adjacent to the existing tributary channels is developed and there is limited opportunity for right-of-way acquisition for more extensive pond networks or habitat improvements. 31 acres of right-of-way acquisition would be required to accommodate the channel side ponds.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is to ensure a reliable future water supply. The LACFCD is investigating solutions to adapt to climate change and continue to further enhance its stormwater capture efforts. Resiliency to future climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it for later within deep groundwater reserves. Stormwater conveyance system solutions could enhance the resiliency of the region and help manage future climate risks. Increased infiltration and stormwater retention from these projects could both replenish local groundwater reserves to provide a more reliable water supply and help mitigate some potential flooding impacts. The channel modifications will promote groundwater recharge and provide resiliency when more water is available.

Stormwater Conveyance System Channel Modifications

Channel	Total Modified Length (ft)
Alhambra Wash	2,707
Aliso Creek	15,448
Arroyo Seco Channel	28,764
Bell Creek	4,590
Big Dalton Wash	16,162
Browns Creek	30,032
Bull Creek	8,034
Burbank Western System	3,132
Eaton Wash	10,882
Rio Hondo	22,321
Rubio Wash	11,638
San Jose Creek	64,072
Tujunga Wash	34,988
Verdugo Wash	22,664
Walnut Creek Channel	24,415
Total	**299,849**

Findings

Implementation of Stormwater Conveyance Systems projects could provide approximately 9,200 acre-feet of stormwater conservation per year (AFY) for the middle climate scenario, 8 acres of habitat improvements, and over 3 miles of recreational trail.

Stormwater Conserved for Stormwater Conveyance Systems

Channel	Middle Projected Climate Scenario (AFY)
Alhambra Wash	73
Aliso Creek	401
Arroyo Seco Channel	932
Bell Creek	118
Big Dalton Wash	487
Browns Creek	601
Bull Creek	257
Burbank Western System	81
Eaton Wash	220
Rio Hondo	740
Rubio Wash	291
San Jose Creek	2,389
Tujunga Wash	1,076
Verdugo Wash	947
Walnut Creek Channel	575
Total	**9,188**

Los Angeles Basin
Stormwater Conservation Study

Regional Solutions
Alternative Capture

KEY FEATURES

- Eight stretches of shallow aquifer recharge ponds to provide soil aquifer treatment
- 24 extraction and 48 injection wells to pump treated water into aquifer
- Approximately 20 acres of total infiltration area
- 5,600 AFY of stormwater captured
- Over 2 miles of recreational trails
- 2 acres of Habitat
- Project Cost: $1,700/acre-feet

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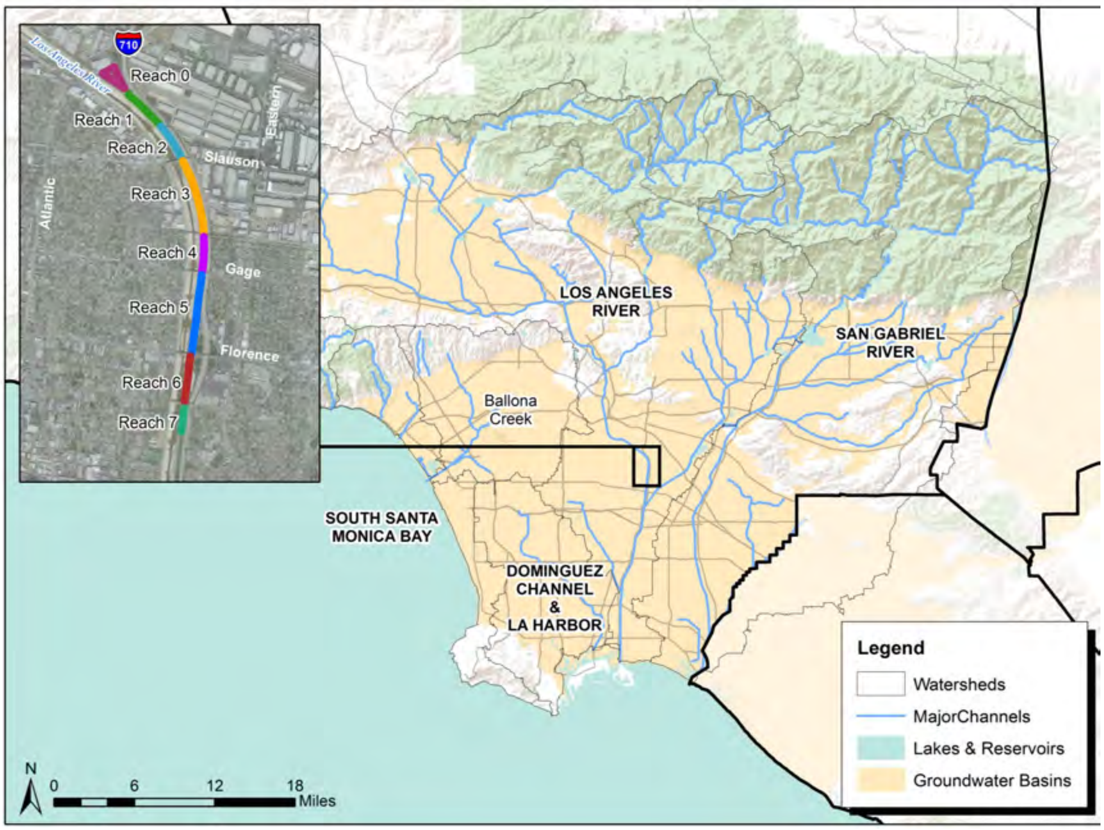
Overview

The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The Alternative Capture Project Group could improve stormwater capture through seven new recharge ponds along the Los Angeles River. Currently, there are no groundwater recharge facilities in the Los Angeles Forebay region of Central Basin due to limited land availability.



Alternative Capture Project

The Water Replenishment District (WRD) Groundwater Basin Master Plan estimates up to 5,000 AFY of stormwater could be captured in the Los Angeles forebay region of Central Basin through an Aquifer Recharge and Recovery Facility. This type of facility could provide stormwater capture as well as soil aquifer treatment and injection/recovery opportunities. Alternative Capture consists of a series of eight shallow aquifer recharge basins which would be located within the existing power line easement along the Los Angeles River. The aquifer recharge basins could perform soil aquifer treatment which is a natural filtration process to remove nitrates, pathogens, and micro-pollutants. Extraction wells along the perimeter of the basins could extract the treated groundwater and inject into a production aquifer. Infrastructure required for the concept includes 24 extraction wells, 48 injection wells, and intake structures. For the project group, 2 miles of trails could be created for recreational use. Additional features could be incorporated including trees, bike paths, and pocket parks.

Summary of Alternative Capture Projects

Reach No.	Infiltration Area (acres)	No. of Extraction Wells	No. of Injection Wells	Reach Length (ft)	Right-of-Way (acres)	Habitat (acres)	Recreation Trails (ft)
0	3.8	4	8	1,300	6.3	0.4	1,300
1	1.5	2	4	1,255	2.5	0.2	1,255
2	2.4	2	4	1,230	4.0	0.2	1,230
3	5.1	6	12	2,530	8.5	0.5	2,530
4	2.7	4	8	1,170	4.5	0.3	1,170
5	2.5	2	4	2,600	4.2	0.3	2,600
6	1.4	2	4	1,355	2.3	0.1	1,355
7	0.7	2	4	1,355	1.2	0.1	1,355
Total	**20.1**	**24**	**48**	**12,795**	**33.5**	**2.0**	**12,795**

Multiple-Benefits & Partner Opportunities

Given the regional benefits of this proposed capture project, there could be potential opportunities for collaboration and partnering among the County of Los Angeles, groundwater water management agencies, and water purveyors, as well as the Los Angeles County Sanitation District for recycled water projects. In addition, other parties with interests related to the multi-benefit components of the project, such as local and city departments, could be other potential project partners.

Implementation Challenges

Additional permitting would be required for the project. Flow at the project site would contain tertiary treated effluent from the Tillman Water Reclamation Plant, so the project would need to comply with the latest Regulations for Groundwater Replenishment Using Recycled Water, including associated design studies and reporting and monitoring requirements. Approximately 34 acres of right-of-way would be required to construct the project.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is ensure a reliable future water supply. The Los Angeles County Flood Control District is investigating solutions to adapt to climate change and continue to further enhance its stormwater capture efforts. Resiliency to future climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it within deep groundwater reserves for later use. Alternative capture solutions could enhance the resiliency of the region and help manage future climate risks. Increased infiltration and stormwater retention from these projects could both replenish local groundwater reserves to provide a more reliable water supply .

Findings

Implementation of the Alternative Capture project group could provide approximately 5,600 acre-feet of stormwater conservation per year (AFY) for the middle climate scenario and create more than 2 miles of recreational trail. Additional habitat and recreational features, including parks, trees, and wildlife areas, could be considered.

Stormwater Conserved for Alternative Capture

Channel	Middle Projected Climate Scenario (AFY)
Los Angeles River	5,587

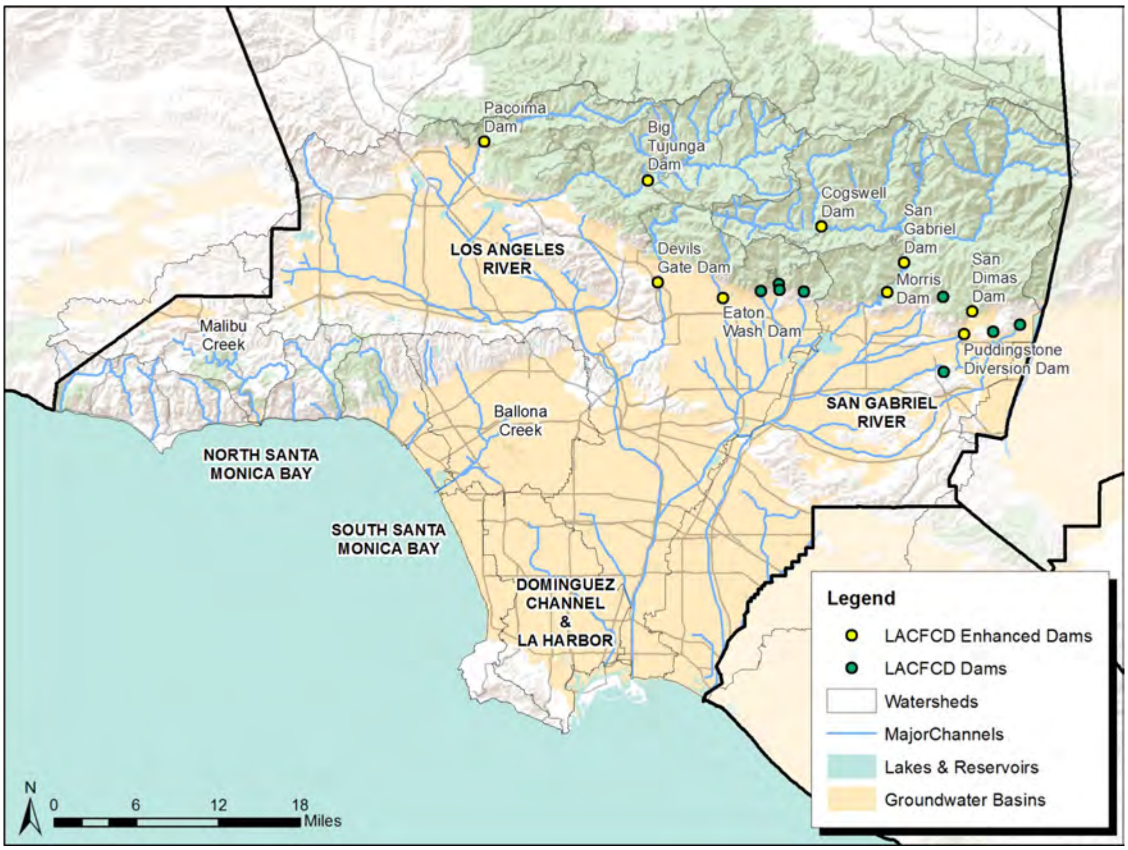
Storage Solutions
LACFCD Dams

KEY FEATURES

- 14 existing Los Angeles County Flood Control District (LACFCD) owned dams evaluated
- 9 Los Angeles County owned dams modified for increased storage
- Average increase of 150,000 AFY of stormwater capture
- Project Cost: $183/acre-foot

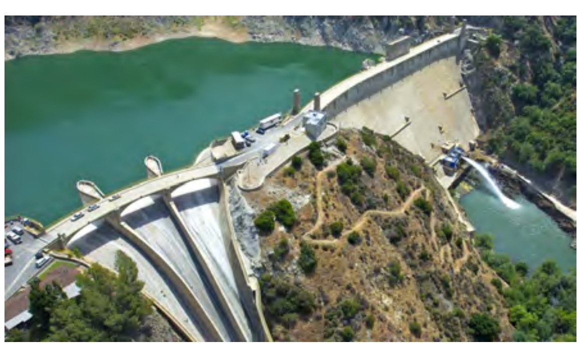
Overview

The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The LACFCD Dams Project Group improves stormwater capture and storage at 9 of the region's 14 water conservation dams. The LACFCD Dams make a major contribution to the local water supply of the Los Angeles Basin by capturing and storing stormwater flows from the mountains above the Basin and releasing it later to downstream spreading grounds. The dams also play a crucial role in Los Angeles County's flood risk management by slowing flows in the downstream drainage system. This project group proposes to install additional operational controls at 9 of the existing Dams to increase capacity to temporarily capture and store stormwater.



LACFCD Dams

LACFCD Dams serve a dual purpose of stormwater capture and flood risk management by temporarily capturing and storing stormwater. Fourteen existing LACFCD dams were evaluated and 9 were selected for modifications which would include construction of additional operable controls at the outflow structures.



COUNTY OF LOS ANGELES PUBLIC WORKS Public Service That Works

LOS ANGELES COUNTY FLOOD CONTROL DISTRICT 100 YEARS 1915–2015

U.S. DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

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Multiple-Benefits & Partner Opportunities

By increasing the capture and storage of stormwater, this project group offers opportunities for increased flood risk management and may also increase the existing water quality benefit of the dams. This project group also provides opportunities for partnering between flood control, groundwater management, and local government agencies.

Implementation Challenges

Implementation of this project group would involve significant permitting considerations. Detailed investigations of changes to the flood risk management and water conservation functions of the dams will need to be performed. Potential impacts on the seismic and structural stability of the dams will also need to be investigated, as well as potential environmental impacts.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is ensure a reliable future water supply. The Los Angeles County Flood Control District is investigating solutions to adapt to climate change and continue to further enhance its stormwater capture efforts. Resiliency to future climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it for later within groundwater reserves. Local stormwater capture solutions can enhance the resiliency of the region and help manage future climate risks. Increased infiltration and stormwater retention from these projects can both replenish local groundwater reserves to provide a more reliable water supply and help mitigate some potential flooding impacts. Sediment loading to the reservoirs behind the dams under the climate scenarios was not evaluated explicitly, but is expected to increase under wet climate scenarios. Periodic sediment removal from the reservoirs will be necessary to maintain the stormwater storage capacity and climate resiliency of this project group

Findings

Construction of additional operable controls at the outflow structures of the 9 dams could increase their capacity to temporarily capture and store stormwater for release later to downstream spreading grounds where it could infiltrate into groundwater reserves. The average annual stormwater conservation benefit for the middle climate scenario is approximately 150,000 acre-feet of stormwater conservation per year (AFY).

Stormwater Conserved for Debris Basin Projects

LACFCD Dam	Median Future Climate Scenario (AFY)
Big Tujunga	11,786
Cogswell	11,762
Devil's Gate	9,747
Eaton Wash	1,277
Morris	71,853
Pacoima	1,259
Puddingstone Diversion	888
San Dimas	2,041
San Gabriel	39,404
Total	**150,015**

Storage Solutions

Debris Basins

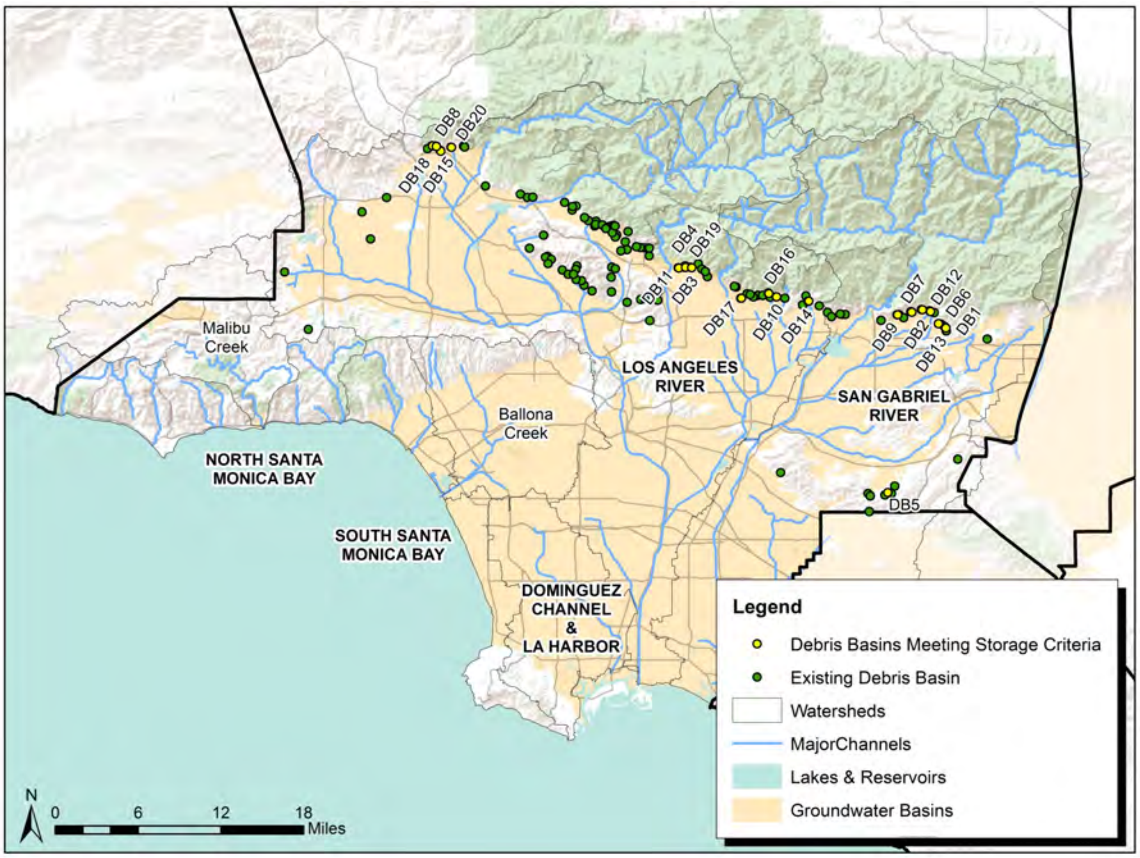
KEY FEATURES

- 121 existing debris basins evaluated
- 20 debris basins modified for storage
- Total 552 ac-ft storage capacity
- Average of 145 AFY of stormwater capture
- Sediment loading may limit climate resiliency
- 1 mile of recreation trails
- Project Cost: $20,500/acre-feet

Visit the Study at **tiny.cc/LABasinStudy**

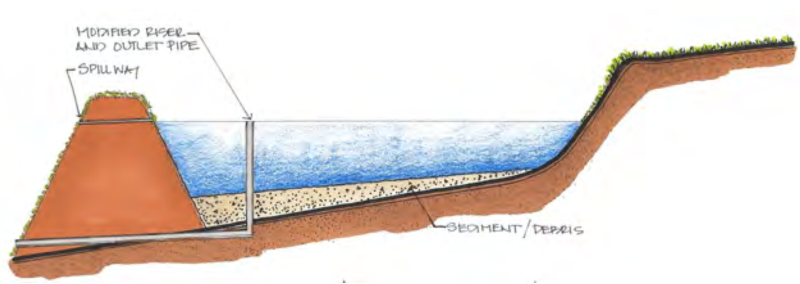
Overview

The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The Debris Basins Project Group could improve stormwater capture and storage beyond the operation of the region's major water conservation dams. Debris basins play a crucial role in Los Angeles County's flood risk management by capturing and preventing sediment, gravel, boulders, and other debris from damaging the downstream drainage system. This project group proposes to install controlled outflow works at 20 existing debris basins to store and release stormwater to downstream spreading grounds serving a dual purpose for stormwater capture.



Debris Basins

Debris basins could temporarily store and release stormwater to downstream spreading grounds and serve a dual purpose for stormwater capture in addition to flood risk management. Over 120 existing debris basins were evaluated and a total of 20 locations were selected. Modifications would include construction of a controlled outflow structure.



Stormwater Conserved for Debris Basin Projects

Watershed	No. of Basins Modified
Los Angeles River	12
San Gabriel River	8
Total	**20**

Multiple-Benefits & Partner Opportunities

Opportunities for partnering occur between flood control, groundwater management, and local government agencies. This project group also includes approximately 1 mile of recreational trails built around a portion of the modified basins. However, habitat improvements are not appropriate because no new right-of-way is included in this project group and maintenance for these facilities requires frequent sediment removal.

Implementation Challenges

No significant permitting obstructions are envisioned. The primary purpose of debris basins is to capture debris before it can impact the downstream drainage system. Therefore, regular maintenance to remove sediment and other debris is needed to maintain the flood control and debris capture function. More frequent sediment removal events than currently performed will be required to maintain storage capacity for stormwater conservation. No additional right-of-way is needed for this alternative, as the project will take place in existing debris basins.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is ensure a reliable future water supply. The Los Angeles County Flood Control District is investigating solutions to adapt to climate change and continue to further enhance its stormwater capture efforts. Resiliency to future climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it for later within deep groundwater reserves. Debris Basin solutions could enhance the resiliency of the region and help manage future climate risks. Increased infiltration and stormwater retention from these projects could both replenish local groundwater reserves to provide a more reliable water supply and help mitigate some potential flooding impacts. Sediment loading to the basins under the climate scenarios was not evaluated explicitly, but sediment loading is expected to increase under wet climate scenarios, which may limit the surface water storage capacity and climate resiliency of this project group

Findings

Modifications at the 20 debris basins could provide a storage capacity of approximately 552 acre-feet which could be infiltrated at the downstream spreading grounds. The average annual stormwater conservation benefit for the middle climate scenario could be 145 acre-feet of stormwater conservation per year (AFY).

Stormwater Conserved for Debris Basin Projects

Watershed	Middle Projected Climate Scenario (AFY)
Los Angeles River	48
San Gabriel River	97
Total	**145**

Los Angeles Basin
Stormwater Conservation Study

Local Solutions

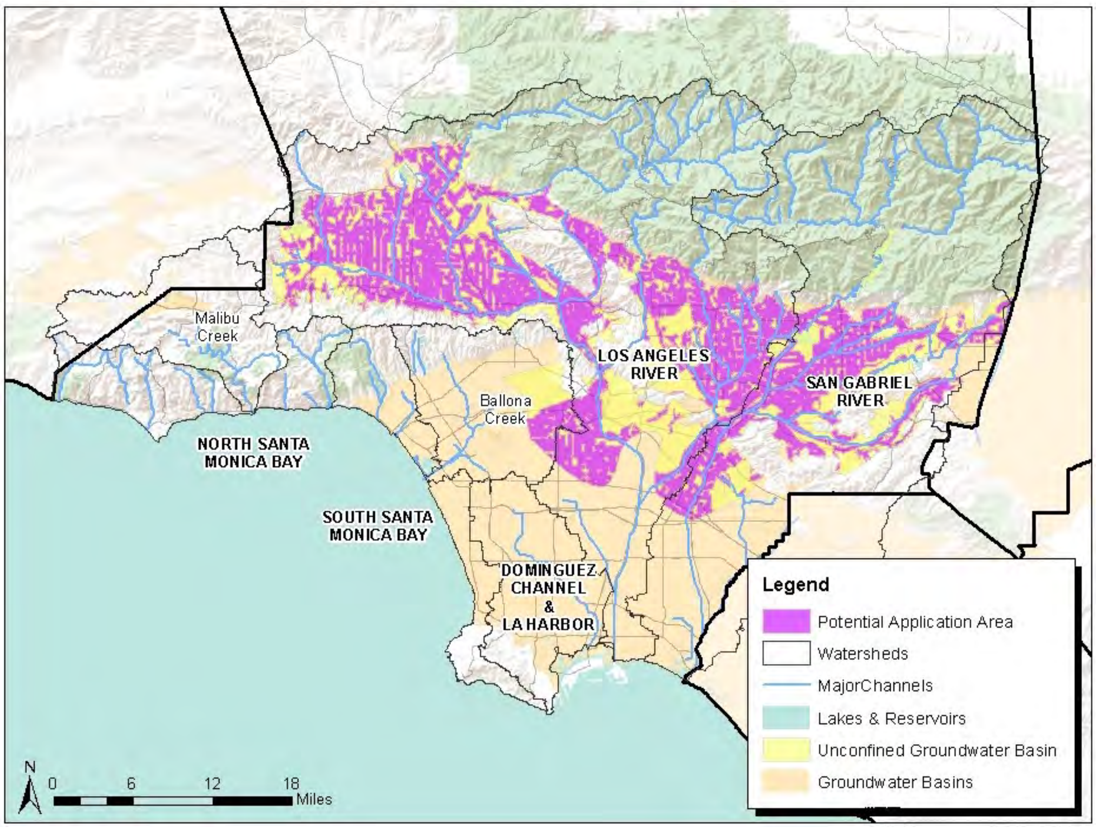
Local Stormwater Capture

KEY FEATURES

- 2,888 local stormwater capture projects
- 23,300 AFY stormwater captured
- 266 acres of habitat
- 204 miles of recreational trails
- Project Cost: $11,900/acre-feet

Overview

The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The Local Stormwater Capture Project Group improves stormwater conservation at the community level through capture and infiltration projects in favorable areas. Stormwater runoff is collected by storm drains and channels and is diverted to local stormwater facilities for infiltration and retention to help increase recharge, improve water quality, enhance the community, and facilitate habitat restoration. Favorable areas were identified based on: unconfined aquifer conditions, permeable soil types, and proximity to drains and channels. Potential project sites include government properties, parks, schools, golf courses, vacant parcels, and Caltrans right-of-way.



Local Stormwater Capture Projects

A total of 2,888 potential project locations were identified. The Los Angeles River and San Gabriel River Watersheds offer the greatest potential to implement local stormwater capture projects. These stormwater capture projects could include green infrastructure such as infiltration chambers at parks, golf courses, and other public right-of-way.


Surface Infiltration Basin


Subsurface Infiltration Basin

Visit the Study at tiny.cc/LABasinStudy

Summary of Local Stormwater Capture Projects

Watershed	Watershed Area (acres)	No. of Projects	Right-of-Way (acres)
Ballona Creek	135,090	73	53.4
Dominguez Channel	70,428	2	-
Los Angeles River	533,840	1,676	1,426.6
Malibu Creek	129,825	0	-
San Gabriel River	434,475	1,137	1,175.4
Total	**1,303,657**	**2,888**	**2,655.4**

Multiple-Benefits & Partner Opportunities

In addition to stormwater conservation, complementary benefits of local stormwater capture projects include flood risk management, water quality, recreation, habitat/connectivity, and climate resilient actions. These other benefits could help to identify project partners as projects with multiple benefits can help to leverage funding. There are opportunities for collaboration and partnering between the County of Los Angeles and other cities within the watershed area. For example, the Municipal Separate Storm Sewer System (MS4) Permit for Los Angeles provides a compliance pathway through the development of Enhanced Watershed Management Programs (EWMPs) to evaluate opportunities within the participating Permittees' collective jurisdictional area in a watershed management area for collaboration among Permittees and other partners on multi-benefit regional projects that retain stormwater.

Implementation Challenges

Local stormwater capture projects would be individually planned and designed specifically for available parcels and constructed on public parcels. The local improvements require the acquisition of approximately 2,655 acres of right-of-way. This acquisition is based on private open space parcels that could be purchased for local stormwater capture and used as small scale infiltration areas. None of the local stormwater capture opportunities have any onerous permitting requirements which would preclude their implementation.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is ensure a reliable future water supply. The Los Angeles County Flood Control District is investigating solutions to adapt to climate change and continue to further enhance its stormwater capture efforts. Resiliency to projected climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it for later within deep groundwater reserves. Local stormwater capture solutions can enhance the resiliency of the region and help manage projected climate risks. Increased infiltration and stormwater retention from these projects can both replenish local groundwater reserves to provide a more reliable water supply and help mitigate some potential flooding impacts.

Stormwater Conserved for Local Stormwater Capture

Watershed	Middle Projected Climate Scenario (AFY)
Ballona Creek	619
Dominguez Channel	3
Los Angeles River	13,988
Malibu Creek	-
San Gabriel River	8,655
Total	**23,265**

Findings

Implementation of local stormwater capture projects could provide approximately 23,300 acre-feet of stormwater conservation per year (AFY) for the middle climate scenario, 26,498 acres of mitigation, 266 acres of habitat, and approximately 204 miles of recreational trails.

Local Solutions

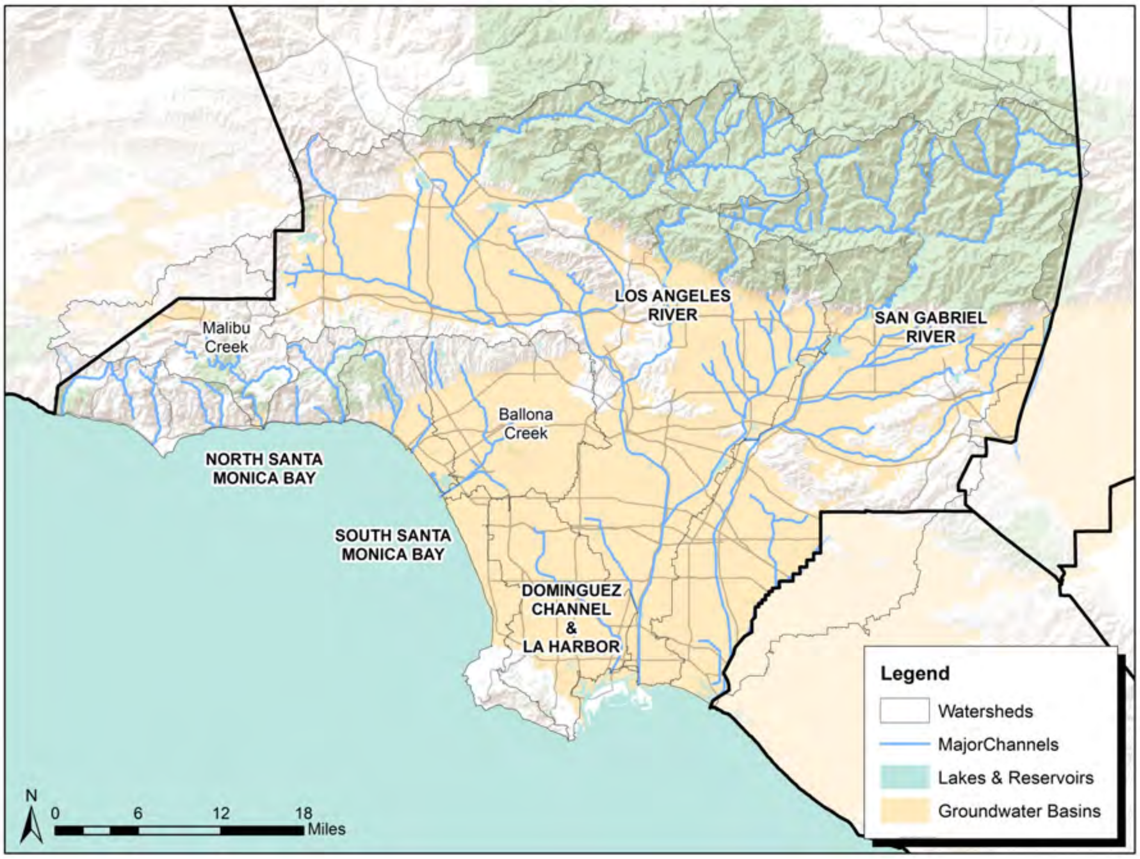
Low Impact Development

KEY FEATURES

- 115,509 acres (40%) of mitigated impervious area
- 115,200 AFY stormwater captured
- Project Cost: $7,800/acre-feet

Overview

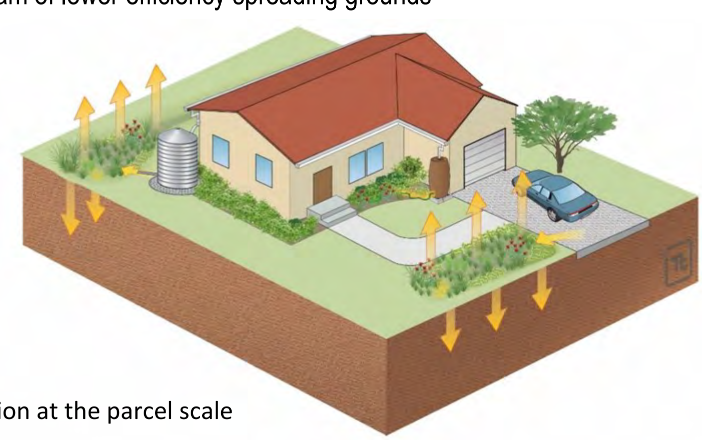
The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The Low Impact Develop Project Group provides stormwater capture through low impact development (LID) measures in residential, commercial, industrial, and institutional areas. Projects include bioretention, permeable pavement, and other infiltration and direct use Best Management Practices (BMPs). For this project group, 115,509 acres of land was modeled as implementing LID.



Low Impact Development

Implementation of LID projects help mitigate the increase of impervious surface resulting from development on both private and public parcels. The most likely LID projects to be built are listed below.

- Construct distributed BMPs upstream of lower efficiency spreading grounds
- Many small projects over the basin ("Urban acupuncture")
- Rain gardens
- Parking lot storage and connectivity
- Green roofs



LID Implementation at the parcel scale

COUNTY OF LOS ANGELES PUBLIC WORKS Public Service That Works

LOS ANGELES COUNTY FLOOD CONTROL DISTRICT 100 YEARS 1915–2015

U.S. DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

Summary of Low Impact Development Projects

Watershed	Watershed Area	Total Impervious Area Excluding Streets (acres)	Implementation Area	Implementation Ratio of
Ballona Creek	135,090	37,585	13,368	36%
Dominguez Channel	70,428	29,825	13,136	44%
Los Angeles River	533,840	119,149	48,063	40%
Malibu Creek	129,825	5,092	1,761	35%
San Gabriel River	434,475	94,778	39,181	41%
Total	**1,303,657**	**286,430**	**115,509**	**40%**

Multiple-Benefits & Partner Opportunities

In addition to stormwater conservation, complementary benefits of local stormwater capture projects include water quality, aesthetics, and heat island mitigation. Compared to local stormwater capture projects that are larger and provide multi-benefits for various stakeholders, LID projects would be implemented in vast numbers at a distributed scale. The LID projects would either be the responsibility of private homeowners, or each individual jurisdiction where the LID project is located. There may be opportunities for collaboration on the development of a residential LID program that incentivizes homeowners to install LID BMPs on residential land (e.g., rain tanks, hardscape removal, etc.).

Implementation Challenges

LID implementation is driven by ordinances in individual cities. To achieve the project level of LID implementation, a framework will have to be in place to promote widespread implementation over the next century, and significant development and redevelopment would be required. None of the low impact development opportunities have any onerous permitting requirements which would preclude their implementation.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is ensure a reliable future water supply. The Los Angeles County Flood Control District is investigating solutions to adapt to climate change and continue to further enhance its stormwater capture efforts. Resiliency to projected climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it for later within deep groundwater reserves. Low Impact Development solutions can enhance the resiliency of the region and help manage projected climate risks. Increased infiltration and stormwater retention from these projects can replenish local groundwater reserves to provide a more reliable water supply.

Findings

Implementation of LID projects could result in approximately 115,200 acre-feet of stormwater conservation per year (AFY) for the middle climate scenario, and 115,509 acres of mitigated impervious surface, representing 40 percent of the overall impervious land use.

Stormwater Conserved for Low Impact Development

Watershed	Middle Projected Climate Scenario (AFY)
Ballona Creek	9,287
Dominguez Channel	8,157
Los Angeles River	51,659
Malibu Creek	1,283
San Gabriel River	44,854
Total	**115,240**

Local Solutions

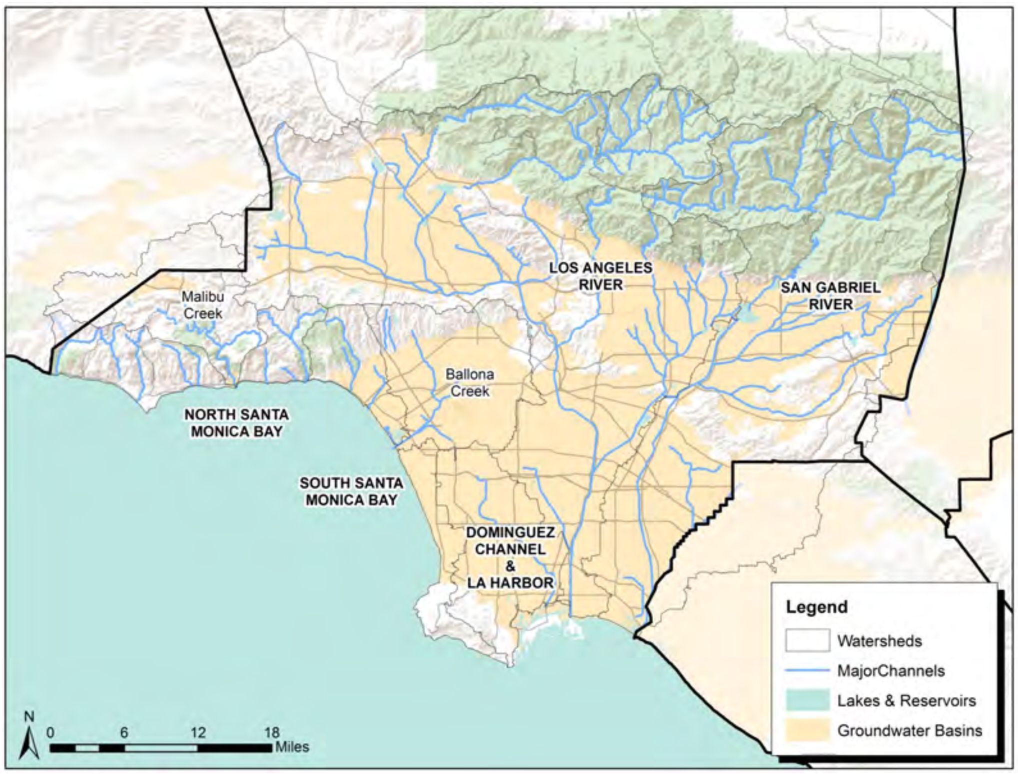
Complete Streets

KEY FEATURES

- 60,400 acres (61%) of mitigated impervious area
- 35,200 AFY stormwater captured
- Project Cost: $14,900/acre-feet

Overview

The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The Complete Streets Project Group utilizes the complete streets initiative to implement stormwater treatment and management. Complete Streets could provide a plan to ensure the safety, accessibility, and convenience of all transportation users, including pedestrians, bicyclists, transit riders, and motorists. This alternative implements stormwater capture and infiltration practices on transportation related land uses, resulting in approximately 60,400 acres of mitigation.



Complete Streets Projects

There is approximately 100,000 acres of transportation related impervious area within the Los Angeles Basin. Complete Streets could provide opportunities for stormwater treatment and management by providing on-site retention, filtration, and infiltration. These projects are typically implemented as bioretention/biofiltration Best Management Practices (BMPs) installed parallel to roadways to supplement parkway landscaping. These BMP systems receive runoff from the gutter via curb cuts. Permeable pavement could also be implemented as part of Complete Streets. Complete Streets projects could include:

- Green streets and stream tributaries stormwater capture
- Parkways and road medians stormwater capture

Complete Streets Schematic

Summary of Complete Streets Projects

Watershed	Watershed Area (acres)	Total Impervious Street Area (acres)	Implementation Area (acres)	Implementation Ratio of Impervious Area
Ballona Creek	135,090	17,942	10,945	61%
Dominguez Channel	70,428	10,258	6,309	62%
Los Angeles River	533,840	46,295	28,371	61%
Malibu Creek	129,825	986	609	62%
San Gabriel River	434,475	23,064	14,192	62%
Total	**1,303,657**	**98,546**	**60,427**	**61%**

Multiple-Benefits & Partner Opportunities

In addition to stormwater management, Complete Streets also provide pedestrian safety and traffic calming, street tree canopy and heat island effect mitigation, increased property values, and a boost in economic activity and visibility of storefront businesses. There are opportunities for the various cities, organizations, and other agencies within the study area to collaborate on a green infrastructure-related streets program. Other street programs could be considered to include other cities, universities, and non-governmental organizations.

Implementation Challenges

Municipalities within the region have adopted ordinances to incorporate green infrastructure requirements for streets projects. These types of programs and ordinances represent the initial stages of developing a comprehensive program. The Complete Streets concept does not have any onerous permitting requirements that could prevent their implementation.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is ensure a reliable future water supply. The Los Angeles County Flood Control District is investigating solutions to adapt to climate change and ways to further enhance its stormwater capture efforts. Resiliency to future climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it for later within deep groundwater reserves. Complete Streets solutions could enhance the resiliency of the region and help manage projected climate risks. Increased infiltration and stormwater retention from these projects could replenish local groundwater reserves to provide a more reliable water supply.

Findings

Implementation of Complete Streets projects could result in approximately 35,200 acre-feet of stormwater conservation per year (AFY) for the middle climate scenario, and 60,427 acres of mitigated impervious surface, representing 61 percent of the overall impervious street area.

Stormwater Conserved for Complete Streets

Watershed	Middle Projected Climate Scenario (AFY)
Ballona Creek	4,835
Dominguez Channel	2,482
Los Angeles River	18,540
Malibu Creek	273
San Gabriel River	9,100
Total	**35,230**

Management Solutions
Stormwater Policies

KEY FEATURES

- 229,414 acres (60%) of mitigated impervious area
- 193,200 AFY stormwater captured
- Project Cost: $9,600/acre-feet

PUBLIC WORKS

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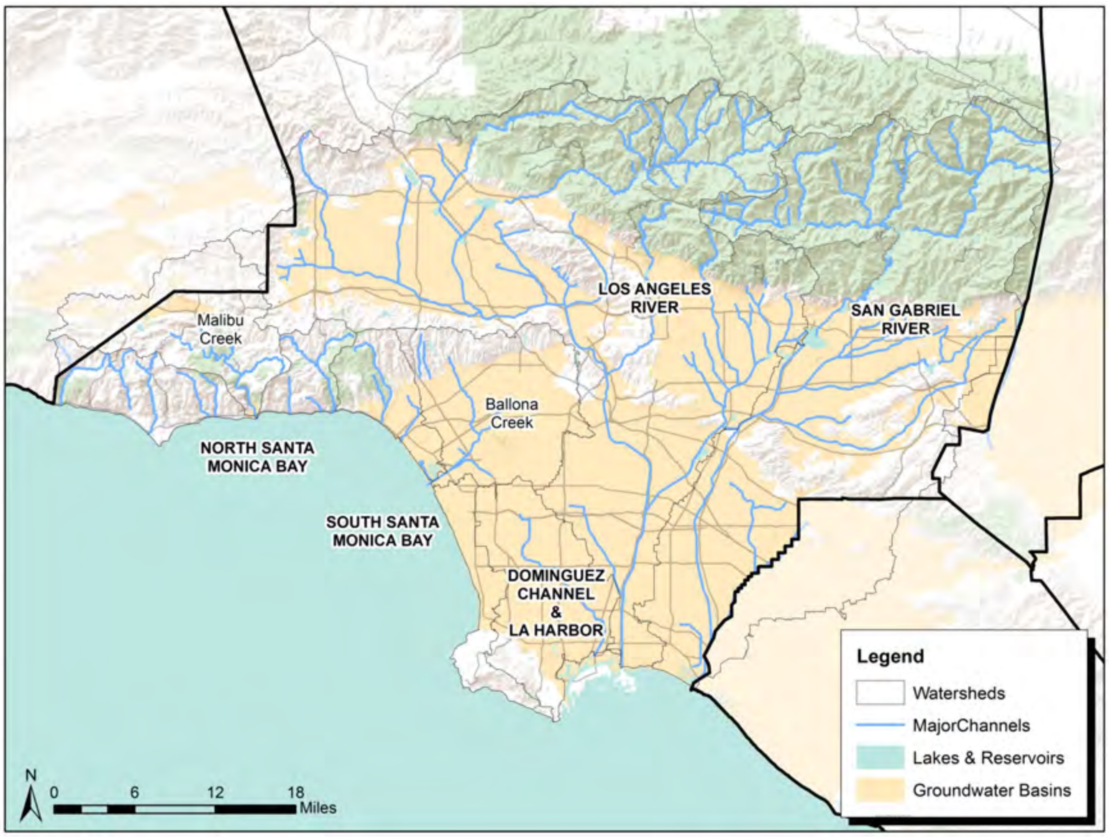
Overview

The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The Stormwater Polices Project Group encourages stormwater conservation through policy and improved regulations. Policies could include incentives or requirements for greater implementation rates and enhanced maintenance to increase performance. Stormwater Polices assume a combination of the Low Impact Development (LID) and Complete Streets local solutions, and increases the stormwater conservation through various changes in stormwater policy. This management solution is estimated to implement decentralized projects over approximately 229,414 acres of impervious area.



Stormwater Policies Projects

Several different changes to policy and regulations can be improved upon such as:

- Utilizing EWMPs for the dual-purpose of water conservation
- Align regulatory and environmental plans with water conservation/supply goals
- Use advanced rainfall-hydrology modeling to quantify pre-storm capture
- Streamline requirements for maintenance of existing infrastructure
- Remove invasive “water thirsty” plants in water conservation system
- Develop “feed in tariff” for groundwater infiltration

Management Solutions – Stormwater Policies

Summary of Stormwater Policies Projects

Watershed	Watershed Area (acres)	Total Impervious Area (acres)	Implementation Area (acres)	Implementation Ratio of Impervious Area
Ballona Creek	135,090	55,528	31,997	58%
Dominguez Channel	70,428	40,083	25,175	63%
Los Angeles River	533,840	165,444	99,519	60%
Malibu Creek	129,825	6,079	3,171	52%
San Gabriel River	434,475	117,842	69,552	59%
Total	**1,303,657**	**384,975**	**229,414**	**60%**

Multiple-Benefits & Partner Opportunities

In addition to stormwater conservation, complementary benefits of LID and Complete Streets include water quality, aesthetics, and heat island mitigation. The strategy of Enhanced Watershed Management Programs (EWMPs) has been to take a collaborative approach to comply with the Los Angeles County Municipal Separate Storm Sewer System (MS4) permit through a watershed management group. A similar collaborative approach could be taken for stormwater conservation to involve multiple stakeholders within a watershed.

Implementation Challenges

Potential implementation challenges and permitting requirements for Low Impact Development and Complete Streets local solutions would apply. LID implementation is driven by ordinances in individual cities. To achieve the project level of LID implementation, a framework will have be in place to promote widespread implementation over the next century, and significant development and redevelopment would be required. Cities within the region have adopted ordinances to incorporate green infrastructure requirements for streets projects. These types of programs and ordinances represent the initial stages of developing a comprehensive program.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is ensure a reliable future water supply. The Los Angeles County Flood Control District is investigating solutions to adapt to climate change and continue to further enhance its stormwater capture efforts. Resiliency to projected climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it for later within deep groundwater reserves. Stormwater policies that increase LID and Complete Streets implementation could enhance the resiliency of the region and help manage future climate risks. Increased infiltration and stormwater retention from these projects could replenish local groundwater reserves to provide a more reliable water supply.

Stormwater Conserved for Stormwater Policies

Watershed	Middle Projected Climate Scenario (AFY)
Ballona Creek	24,378
Dominguez Channel	17,353
Los Angeles River	86,201
Malibu Creek	2,536
San Gabriel River	62,713
Total	**193,181**

Findings

Implementation of stormwater policies could result in approximately 193,200 acre-feet of stormwater conservation per year (AFY) for the middle climate scenario, and 229,400 acres of mitigated impervious surface, representing 60 percent of the overall impervious land use.

Los Angeles Basin
Stormwater Conservation Study

Management Solutions

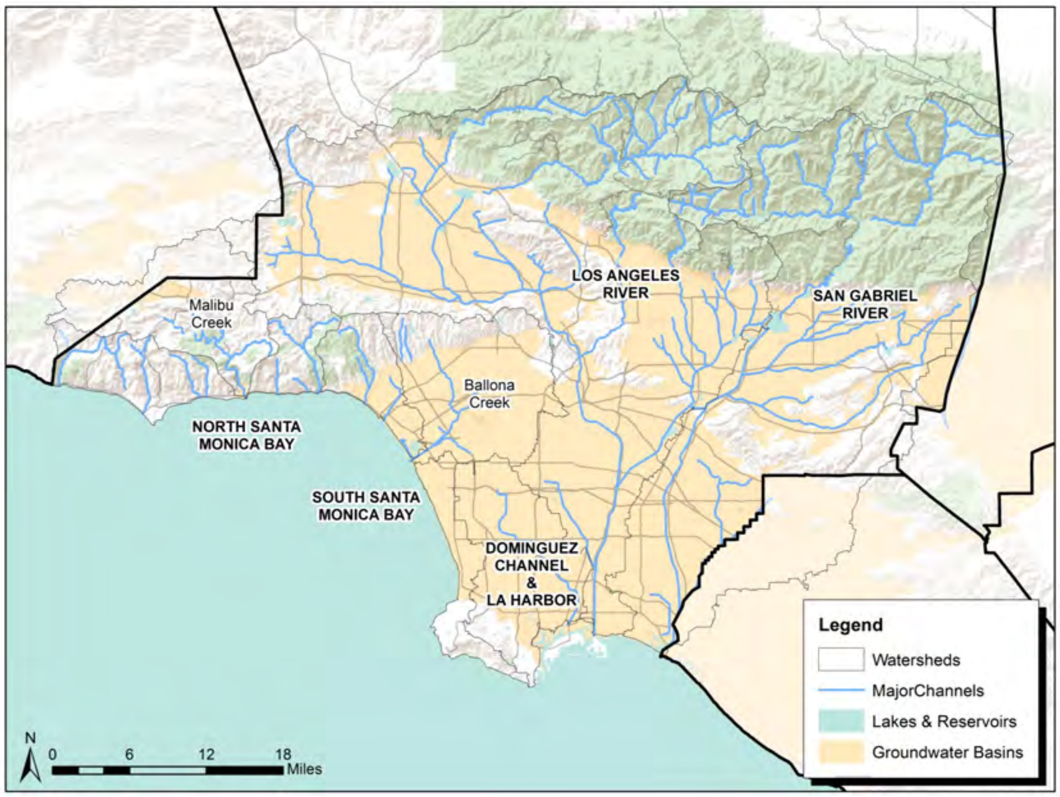
Green Infrastructure Programs

KEY FEATURES

- ► **151,194 acres (53%) of mitigated impervious area**
- ► **139,400 AFY stormwater captured**
- ► **Project Cost: $8,200/acre-feet**

Overview

The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The Green Infrastructure Programs Project Group encourages implementation of LID through green infrastructure programs. When deployed across the basin, LID projects could make significant impact on stormwater capture. Green Infrastructure Programs assume increases in stormwater conservation through green infrastructure.



Green Infrastructure Programs Projects

The MS4 Permit and local ordinances require significant development and redevelopment projects to incorporate LID concepts into their site design. Existing residential parcels could also provide an important opportunity for LID implementation. Runoff from residential parcels often flow directly to a curb and gutter or other conveyance system on the street. A well-designed residential LID program can engage individual homeowners to reduce their contribution to stormwater runoff. Potential solutions to implement additional green infrastructure could include:

- ► Low Impact Development/Best Management Practices for Stormwater
- ► Increase permeable space to balance water conservation goals
- ► Increase urban permeability
- ► Emphasize residential infiltration in high-density locations
- ► Encourage residential land changes for promoting infiltration

Many of the programs could reduce the time it takes to reach full-scale implementation, but may not increase the final value. However, programs focused on residential land uses may encourage homeowners to willingly participate in LID implementation.

Visit the Study at **tiny.cc/LABasinStudy**

Management Solutions – Green Infrastructure Programs

Summary of Green Infrastructure Programs Projects

Watershed	Watershed Area (acres)	Total Impervious Area Excluding Streets (acres)	Implementation Area (acres)	Implementation Ratio of Impervious Area
Ballona Creek	135,090	37,585	19,180	51%
Dominguez Channel	70,428	29,825	15,877	53%
Los Angeles River	533,840	119,149	63,052	53%
Malibu Creek	129,825	5,092	2,547	50%
San Gabriel River	434,475	94,778	50,537	53%
Total	**1,303,657**	**286,430**	**151,194**	**53%**

Multiple-Benefits & Partner Opportunities

In addition to stormwater conservation, complementary benefits of LID projects include water quality, aesthetics, and heat island mitigation. Compared to local stormwater capture projects that are larger and provide multi-benefits for various stakeholders, LID projects could be implemented wide-scale. The LID projects would be the responsibility of land owners, or the LID jurisdiction. There could be opportunities for collaboration on the development of a residential LID program that incentivizes homeowners to install LID BMPs on residential land (rain tanks, hardscape removal, etc.).

Implementation Challenges

LID implementation is driven by individual cities. To achieve widespread LID implementation, an LID framework would have be in place. In addition to the County requirements, owners/developers of some project sites may be subject to the Industrial General Permit and/or the Construction General Permit. None of the LID opportunities have any onerous permitting requirements which would preclude their implementation.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is ensure a reliable future water supply. The Los Angeles County Flood Control District is investigating solutions to adapt to climate change and continue to further enhance its stormwater capture efforts. Resiliency to future climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it for later within deep groundwater reserves. Green infrastructure programs could enhance the resiliency of the region and help manage projected climate risks.
Increased infiltration and stormwater retention from these projects could replenish local groundwater reserves to provide a more reliable water supply.

Findings

Implementation of green infrastructure programs could result in approximately 139,400 acre-feet of stormwater conservation per year (AFY) for the middle climate scenario, and 151,194 acres of mitigated impervious surface, representing 53 percent of the overall impervious land use.

Stormwater Conserved for Green Infrastructure Programs

Watershed	Middle Projected Climate Scenario (AFY)
Ballona Creek	13,320
Dominguez Channel	9,886
Los Angeles River	61,707
Malibu Creek	1,859
San Gabriel River	52,635
Total	**139,407**

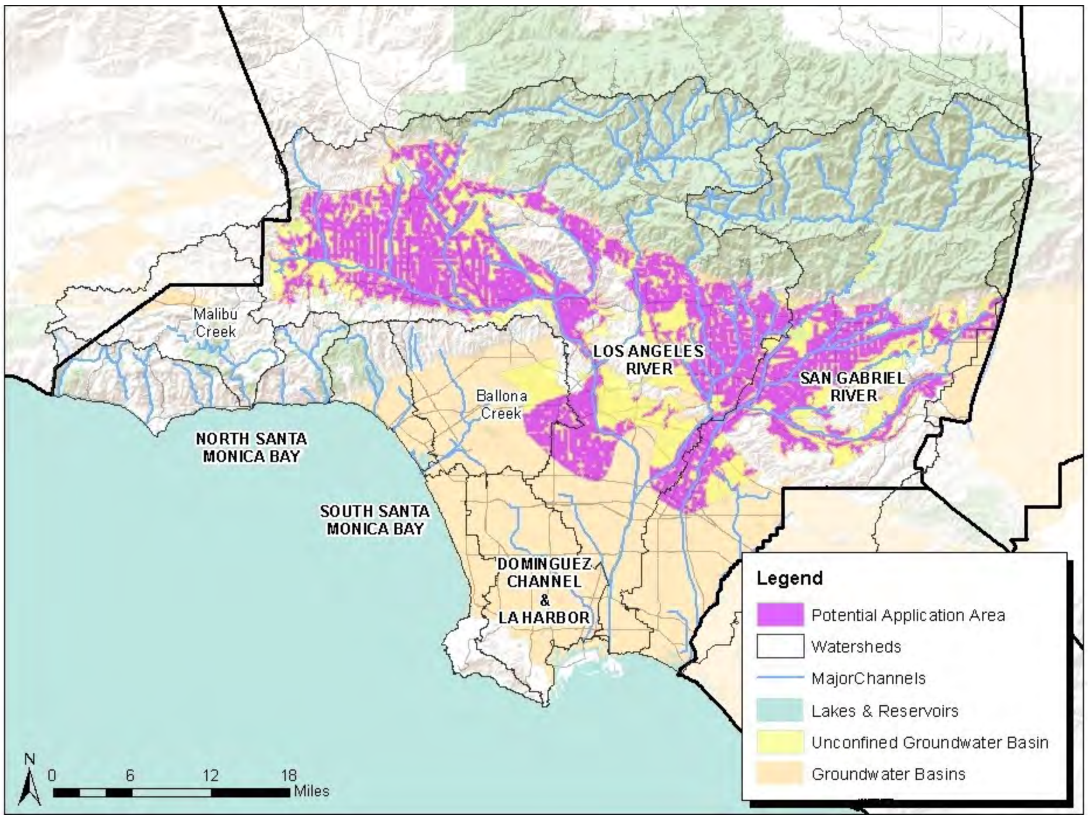
Management Solutions
Regional Impact Programs

KEY FEATURES

- 2,888 Regional Impact Programs Projects
- 29,000 AFY stormwater captured
- 266 acres of habitat
- 204 miles of recreational trails
- Project Cost: $10,300/acre-feet

Overview

The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The Regional Impact Programs Project Group encourages local stormwater capture solutions through regional programs that will have a large-scale impact. Local stormwater capture concepts are comprised of facilities that receive large volumes of stormwater runoff from upstream areas for infiltration and stormwater retention. Aside from increasing recharge, local stormwater capture projects can improve water quality, enhance the community, and facilitate habitat restoration. Management Solution 3 assumes a model baseline of implementing local stormwater capture solutions, and increases the stormwater conservation through regional impact programs.



Regional Impact Programs Projects

Regional Impact Programs could include the following strategies:

- Promote and value open space for its stormwater benefits
- Utilize government parcels first for stormwater capture, storage, and infiltration
- Investigate recharge along river embankments
- County-wide parcel fee with mitigation rebate
- School stormwater improvements
- Programs to implement stormwater projects at public parks and schools
- Depress all sports fields for stormwater capture

Regional impact programs would encourage local stormwater capture across the watershed. Most of the programs may reduce the time it takes to reach full-scale implementation, but may not increase the total conservation. However, for open space areas, the percentage of the parcel used for infiltration was increased to account for regional impact programs.

Visit the Study at **tiny.cc/LABasinStudy**

Management Solutions – Regional Impact Programs

Summary of Regional Impact Programs Projects

Watershed	Watershed Area (acres)	No. of Projects	Right-of-Way (acres)
Ballona Creek	135,090	73	53.4
Dominguez Channel	70,428	2	0.0
Los Angeles River	533,840	1,676	1,426.6
Malibu Creek	129,825	0	0.0
San Gabriel River	434,475	1,137	1,175.4
Total	**1,303,657**	**2,888**	**2,655.4**

Multiple-Benefits & Partner Opportunities

In addition to stormwater conservation, complementary benefits of local stormwater capture projects include flood risk management, water quality, recreation, habitat/connectivity, and climate resilient actions. These other benefits could help to identify project partners as projects with multiple benefits can help to leverage funding. There are opportunities for collaboration and partnering between the County of Los Angeles and other cities within the watershed area. For example, the Municipal Separate Storm Sewer System (MS4) Permit for Los Angeles provides a compliance pathway through the development of Enhanced Watershed Management Programs (EWMP) to evaluate opportunities within the participating Permittees' collective jurisdictional area for collaboration among Permittees and other partners on multi-

Implementation Challenges

The local improvements could require the purchase of approximately 2,655 acres of right-of-way. This acquisition is based on private open space parcels that could be purchased for local stormwater capture and used as small scale infiltration areas. Local stormwater capture projects would likely be individually planned and designed specifically for available parcels and constructed on public parcels. None of the local storwmwater capture opportunities or regional impact programs have any onerous permitting requirements which would preclude their implementation.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is ensure a reliable future water supply. The Los Angeles County Flood Control District is investigating solutions to adapt to climate change and continue to further enhance its stormwater capture efforts. Resiliency to projected climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it for later within deep groundwater reserves. Local stormwater capture projects and regional impact programs can enhance the resiliency of the region and help manage future climate risks. Increased infiltration and stormwater retention from these projects can both replenish local groundwater reserves to provide a more reliable water supply and help mitigate some potential flooding impacts.

Stormwater Conserved for Regional Impact Programs

Watershed	Middle Projected Climate Scenario (AFY)
Ballona Creek	776
Dominguez Channel	3
Los Angeles River	17,221
Malibu Creek	-
San Gabriel River	10,983
Total	**28,984**

Findings

Regional impact programs could result in approximately 29,900 acre-feet of stormwater conservation per year (AFY) for the middle climate scenario, 33,327 acres of mitigation, 266 acres of habitat, and 204 miles of recreational trails.

Regional Stormwater Capture

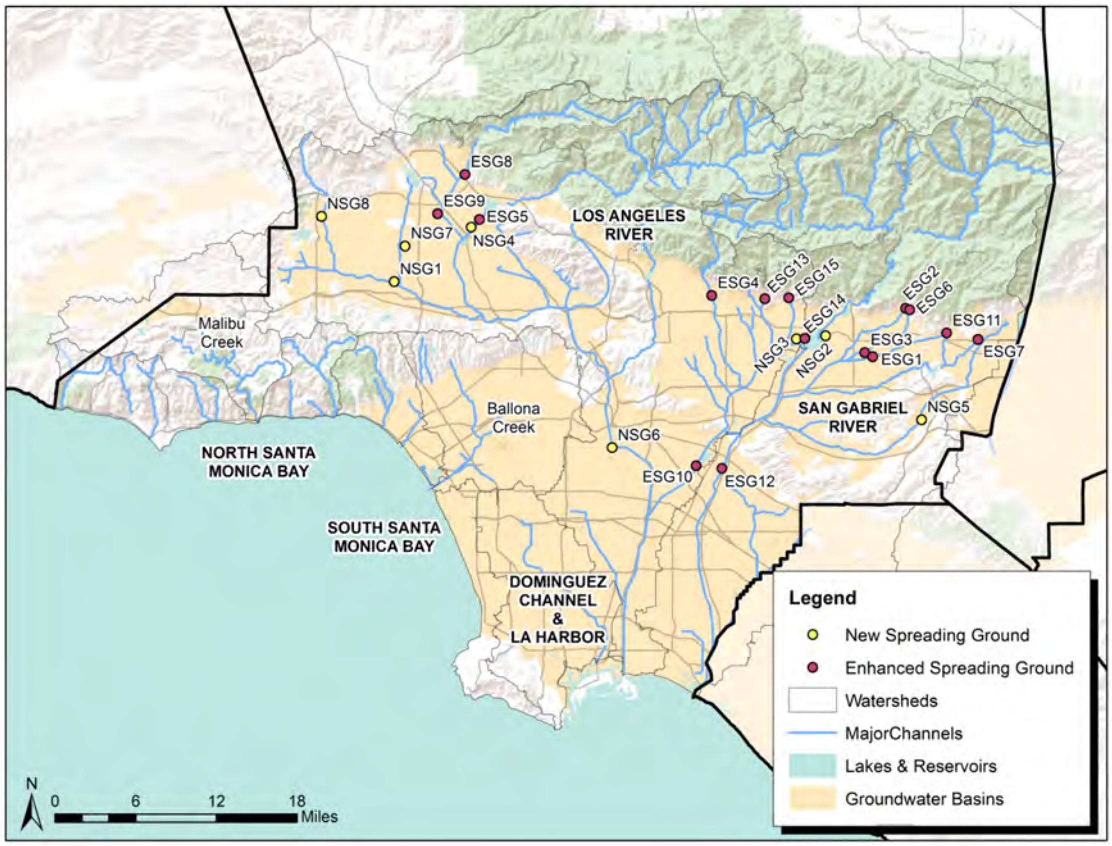
KEY FEATURES

- Eight new spreading grounds with 10 percent dedicated habitat and trails
- 15 enhanced spreading grounds using soil management practices
- Average 43,300 AFY stormwater captured
- 42 acres of new habitat
- Over 12 miles of recreational trails
- Project Cost: $1,300/acre-feet

Visit the Study at **tiny.cc/LABasinStudy**

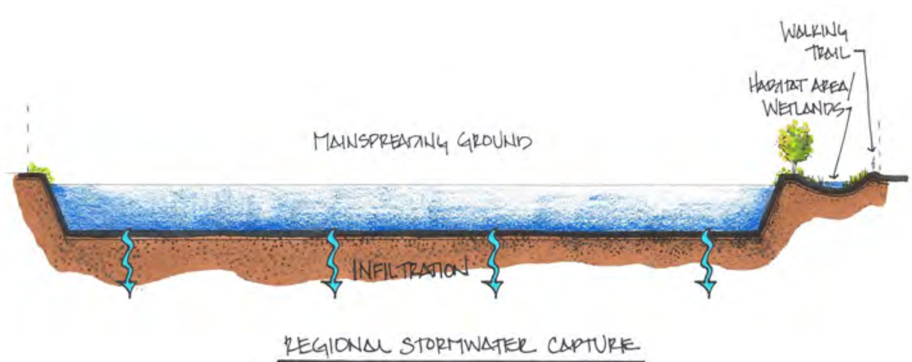
Overview

The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The Regional Stormwater Capture Project Group could improve groundwater recharge through construction of 8 new spreading grounds and enhanced maintenance at 15 existing spreading grounds. Aside from increasing stormwater recharge, spreading grounds also offer recreational opportunities and potential wildlife habitat improvements.



Regional Stormwater Capture Projects

Potential locations for new spreading basins were identified based on previous reports and a search of vacant properties near main channel features in recharge areas. Existing gravel pits in favorable areas were assumed to be repurposed as spreading basins where appropriate. Task 4 of the study ranked the existing spreading grounds based on performance levels. Of the 25 Existing spreading grounds analyzed in Task 4, 16 were identified as candidates for increasing maintenance to enhance recharge capacity.



Multiple-Benefits & Partner Opportunities

Given the regional benefits of these stormwater capture projects, there could be potential opportunities for collaboration and partnering among the County of Los Angeles, groundwater water management agencies, and water purveyors, as well as Los Angeles County Sanitation District for recycled water projects. In addition, other parties with interests related to the multi-benefit components of the project could be other potential project partners. 10-percent of new basins were assumed dedicated to habitat.

Implementation Challenges

Significant land acquisition would be required to construct the eight new recharge basins. Construction of the new basins would require acquisition of 682 acres of right-of-way.

Additional permitting requirements would be required for new basins located downstream of waste water treatment plant outfalls. Flow in the Los Angeles River below Sepulveda Dam contains tertiary treated effluent, and basins located downstream of Sepulveda Dam would need to comply with the latest Regulations for Groundwater Replenishment Using Recycled Water.

None of the other basins are expected to have permitting requirements that would preclude their implementation.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is ensure a reliable future water supply. The Los Angeles County Flood Control District is investigating solutions to adapt to climate change and continue to further enhance its stormwater capture efforts. Resiliency to future climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it for later within deep groundwater reserves. Regional stormwater capture solutions could enhance the resiliency of the region and help manage future climate risks. Increased infiltration and stormwater retention from these projects could both replenish local groundwater reserves to provide a more reliable water supply and help mitigate some potential flooding impacts. The Regional Stormwater Capture Projects are intended to capture and infiltrate stormwater which will help promote groundwater recharge and provide resiliency when more water is available .

New and Enhanced Basins

ID	Location
New Basins	
NSG1	Miller Pit
NSG2	New Tujunga Spreading Grounds
NSG3	Rock Pit No. 3
NSG4	Sepulveda Dam
NSG5	Spadra Basin
NSG6	LA Forbay Spreading Ground
NSG7	Bull Creak Area Spreading Grounds
NSG8	Browns Creak Area Spreading Grounds
Enhanced Basins	
ESG1	Ben Lomond
ESG2	Big Dalton
ESG3	Citrus
ESG4	Eaton Wash
ESG5	Hansen/Tujunga
ESG6	Little Dalton
ESG7	Live Oak
ESG8	Lopez
ESG9	Pacoima
ESG10	Rio Hondo
ESG11	San Dimas
ESG12	San Gabriel Coastal
ESG13	Santa Anita
ESG14	Santa Fe
ESG15	Sawpit

Findings

Implementation of Regional Stormwater Capture projects could provide approximately 43,300 acre-feet of stormwater conservation per year (AFY) based on average for the results from the middle climate scenario, 42 acres of wetland habitat, and over 12 miles of recreational trails.

Stormwater Conserved for Regional Stormwater Capture

Recharge Basin	Middle Projected Climate Scenario (AFY)
Existing and Enhanced Basins	13,381
Expanded and New Basins	29,930
Net Change	**43,311**

Regional Solutions

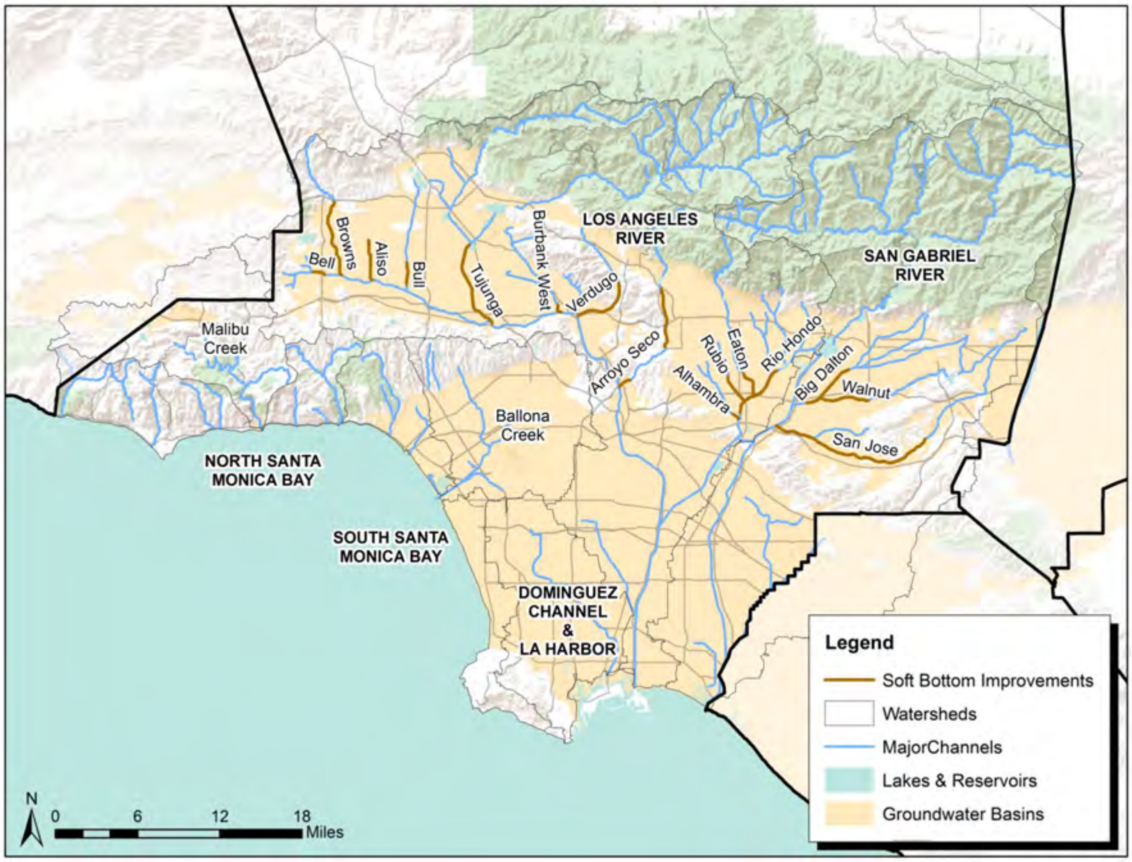
Stormwater Conveyance Systems

KEY FEATURES

- Over 57 miles of soft bottom or side pond improvements along 15 different channels
- Average 9,200 AFY stormwater captured
- Over 3 miles of recreational trails
- Over 8 acres of habitat
- Project Cost: $46,300/acre-feet

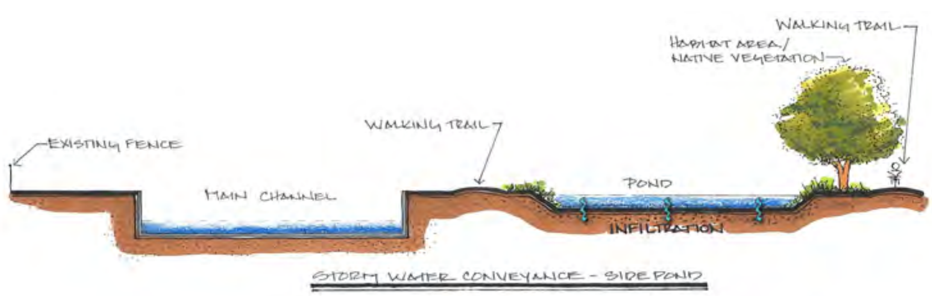
Overview

The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The Stormwater Conveyance Systems Project Group could improve stormwater conservation through soft bottom channel modifications. There are many concrete lined channels in Los Angeles County, and converting some to soft bottom could improve groundwater recharge, improve water quality, and provide opportunities for recreational trails, parkways, and riparian habitat corridors. However, the region's need for increased stormwater capture must still balance the dual goal of flood risk management.



Stormwater Conveyance Systems Projects

The proposed projects targeted for soft bottom conversion focus on tributary reaches with larger channels that have favorable soil conditions for recharging stormwater. Two approaches were evaluated to enhance short term stormwater detention within existing or converted soft bottom channels areas. "River speed bumps", small in-channel earthen detention structures, were assumed for all modified channel reaches. Channel side ponds were considered where easements or land appears available for their installation.



Regional Solutions – Stormwater Conveyance Systems

Multiple-Benefits & Partner Opportunities

Potential opportunities for collaboration and partnering could be with the County of Los Angeles, groundwater water management agencies, and water purveyors, as well as Los Angeles County Snatiation District for recycled water projects. In addition, other parties with interests related to the multi-benefit components of the project (local city departments for example) are other potential project partners. Multiple-benefit opportunities including habitat and recreational improvements could be incorporated into these projects.

Implementation Challenges

The region's need for increased stormwater capture must still balance the dual goal of flood risk management. The channel modifications would need to preserve existing flood protection and flow capacity. Significant permitting challenges are associated with the proposed channel modifications. Detailed hydrology and hydraulics studies would need to be performed to confirm the modified channels provide adequate flood mitigation, and coordination among local governments, the Army Corps of Engineers, and the Los Angeles County Flood Control District (LACFCD) would be required.

Additionally, most of the land adjacent to the existing tributary channels is developed and there is limited opportunity for right-of-way acquisition for more extensive pond networks or habitat improvements. 31 acres of right-of-way acquisition would be required to accommodate the channel side ponds.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is to ensure a reliable future water supply. The LACFCD is investigating solutions to adapt to climate change and continue to further enhance its stormwater capture efforts. Resiliency to future climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it for later within deep groundwater reserves. Stormwater conveyance system solutions could enhance the resiliency of the region and help manage future climate risks. Increased infiltration and stormwater retention from these projects could both replenish local groundwater reserves to provide a more reliable water supply and help mitigate some potential flooding impacts. The channel modifications will promote groundwater recharge and provide resiliency when more water is available.

Stormwater Conveyance System Channel Modifications

Channel	Total Modified Length (ft)
Alhambra Wash	2,707
Aliso Creek	15,448
Arroyo Seco Channel	28,764
Bell Creek	4,590
Big Dalton Wash	16,162
Browns Creek	30,032
Bull Creek	8,034
Burbank Western System	3,132
Eaton Wash	10,882
Rio Hondo	22,321
Rubio Wash	11,638
San Jose Creek	64,072
Tujunga Wash	34,988
Verdugo Wash	22,664
Walnut Creek Channel	24,415
Total	**299,849**

Findings

Implementation of Stormwater Conveyance Systems projects could provide approximately 9,200 acre-feet of stormwater conservation per year (AFY) for the middle climate scenario, 8 acres of habitat improvements, and over 3 miles of recreational trail.

Stormwater Conserved for Stormwater Conveyance Systems

Channel	Middle Projected Climate Scenario (AFY)
Alhambra Wash	73
Aliso Creek	401
Arroyo Seco Channel	932
Bell Creek	118
Big Dalton Wash	487
Browns Creek	601
Bull Creek	257
Burbank Western System	81
Eaton Wash	220
Rio Hondo	740
Rubio Wash	291
San Jose Creek	2,389
Tujunga Wash	1,076
Verdugo Wash	947
Walnut Creek Channel	575
Total	**9,188**

Los Angeles Basin
Stormwater Conservation Study

Regional Solutions
Alternative Capture

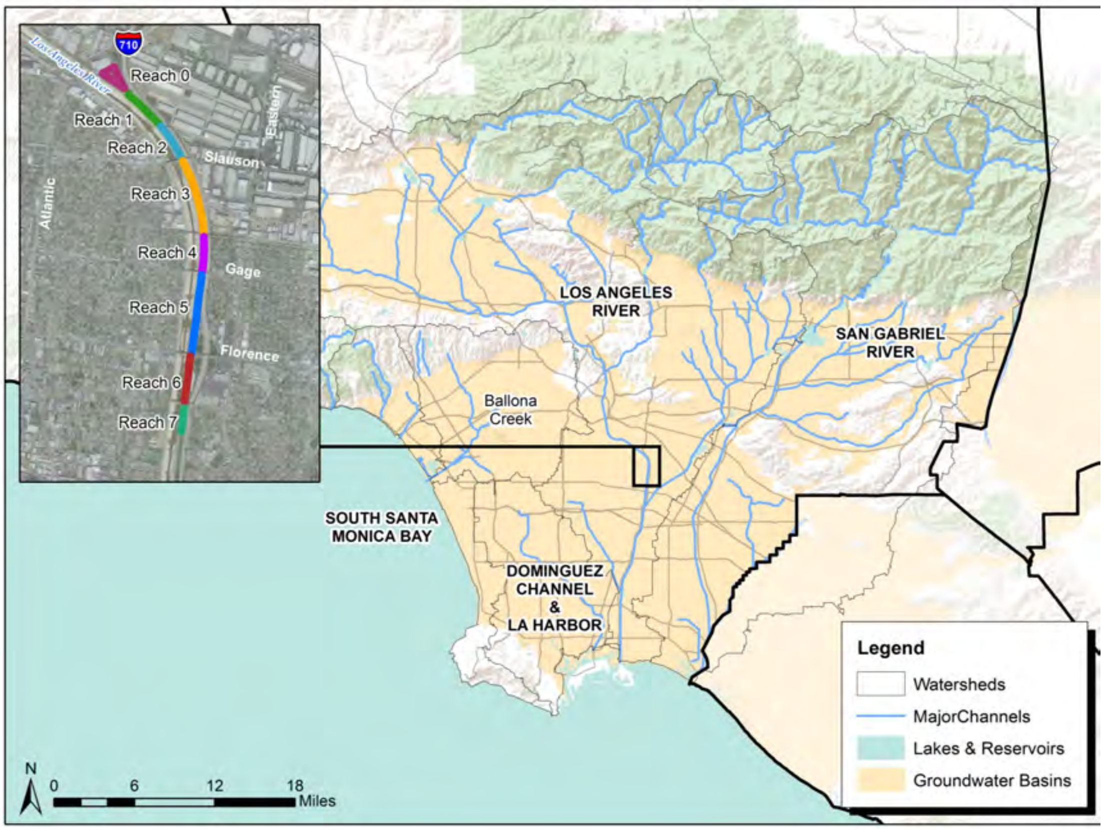
KEY FEATURES

- Eight stretches of shallow aquifer recharge ponds to provide soil aquifer treatment
- 24 extraction and 48 injection wells to pump treated water into aquifer
- Approximately 20 acres of total infiltration area
- 5,600 AFY of stormwater captured
- Over 2 miles of recreational trails
- 2 acres of Habitat
- Project Cost: $1,700/acre-feet

Visit the Study at tiny.cc/LABasinStudy

Overview

The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The Alternative Capture Project Group could improve stormwater capture through seven new recharge ponds along the Los Angeles River. Currently, there are no groundwater recharge facilities in the Los Angeles Forebay region of Central Basin due to limited land availability.



Alternative Capture Project

The Water Replenishment District (WRD) Groundwater Basin Master Plan estimates up to 5,000 AFY of stormwater could be captured in the Los Angeles forebay region of Central Basin through an Aquifer Recharge and Recovery Facility. This type of facility could provide stormwater capture as well as soil aquifer treatment and injection/recovery opportunities. Alternative Capture consists of a series of eight shallow aquifer recharge basins which would be located within the existing power line easement along the Los Angeles River. The aquifer recharge basins could perform soil aquifer treatment which is a natural filtration process to remove nitrates, pathogens, and micro-pollutants. Extraction wells along the perimeter of the basins could extract the treated groundwater and inject into a production aquifer. Infrastructure required for the concept includes 24 extraction wells, 48 injection wells, and intake structures. For the project group, 2 miles of trails could be created for recreational use. Additional features could be incorporated including trees, bike paths, and pocket parks.

Regional Solutions – Alternative Capture

Summary of Alternative Capture Projects

Reach No.	Infiltration Area (acres)	No. of Extraction Wells	No. of Injection Wells	Reach Length (ft)	Right-of-Way (acres)	Habitat (acres)	Recreation Trails (ft)
0	3.8	4	8	1,300	6.3	0.4	1,300
1	1.5	2	4	1,255	2.5	0.2	1,255
2	2.4	2	4	1,230	4.0	0.2	1,230
3	5.1	6	12	2,530	8.5	0.5	2,530
4	2.7	4	8	1,170	4.5	0.3	1,170
5	2.5	2	4	2,600	4.2	0.3	2,600
6	1.4	2	4	1,355	2.3	0.1	1,355
7	0.7	2	4	1,355	1.2	0.1	1,355
Total	**20.1**	**24**	**48**	**12,795**	**33.5**	**2.0**	**12,795**

Multiple-Benefits & Partner Opportunities

Given the regional benefits of this proposed capture project, there could be potential opportunities for collaboration and partnering among the County of Los Angeles, groundwater water management agencies, and water purveyors, as well as the Los Angeles County Sanitation District for recycled water projects. In addition, other parties with interests related to the multi-benefit components of the project, such as local and city departments, could be other potential project partners.

Implementation Challenges

Additional permitting would be required for the project. Flow at the project site would contain tertiary treated effluent from the Tillman Water Reclamation Plant, so the project would need to comply with the latest Regulations for Groundwater Replenishment Using Recycled Water, including associated design studies and reporting and monitoring requirements. Approximately 34 acres of right-of-way would be required to construct the project.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is ensure a reliable future water supply. The Los Angeles County Flood Control District is investigating solutions to adapt to climate change and continue to further enhance its stormwater capture efforts. Resiliency to future climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it within deep groundwater reserves for later use. Alternative capture solutions could enhance the resiliency of the region and help manage future climate risks. Increased infiltration and stormwater retention from these projects could both replenish local groundwater reserves to provide a more reliable water supply .

Findings

Implementation of the Alternative Capture project group could provide approximately 5,600 acre-feet of stormwater conservation per year (AFY) for the middle climate scenario and create more than 2 miles of recreational trail. Additional habitat and recreational features, including parks, trees, and wildlife areas, could be considered.

Stormwater Conserved for Alternative Capture

Channel	Middle Projected Climate Scenario (AFY)
Los Angeles River	5,587

Los Angeles Basin
Stormwater Conservation Study

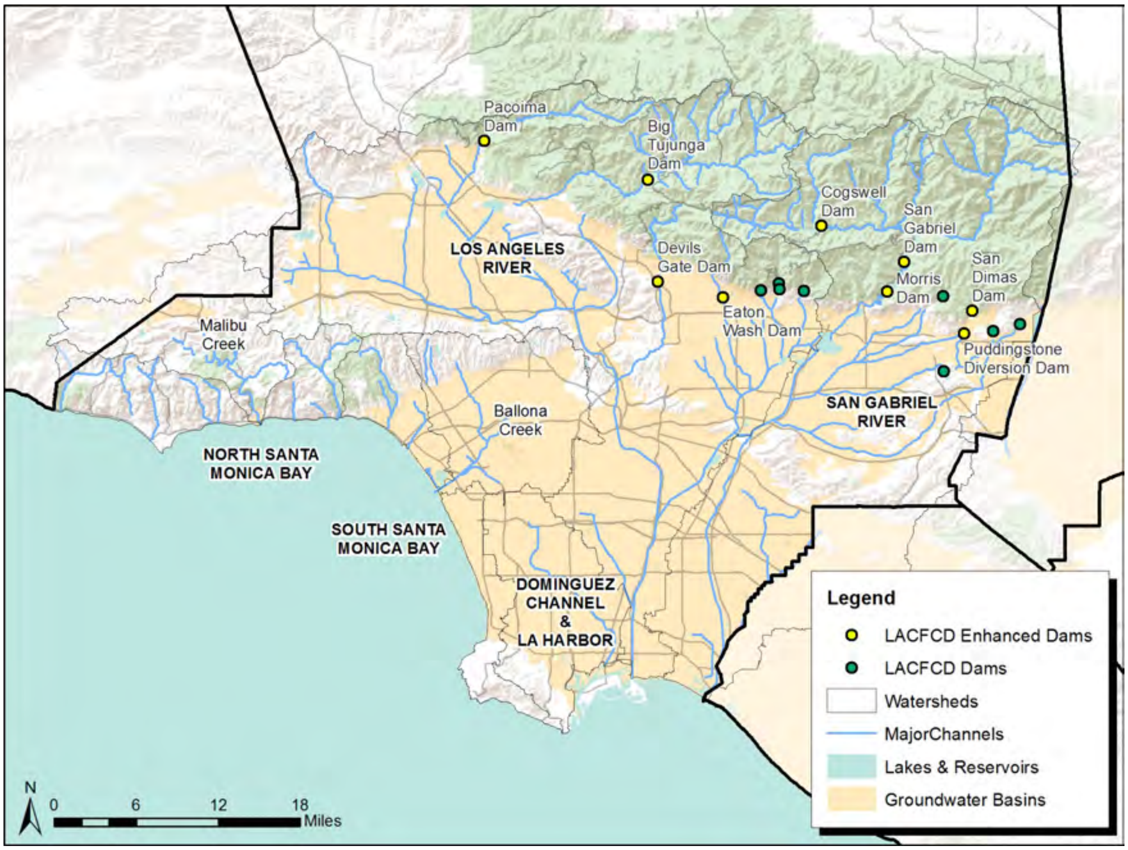
Storage Solutions
LACFCD Dams

KEY FEATURES

- 14 existing Los Angeles County Flood Control District (LACFCD) owned dams evaluated
- 9 Los Angeles County owned dams modified for increased storage
- Average increase of 150,000 AFY of stormwater capture
- Project Cost: $183/acre-foot

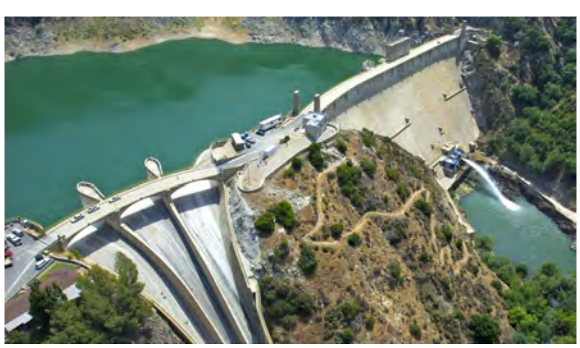
Overview

The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The LACFCD Dams Project Group improves stormwater capture and storage at 9 of the region's 14 water conservation dams. The LACFCD Dams make a major contribution to the local water supply of the Los Angeles Basin by capturing and storing stormwater flows from the mountains above the Basin and releasing it later to downstream spreading grounds. The dams also play a crucial role in Los Angeles County's flood risk management by slowing flows in the downstream drainage system. This project group proposes to install additional operational controls at 9 of the existing Dams to increase capacity to temporarily capture and store stormwater.



LACFCD Dams

LACFCD Dams serve a dual purpose of stormwater capture and flood risk management by temporarily capturing and storing stormwater. Fourteen existing LACFCD dams were evaluated and 9 were selected for modifications which would include construction of additional operable controls at the outflow structures.



COUNTY OF LOS ANGELES
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LOS ANGELES COUNTY FLOOD CONTROL DISTRICT
100 YEARS 1915–2015

U.S. DEPARTMENT OF THE INTERIOR
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Multiple-Benefits & Partner Opportunities

By increasing the capture and storage of stormwater, this project group offers opportunities for increased flood risk management and may also increase the existing water quality benefit of the dams. This project group also provides opportunities for partnering between flood control, groundwater management, and local government agencies.

Implementation Challenges

Implementation of this project group would involve significant permitting considerations. Detailed investigations of changes to the flood risk management and water conservation functions of the dams will need to be performed. Potential impacts on the seismic and structural stability of the dams will also need to be investigated, as well as potential environmental impacts.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is ensure a reliable future water supply. The Los Angeles County Flood Control District is investigating solutions to adapt to climate change and continue to further enhance its stormwater capture efforts. Resiliency to future climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it for later within groundwater reserves. Local stormwater capture solutions can enhance the resiliency of the region and help manage future climate risks. Increased infiltration and stormwater retention from these projects can both replenish local groundwater reserves to provide a more reliable water supply and help mitigate some potential flooding impacts. Sediment loading to the reservoirs behind the dams under the climate scenarios was not evaluated explicitly, but is expected to increase under wet climate scenarios. Periodic sediment removal from the reservoirs will be necessary to maintain the stormwater storage capacity and climate resiliency of this project group

Findings

Construction of additional operable controls at the outflow structures of the 9 dams could increase their capacity to temporarily capture and store stormwater for release later to downstream spreading grounds where it could infiltrate into groundwater reserves. The average annual stormwater conservation benefit for the middle climate scenario is approximately 150,000 acre-feet of stormwater conservation per year (AFY).

Stormwater Conserved for Debris Basin Projects

LACFCD Dam	Median Future Climate Scenario (AFY)
Big Tujunga	11,786
Cogswell	11,762
Devil's Gate	9,747
Eaton Wash	1,277
Morris	71,853
Pacoima	1,259
Puddingstone Diversion	888
San Dimas	2,041
San Gabriel	39,404
Total	**150,015**

Los Angeles Basin
Stormwater Conservation Study

Storage Solutions
Debris Basins

KEY FEATURES

- 121 existing debris basins evaluated
- 20 debris basins modified for storage
- Total 552 ac-ft storage capacity
- Average of 145 AFY of stormwater capture
- Sediment loading may limit climate resiliency
- 1 mile of recreation trails
- Project Cost: $20,500/acre-feet

COUNTY OF LOS ANGELES PUBLIC WORKS Public Service That Works

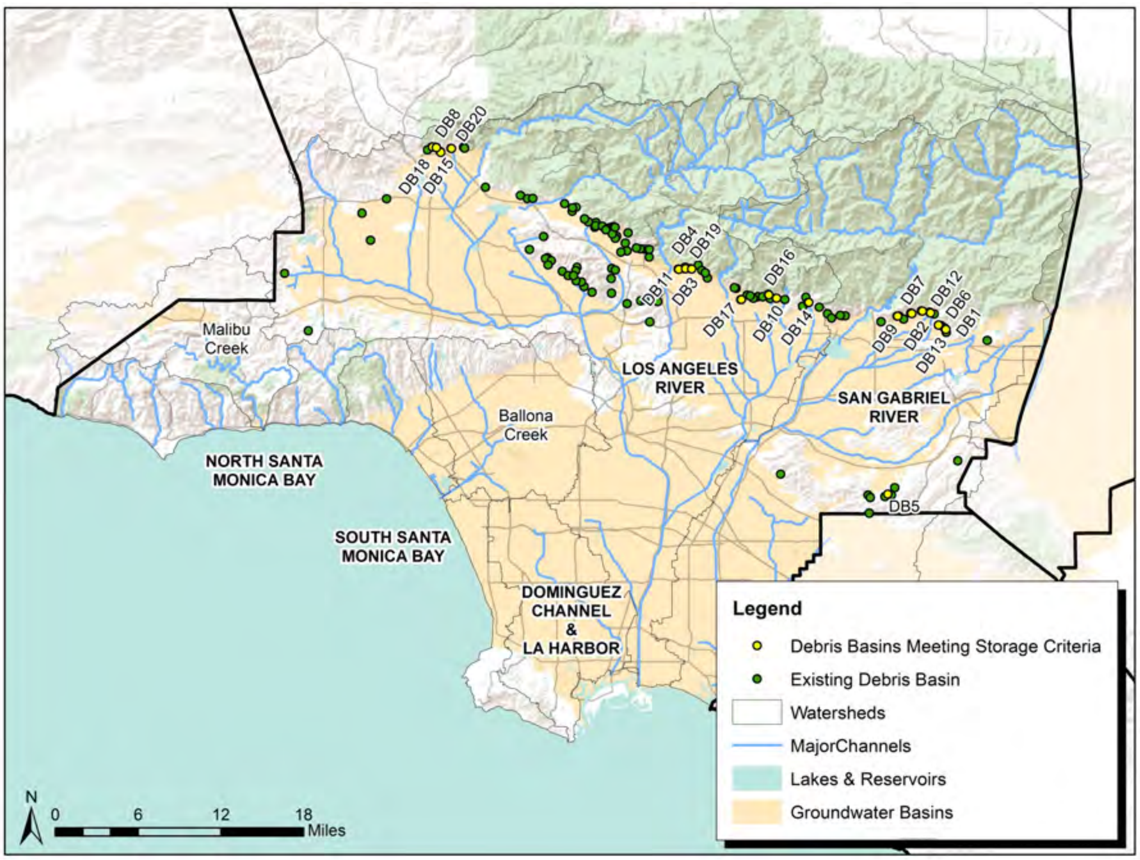
LOS ANGELES COUNTY FLOOD CONTROL DISTRICT 100 YEARS 1915–2015

U.S. DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

Visit the Study at **tiny.cc/LABasinStudy**

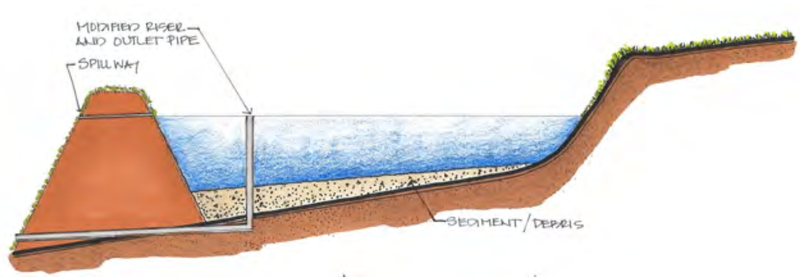
Overview

The LA Basin Study provides recommendations for potential modifications and changes in the operation of the existing stormwater capture systems, and for the development of new facilities which could help to resolve projected water supply and flood control issues. The Debris Basins Project Group could improve stormwater capture and storage beyond the operation of the region's major water conservation dams. Debris basins play a crucial role in Los Angeles County's flood risk management by capturing and preventing sediment, gravel, boulders, and other debris from damaging the downstream drainage system. This project group proposes to install controlled outflow works at 20 existing debris basins to store and release stormwater to downstream spreading grounds serving a dual purpose for stormwater capture.



Debris Basins

Debris basins could temporarily store and release stormwater to downstream spreading grounds and serve a dual purpose for stormwater capture in addition to flood risk management. Over 120 existing debris basins were evaluated and a total of 20 locations were selected. Modifications would include construction of a controlled outflow structure.



Stormwater Conserved for Debris Basin Projects

Watershed	No. of Basins Modified
Los Angeles River	12
San Gabriel River	8
Total	**20**

Multiple-Benefits & Partner Opportunities

Opportunities for partnering occur between flood control, groundwater management, and local government agencies. This project group also includes approximately 1 mile of recreational trails built around a portion of the modified basins. However, habitat improvements are not appropriate because no new right-of-way is included in this project group and maintenance for these facilities requires frequent sediment removal.

Implementation Challenges

No significant permitting obstructions are envisioned. The primary purpose of debris basins is to capture debris before it can impact the downstream drainage system. Therefore, regular maintenance to remove sediment and other debris is needed to maintain the flood control and debris capture function. More frequent sediment removal events than currently performed will be required to maintain storage capacity for stormwater conservation. No additional right-of-way is needed for this alternative, as the project will take place in existing debris basins.

Resiliency to Climate Change

The region is preparing for climate change in numerous ways, one of which is ensure a reliable future water supply. The Los Angeles County Flood Control District is investigating solutions to adapt to climate change and continue to further enhance its stormwater capture efforts. Resiliency to future climate change means safeguarding the existing stormwater conservation system and improving upon it to make the most of stormwater when it is available, as well as storing it for later within deep groundwater reserves. Debris Basin solutions could enhance the resiliency of the region and help manage future climate risks. Increased infiltration and stormwater retention from these projects could both replenish local groundwater reserves to provide a more reliable water supply and help mitigate some potential flooding impacts. Sediment loading to the basins under the climate scenarios was not evaluated explicitly, but sediment loading is expected to increase under wet climate scenarios, which may limit the surface water storage capacity and climate resiliency of this project group

Findings

Modifications at the 20 debris basins could provide a storage capacity of approximately 552 acre-feet which could be infiltrated at the downstream spreading grounds. The average annual stormwater conservation benefit for the middle climate scenario could be 145 acre-feet of stormwater conservation per year (AFY).

Stormwater Conserved for Debris Basin Projects

Watershed	Middle Projected Climate Scenario (AFY)
Los Angeles River	48
San Gabriel River	97
Total	**145**

Appendix C: Modeling Approach and Assumptions

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Appendix C: Modeling Approach and Assumptions

Page

Figures

Tables

Page

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 Solution – Stormwater Capture

2.1.1. Project Description and Modeling Assumptions

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.

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 85^{th} 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 85th 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 85th 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 fist 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 molded 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 low 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 multifamily residential land use defined in the WMMS database, 25 acres was moved into the land use 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 projection 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 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 – Stormwater Capture

2.4.1. Project Descriptions and Modeling Assumption

The Regional Solutions 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

2.5.1. Project Descriptions and Modeling Assumption

The Regional Solution Stormwater Conveyance 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 – Debris Basins

2.7.1. 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.

2.7.2. 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-8 below shows the volume and depth used to create the F-Table for each basin.

Table C-8. 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

Table C-8. Modeled Debris Basin Volumes and Depths

Facility Name	Volume[a] (ac-ft)	Estimated Depth[b] (feet)
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.

2.8. 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-9 in Appendix C describes the specific rates and capture depths 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-9. 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)

2.9. 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-10 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-10. 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)

2.10. Management Solutions – Regional Impacts Program

The Management Solution Regional Impacts Program project group could encourage local capture across the watershed. This is similar to the Local Capture Model and, therefore, modeling methodology closely followed that project type.

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 for the model.

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.

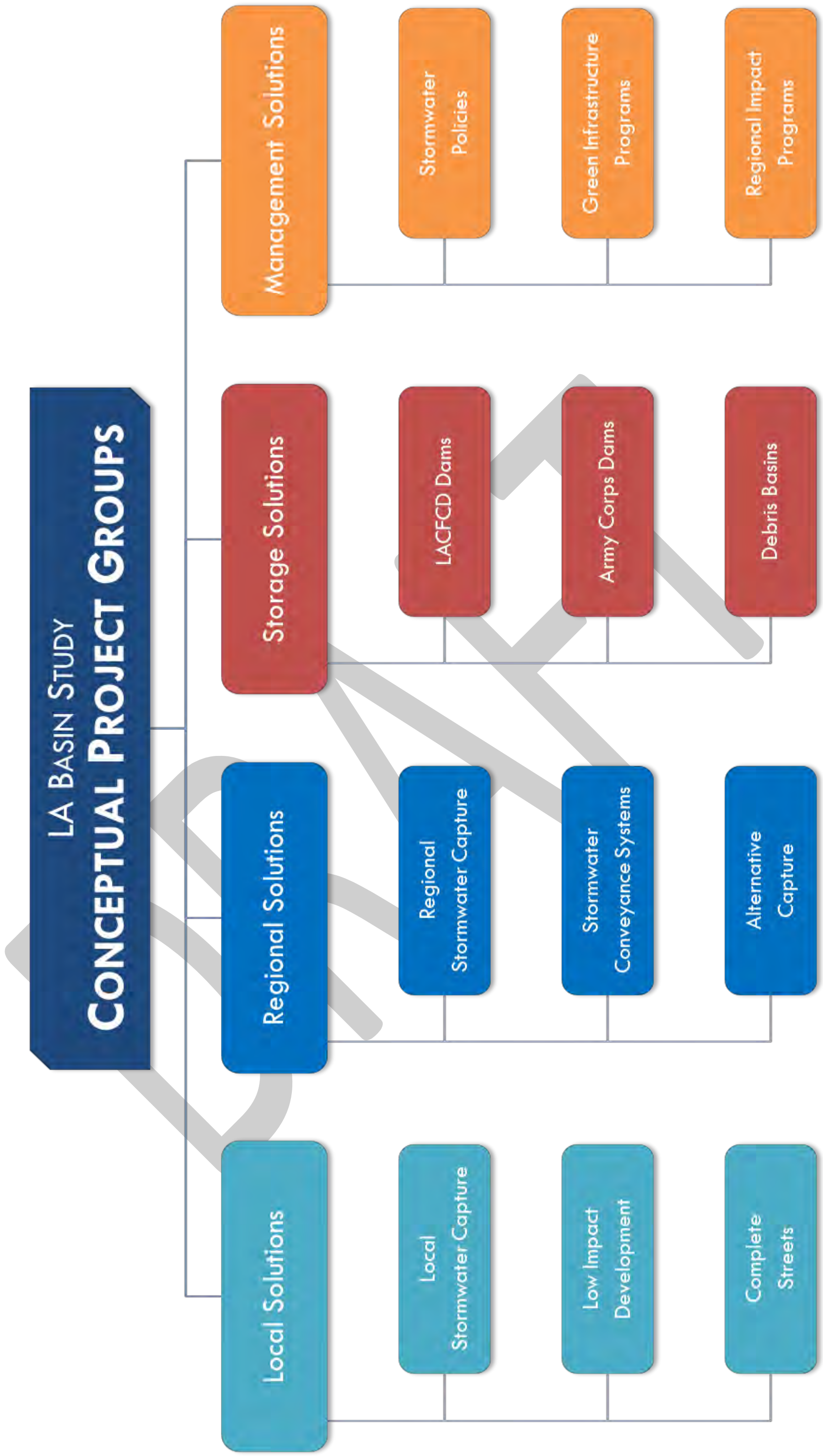

Figure C-1. Los Angeles Basin Stormwater Conservation Study Conceptual Project Groups

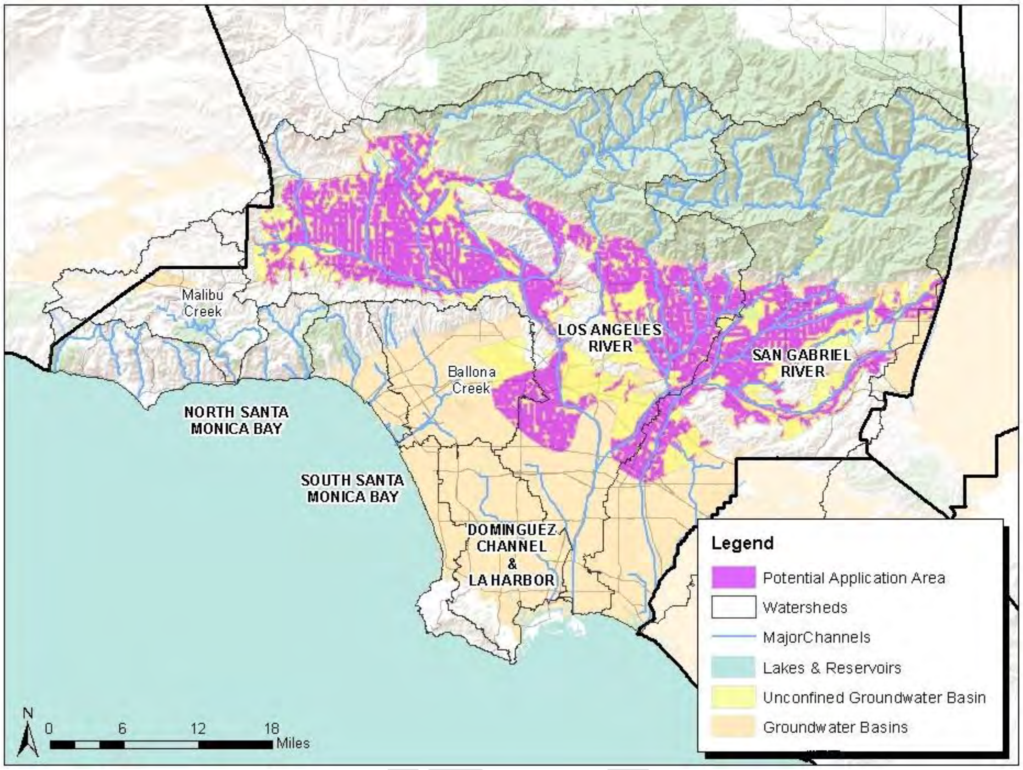

Figure C-2. Local Stormwater Capture Project Area

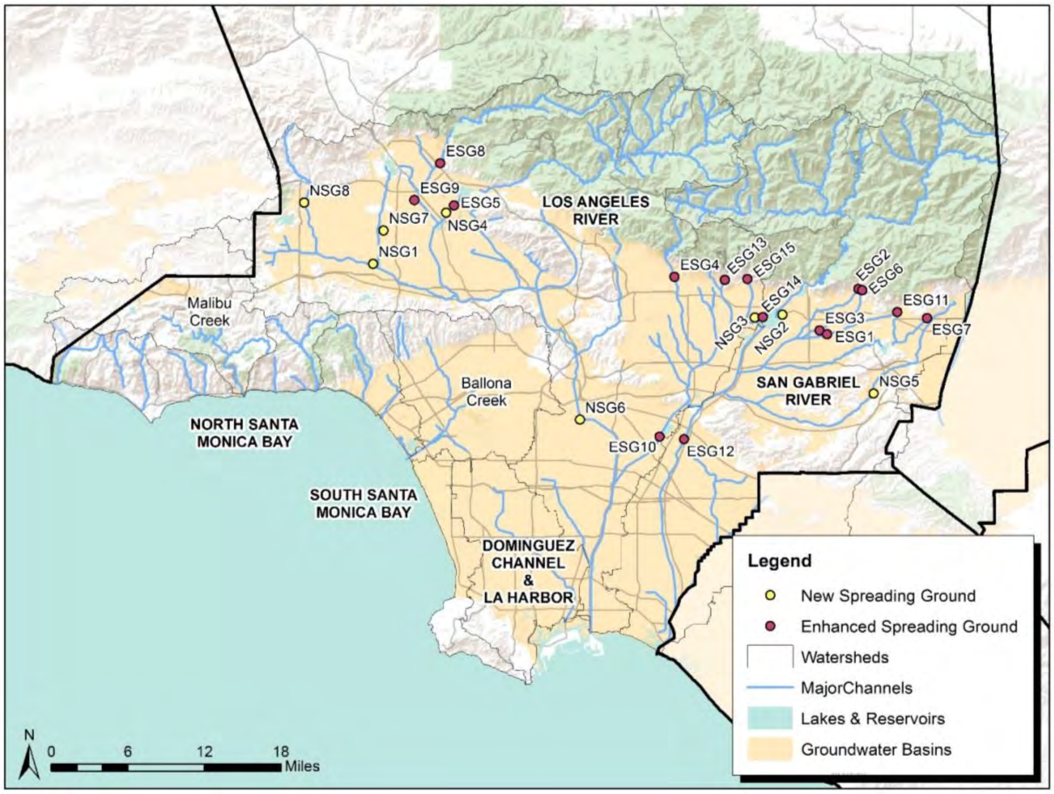

Figure C-3. Regional Stormwater Capture

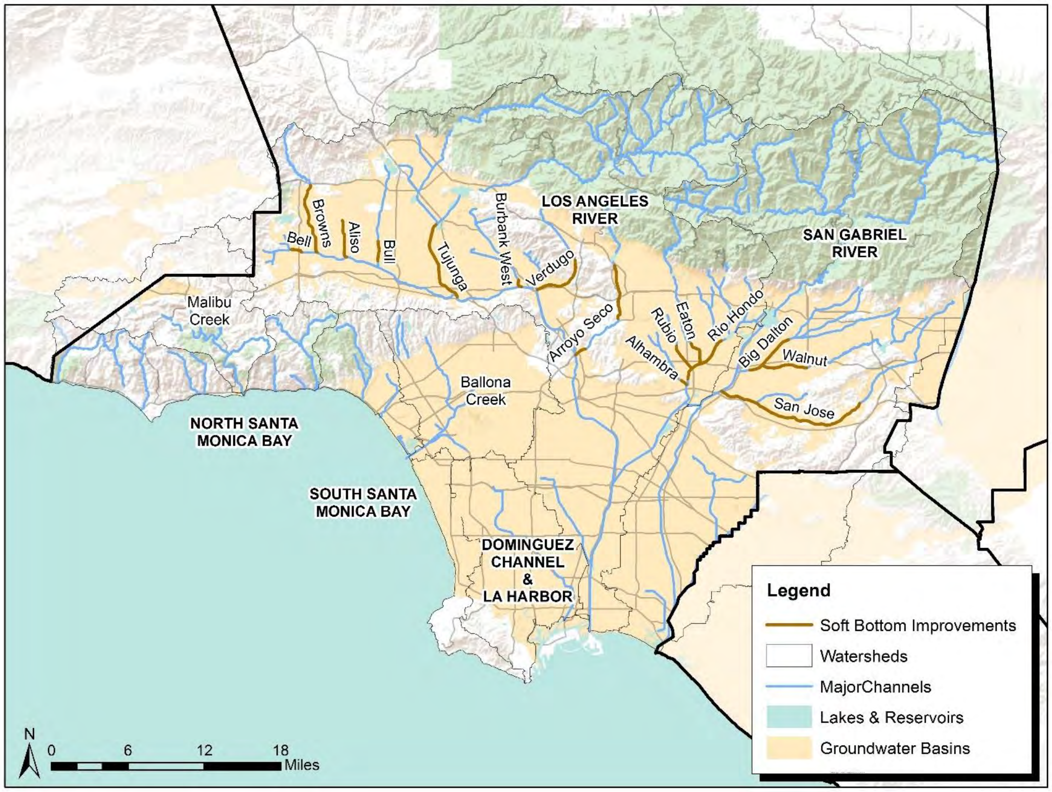

Figure C-4. Stormwater Conveyance Systems

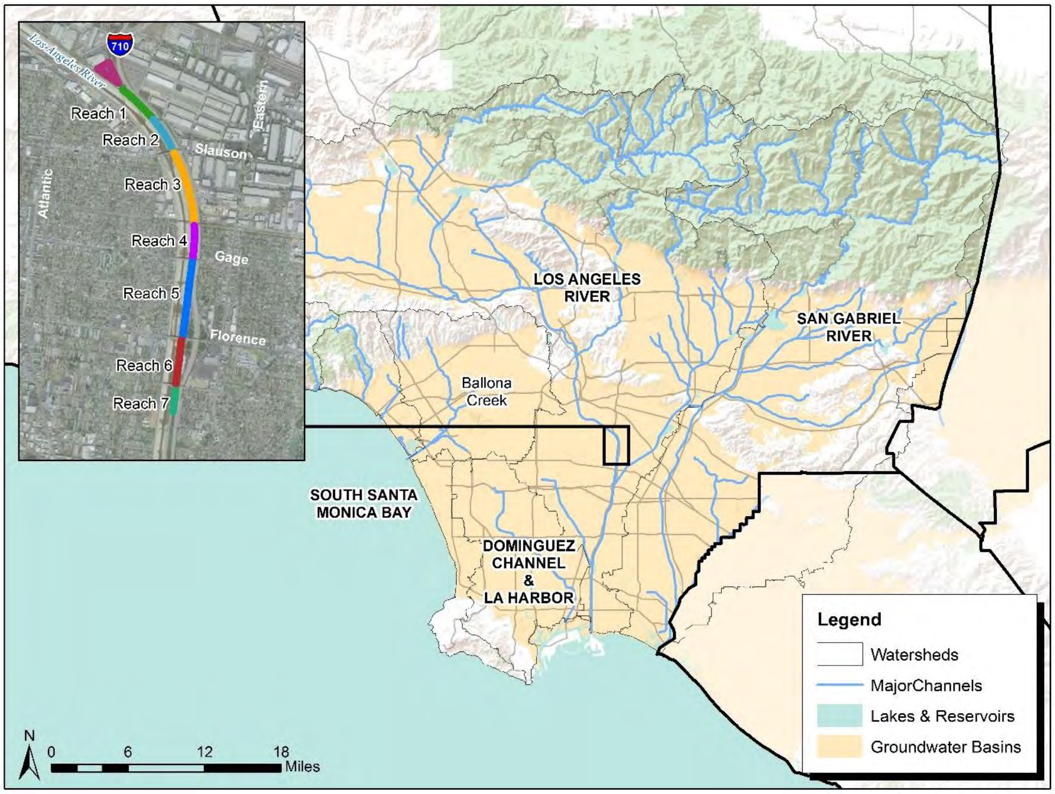

Figure C-5. Alternative Capture

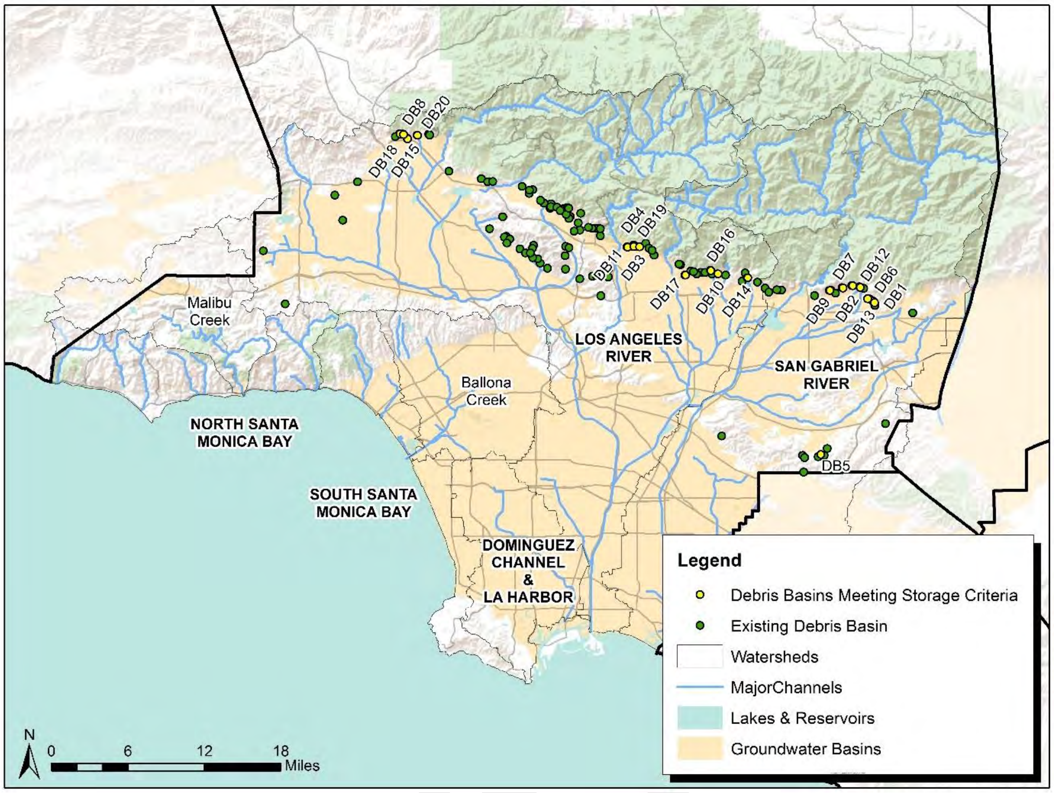

Figure C-6. Debris Basins

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Appendix D: Project Group Cost Estimates

See separate excel files:

- *“Appendix D Local and Management Costs.xlsx”*
- *“Appendix D Regional 1 Costs.xlsx”*
- *“Appendix D Regional 2 Costs.xlsx”*
- *“Appendix D Regional 3 Costs.xlsx”*
- *“Appendix D Storage 3 Costs.xlsx”*

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Appendix E: LACFCD Dam Hydrology and Cost Estimates

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Appendix E: LACFCD Dam Hydrology and Cost Estimates

Page

Tables

Figures

Supplemental Section

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Table E-1. Big Tujunga Dam Structural Concept Results

Scenario	Mean Annual Inflow (ac-ft)		Mean Annual Volume Captured (ac-ft)		Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio		Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Events	
	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
Historical	20,016	NA	12,845	NA	7,079	NA	64.2%	NA	NA	NA	0.58	NA
High 1	53,683	53,695	19,299	40,753	34,289	12,846	35.9%	75.9%	-28.2%	11.7%	1.85	3.61
Medium 2	31,069	31,074	14,699	26,485	16,277	4,496	47.3%	85.2%	-16.9%	21.1%	1.24	1.48
Low 1	14,439	14,441	8,910	12,509	5,425	1,827	61.7%	86.6%	-2.5%	22.5%	0.50	0.45
Low 2	25,103	25,106	14,160	22,480	10,841	2,523	56.4%	89.5%	-7.8%	25.4%	1.15	1.06

Table E-2. Cogswell Dam Structural Concept Results

Scenario	Mean Annual Inflow (ac-ft)		Mean Annual Volume Captured (ac-ft)		Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio		Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Events	
	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
Historical	25,524	NA	19,282	NA	6,208	NA	75.5%	NA	NA	NA	0.44	NA
High 1	53,339	53,353	27,397	51,680	25,898	1,624	51.4%	96.9%	-24.2%	21.3%	1.82	0.36
Medium 2	34,701	34,708	22,187	33,949	12,477	721	63.9%	97.8%	-11.6%	22.3%	1.06	0.18
Low 1	19,034	19,039	14,593	18,630	4,404	370	76.7%	97.9%	1.1%	22.3%	0.43	0.10
Low 2	29,393	29,398	21,199	29,000	8,158	359	72.1%	98.6%	-3.4%	23.1%	0.90	0.11

Table E-3. Devil's Gate Dam Structural Concept Results

Scenario	Mean Annual Inflow (ac-ft)		Mean Annual Volume Captured (ac-ft)		Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio		Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Events	
	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
Historical	14,295	NA	9,570	NA	4,725	NA	66.9%	NA	NA	NA	1.56	NA
High 1	32,202	32,204	12,925	32,204	19,277	0	40.1%	100.0%	-26.8%	33.1%	2.94	0.00
Medium 2	20,098	20,099	10,324	20,071	9,774	28	51.4%	99.9%	-15.6%	32.9%	2.04	0.02
Low 1	10,649	10,649	6,879	10,649	3,770	0	64.6%	100.0%	-2.3%	33.1%	0.93	0.00
Low 2	16,229	16,230	10,103	16,230	6,127	0	62.2%	100.0%	-4.7%	33.1%	1.85	0.00

Table E-4. Eaton Wash Dam Structural Concept Results

Scenario	Mean Annual Inflow (ac-ft)		Mean Annual Volume Captured (ac-ft)		Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio		Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Events	
	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
Historical	4,249	NA	3,681	NA	568	NA	86.6%	NA	NA	NA	1.52	NA
High 1	9,165	9,166	6,426	9,105	2,739	61	70.1%	99.3%	-16.5%	12.7%	5.46	0.10
Medium 2	6,071	6,072	4,780	6,057	1,291	15	78.7%	99.8%	-7.9%	13.1%	3.14	0.04
Low 1	3,366	3,367	2,867	3,351	500	15	85.2%	99.5%	-1.5%	12.9%	NA	0.02
Low 2	5,080	5,081	4,226	5,064	854	16	83.2%	99.7%	-3.4%	13.0%	2.20	0.06

Table E-5.Morris Dam Structural Concept Results

Scenario	Mean Annual Inflow (ac-ft)		Mean Annual Volume Captured (ac-ft)		Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio		Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Events	
	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
Historical	113,078	NA	44,980	NA	68,045	NA	39.8%	NA	NA	NA	0.64	NA
High 1	242,483	242,576	53,120	156,526	189,341	86,017	21.9%	64.5%	-17.9%	24.7%	0.96	1.49
Medium 2	156,519	156,567	46,560	118,413	109,910	38,094	29.7%	75.6%	-10.0%	35.9%	0.76	0.83
Low 1	85,657	85,688	42,070	72,169	43,516	13,435	49.1%	84.2%	9.3%	44.4%	0.46	0.32
Low 2	130,601	130,631	46,067	109,524	84,465	21,026	35.3%	83.8%	-4.5%	44.1%	0.76	0.56

Table E-6. Pacoima Dam Structural Concept Results

Scenario	Mean Annual Inflow (ac-ft)		Mean Annual Volume Captured (ac-ft)		Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio		Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Events	
	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
Historical	7,144	NA	6,219	NA	899	NA	87.0%	NA	NA	NA	0.32	NA
High 1	18,509	18,509	14,354	18,009	4,123	468	77.6%	97.3%	-9.5%	10.3%	1.70	0.49
Medium 2	10,854	10,854	9,419	10,678	1,404	145	86.8%	98.4%	-0.3%	11.3%	0.57	0.08
Low 1	5,034	5,034	4,387	4,977	613	23	87.1%	98.9%	0.1%	11.8%	0.20	0.01
Low 2	8,611	8,611	7,927	8,546	651	31	92.1%	99.3%	5.0%	12.2%	0.44	0.02

Table E-7. Puddingstone Diversion Dam Structural Concept Results

Scenario	Mean Annual Inflow (ac-ft)		Mean Annual Volume Captured (ac-ft)		Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio		Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Events	
	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
Historical	6,802	NA	6,452	NA	349	NA	94.9%	NA	NA	NA	0.88	NA
High 1	14,081	14,082	12,106	14,053	1,975	29	86.0%	99.8%	-8.9%	4.9%	3.54	0.02
Medium 2	8,905	8,906	8,010	8,898	895	7	90.0%	99.9%	-4.9%	5.1%	1.77	0.01
Low 1	4,694	4,694	4,323	4,686	371	8	92.1%	99.8%	-2.8%	5.0%	0.62	0.01
Low 2	7,317	7,317	6,783	7,298	533	19	92.7%	99.7%	-2.2%	4.9%	0.94	0.02

Table E-8. San Dimas Dam Structural Concept Results

Scenario	Mean Annual Inflow (ac-ft)		Mean Annual Volume Captured (ac-ft)		Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio		Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Events	
	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
Historical	5,451	NA	4,474	NA	957	NA	82.1%	NA	NA	NA	0.72	NA
High 1	10,884	10,884	6,798	10,771	4,066	93	62.5%	99.0%	-19.6%	16.9%	2.00	0.15
Medium 2	6,937	6,937	4,823	6,864	2,094	53	69.5%	99.0%	-12.6%	16.9%	1.45	0.08
Low 1	3,645	3,645	2,883	3,592	740	31	79.1%	98.5%	-3.0%	16.4%	0.49	0.05
Low 2	5,636	5,636	4,471	5,564	1,144	50	79.3%	98.7%	-2.8%	16.7%	0.94	0.08

Table E-9. San Gabriel Dam Structural Concept Results

Scenario	Mean Annual Inflow (ac-ft)		Mean Annual Volume Captured (ac-ft)		Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio		Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Events	
	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
Historical	110,658	NA	90,825	NA	19,825	NA	82.1%	NA	NA	NA	0.52	NA
High 1	235,551	235,608	140,764	224,166	94,785	11,438	59.8%	95.1%	-22.3%	13.1%	1.89	0.88
Medium 2	152,736	152,760	108,576	147,980	44,151	4,770	71.1%	96.9%	-11.0%	14.8%	1.18	0.25
Low 1	84,125	84,139	68,813	82,523	15,302	1,603	81.8%	98.1%	-0.3%	16.0%	0.42	0.13
Low 2	127,561	127,575	102,910	125,292	24,640	2,270	80.7%	98.2%	-1.4%	16.1%	0.88	0.15

Table E-10. LACFCD Dams Non-Structural Concept Results – High 1 Scenario

Dam Name	Mean Annual Volume Captured (ac-ft)			Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio			Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Event	
	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
4 Devil's Gate	9,570	12,925	11,677	19,277	19,898	66.9%	40.1%	36.3%	-26.8%	-30.7%	2.94	4.14
5 Eaton Wash	3,681	6,426	3,183	2,739	5,284	86.6%	70.1%	34.7%	-16.5%	-51.9%	5.46	25.15
13 Santa Anita	3,312	6,775	6,412	1,862	2,176	92.9%	78.4%	74.2%	-14.5%	-18.7%	2.38	3.52
Totals	**16,564**	**26,126**	**21,272**	**23,877**	**27,357**	**74.9%**	**52.2%**	**42.5%**	**-22.7%**	**-32.4%**	**NA**	**NA**

Table E-11. LACFCD Dams Non-Structural Concept Results – Low 1 Scenario

	Mean Annual Volume Captured (ac-ft)			Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio			Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Event	
Dam Name	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
4 Devil's Gate	9,570	6,879	6,131	3,770	4,090	66.9%	64.6%	57.6%	-2.3%	-9.4%	0.93	1.45
5 Eaton Wash	3,681	2,867	1,271	500	1,508	86.6%	85.2%	37.7%	-1.5%	-48.9%	1.12	9.52
13 Santa Anita	3,312	2,382	2,291	282	323	92.9%	89.2%	85.8%	-3.6%	-7.0%	0.49	0.63
Totals	**16,564**	**12,127**	**9,693**	**4,552**	**5,922**	**74.9%**	**72.7%**	**58.1%**	**-2.2%**	**-16.8%**	**NA**	**NA**

Table E-12. LACFCD Dams Non-Structural Concept Results – Low 2 Scenario

Dam Name	Mean Annual Volume Captured (ac-ft)			Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio			Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Event	
	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
4 Devil's Gate	9,570	10,103	9,658	6,127	6,353	66.9%	62.2%	59.5%	-4.7%	-7.4%	1.85	2.24
5 Eaton Wash	3,681	4,226	2,030	854	2,432	86.6%	83.2%	40.0%	-3.4%	-46.7%	2.20	14.96
13 Santa Anita	3,312	3,919	3,800	382	472	92.9%	91.0%	88.3%	-1.8%	-4.6%	0.69	1.15
Totals	**16,564**	**18,248**	**15,487**	**7,362**	**9,257**	**74.9%**	**71.2%**	**60.5%**	**-3.7%**	**-14.4%**	**NA**	**NA**

Table E-13. LACFCD Dams Summary of Estimated Costs of Structural Concepts

Dam Name	Estimated Total Annual Cost	Change of Mean Annual Volume Captured (ac-ft)				Estimated Annual Cost per Ac-Ft of Additional Volume Captured			
		High 1	Medium 2	Low 1	Low 2	High 1	Medium 2	Low 1	Low 2
Big Tajunga	$1,099,474	21,454	11,786	3,599	8,320	$51	$93	$305	$132
Cogswell	$1,145,670	24,283	11,762	4,036	7,801	$47	$97	$284	$147
Devil's Gate	$4,634,504	19,279	9,747	3,770	6,127	$240	$475	$1,229	$756
Eaton Wash	$1,351,402	2,679	1,277	485	838	$504	$1,059	$2,788	$1,613
Morris	$3,798,384	103,406	71,853	30,099	63,457	$37	$53	$126	$60
Pacoima	$3,029,836	3,655	1,259	591	619	$829	$2,407	$5,130	$4,892
Puddingstone Diversion	$466,349	1,947	888	363	515	$239	$525	$1,286	$906
San Dimas	$1,366,958	3,973	2,041	709	1,094	$344	$6703	$1,929	$1,250
San Gabriel	$10,550,903	83,402	39,404	13,710	22,382	$127	$268	$770	$471
Totals	**$27,443,480**	**264,079**	**150,015**	**57,362**	**111,153**	**$104**	**$183**	**$478**	**$247**

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Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
RAISED SPILLWAY COSTS (GATES)					
14 Foot Tall Pneumatically Actuated Gate	122	LF	$ 12,600	$ 1,537,200	Pneumatic Gate Cost Estimates derived from market research (Obermeyer Hydro). Costs include clamping and anchoring, materials & equipment, shipping charges, and installation supervision.
SUBTOTAL				**$ 1,537,200**	
PROGRAMMABLE LOGIC CONTROLLER COSTS					
PLC Controller (% of Gate Cost)	8%	%	$ 1,537,200	$ 122,976	Programmable Logic Controller (PLC) cost derived from Hydrotech and Obermeyer Hydro. PLC Cost are estimated at 8% of Rubber Dam or Pneumatically Actuated Gate (or Slide Gate) Costs.
SUBTOTAL				**$ 122,976**	
INSTALLATION COSTS					
14 Foot Tall Raised Spillway	122	LF	$ 15,120	$ 1,844,640	Labor, equipment and installation costs for construction/installation of raised spillway gates derived from market research (Hydrotech and Obermeyer Hydro) and estimated at 60% of gate cost with multiplier of 2.0 to adjust for difficulty of site access and constricted spaces.
SUBTOTAL				**$ 1,844,640**	
GENERAL CONDITIONS					
SUBTOTAL	10%	%	$ 3,504,816	**$ 350,482**	Percentage of estimated construction costs

Figure E-1. Cost Estimate for Big Tujunga Dam Structural Concept
(Sheet 1 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
NON-CONTRACT COSTS					
Feasibility Studies, Surveys & Design Data	30%	%	$ 3,855,298	$ 1,156,589	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($1.0M/$4.0M)
Designs & Specifications	15%	%	$ 3,855,298	$ 578,295	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($0.5M/$2.0M)
Materials, Structural & Seismic Testing	5%	%	$ 3,855,298	$ 192,765	Percentage of estimated construction costs (including General Conditions)
Project Management	11%	%	$ 7,517,830	$ 826,961	Percentage of estimated construction costs & other non-contract costs
Legal	5%	%	$ 3,855,298	$ 192,765	Percentage of estimated construction costs (including General Conditions)
Permitting	30%	%	$ 3,855,298	$ 1,156,589	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($1.0M/$4.0M)
Construction Management	10%	%	$ 3,855,298	$ 385,530	Percentage of estimated construction costs (including General Conditions)
SUBTOTAL				**$ 4,489,494**	
CONTINGENCIES					
SUBTOTAL	30%	%	$ 8,344,792	**$ 2,503,437**	15% to 40% of estimated construction costs & non-contract costs
TOTAL CONSTRUCTION COST					
TOTAL				**$ 10,848,229**	

Figure E-1. Cost Estimate for Big Tujunga Dam Structural Concept
(Sheet 2 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
ANNUAL CAPITAL COST					
Project Life (n)	50	Yrs			
Federal Project Planning Rate (i)	3.375%	%			
Annual Cost	0.0417		$ 10,848,229	$ 452,124	Annual Cost ($) = Total Cost ($)*(i/(1-(1/(1+i)^n))
SUBTOTAL				**$ 452,124**	
ANNUAL OPERATING, MAINTENANCE & REPLACEMENT COSTS					
Structural Concept Analysis Results:					
Mean Annual Volume Captured	11,786	Ac-Ft			Data specific to dam from Task 5 results for Medium 2 Future Climate Scenario
Number of Events per Year	1.5	EA			
Number of Hours per Year	8.3	Hrs			
Annual Power Cost:					
Electric Cost per kW-hr		kW-hr	$ 0.15		
Pneumatic Gate Pump	5	HP		$ 6	Annual Power Cost ($)=[($ kW-hr)(0.7457 kW/hp)(hp)(t)]/0.84 for the combined horsepower for all motors, provided by vendors.
Slide Gate Motor	300	HP		$ 332	
Annual Operation & Maintenance Cost	5%	%	$ 3,855,298	$ 486,334	Percentage of estimated construction costs (not including non-contract cost or contingencies)
Annual Replacement Cost (Pneumatically Actuated Gates):					
Useful Life	25	Yrs			Useful Life (25 years) provided by vendors.
Present Value of Replacement at 25 Years			$ 3,855,298		Annual Cost multiplier applied to Present Value of materials, installation and general conditions costs of Pneumatically Actuated Gates, only.
Annual Replacement Cost	0.0417			$ 160,678	
SUBTOTAL				**$ 647,350**	

Figure E-1. Cost Estimate for Big Tujunga Dam Structural Concept
(Sheet 3 of 4)

Identifier	Material or Rating	Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
		SUMMARY					
		TOTAL CONSTRUCTION COST				$ 10,848,229	
		ANNUAL CAPITAL COST				$ 452,124	
		ANNUAL OPERATING, MAINTENANCE & REPLACEMENT COSTS				$ 647,350	
		TOTAL ANNUAL COST				$ 1,099,474	
		TOTAL ANNUAL COST per Ac-Ft (Medium 2 Scenario)	11,786	Ac-Ft		$ 93	

NOTES:

1 - This cost estimate is conceptual in nature and is appropriate for strategic planning, business development, project screening, alternative scheme analysis, confirmation of technical and/or economic feasibility, and preliminary approval to proceed. While these estimates are appropriate for the appraisal level analysis required for the purposes of this document, they are not appropriate for budget authorization, funding agreements, bid, or tender offers. Accuracy ranges are considered to be -15% to -30% on the low side and +20% to +50% on the high side.

2 - All costs are presented in 2015 dollars.

3 - Taxes & contractor OH&P are included in the unit prices.

4 - Distributive Costs include but are not limited to additional planning efforts, investigations, analysis, regulatory compliance, acquisition, contract administration, construction management, inspection, etc.

5 - The RSMeans construction data was used to derive Feasibility, Design, Material Testing, Structural, and Seismic Testing percentages. The total materials and labor costs are used for the percent cost.

Figure E-1. Cost Estimate for Big Tujunga Dam Structural Concept
(Sheet 4 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
RAISED SPILLWAY COSTS (GATES)					
13 Foot Tall Pneumatically Actuated Gate	145	LF	$ 11,050.00	$ 1,602,250	Pneumatic Gate Cost Estimates derived from market research (Obermeyer Hydro). Costs include clamping and anchoring, materials & equipment, shipping charges, and installation supervision.
SUBTOTAL				**$ 1,602,250**	
PROGRAMMABLE LOGIC CONTROLLER COSTS					
PLC Controller (% of Gate Cost)	8%	%	$ 1,602,250	$ 128,180	Programmable Logic Controller (PLC) cost derived from Hydrotech and Obermeyer Hydro. PLC Cost are estimated at 8% of Rubber Dam or Pneumatically Actuated Gate (or Slide Gate) Costs.
SUBTOTAL				**$ 128,180**	
INSTALLATION COSTS					
					Labor, equipment and installation costs for construction/installation of raised spillway gates derived from market research (Hydrotech and Obermeyer Hydro) and estimated at 60% of gate cost with multiplier of 2.0 to adjust for difficulty of site access and constricted spaces.
13 Foot Tall Raised Spillway	145	LF	$ 13,260	$ 1,922,700	
SUBTOTAL				**$ 1,922,700**	
GENERAL CONDITIONS					
SUBTOTAL	10%	%	$ 3,653,130	**$ 365,313**	Percentage of estimated construction costs

Figure E-2. Cost Estimate for Cogswell Dam Structural Concept
(Sheet 1 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
NON-CONTRACT COSTS					
Feasibility Studies, Surveys & Design Data	30%	%	$ 4,018,443	$ 1,205,533	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($1.0M/$4.0M)
Designs & Specifications	15%	%	$ 4,018,443	$ 602,766	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($0.5M/$2.0M)
Materials, Structural & Seismic Testing	5%	%	$ 4,018,443	$ 200,922	Percentage of estimated construction costs (including General Conditions)
Project Management	11%	%	$ 7,835,964	$ 861,956	Percentage of estimated construction costs & other non-contract costs
Legal	5%	%	$ 4,018,443	$ 200,922	Percentage of estimated construction costs (including General Conditions)
Permitting	30%	%	$ 4,018,443	$ 1,205,533	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($1.0M/$4.0M)
Construction Management	10%	%	$ 4,018,443	$ 401,844	Percentage of estimated construction costs (including General Conditions)
SUBTOTAL				**$ 4,679,477**	
CONTINGENCIES					
SUBTOTAL	30%	%	$ 8,697,920	**$ 2,609,376**	15% to 40% of estimated construction costs & non-contract costs
TOTAL CONSTRUCTION COST					
TOTAL				**$ 11,307,296**	

Figure E-2. Cost Estimate for Cogswell Dam Structural Concept
(Sheet 2 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
ANNUAL CAPITAL COST					
Project Life (n)	50	Yrs			
Federal Project Planning Rate (i)	3.375%	%			
Annual Cost	0.0417		$ 11,307,296	$ 471,257	Annual Cost ($) = Total Cost ($)*(i/(1-(1/(1+i)^n))
SUBTOTAL				**$ 471,257**	
ANNUAL OPERATING, MAINTENANCE & REPLACEMENT COSTS					
Structural Concept Analysis Results:					
Mean Annual Volume Captured	11,762	Ac-Ft			Data specific to dam from Task 5 results for Medium 2 Future Climate Scenario
Number of Events per Year	0.2	EA			
Number of Hours per Year	0.5	Hrs			
Annual Power Cost:					
Electric Cost per kW-hr		kW-hr	$ 0.15		
Pneumatic Gate Pump	5	HP		$ 0	Annual Power Cost ($)=[($ kW-hr)(0.7457 kW/hp)(hp)(t)]/0.84 for the combined horsepower for all motors, provided by vendors.
Slide Gate Motor	300	HP		$ 20	
Annual Operation & Maintenance Cost	5%	%	$ 4,018,443	$ 506,915	Percentage of estimated construction costs (not including non-contract cost or contingencies)
Annual Replacement Cost (Pneumatically Actuated Gates):					
Useful Life	25	Yrs			Useful Life (25 years) provided by vendors.
Present Value of Replacement at 25 Years			$ 4,018,443		Annual Cost multiplier applied to Present Value of materials, installation and general conditions costs of Pneumatically Actuated Gates, only.
Annual Replacement Cost	0.0417			$ 167,478	
SUBTOTAL				**$ 674,413**	

Figure E-2. Cost Estimate for Cogswell Dam Structural Concept
(Sheet 3 of 4)

Identifier	Material or Rating	Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
		SUMMARY					
		TOTAL CONSTRUCTION COST				$ 11,307,296	
		ANNUAL CAPITAL COST				$ 471,257	
		ANNUAL OPERATING, MAINTENANCE & REPLACEMENT COSTS				$ 674,413	
		TOTAL ANNUAL COST				$ 1,145,670	
		TOTAL ANNUAL COST per Ac-Ft (Medium 2 Scenario)	11,762	Ac-Ft		$ 97	

NOTES:

1 - This cost estimate is conceptual in nature and is appropriate for strategic planning, business development, project screening, alternative scheme analysis, confirmation of technical and/or economic feasibility, and preliminary approval to proceed. While these estimates are appropriate for the appraisal level analysis required for the purposes of this document, they are not appropriate for budget authorization, funding agreements, bid, or tender offers. Accuracy ranges are considered to be -15% to -30% on the low side and +20% to +50% on the high side.

2 - All costs are presented in 2015 dollars.

3 - Taxes & contractor OH&P are included in the unit prices.

4 - Distributive Costs include but are not limited to additional planning efforts, investigations, analysis, regulatory compliance, acquisition, contract administration, construction management, inspection, etc.

5 - The RSMeans construction data was used to derive Feasibility, Design, Material Testing, Structural, and Seismic Testing percentages. The total materials and labor costs are used for the percent cost.

Figure E-2. Cost Estimate for Cogswell Dam Structural Concept
(Sheet 4 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
RAISED SPILLWAY COSTS (GATES)					
					Pneumatic Gate Cost Estimates derived from market research (Obermeyer Hydro). Costs include clamping and anchoring, materials & equipment, shipping charges, and installation supervision.
5 Foot Tall Pneumatically Actuated Gate	171	LF	$ 2,250.00	$ 384,750	
(W' X H') 12.75' X 4' Slide Gate	8	EA	$ 562,100.00	$ 4,496,800	
(W X H') 14' X 4' Slide Gate	3	EA	$ 606,350.00	$ 1,819,050	Slide Gate Cost Estimates derived from USBR historical bids from the Expect Database Search at the Technical Service Center (TSC) in Denver. Rectangular and square gates are measured width by height (W' X H').
SUBTOTAL				**$ 6,700,600**	
PROGRAMMABLE LOGIC CONTROLLER COSTS					
PLC Controller (% of Gate Cost)	8%	%	$ 6,700,600	$ 536,048	Programmable Logic Controller (PLC) cost derived from Hydrotech and Obermeyer Hydro. PLC Cost are estimated at 8% of Rubber Dam or Pneumatically Actuated Gate (or Slide Gate) Costs.
SUBTOTAL				**$ 536,048**	
INSTALLATION COSTS					
5 Foot Tall Raised Spillway	171	LF	$ 2,700	$ 461,700	Labor, equipment and installation costs for construction/installation of raised spillway gates derived from market research (Hydrotech and Obermeyer Hydro) and estimated at 60% of gate cost with multiplier of 2.0 to adjust for difficulty of site access and constricted spaces.
12.75' X 4' Slide Gate	8	EA	$ 674,520	$ 5,396,160	
14' X 4' Slide Gate	3	EA	$ 727,620	$ 2,182,860	
SUBTOTAL				**$ 8,040,720**	
GENERAL CONDITIONS					
SUBTOTAL	10%	%	$ 15,277,368	**$ 1,527,737**	Percentage of estimated construction costs

Figure E-3. Cost Estimate for Devils Gate Dam Structural Concept
(Sheet 1 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
NON-CONTRACT COSTS					
Feasibility Studies, Surveys & Design Data	1	LS		$ 4,000,000	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($1.0M/$4.0M)
Designs & Specifications	1	LS		$ 2,000,000	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($0.5M/$2.0M)
Materials, Structural & Seismic Testing	5%	%	$ 16,805,105	$ 840,255	Percentage of estimated construction costs (including General Conditions)
Project Management	11%	%	$ 30,166,126	$ 3,318,274	Percentage of estimated construction costs & other non-contract costs
Legal	5%	%	$ 16,805,105	$ 840,255	Percentage of estimated construction costs (including General Conditions)
Permitting	1	LS		$ 4,000,000	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($1.0M/$4.0M)
Construction Management	10%	%	$ 16,805,105	$ 1,680,510	Percentage of estimated construction costs (including General Conditions)
SUBTOTAL				**$ 16,679,295**	
CONTINGENCIES					
SUBTOTAL	30%	%	$ 33,484,400	**$ 10,045,320**	15% to 40% of estimated construction costs & non-contract costs
TOTAL CONSTRUCTION COST					
TOTAL				**$ 43,529,719**	
ANNUAL CAPITAL COST					
Project Life (n)	50	Yrs			
Federal Project Planning Rate (i)	3.375%	%			
Annual Cost	0.0417		$ 43,529,719	$ 1,814,199	Annual Cost ($) = Total Cost ($)*(i/(1-(1/(1+i)^n))
SUBTOTAL				**$ 1,814,199**	

Figure E-3. Cost Estimate for Devils Gate Dam Structural Concept
(Sheet 2 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
ANNUAL CAPITAL COST					
Project Life (n)	50	Yrs			
Federal Project Planning Rate (i)	3.375%	%			
Annual Cost	0.0417		$ 43,529,719	$ 1,814,199	Annual Cost ($) = Total Cost ($)*(i/(1-(1/(1+i)^n))
SUBTOTAL				**$ 1,814,199**	
ANNUAL OPERATING, MAINTENANCE & REPLACEMENT COSTS					
Structural Concept Analysis Results:					
Mean Annual Volume Captured	9,747	Ac-Ft			Data specific to dam from Task 5 results for Medium 2 Future Climate Scenario
Number of Events per Year	0.0	EA			
Number of Hours per Year	0.0	Hrs			
Annual Power Cost:					
Electric Cost per kW-hr		kW-hr	$ 0.15		
Pneumatic Gate Pump	5	HP		$ -	Annual Power Cost ($)=[($ kW-hr)(0.7457 kW/hp)(hp)(t)]/0.84 for the combined horsepower for all motors, provided by vendors.
Slide Gate Motor	300	HP		$ -	
Annual Operation & Maintenance Cost	5%	%	$ 16,805,105	$ 2,119,914	Percentage of estimated construction costs (not including non-contract cost or contingencies)
Annual Replacement Cost (Pneumatically Actuated Gates):					
Useful Life	25	Yrs			Useful Life (25 years) provided by vendors.
Present Value of Replacement at 25 Years			$ 16,805,105		Annual Cost multiplier applied to Present Value of materials, installation and general conditions costs of Pneumatically Actuated Gates, only.
Annual Replacement Cost	0.0417			$ 700,391	
SUBTOTAL				**$ 2,820,305**	

Figure E-3. Cost Estimate for Devils Gate Dam Structural Concept
(Sheet 3 of 4)

Identifier	Material or Rating	Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
		SUMMARY					
		TOTAL CONSTRUCTION COST				$ 43,529,719	
		ANNUAL CAPITAL COST				$ 1,814,199	
		ANNUAL OPERATING, MAINTENANCE & REPLACEMENT COSTS				$ 2,820,305	
		TOTAL ANNUAL COST				$ 4,634,504	
		TOTAL ANNUAL COST per Ac-Ft (Medium 2 Scenario)	9,747	Ac-Ft		$ 475	

NOTES:

1 - This cost estimate is conceptual in nature and is appropriate for strategic planning, business development, project screening, alternative scheme analysis, confirmation of technical and/or economic feasibility, and preliminary approval to proceed. While these estimates are appropriate for the appraisal level analysis required for the purposes of this document, they are not appropriate for budget authorization, funding agreements, bid, or tender offers. Accuracy ranges are considered to be -15% to -30% on the low side and +20% to +50% on the high side.

2 - All costs are presented in 2015 dollars.

3 - Taxes & contractor OH&P are included in the unit prices.

4 - Distributive Costs include but are not limited to additional planning efforts, investigations, analysis, regulatory compliance, acquisition, contract administration, construction management, inspection, etc.

5 - The RSMeans construction data was used to derive Feasibility, Design, Material Testing, Structural, and Seismic Testing percentages. The total materials and labor costs are used for the percent cost.

Figure E-3. Cost Estimate for Devils Gate Dam Structural Concept
(Sheet 4 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
RAISED SPILLWAY COSTS (GATES)					
10 Foot Tall Pneumatically Actuated Gate	270	LF	$ 7,000	$ 1,890,000	Pneumatic Gate Cost Estimates derived from market research (Obermeyer Hydro). Costs include clamping and anchoring, materials & equipment, shipping charges, and installation supervision.
SUBTOTAL				**$ 1,890,000**	
PROGRAMMABLE LOGIC CONTROLLER COSTS					
PLC Controller (% of Gate Cost)	8%	%	$ 1,890,000	$ 151,200	Programmable Logic Controller (PLC) cost derived from Hydrotech and Obermeyer Hydro. PLC Cost are estimated at 8% of Rubber Dam or Pneumatically Actuated Gate (or Slide Gate) Costs.
SUBTOTAL				**$ 151,200**	
INSTALLATION COSTS					
10 Foot Tall Raised Spillway	270	LF	$ 8,400	$ 2,268,000	Labor, equipment and installation costs for construction/installation of raised spillway gates derived from market research (Hydrotech and Obermeyer Hydro) and estimated at 60% of gate cost with multiplier of 2.0 to adjust for difficulty of site access and constricted spaces.
SUBTOTAL				**$ 2,268,000**	
GENERAL CONDITIONS					
SUBTOTAL	10%	%	$ 4,309,200	**$ 430,920**	Percentage of estimated construction costs

Figure E-4. Cost Estimate for Eaton Wash Dam Structural Concept
(Sheet 1 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
NON-CONTRACT COSTS					
Feasibility Studies, Surveys & Design Data	30%	%	$ 4,740,120	$ 1,422,036	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($1.0M/$4.0M)
Designs & Specifications	15%	%	$ 4,740,120	$ 711,018	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($0.5M/$2.0M)
Materials, Structural & Seismic Testing	5%	%	$ 4,740,120	$ 237,006	Percentage of estimated construction costs (including General Conditions)
Project Management	11%	%	$ 9,243,234	$ 1,016,756	Percentage of estimated construction costs & other non-contract costs
Legal	5%	%	$ 4,740,120	$ 237,006	Percentage of estimated construction costs (including General Conditions)
Permitting	30%	%	$ 4,740,120	$ 1,422,036	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($1.0M/$4.0M)
Construction Management	10%	%	$ 4,740,120	$ 474,012	Percentage of estimated construction costs (including General Conditions)
SUBTOTAL				**$ 5,519,870**	
CONTINGENCIES					
SUBTOTAL	30%	%	$ 10,259,990	**$ 3,077,997**	15% to 40% of estimated construction costs & non-contract costs
TOTAL CONSTRUCTION COST					
TOTAL				**$ 13,337,987**	

Figure E-4. Cost Estimate for Eaton Wash Dam Structural Concept
(Sheet 2 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
ANNUAL CAPITAL COST					
Project Life (n)	50	Yrs			
Federal Project Planning Rate (i)	3.375%	%			
Annual Cost	0.0417		$ 13,337,987	$ 555,891	Annual Cost ($) = Total Cost ($)*(i/(1-(1/(1+i)^n))
SUBTOTAL				**$ 555,891**	
ANNUAL OPERATING, MAINTENANCE & REPLACEMENT COSTS					
Structural Concept Analysis Results:					
Mean Annual Volume Captured	1,277	Ac-Ft			Data specific to dam from Task 5 results for Medium 2 Future Climate Scenario
Number of Events per Year	0.0	EA			
Number of Hours per Year	0.1	Hrs			
Annual Power Cost:					
Electric Cost per kW-hr		kW-hr	$ 0.15		
Pneumatic Gate Pump	5	HP		$ 0	Annual Power Cost ($)=[($ kW-hr)(0.7457 kW/hp)(hp)(t)]/0.84 for the combined horsepower for all motors, provided by vendors.
Slide Gate Motor	300	HP		$ 4	
Annual Operation & Maintenance Cost	5%	%	$ 4,740,120	$ 597,952	Percentage of estimated construction costs (not including non-contract cost or contingencies)
Annual Replacement Cost (Pneumatically Actuated Gates):					
Useful Life	25	Yrs			Useful Life (25 years) provided by vendors.
Present Value of Replacement at 25 Years			$ 4,740,120		Annual Cost multiplier applied to Present Value of materials, installation and general conditions costs of Pneumatically Actuated Gates, only.
Annual Replacement Cost	0.0417			$ 197,555	
SUBTOTAL				**$ 795,511**	

Figure E-4. Cost Estimate for Eaton Wash Dam Structural Concept
(Sheet 3 of 4)

Identifier	Material or Rating	Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
		SUMMARY					
		TOTAL CONSTRUCTION COST				$ 13,337,987	
		ANNUAL CAPITAL COST				$ 555,891	
		ANNUAL OPERATING, MAINTENANCE & REPLACEMENT COSTS				$ 795,511	
		TOTAL ANNUAL COST				$ 1,351,402	
		TOTAL ANNUAL COST per Ac-Ft (Medium 2 Scenario)	1,277	Ac-Ft		$ 1,058	

NOTES:

1 - This cost estimate is conceptual in nature and is appropriate for strategic planning, business development, project screening, alternative scheme analysis, confirmation of technical and/or economic feasibility, and preliminary approval to proceed. While these estimates are appropriate for the appraisal level analysis required for the purposes of this document, they are not appropriate for budget authorization, funding agreements, bid, or tender offers. Accuracy ranges are considered to be -15% to -30% on the low side and +20% to +50% on the high side.

2 - All costs are presented in 2015 dollars.

3 - Taxes & contractor OH&P are included in the unit prices.

4 - Distributive Costs include but are not limited to additional planning efforts, investigations, analysis, regulatory compliance, acquisition, contract administration, construction management, inspection, etc.

5 - The RSMeans construction data was used to derive Feasibility, Design, Material Testing, Structural, and Seismic Testing percentages. The total materials and labor costs are used for the percent cost.

Figure E-4. Cost Estimate for Eaton Wash Dam Structural Concept
(Sheet 4 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
RAISED SPILLWAY COSTS (GATES)					
23 Foot Tall Pneumatically Actuated Gate	171	LF	$ 31,050	$ 5,309,550	Pneumatic Gate Cost Estimates derived from market research (Obermeyer Hydro). Costs include clamping and anchoring, materials & equipment, shipping charges, and installation supervision.
SUBTOTAL				**$ 5,309,550**	
PROGRAMMABLE LOGIC CONTROLLER COSTS					
PLC Controller (% of Gate Cost)	8%	%	$ 5,309,550	$ 424,764	Programmable Logic Controller (PLC) cost derived from Hydrotech and Obermeyer Hydro. PLC Cost are estimated at 8% of Rubber Dam or Pneumatically Actuated Gate (or Slide Gate) Costs.
SUBTOTAL				**$ 424,764**	
INSTALLATION COSTS					
23 Foot Tall Raised Spillway	171	LF	$ 37,260	$ 6,371,460	Labor, equipment and installation costs for construction/installation of raised spillway gates derived from market research (Hydrotech and Obermeyer Hydro) and estimated at 60% of gate cost with multiplier of 2.0 to adjust for difficulty of site access and constricted spaces.
SUBTOTAL				**$ 6,371,460**	
GENERAL CONDITIONS					
SUBTOTAL	10%	%	$ 12,105,774	**$ 1,210,577**	Percentage of estimated construction costs

Figure E-5. Cost Estimate for Morris Dam Structural Concept
(Sheet 1 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
NON-CONTRACT COSTS					
Feasibility Studies, Surveys & Design Data	30%	%	$ 13,316,351	$ 3,994,905	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($1.0M/$4.0M)
Designs & Specifications	15%	%	$ 13,316,351	$ 1,997,453	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($0.5M/$2.0M)
Materials, Structural & Seismic Testing	5%	%	$ 13,316,351	$ 665,818	Percentage of estimated construction costs (including General Conditions)
Project Management	11%	%	$ 25,966,885	$ 2,856,357	Percentage of estimated construction costs & other non-contract costs
Legal	5%	%	$ 13,316,351	$ 665,818	Percentage of estimated construction costs (including General Conditions)
Permitting	30%	%	$ 13,316,351	$ 3,994,905	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($1.0M/$4.0M)
Construction Management	10%	%	$ 13,316,351	$ 1,331,635	Percentage of estimated construction costs (including General Conditions)
SUBTOTAL				**$ 15,506,891**	
CONTINGENCIES					
SUBTOTAL	30%	%	$ 28,823,243	**$ 8,646,973**	15% to 40% of estimated construction costs & non-contract costs
TOTAL CONSTRUCTION COST					
TOTAL				**$ 37,470,215**	

Figure E-5. Cost Estimate for Morris Dam Structural Concept
(Sheet 2 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
ANNUAL CAPITAL COST					
Project Life (n)	50	Yrs			
Federal Project Planning Rate (i)	3.375%	%			
Annual Cost	0.0417		$ 37,470,215	$ 1,561,656	Annual Cost ($) = Total Cost ($)*(i/(1-(1/(1+i)^n))
SUBTOTAL				**$ 1,561,656**	
ANNUAL OPERATING, MAINTENANCE & REPLACEMENT COSTS					
Structural Concept Analysis Results:					
Mean Annual Volume Captured	71,853	Ac-Ft			Data specific to dam from Task 5 results for Medium 2 Future Climate Scenario
Number of Events per Year	0.8	EA			
Number of Hours per Year	47.3	Hrs			
Annual Power Cost:					
Electric Cost per kW-hr		kW-hr	$ 0.15		
Pneumatic Gate Pump	5	HP		$ 31	Annual Power Cost ($)=[($ kW-hr)(0.7457 kW/hp)(hp)(t)]/0.84 for the combined horsepower for all motors, provided by vendors.
Slide Gate Motor	300	HP		$ 1,890	
Annual Operation & Maintenance Cost	5%	%	$ 13,316,351	$ 1,679,818	Percentage of estimated construction costs (not including non-contract cost or contingencies)
Annual Replacement Cost (Pneumatically Actuated Gates):					
Useful Life	25	Yrs			Useful Life (25 years) provided by vendors.
Present Value of Replacement at 25 Years			$ 13,316,351		Annual Cost multiplier applied to Present Value of materials, installation and general conditions costs of Pneumatically Actuated Gates, only.
Annual Replacement Cost	0.0417			$ 554,989	
SUBTOTAL				**$ 2,236,728**	

Figure E-5. Cost Estimate for Morris Dam Structural Concept
(Sheet 3 of 4)

Identifier	Material or Rating	Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
		SUMMARY					
		TOTAL CONSTRUCTION COST				$ 37,470,215	
		ANNUAL CAPITAL COST				$ 1,561,656	
		ANNUAL OPERATING, MAINTENANCE & REPLACEMENT COSTS				$ 2,236,728	
		TOTAL ANNUAL COST				$ 3,798,384	
		TOTAL ANNUAL COST per Ac-Ft (Medium 2 Scenario)	71,853	Ac-Ft		$ 53	

NOTES:

1 - This cost estimate is conceptual in nature and is appropriate for strategic planning, business development, project screening, alternative scheme analysis, confirmation of technical and/or economic feasibility, and preliminary approval to proceed. While these estimates are appropriate for the appraisal level analysis required for the purposes of this document, they are not appropriate for budget authorization, funding agreements, bid, or tender offers. Accuracy ranges are considered to be -15% to -30% on the low side and +20% to +50% on the high side.

2 - All costs are presented in 2015 dollars.

3 - Taxes & contractor OH&P are included in the unit prices.

4 - Distributive Costs include but are not limited to additional planning efforts, investigations, analysis, regulatory compliance, acquisition, contract administration, construction management, inspection, etc.

5 - The RSMeans construction data was used to derive Feasibility, Design, Material Testing, Structural, and Seismic Testing percentages. The total materials and labor costs are used for the percent cost.

Figure E-5. Cost Estimate for Morris Dam Structural Concept
(Sheet 4 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
RAISED SPILLWAY COSTS (GATES)					
(W' X H') 14' X 14' Slide Gate	2	EA	$ 2,118,680	$ 4,237,360	Slide Gate Cost Estimates derived from USBR historical bids from the Expect Database Search at the Technical Service Center (TSC) in Denver. Rectangular and square gates are measured width by height (W' X H').
SUBTOTAL				**$ 4,237,360**	
PROGRAMMABLE LOGIC CONTROLLER COSTS					
PLC Controller (% of Gate Cost)	8%	%	$ 4,237,360	$ 338,989	Programmable Logic Controller (PLC) cost derived from Hydrotech and Obermeyer Hydro. PLC Cost are estimated at 8% of Rubber Dam or Pneumatically Actuated Gate (or Slide Gate) Costs.
SUBTOTAL				**$ 338,989**	
INSTALLATION COSTS					
14' X 14' Slide Gate	2	EA	$ 2,542,416	$ 5,084,832	Labor, equipment and installation costs for construction/installation of raised spillway gates derived from market research (Hydrotech and Obermeyer Hydro) and estimated at 60% of gate cost with multiplier of 2.0 to adjust for difficulty of site access and constricted spaces.
SUBTOTAL				**$ 5,084,832**	
GENERAL CONDITIONS					
SUBTOTAL	10%	%	$ 9,661,181	**$ 966,118**	Percentage of estimated construction costs

Figure E-6. Cost Estimate for Pacoima Dam Structural Concept
(Sheet 1 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
NON-CONTRACT COSTS					
Feasibility Studies, Surveys & Design Data	30%	%	$ 10,627,299	$ 3,188,190	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($1.0M/$4.0M)
Designs & Specifications	15%	%	$ 10,627,299	$ 1,594,095	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($0.5M/$2.0M)
Materials, Structural & Seismic Testing	5%	%	$ 10,627,299	$ 531,365	Percentage of estimated construction costs (including General Conditions)
Project Management	11%	%	$ 20,723,233	$ 2,279,556	Percentage of estimated construction costs & other non-contract costs
Legal	5%	%	$ 10,627,299	$ 531,365	Percentage of estimated construction costs (including General Conditions)
Permitting	30%	%	$ 10,627,299	$ 3,188,190	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($1.0M/$4.0M)
Construction Management	10%	%	$ 10,627,299	$ 1,062,730	Percentage of estimated construction costs (including General Conditions)
SUBTOTAL				**$ 12,375,490**	
CONTINGENCIES					
SUBTOTAL	30%	%	$ 23,002,788	**$ 6,900,837**	15% to 40% of estimated construction costs & non-contract costs
TOTAL CONSTRUCTION COST					
TOTAL				**$ 29,903,625**	

Figure E-6. Cost Estimate for Pacoima Dam Structural Concept
(Sheet 2 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
ANNUAL CAPITAL COST					
Project Life (n)	50	Yrs			
Federal Project Planning Rate (i)	3.375%	%			
Annual Cost	0.0417		$ 29,903,625	$ 1,246,301	Annual Cost ($) = Total Cost ($)*(i/(1-(1/(1+i)^n))
SUBTOTAL				**$ 1,246,301**	
ANNUAL OPERATING, MAINTENANCE & REPLACEMENT COSTS					
Structural Concept Analysis Results:					
Mean Annual Volume Captured	1,259	Ac-Ft			Data specific to dam from Task 5 results for Medium 2 Future Climate Scenario
Number of Events per Year	0.1	EA			
Number of Hours per Year	0.4	Hrs			
Annual Power Cost:					
Electric Cost per kW-hr		kW-hr	$ 0.15		
Pneumatic Gate Pump	5	HP		$ 0	Annual Power Cost ($)=[($ kW-hr)(0.7457 kW/hp)(hp)(t)]/0.84 for the combined horsepower for all motors, provided by vendors.
Slide Gate Motor	300	HP		$ 16	
Annual Operation & Maintenance Cost	5%	%	$ 10,627,299	$ 1,340,602	Percentage of estimated construction costs (not including non-contract cost or contingencies)
Annual Replacement Cost (Pneumatically Actuated Gates):					
Useful Life	25	Yrs			Useful Life (25 years) provided by vendors.
Present Value of Replacement at 25 Years			$ 10,627,299		Annual Cost multiplier applied to Present Value of materials, installation and general conditions costs of Pneumatically Actuated Gates, only.
Annual Replacement Cost	0.0417			$ 442,917	
SUBTOTAL				**$ 1,783,535**	

Figure E-6. Cost Estimate for Pacoima Dam Structural Concept
(Sheet 3 of 4)

Identifier	Material or Rating	Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
		SUMMARY					
		TOTAL CONSTRUCTION COST				$ 29,903,625	
		ANNUAL CAPITAL COST				$ 1,246,301	
		ANNUAL OPERATING, MAINTENANCE & REPLACEMENT COSTS				$ 1,783,535	
		TOTAL ANNUAL COST				$ 3,029,836	
		TOTAL ANNUAL COST per Ac-Ft (Medium 2 Scenario)	1,259	Ac-Ft		$ 2,407	

NOTES:

1 - This cost estimate is conceptual in nature and is appropriate for strategic planning, business development, project screening, alternative scheme analysis, confirmation of technical and/or economic feasibility, and preliminary approval to proceed. While these estimates are appropriate for the appraisal level analysis required for the purposes of this document, they are not appropriate for budget authorization, funding agreements, bid, or tender offers. Accuracy ranges are considered to be -15% to -30% on the low side and +20% to +50% on the high side.

2 - All costs are presented in 2015 dollars.

3 - Taxes & contractor OH&P are included in the unit prices.

4 - Distributive Costs include but are not limited to additional planning efforts, investigations, analysis, regulatory compliance, acquisition, contract administration, construction management, inspection, etc.

5 - The RSMeans construction data was used to derive Feasibility, Design, Material Testing, Structural, and Seismic Testing percentages. The total materials and labor costs are used for the percent cost.

Figure E-6. Cost Estimate for Pacoima Dam Structural Concept
(Sheet 4 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
RAISED SPILLWAY COSTS (GATES)					
6 Foot Tall Pneumatically Actuated Gate	175	LF	$ 3,000	$ 525,000	Pneumatic Gate Cost Estimates derived from market research (Obermeyer Hydro). Costs include clamping and anchoring, materials & equipment, shipping charges, and installation supervision.
SUBTOTAL				**$ 525,000**	
PROGRAMMABLE LOGIC CONTROLLER COSTS					
PLC Controller (% of Gate Cost)	8%	%	$ 525,000	$ 42,000	Programmable Logic Controller (PLC) cost derived from Hydrotech and Obermeyer Hydro. PLC Cost are estimated at 8% of Rubber Dam or Pneumatically Actuated Gate (or Slide Gate) Costs.
SUBTOTAL				**$ 42,000**	
INSTALLATION COSTS					
6 Foot Tall Raised Spillway	175	LF	$ 3,600	$ 630,000	Labor, equipment and installation costs for construction/installation of raised spillway gates derived from market research (Hydrotech and Obermeyer Hydro) and estimated at 60% of gate cost with multiplier of 2.0 to adjust for difficulty of site access and constricted spaces.
SUBTOTAL				**$ 630,000**	
GENERAL CONDITIONS					
SUBTOTAL	10%	%	$ 1,197,000	**$ 119,700**	Percentage of estimated construction costs

Figure E-7. Cost Estimate for Puddingstone Diversion Dam Structural Concept
(Sheet 1 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
NON-CONTRACT COSTS					
Feasibility Studies, Surveys & Design Data	1	LS		$ 1,000,000	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($1.0M/$4.0M)
Designs & Specifications	1	LS		$ 500,000	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($0.5M/$2.0M)
Materials, Structural & Seismic Testing	5%	%	$ 1,316,700	$ 65,835	Percentage of estimated construction costs (including General Conditions)
Project Management	11%	%	$ 4,080,040	$ 448,804	Percentage of estimated construction costs & other non-contract costs
Legal	5%	%	$ 1,316,700	$ 65,835	Percentage of estimated construction costs (including General Conditions)
Permitting	1	LS		$ 1,000,000	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($1.0M/$4.0M)
Construction Management	10%	%	$ 1,316,700	$ 131,670	Percentage of estimated construction costs (including General Conditions)
SUBTOTAL				**$ 3,212,144**	
CONTINGENCIES					
SUBTOTAL	30%	%	$ 4,528,844	**$ 1,358,653**	15% to 40% of estimated construction costs & non-contract costs
TOTAL CONSTRUCTION COST					
TOTAL				**$ 5,887,498**	

Figure E-7. Cost Estimate for Puddingstone Diversion Dam Structural Concept
(Sheet 2 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
ANNUAL CAPITAL COST					
Project Life (n)	50	Yrs			
Federal Project Planning Rate (i)	3.375%	%			
Annual Cost	0.0417		$ 5,887,498	$ 245,375	Annual Cost ($) = Total Cost ($)*(i/(1-(1/(1+i)^n))
SUBTOTAL				**$ 245,375**	
ANNUAL OPERATING, MAINTENANCE & REPLACEMENT COSTS					
Structural Concept Analysis Results:					
Mean Annual Volume Captured	888	Ac-Ft			Data specific to dam from Task 5 results for Medium 2 Future Climate Scenario
Number of Events per Year	0.0	EA			
Number of Hours per Year	0.0	Hrs			
Annual Power Cost:					
Electric Cost per kW-hr		kW-hr	$ 0.15		
Pneumatic Gate Pump	5	HP		$ -	Annual Power Cost ($)=[($ kW-hr)(0.7457 kW/hp)(hp)(t)]/0.84 for the combined horsepower for all motors, provided by vendors.
Slide Gate Motor	300	HP		$ -	
Annual Operation & Maintenance Cost	5%	%	$ 1,316,700	$ 166,098	Percentage of estimated construction costs (not including non-contract cost or contingencies)
Annual Replacement Cost (Pneumatically Actuated Gates):					
Useful Life	25	Yrs			Useful Life (25 years) provided by vendors.
Present Value of Replacement at 25 Years			$ 1,316,700		Annual Cost multiplier applied to Present Value of materials, installation and general conditions costs of Pneumatically Actuated Gates, only.
Annual Replacement Cost	0.0417			$ 54,876	
SUBTOTAL				**$ 220,974**	

Figure E-7. Cost Estimate for Puddingstone Diversion Dam Structural Concept
(Sheet 3 of 4)

Identifier	Material or Rating	Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
		SUMMARY					
		TOTAL CONSTRUCTION COST				$ 5,887,498	
		ANNUAL CAPITAL COST				$ 245,375	
		ANNUAL OPERATING, MAINTENANCE & REPLACEMENT COSTS				$ 220,974	
		TOTAL ANNUAL COST				$ 466,349	
		TOTAL ANNUAL COST per Ac-Ft (Medium 2 Scenario)	888	Ac-Ft		$ 525	

NOTES:

1 - This cost estimate is conceptual in nature and is appropriate for strategic planning, business development, project screening, alternative scheme analysis, confirmation of technical and/or economic feasibility, and preliminary approval to proceed. While these estimates are appropriate for the appraisal level analysis required for the purposes of this document, they are not appropriate for budget authorization, funding agreements, bid, or tender offers. Accuracy ranges are considered to be -15% to -30% on the low side and +20% to +50% on the high side.

2 - All costs are presented in 2015 dollars.

3 - Taxes & contractor OH&P are included in the unit prices.

4 - Distributive Costs include but are not limited to additional planning efforts, investigations, analysis, regulatory compliance, acquisition, contract administration, construction management, inspection, etc.

5 - The RSMeans construction data was used to derive Feasibility, Design, Material Testing, Structural, and Seismic Testing percentages. The total materials and labor costs are used for the percent cost.

Figure E-7. Cost Estimate for Puddingstone Diversion Dam Structural Concept
(Sheet 4 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
RAISED SPILLWAY COSTS (GATES)					
11 Foot Tall Pneumatically Actuated Gate	135	LF	$ 8,250	$ 1,113,750	Pneumatic Gate Cost Estimates derived from market research (Obermeyer Hydro). Costs include clamping and anchoring, materials & equipment, shipping charges, and installation supervision.
19 Foot Tall Pneumatically Actuated Gate	35	LF	$ 22,800	$ 798,000	
SUBTOTAL				**$ 1,911,750**	
PROGRAMMABLE LOGIC CONTROLLER COSTS					
PLC Controller (% of Gate Cost)	8%	%	$ 1,911,750	$ 152,940	Programmable Logic Controller (PLC) cost derived from Hydrotech and Obermeyer Hydro. PLC Cost are estimated at 8% of Rubber Dam or Pneumatically Actuated Gate (or Slide Gate) Costs.
SUBTOTAL				**$ 152,940**	
INSTALLATION COSTS					
11 Foot Tall Raised Spillway	135	LF	$ 9,900	$ 1,336,500	Labor, equipment and installation costs for construction/installation of raised spillway gates derived from market research (Hydrotech and Obermeyer Hydro) and estimated at 60% of gate cost with multiplier of 2.0 to adjust for difficulty of site access and constricted spaces.
19 Foot Tall Raised Spillway	35	LF	$ 27,360	$ 957,600	
SUBTOTAL				**$ 2,294,100**	
GENERAL CONDITIONS					
SUBTOTAL	10%	%	$ 4,358,790	**$ 435,879**	Percentage of estimated construction costs

Figure E-8. Cost Estimate for San Dimas Dam Structural Concept
(Sheet 1 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
NON-CONTRACT COSTS					
Feasibility Studies, Surveys & Design Data	30%	%	$ 4,794,669	$ 1,438,401	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($1.0M/$4.0M)
Designs & Specifications	15%	%	$ 4,794,669	$ 719,200	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($0.5M/$2.0M)
Materials, Structural & Seismic Testing	5%	%	$ 4,794,669	$ 239,733	Percentage of estimated construction costs (including General Conditions)
Project Management	11%	%	$ 9,349,605	$ 1,028,457	Percentage of estimated construction costs & other non-contract costs
Legal	5%	%	$ 4,794,669	$ 239,733	Percentage of estimated construction costs (including General Conditions)
Permitting	30%	%	$ 4,794,669	$ 1,438,401	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($1.0M/$4.0M)
Construction Management	10%	%	$ 4,794,669	$ 479,467	Percentage of estimated construction costs (including General Conditions)
SUBTOTAL				**$ 5,583,392**	
CONTINGENCIES					
SUBTOTAL	30%	%	$ 10,378,061	**$ 3,113,418**	15% to 40% of estimated construction costs & non-contract costs
TOTAL CONSTRUCTION COST					
TOTAL				**$ 13,491,479**	

Figure E-8. Cost Estimate for San Dimas Dam Structural Concept
(Sheet 2 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
ANNUAL CAPITAL COST					
Project Life (n)	50	Yrs			
Federal Project Planning Rate (i)	3.375%	%			
Annual Cost	0.0417		$ 13,491,479	$ 562,288	Annual Cost ($) = Total Cost ($)*(i/(1-(1/(1+i)^n))
SUBTOTAL				**$ 562,288**	
ANNUAL OPERATING, MAINTENANCE & REPLACEMENT COSTS					
Structural Concept Analysis Results:					
Mean Annual Volume Captured	2,041	Ac-Ft			Data specific to dam from Task 5 results for Medium 2 Future Climate Scenario
Number of Events per Year	0.1	EA			
Number of Hours per Year	0.2	Hrs			
Annual Power Cost:					
Electric Cost per kW-hr		kW-hr	$ 0.15		
Pneumatic Gate Pump	5	HP		$ 0	Annual Power Cost ($)=[($ kW-hr)(0.7457 kW/hp)(hp)(t)]/0.84 for the combined horsepower for all motors, provided by vendors.
Slide Gate Motor	300	HP		$ 8	
Annual Operation & Maintenance Cost	5%	%	$ 4,794,669	$ 604,833	Percentage of estimated construction costs (not including non-contract cost or contingencies)
Annual Replacement Cost (Pneumatically Actuated Gates):					
Useful Life	25	Yrs			Useful Life (25 years) provided by vendors.
Present Value of Replacement at 25 Years			$ 4,794,669		Annual Cost multiplier applied to Present Value of materials, installation and general conditions costs of Pneumatically Actuated Gates, only.
Annual Replacement Cost	0.0417			$ 199,829	
SUBTOTAL				**$ 804,670**	

Figure E-8. Cost Estimate for San Dimas Dam Structural Concept
(Sheet 3 of 4)

Identifier	Material or Rating	Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
		SUMMARY					
		TOTAL CONSTRUCTION COST				$ 13,491,479	
		ANNUAL CAPITAL COST				$ 562,288	
		ANNUAL OPERATING, MAINTENANCE & REPLACEMENT COSTS				$ 804,670	
		TOTAL ANNUAL COST				$ 1,366,958	
		TOTAL ANNUAL COST per Ac-Ft (Medium 2 Scenario)	2,041	Ac-Ft		$ 670	

NOTES:

1 - This cost estimate is conceptual in nature and is appropriate for strategic planning, business development, project screening, alternative scheme analysis, confirmation of technical and/or economic feasibility, and preliminary approval to proceed. While these estimates are appropriate for the appraisal level analysis required for the purposes of this document, they are not appropriate for budget authorization, funding agreements, bid, or tender offers. Accuracy ranges are considered to be -15% to -30% on the low side and +20% to +50% on the high side.

2 - All costs are presented in 2015 dollars.

3 - Taxes & contractor OH&P are included in the unit prices.

4 - Distributive Costs include but are not limited to additional planning efforts, investigations, analysis, regulatory compliance, acquisition, contract administration, construction management, inspection, etc.

5 - The RSMeans construction data was used to derive Feasibility, Design, Material Testing, Structural, and Seismic Testing percentages. The total materials and labor costs are used for the percent cost.

Figure E-8. Cost Estimate for San Dimas Dam Structural Concept
(Sheet 4 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
RAISED SPILLWAY COSTS (GATES)					
25 Foot Tall Pneumatically Actuated Gate	456	LF	$ 36,250	$ 16,530,000	Pneumatic Gate Cost Estimates derived from market research (Obermeyer Hydro). Costs include clamping and anchoring, materials & equipment, shipping charges, and installation supervision.
SUBTOTAL				**$ 16,530,000**	
PROGRAMMABLE LOGIC CONTROLLER COSTS					
PLC Controller (% of Gate Cost)	8%	%	$ 16,530,000	$ 1,322,400	Programmable Logic Controller (PLC) cost derived from Hydrotech and Obermeyer Hydro. PLC Cost are estimated at 8% of Rubber Dam or Pneumatically Actuated Gate (or Slide Gate) Costs.
SUBTOTAL				**$ 1,322,400**	
INSTALLATION COSTS					
25 Foot Tall Raised Spillway	456	LF	$ 43,500	$ 19,836,000	Labor, equipment and installation costs for construction/installation of raised spillway gates derived from market research (Hydrotech and Obermeyer Hydro) and estimated at 60% of gate cost with multiplier of 2.0 to adjust for difficulty of site access and constricted spaces.
SUBTOTAL				**$ 19,836,000**	
GENERAL CONDITIONS					
SUBTOTAL	10%	%	$ 37,688,400	**$ 3,768,840**	Percentage of estimated construction costs

Figure E-9. Cost Estimate for San Gabriel Dam Structural Concept
(Sheet 1 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
NON-CONTRACT COSTS					
Feasibility Studies, Surveys & Design Data	1	LS		$ 4,000,000	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($1.0M/$4.0M)
Designs & Specifications	1	LS		$ 2,000,000	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($0.5M/$2.0M)
Materials, Structural & Seismic Testing	5%	%	$ 41,457,240	$ 2,072,862	Percentage of estimated construction costs (including General Conditions)
Project Management	11%	%	$ 59,748,688	$ 6,572,356	Percentage of estimated construction costs & other non-contract costs
Legal	5%	%	$ 41,457,240	$ 2,072,862	Percentage of estimated construction costs (including General Conditions)
Permitting	1	LS		$ 4,000,000	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($1.0M/$4.0M)
Construction Management	10%	%	$ 41,457,240	$ 4,145,724	Percentage of estimated construction costs (including General Conditions)
SUBTOTAL				**$ 24,863,804**	
CONTINGENCIES					
SUBTOTAL	30%	%	$ 66,321,044	**$ 19,896,313**	15% to 40% of estimated construction costs & non-contract costs
TOTAL CONSTRUCTION COST					
TOTAL				**$ 86,217,357**	

Figure E-9. Cost Estimate for San Gabriel Dam Structural Concept
(Sheet 2 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
ANNUAL CAPITAL COST					
Project Life (n)	50	Yrs			
Federal Project Planning Rate (i)	3.375%	%			
Annual Cost	0.0417		$ 86,217,357	$ 3,593,303	Annual Cost ($) = Total Cost ($)*(i/(1-(1/(1+i)^n))
SUBTOTAL				**$ 3,593,303**	
ANNUAL OPERATING, MAINTENANCE & REPLACEMENT COSTS					
Structural Concept Analysis Results:					
Mean Annual Volume Captured	39,404	Ac-Ft			Data specific to dam from Task 5 results for Medium 2 Future Climate Scenario
Number of Events per Year	0.3	EA			
Number of Hours per Year	1.7	Hrs			
Annual Power Cost:					
Electric Cost per kW-hr		kW-hr	$ 0.15		
Pneumatic Gate Pump	5	HP		$ 1	Annual Power Cost ($)=[($ kW-hr)(0.7457 kW/hp)(hp)(t)]/0.84 for the combined horsepower for all motors, provided by vendors.
Slide Gate Motor	300	HP		$ 68	
Annual Operation & Maintenance Cost	5%	%	$ 41,457,240	$ 5,229,707	Percentage of estimated construction costs (not including non-contract cost or contingencies)
Annual Replacement Cost (Pneumatically Actuated Gates):					
Useful Life	25	Yrs			Useful Life (25 years) provided by vendors.
Present Value of Replacement at 25 Years			$ 41,457,240		Annual Cost multiplier applied to Present Value of materials, installation and general conditions costs of Pneumatically Actuated Gates, only.
Annual Replacement Cost	0.0417			$ 1,727,824	
SUBTOTAL				**$ 6,957,600**	

Figure E-9. Cost Estimate for San Gabriel Dam Structural Concept
(Sheet 3 of 4)

Identifier	Material or Rating	Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
		SUMMARY					
		TOTAL CONSTRUCTION COST				$ 86,217,357	
		ANNUAL CAPITAL COST				$ 3,593,303	
		ANNUAL OPERATING, MAINTENANCE & REPLACEMENT COSTS				$ 6,957,600	
		TOTAL ANNUAL COST				$ 10,550,903	
		TOTAL ANNUAL COST per Ac-Ft (Medium 2 Scenario)	39,404	Ac-Ft		$ 268	

NOTES:

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2 - All costs are presented in 2015 dollars.

3 - Taxes & contractor OH&P are included in the unit prices.

4 - Distributive Costs include but are not limited to additional planning efforts, investigations, analysis, regulatory compliance, acquisition, contract administration, construction management, inspection, etc.

5 - The RSMeans construction data was used to derive Feasibility, Design, Material Testing, Structural, and Seismic Testing percentages. The total materials and labor costs are used for the percent cost.

Figure E-9. Cost Estimate for San Gabriel Dam Structural Concept
(Sheet 4 of 4)

E-1 Storage Solutions – LACFCD Santa Anita Dam

E-1.1 Structural Concept

As discussed in Section 2.4.3.1 of the report (Task 5 Infrastructure & Operations Concepts Report of the Los Angeles Basin Stormwater Conservation Study), Santa Anita Dam was recently modified to allow uncontrolled releases when reservoir elevation is above the seismically safe water elevation. A structural concept was developed for Santa Anita Dam that does not account for seismic constraints. Buttressing the dam would be necessary to address those seismic issues and allow the structural concept to be implemented. Therefore, the structural concept for Santa Anita Dam is excluded from subsequent discussions in the report of the nine other LACFCD dams for which structural concepts were developed.

The structural concept for Santa Anita Dam was developed using the same approach used for the nine other LACFCD dams described in Section 2.4.3.1 of the report; and the same modeling approach was used, as well. The structural concept includes pneumatic gate at a covered channel spillway and a slide gate on the outlet of a semi-circular weir outlet, to allow stormwater to be captured at elevations above the spillway crest.

E-1.2 Results

A summary of the results for Santa Anita Dam for each of the four scenarios analyzed in Task 5 is presented in Table E-14 below. The Task 5 results for the key metrics are presented Santa Anita Dam alongside the corresponding Task 4 results for ease of comparison. Selected results are also provided for the Historical period for comparison.

E-1.3 Capital and Operational Costs

A cost estimate was developed for the structural concept for Santa Anita Dam by identifying major characteristics of the spillway facilities, including spillway types, dimensions and operational controls.

E-1.4 Other Project Characteristics and Benefits

Like the structural concepts for the other LACFCD dams, the structural concept for Santa Anita Dam is climate resilient. If (or when) buttressing the dam is implemented to remedy the seismic issues, the structural concept could be implemented to increase the capture and storage of stormwater. Like the structural concepts for the other LACFCD dams, this concept also offers an opportunity for increased flood risk management. These concepts may also provide a water quality benefit. However, the combined cost of buttressing Santa Anita Dam and implementation of the structural concept would be extraordinarily high in comparison with the costs of the structural concepts for other LACFCD dams, particularly in light of the relatively small volume of additional stormwater capture at this dam (431 AFY for the Mid 2 scenario).

Table E-14. Santa Anita Dam Structural Concept Results

Scenario	Mean Annual Inflow (ac-ft)		Mean Annual Volume Captured (ac-ft)		Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio		Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Events	
	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
Historical	3,566	NA	3,312	NA	250	NA	92.9%	NA	NA	NA	0.40	NA
High 1	8,641	8,641	6,775	7,897	1,862	740	78.4%	91.4%	-14.5%	-1.5%	2.38	1.45
Medium 2	5,238	5,238	4,589	5,020	644	213	87.6%	95.8%	-5.3%	3.0%	1.15	0.52
Low 1	2,669	2,669	2,382	2,528	282	136	89.2%	94.7%	-3.6%	1.8%	0.49	0.29
Low 2	4,306	4,306	3,919	4,164	382	137	91.0%	96.7%	-1.8%	3.8%	0.69	0.31

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
RAISED SPILLWAY COSTS (GATES)					
					Pneumatic Gate Cost Estimates derived from market research (Obermeyer Hydro). Costs include clamping and anchoring, materials & equipment, shipping charges, and installation supervision.
9 Foot Tall Pneumatically Actuated Gate	27	LF	$ 5,850	$ 157,950	
(W' X H') 8' X 8' Slide Gate	1	EA	$ 691,820	$ 691,820	
SUBTOTAL				**$ 849,770**	Slide Gate Cost Estimates derived from USBR historical bids from the Expect Database Search at the Technical Service Center (TSC) in Denver. Rectangular and square gates are measured width by height (W' X H').
PROGRAMMABLE LOGIC CONTROLLER COSTS					
PLC Controller (% of Gate Cost)	8%	%	$ 849,770	$ 67,982	Programmable Logic Controller (PLC) cost derived from Hydrotech and Obermeyer Hydro. PLC Cost are estimated at 8% of Rubber Dam or Pneumatically Actuated Gate (or Slide Gate) Costs.
SUBTOTAL				**$ 67,982**	
INSTALLATION COSTS					
9 Foot Tall Raised Spillway	27	LF	$ 7,020	$ 189,540	Labor, equipment and installation costs for construction/installation of raised spillway gates derived from market research (Hydrotech and Obermeyer Hydro) and estimated at 60% of gate cost with multiplier of 2.0 to adjust for difficulty of site access and constricted spaces.
8' X 8' Slide Gate	1	EA	$ 830,184	$ 830,184	
SUBTOTAL				**$ 1,019,724**	
GENERAL CONDITIONS					
SUBTOTAL	10%	%	$ 1,937,476	**$ 193,748**	Percentage of estimated construction costs

Figure E-10. Cost Estimate for Santa Anita Dam Structural Concept
(Sheet 1 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
NON-CONTRACT COSTS					
Feasibility Studies, Surveys & Design Data	1	LS		$ 1,000,000	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($1.0M/$4.0M)
Designs & Specifications	1	LS		$ 500,000	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($0.5M/$2.0M)
Materials, Structural & Seismic Testing	5%	%	$ 2,131,223	$ 106,561	Percentage of estimated construction costs (including General Conditions)
Project Management	11%	%	$ 5,057,468	$ 556,321	Percentage of estimated construction costs & other non-contract costs
Legal	5%	%	$ 2,131,223	$ 106,561	Percentage of estimated construction costs (including General Conditions)
Permitting	1	LS		$ 1,000,000	Percentage of estimated construction costs (including General Conditions) with min./max. LS cost ($1.0M/$4.0M)
Construction Management	10%	%	$ 2,131,223	$ 213,122	Percentage of estimated construction costs (including General Conditions)
SUBTOTAL				**$ 3,482,566**	
CONTINGENCIES					
SUBTOTAL	30%	%	$ 5,613,789	**$ 1,684,137**	15% to 40% of estimated construction costs & non-contract costs
TOTAL CONSTRUCTION COST					
TOTAL				**$ 7,297,926**	

Figure E-10. Cost Estimate for Santa Anita Dam Structural Concept
(Sheet 2 of 4)

Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
ANNUAL CAPITAL COST					
Project Life (n)	50	Yrs			
Federal Project Planning Rate (i)	3.375%	%			
Annual Cost	0.0417		$ 7,297,926	$ 304,158	Annual Cost ($) = Total Cost ($)*(i/(1-(1/(1+i)^n))
SUBTOTAL				**$ 304,158**	
ANNUAL OPERATING, MAINTENANCE & REPLACEMENT COSTS					
Structural Concept Analysis Results:					
Mean Annual Volume Captured	431	Ac-Ft			Data specific to dam from Task 5 results for Medium 2 Future Climate Scenario
Number of Events per Year	0.5	EA			
Number of Hours per Year	0.9	Hrs			
Annual Power Cost:					
Electric Cost per kW-hr		kW-hr	$ 0.15		
Pneumatic Gate Pump	5	HP		$ 1	Annual Power Cost ($)=[($ kW-hr)(0.7457 kW/hp)(hp)(t)]/0.84 for the combined horsepower for all motors, provided by vendors.
Slide Gate Motor	300	HP		$ 36	
Annual Operation & Maintenance Cost	5%	%	$ 2,131,223	$ 268,847	Percentage of estimated construction costs (not including non-contract cost or contingencies)
Annual Replacement Cost (Pneumatically Actuated Gates):					
Useful Life	25	Yrs			Useful Life (25 years) provided by vendors.
Present Value of Replacement at 25 Years			$ 2,131,223		Annual Cost multiplier applied to Present Value of materials, installation and general conditions costs of Pneumatically Actuated Gates, only.
Annual Replacement Cost	0.0417			$ 88,824	
SUBTOTAL				**$ 357,708**	

Figure E-10. Cost Estimate for Santa Anita Dam Structural Concept
(Sheet 3 of 4)

Identifier	Material or Rating	Description	Quantity	Units	Unit Cost $/Unit	Estimated Cost	Notes
		SUMMARY					
		TOTAL CONSTRUCTION COST				$ 7,297,926	
		ANNUAL CAPITAL COST				$ 304,158	
		ANNUAL OPERATING, MAINTENANCE & REPLACEMENT COSTS				$ 357,708	
		TOTAL ANNUAL COST				$ 661,865	
		TOTAL ANNUAL COST per Ac-Ft (Medium 2 Scenario)	431	Ac-Ft		$ 1,536	

NOTES:

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2 - All costs are presented in 2015 dollars.

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4 - Distributive Costs include but are not limited to additional planning efforts, investigations, analysis, regulatory compliance, acquisition, contract administration, construction management, inspection, etc.

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Figure E-10. Cost Estimate for Santa Anita Dam Structural Concept
(Sheet 4 of 4)