INTEGRATED FLOOD MANAGEMENT PLANNING

SAN DIEGO
Integrated Regional Water Management

APRIL 2013

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1 Introduction

1.1 Background

Flooding is a chronic problem that is experienced throughout the San Diego County region, even with a semi-arid climate, which can result in significant losses and economic damages. The San Diego County region is comprised of 11 watershed units which are unique in their hydrologic responses, as well as their floodplain functions, which lend the flood management planning assessments to a watershed approach. However, flood and stormwater runoff generated from watersheds can also represent a valuable water resource that can be managed successfully rather than just being typically viewed as a hazard. This report has been prepared as a companion document to support the addition of multi-benefit floodplain management into the *San Diego Integrated Regional Water Management (IRWM) Plan Update* as a key water resource element in regional water planning. Floodplain management and flood hazard mitigation is extremely complex with multiple issues and different watershed responses throughout the region to storm/rainfall events. There is not a one size fits all solution, but comprehensive planning is required on a watershed basis to develop an implementable system-wide answer. **Integrated Flood Management (IFM)** combines land and water resources development in a floodplain, within the context of IRWM with a view to maximize the efficient use of the floodplains and minimize loss of property and life.

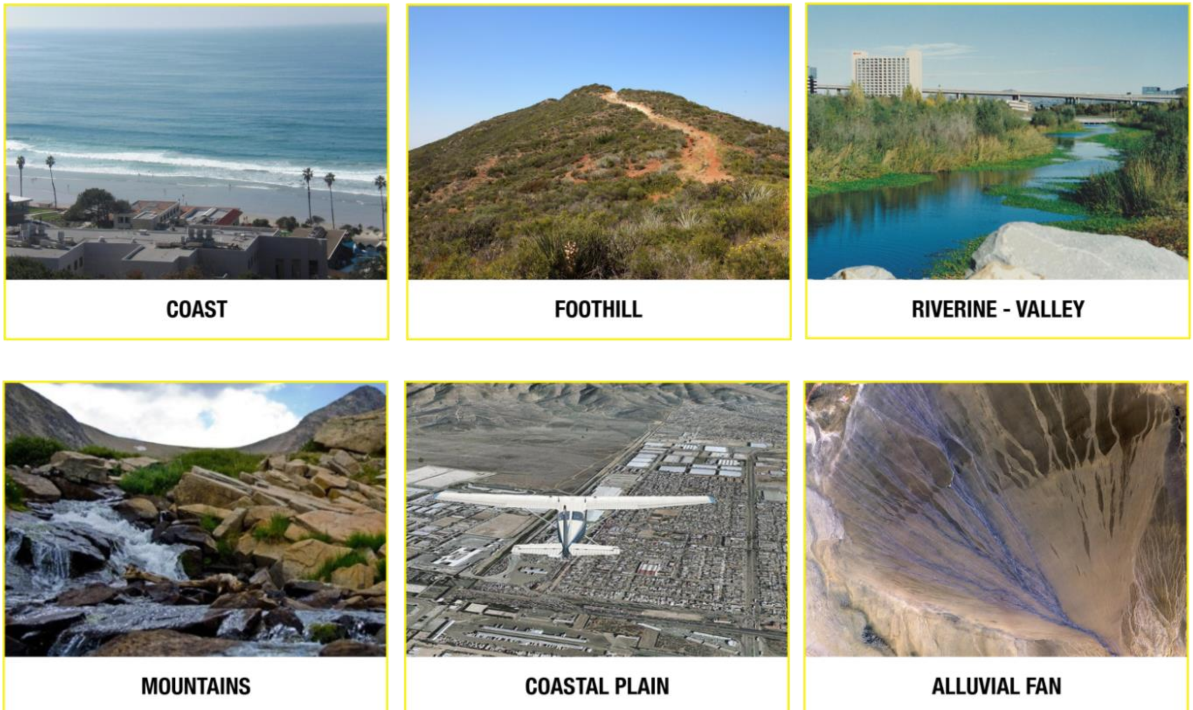

Figure 1-1: San Diego region has a range of different type of flood hazards and associated watershed response based on watershed characteristics

This regional study is not the traditional watershed/flood management planning document since it does not provide specific regional flood mitigation projects as a conventional masterplan would provide. However, the report is intended as a "guidance document" to facilitate an integrated water resources approach to flood management. This assessment is based on readily available information to perform planning level risk assessment in order to provide high level recommendations. In addition, it defines general applicable strategies/approaches, as well as provides planning level tools, to guide flood management decision making on a watershed basis. Watershed management embraces a wide range of watershed considerations and specialized control strategies to preserve the hydrologic functions of the watershed and corresponding water resources. The approach embraces an understanding that with responsible planning of the watershed to take care in protecting the natural integrity of the floodplain and to ensure the maximum value will be realized from protecting key natural resources. The focus of integrated planning is on balancing the community flood management needs with the environmental constraints and watershed resources which will ensure an acceptable solution with the flexibility to adapt to future changes. A sustainable flood and water management approach would recognize the:

- Interconnection of flood risk management actions within broader water resources management, ecosystems, and land use planning
- Value of coordinating across geographic and agency boundaries
- Need to evaluate opportunities and potential impacts from a system perspective

- Importance of environmental stewardship and sustainability
- Need for system flexibility and resiliency in response to changing conditions, such as climate change and population growth

1.2 Integrated Flood Management Approach

IFM is an approach that varies from traditional flood protection with a focus on maximizing the efficient use/net benefit of a floodplain while promoting public safety. IFM is a process that promotes an integrated, rather than fragmented, approach to flood management, and that recognizes the connection of flood management actions to water resources management, land use planning, environmental stewardship, and sustainability. Flood risk management requires the holistic development of a long-term strategy, balancing current needs with future sustainability. Incorporating sustainability means looking for way of working towards identifying opportunities to enhance the performance of a watershed system as a whole.

An integrated strategy usually requires the use of both structural and non-structural solutions. Depending on the characteristic of an individual watershed, various resource management strategies may be used such as: land stewardship, conjunctive water management, conveyance, ecosystem restoration, forest management, land use planning and management, surface storage, urban runoff management, and watershed management. It is important to recognize the level and characteristics of existing risk and likely future changes in risk. Integrated flood management also includes the recognition that flood risk can never be entirely eliminated and that resilience to flood risk can include enhancing the capacity of people and communities to adapt to and cope with flooding.

The benefit of using a regional and system-wide approach is that it takes into account a wide range of causes and effects, reducing potential negative unintended consequences in nearby regions. Regional approaches allow for the best use of public resources by increasing the number of issues considered. This also promotes system flexibility and resiliency by developing solutions that provide the best benefit to the overall system or region. In contrast, localized and narrowly focused projects may solve an issue or problem while transferring the problem up or downstream. One of the benefits of using an IFM approach is the potential to access funding sources that might not have been available to single-benefit projects. This can lead to achieving sufficient and stable funding for long-term flood management.

1.3 General Regional Flood Management Issues

Infrastructure project development, implementation, and operation constraints have changed as public values have evolved. Today, infrastructure projects, including flood management projects, face increased stakeholder involvement, land use constraints, changing regulatory requirements, and new environmental considerations. These issues have led to an increase in the cost of flood management. Addressing these issues will require a move away from the traditional approach to developing flood management projects. Many of these issues were identified during the stakeholder meetings that were conducted as part of the flood management study process. The stakeholders cited specific examples of flood management problems and roadblocks associated with implementation. Many of these same issues have also been encountered by other communities which have been identified during the statewide Flood Management Program Study (see *Section 1.4*).

Specific issues impacting flood management projects include the following:

- **Projects require extensive stakeholder involvement, which increases project planning costs.** Stakeholders have become more educated about project development and environmental requirements. Successful projects require proper engagement of a diverse set of stakeholders. The cost associated with stakeholder engagement activities must be included in planning and implementation costs.
- **Flood management responsibility is fragmented**. Responsibilities for planning, administering, financing, and maintaining flood management facilities and emergency response programs are usually spread among several agencies or between departments within a large agency. There is not a centralized agency coordinating all the flood management activities within the County which make San Diego unique. Flood management responsibilities are often spread out within and between these agencies.
- **Different methodologies and inadequate data make risk assessment complex and costly to complete.** Insufficient data on the specifics of flood hazards in many areas makes it difficult to assess the level of problems. Much of the available data is based on FEMA flood hazard mapping, but this does not identify the chronic flood problems which current on a frequent basis and on smaller storm events other than a 100-year event. In addition, the data related to existing drainage facilities and the original design capacities is not readily available in digital format which makes it difficult to perform rapid assessments at a regional scale.
- **Land use decisions may not adequately prioritize public safety.** Uninformed residents and policymakers can make decisions that inadvertently put people and property at increased risk. In some cases, providing adequate space for flood management facilities to meet existing and future needs during the development approval process would reduce flooding impacts. Internal and intra-agency coordination is important when local agencies make development decisions. Improving coordination within and between agencies could inform the potential land use decisions to considerations in General Plans, flood managers are not always included in land use discussions.
- **Delayed permit approvals and complex permit requirements are obstacles to flood risk reduction.** Many agencies wait years for permits, resulting in poorly maintained projects and missed funding opportunities for new projects. Often, agencies face conflicting or confusing requirements regarding project permits. Also, regulatory requirements to renew existing permits or obtain new permits frequently require extensive mitigation. This mitigation can greatly increase project costs and cause project delays.
- **Flood management projects are not prioritized from a "watershed" system-wide or multi-benefit perspective.** State and Federal flood management funding has traditionally been provided to local projects by analyzing a narrowly focused and localized set of

benefits. In addition, funding levels for flood management are often set without regard to a system-wide prioritization of needs.

- **Flood risk funding as well as long term funding for operations and maintenance.** Funding for flood projects is based upon the potential that a significant flood will occur, rather than providing for day-to-day flood management needs. Inadequate funding for flood management maintenance, operations, and improvements makes flood risk reduction difficult or impossible for many local agencies. Agencies at all levels are facing funding constraints. Local agency funding is often based on county general funds, which have been impacted by the economic downturn. Reductions in Federal funding have occurred, resulting in potential reductions in funding levels for flood risk studies and projects.

1.4 California Statewide Flood Management Program Study

California Department of Water Resources (DWR) has recently completed the initial phase of a Statewide flood management planning study which is similar in many respects to the flood management planning study being development for the San Diego IRWM. The database development for this study mirrored the Statewide information process and resulted in the similar database, as well as inventory issues. The results of the initial Statewide study are available to the public. This report, *California's Flood Future: Recommendations for Managing the State's Flood Risk* (Flood Future Report) presents an overview of the flood threats facing the state, approaches for reducing flood risk, and recommendations for managing California's flood risk. The Flood Future Report is the first statewide report to be developed through collaboration between DWR and the United States Army Corps of Engineers (USACE). This report is the first product of DWR's State Flood Management Planning (SFMP) Program. The SFMP Program was developed under the FloodSAFE Initiative to expand the focus of California's flood management planning statewide in compliance with Public Resources Code (PRC) Section 75032. The SFMP Program was funded under Proposition 84 as part of the DWR FloodSAFE Initiative and IRWM Program.

The first step of the Flood Future Report was accomplished by interviewing representatives of 142 local flood management agencies throughout the state, and asking them to define and characterize the type and location of existing and future flood threats and issues in their local area. Agencies were interviewed regarding existing flood infrastructure, planned flood management projects (including IRWM projects with flood benefits), and flood management challenges and opportunities facing the agency. As a result of the meetings with local agencies, more than 3,800 different documents related to flood management in California were collected. A review of these documents, combined with information from interviews, formed the foundation to explore approaches that address the array of flood risk management issues identified. Using this information, an analysis of exposure to flood hazards was completed to expand the understanding of the exposure threat to flooding statewide. This analysis identified population, structures, crops, and endangered species exposed to flood hazards statewide. Once a basic understanding of the flood threats in California was attained, different approaches to flood management, including structural and nonstructural measures and IWM. Financing and institutional strategies also were explored based on past funding and new, innovative ideas. Finally, an appropriate path forward to manage California's flood risk was identified by formulating technical, legislative, policy, financial, and other recommendations. These recommendations were synthesized from information developed as part of the SFMP Program, including suggestions from flood experts, previous flood management studies, and local agency recommendations.

1.5 Work Program and Objectives

The object of this planning study is to develop planning level tools and processes and the guidance framework/structure for regional collaborative planning of watershed and flood risk management. Developing solutions for effectively managing flood risks requires a watershed approach which allows holistic strategies that can also address "beneficial uses" as well as watershed functions. The goal is to provide the forum and guidelines to allow for improved regional flood management planning on a watershed basis, as well as defining the global strategies, to form the foundation in developing prospective projects for funding. The steps used in this planning study include the following:

1. **Watershed / Floodplain Managers Stakeholder Involvement -** The actual planning process involves the flood managers and stakeholders to assist shaping and defining the scope of the program as well as setting the goals/objectives. The stakeholders provide the local knowledge/information and identify the different flood risks, issues of concerns, opportunities, constraints, and propose different global management strategies that can be used to guide implementation of different projects in the future. Stakeholder workshops were held on June 26, 2012 and December 4, 2012 to provide the forum for developing an understanding of the existing problems and focusing on the critical issues.

2. **Understanding Problems / Flood Risks** – A key element in developing a management plan is first understanding the actual problems that require solutions, specifically defining the flood risks, level of risks, priorities, and the associated sources of flooding for those risks. These flood risk include the existing flooding risks as well as future risks in expected growth areas in the different watershed.

3. **Define Watershed Goals / Objectives** – It is important to develop the watershed goals and objectives of the plan since this defines the measure to assess the different potential management strategies.

4. **Identify Global Opportunities / Constraints** – The opportunities and constraints are the next step required in order to develop strategies. The opportunities will help define the types of potential strategies and areas where different water resources may be managed collectively. In addition, this allows effectively addressing the multiple functions within the watershed by specifically focusing on **"beneficial uses"** such as groundwater recharge, recreation, habitat, and water supply. Understanding the different constraints will also shape the management strategies in order to ensure success. This assessment can be performed at different levels or scales (i.e. global, regional, watershed, or even reach specific) corresponding to the scale of the different strategies.

5. **Identify Possible Global Management Strategies/Approaches** - The different general categories of management techniques can then be defined at a global level through the stakeholder workshop process that is either a structural or non-structural approach. These

approaches can include watershed planning principles such as (1) landuse planning, (2) floodplain vegetation management, (3) regional runoff storage/infiltration, (4) sustainable systems, (5) drainage ordinances, and (6) risk management reduction.

6. **Planning Guidance Document –** This step involves building a cohesive guidance document to specifically define the regional watershed and flood management planning program and global strategies. The program will define the controls and communication measures to allow collaboration of the different regional and local agencies/flood managers as well as stakeholders. The plan will provide the basic framework with different categories for the types of global strategies and approaches, as well as the corresponding objectives. This step also involves documentation of the formalized watershed planning process and adopted global strategies that define the plan. This results in an adaptive plan which is flexible to respond to changes in the watershed and rapidly changing regulatory environment.

7. **Implementation Prioritization Evaluation Criteria** – Finally, a screening process is developed to evaluate different potential projects that are generated in the different management strategy categories. The screening will identify which projects should be prioritized for funding implementation. A specialized "analytical hierarchy process" can be used to objectively numerical rank the projects based on how well they achieve the watershed objectives.

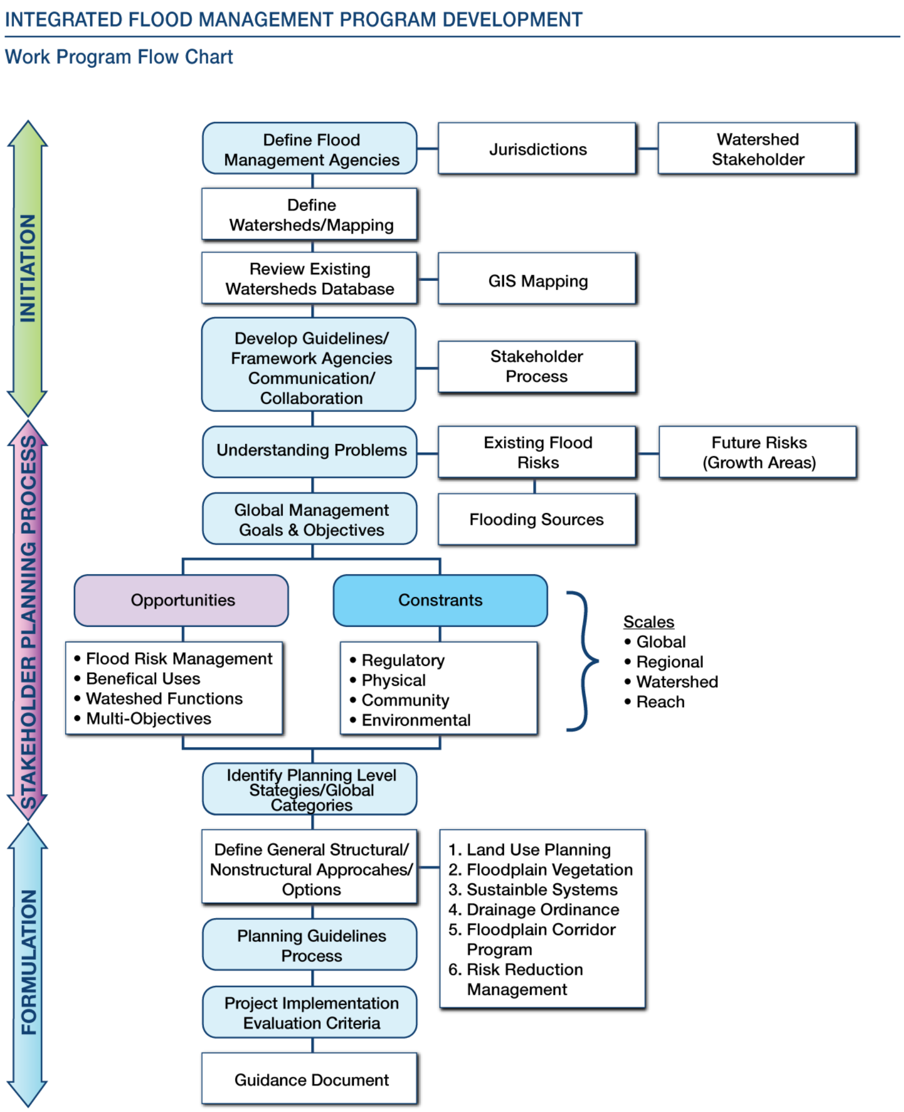

Figure 1-2: Overview of general work plan for the IRWM Integrated Flood Management Study

1.6 Watershed Stakeholder Involvement

Stakeholder outreach was performed as part of the study process in order to involve different agencies and community groups in the development of the floodplain management study. This included the development of the initial information and provided an opportunity to understand the current issues with implementation of floodplain management projects. Stakeholder participation was provided during study and plan formulation process at a general forum within the Workgroup meetings with all interested stakeholders that provided local input, project background, guidance, and specialized technical information. The effort is aimed at developing a strategic planning that will result in understanding watershed guidance needs and flood protection strategy that are compatible with both the physical, political, environmental, and regulatory constraints. The stakeholder meetings were divided into three different periods during the overall study process and included different objectives to solicit input from the stakeholders as well as provide information on the progress of the study: **Workshop No.1 – Background and Inventory of Watersheds**

- Topics – Discuss the overall objective of the program and how integrated flood management can be develop and work effectively for the stakeholders. Define the meaning of integrated flood management. Focus discussion will include developing an understanding of the existing flood programs, common issues in each of the different watersheds, obstacles and constraints encountered with flood management, priority flood hazards in the different watersheds, understanding how flood risks are evaluated.
- Feedback – Additional data sources and inventory from the stakeholders, defining lines of communication, understanding the needs within the different watershed for flood management, existing and future planned project for flood management, current flood management planning process.
- Deliverable – Watershed mapping worksheet with mapped flood hazards

Workshop No.2 – Define Opportunities / Goals / Strategies

- Topics – Defining the different underlying principles for integrated flood management and the guiding policies to set framework for the planning program.
- Feedback – Input on the development of regional types of opportunities, defining the goals of the integrated flood management, and development of the initial alternative strategies
- Deliverable – Updated watershed mapping identifying different levels of flood risks, matrix of existing management agencies and programs, summary matrix of common issues and flood risk.

Workshop No.3 – Review DRAFT Planning Guidance Document

- Topics – Present the DRAFT Guidance Document which will focus on the planning and the underlying principles and alternative strategies
- Feedback – Input and comments on the DRAFT document

2 Flood Management Database

2.1 Data Needs

A wide range of data was required to develop a minimum "baseline" database that would assist in developing background and understanding in order to characterize the existing watershed and flooding conditions. The general categories and types of data that were researched as part of the initial "baseline included the following:

- **Watershed** – Data related to characterizing the watershed conditions, including hydrologic parameters
- **Hydrology** – Studies and information related to estimates of the surface hydrology quantities and watershed response for different storm events
- **Meteorological** – Information related to the types of rainfall events characteristic of the region and the historical rainfall magnitudes including frequency as well as aerial distribution
- **Flood Control Facilities** – Existing regional flood control facilities within the watershed that have been constructed
- **Urban Drainage Facilities** – Existing local drainage facilities that have been installed
- **Drainage Facility Masterplans** – Watershed plans for proposed drainage facilities
- **Floodplain Mapping** – Studies delineating the existing floodplain boundaries, which define the limits of flood hazards
- **Historical Flooding** – Locations where existing flooding has historically occurred from storm events and locations chronic flood locations
- **Flood Damage Estimates** – Monetary estimates of the amount of flood damage associated with different storm events
- **Geomorphology** – Historical information on landform changes within the watershed and particularly trends for changes within the alluvial creeks of the floodplains
- **Erosion/Sedimentation** – Different erosion/sedimentation processes occurring within the watershed including historical trends related to locations of sedimentation and erosion hazards
- **Biological** – Existing biologic resources and habitat within the floodplain
- **Environmental / Regulatory** – Existing environmental permitting requirements related to restrictions for modifications within the active floodplains

Table 2-1 provides a detailed listing of the data and information collected as part of this planning study.

Table 2-1: Data and Information Collected

Flood Hazards / Floodplain Analysis
Historical Flooding Locations / Issues
Flood Maintenance Records
FEMA Floodplain Mapping / DFIRM
FEMA Technical Backup / Floodplain Models
Floodplain Hydraulic Models (other than FEMA)
Environmental Documentation
MSHCP / SAMP documentation
Biology / Wildlife
Plant Community Maps
Critical Habitat Maps
Animal Communities Maps
Riparian Habitat Maps
Prior Reports, Studies, or Data on Biological Resources, Species Occupation & Wildlife Movement
Water Quality
Point Sources
Non-Point Sources
Municipal NPDES Permit
Previous Watershed Hydrology / Hydraulic Studies
Municipal Drainage Masterplans
Development Drainage Masterplans / Hydrology Studies
Flood Control Deficiency Studies
Hydrology Studies – Proposed Developments
Development Drainage Masterplans / Hydrology Studies
Hydraulic Studies – Roadway Bridges / Culvert Crossings
USACE Regional Watershed Studies or Flood Control Planning Studies
Landuse
General Plan - landuse
Future Landuse Plans
Census Population Demographic data
Available GIS Mapping Data Layers
Soils
Geologic Features
Property Ownership / Property Boundaries / APN
Existing Landuse
Planned Development
Utilities
Roadways
Vegetation
Jurisdictional Boundaries (ACOE, CDFG, etc.)
Habitat / Wildlife / Endangered Species / Conservation Areas

Table 2-1: Data and Information Collected

FEMA Flood Hazard Zones
Existing Condition Floodplain Boundaries
Government / Civic Boundaries
Tract Maps
Parcel Maps
Right of Way Data
Plot Plans
Traffic Circulation Elements
Specific Plans
EIR
County / City Maintained Flood Control / Stormwater Facilities
Alquist - Priolo
Mapping / Right-of-Way
Topographic Mapping - Digital DTM
Aerial Photography – Rectified Digital Color
Property Ownership / Property Boundaries / APN

2.2 Data Sources

The information about watershed characteristics and existing flooding was gathered in order to establish a database of the baseline flood problem conditions in the region and was obtained in the following ways:

- **Existing flood documents -** A search was conducted for existing flood-related documents. This included flood control plans, stormwater/flood evaluation studies, surface flow studies, Federal Emergency Management Agency (FEMA) maps, drainage plans, master plans, general plans, flood assessments, and other documents related to climate change and wetlands.

- **Historical Flooding –** Locations of historical flooding, flood damage, and chronic flooding areas based on eye witness accounts, maintenance efforts, and newspaper articles. This information was obtained through phone calls, emails, outreach efforts, and periodical searches.

- **Data requests** - Specific data requests were made to participating municipalities and floodplain management agencies for records of current, ongoing flood problems in their respective municipal and unincorporated areas. A similar request for available data was also solicited to the "flood committee" members related to existing reference documentation, studies, and data related to watershed flood information. An attempt to maximize the initial information gathering effort by contacting multi-agency and/or multi-regional entities with known flood management responsibilities in the county. In addition, stakeholder outreach provided an opportunity to initiate relationship building between watershed stakeholders utilizing the floodplain managers' forum. Once provided, this information was used to develop maps of flood hazards and watershed information

- **Existing GIS databases** – Available digital geographic information databases were consulted through a variety of agencies. In particular, the local database generated through the County of San Diego was utilized as the initial data source, SanGIS (San Diego Geographic Information Source), such as the existing landuse data.

2.3 Data Gaps

Available information was limited to fulfill the data needs, particularly in a geographic information format to facilitate regional planning. This is similar to the issues encountered by the contractor for the Flood Future Report. Flood infrastructure information is very limited and it is difficult to obtain digital mapping to inventory existing facilities on a regional basis or within local municipalities. No single agency in the county was familiar with all existing infrastructure across the county. In many cases, agencies did not have a complete inventory of infrastructure that they owned and/or maintained. In addition, it was difficult to find information related to locations of flood deficiencies, problem "hot spots," and recurring problem areas. Some of the issues in the development of a comprehensive database sufficient for watershed planning on a system wide basis include:

- Database utilized for the current study is limited to primarily to the available GIS data
- Data inventory conducted at a regional scale
- Existing flood hazards data limited to FEMA and DWR database
- Not sufficient information to identify locations of flood problem sources and deficiencies
- Insufficient information to generate a comprehensive inventory of existing flood protection infrastructure

3 Existing Flood Hazards and Management Programs

3.1 Definition of Flood and Nature of Hazard

A flood occurs when excess water from snowmelt, rainfall, or storm surge accumulates and overflows onto a river's bank or adjacent floodplains. Floodplains are lowlands adjacent to rivers, lakes, and oceans that are subject to recurring floods. Most injury and death from floods occur when people are swept away by flood currents, and property damage typically occurs as a result of inundation by sediment-filled water.

Several factors determine the severity of floods, including rainfall intensity and duration. A large amount of rainfall over a short time span can result in flash flood conditions. A sudden thunderstorm or heavy rain, dam failure, or sudden spills can cause flash flooding. The National Weather Service's definition of a flash flood is a flood occurring in a watershed where the time of travel of the peak of flow from one end of the watershed to the other is less than six hours. There are no watersheds in the County that have a longer response time than six hours. Flash floods in the County range from the stereotypical wall of water to a gradually rising stream. The central and eastern portions of the County of San Diego are most susceptible to flash floods where mountain canyons, dry creek beds, and high deserts are the prevailing terrain.

The County is also subject to shallow flooding. Shallow flooding occurs in areas where a lack of channels means water cannot drain away easily. Shallow flooding problems fall into three categories: sheet low, ponding, and urban drainage. Sheet low occurs where there are inadequate or no defined channels, floodwater spreads out over an area at a somewhat uniform depth. Sheet low flooding is common after intense or prolonged rainfall during which the rain cannot soak into the ground. In some flat areas, runoff collects in depressions and cannot drain out, creating a ponding effect. Ponding floodwaters do not move or low away. Floodwaters will remain in the temporary ponds until they can infiltrate, evaporate, or are pumped out.

An urban drainage system comprises the ditches, storm pipes, retention ponds and other facilities constructed to store runoff or carry it to a receiving stream, lake, or ocean. Other constructed features in such a system include swales that collect runoff and direct it to storm drains and ditches. Most systems are designed to handle the amount of water expected during a 10-year storm. Larger storms overload them and the resulting backed-up storm drains and ditches produce shallow flooding.

Dam failures can result in severe flood events. When a dam fails, a large quantity of water is suddenly released with a great potential to cause human casualties, economic loss, lifeline disruption, and environmental damage. A dam failure is usually the result of age, poor design, or structural damage caused by a major event such as an earthquake or flood.

The most common flooding types in the County of San Diego are riverine flooding and flash flood events.

Table 3-1: Characteristic Flooding Types within San Diego

Flood Hazard	Description Cause
Coastal Flooding	Winter and spring coastal storm, high winds and storm surges
Debris Flow Flooding	Heavy localized rainstorms on hillsides and high sediment producing or unstable areas subject to erosion or post-watershed fires
Slow Rise Flooding	Floodplain with limited hydraulic capacity and heavy precipitation generate runoff greater than capacity
Flash Flooding	High volume rainstorm, thunderstorms, or slow moving storms
Alluvial Fan Flooding	High volume rainstorm and thunderstorm displacing high volume of sediment to alluvial fan geographic features
Urban Drainage Flooding	Large rainstorms which exceed the capacity of the local urban drainage system resulting in flooding

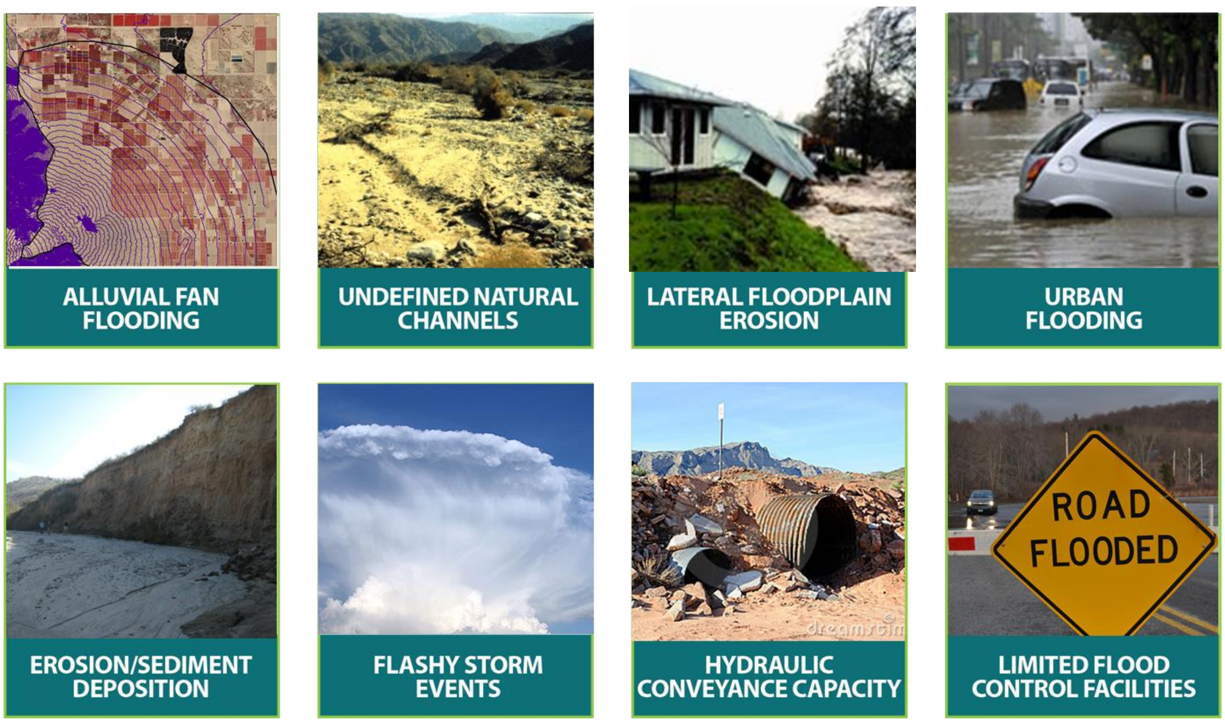

Figure 3-1: Common flooding and flood hazard issues encountered throughout the County

3.1.1 Critical Flood Prone Facilities/Assets

Flood hazards and the potential damage or loss of “critical facilities” is an important consideration in watershed planning as well as for prioritization of flood management projects. A critical facility is a facility in either the public or private sector that provides essential products and services to the general public, is otherwise necessary to preserve the welfare and quality of life in the County, or fulfills important public safety, emergency response, and/or disaster recovery functions. These critical assets can also be “lifeline” type facilities which are essential for the public. Some of the common critical facilities identified hospitals and other health care facilities, emergency operations facilities, fire stations, and police stations, schools, hazardous material sites, airport facilities, bridges, bus facilities, rail facilities, and highways; utility systems that include electric power facilities, natural gas facilities, crude and refined oil facilities, potable and waste water facility, and communications facilities and utilities, government office/civic centers, jails, prisons, military facilities, religious facilities, and post offices.

3.2 Existing Floodplain Management Programs and Agencies

The San Diego County Flood Control District (SDFCD) is responsible for the floodplain management within the unincorporated areas of San Diego County, while the other 18 cities within the IRWM Region have similar responsibility within their respective municipality. In most counties there is usually a single agency which has the responsibility for coordinating all the different flood management activities regionally, however, in San Diego this does not exist. The different agencies responsible for floodplain management within the County region include:

Table 3-2: Jurisdictions Responsible for Floodplain Management in San Diego County

County of San Diego	City of El Cajon	City of Lemon Grove	City of San Marcos
City of Carlsbad	City of Encinitas	City of National City	City of Santee
City of Chula Vista	City of Escondido	City of Oceanside	City of Solana Beach
City of Coronado	City of Imperial Beach	City of Poway	City of Vista
City of Del Mar	City of La Mesa	City of San Diego	

The SDFCD's role is to provide for the control of the flood and storm waters within the District and of the flood and storm waters that flow into the District. It is to preserve such waters for beneficial use such as water supply, groundwater percolation, recreation, and environment. It is to protect the land, properties, facilities, and people within the District from damage caused by storm and flood waters. The SDFCD has an adopted *Floodplain Management Plan* (FMP) for the County's unincorporated areas which assesses the flood hazards, summarizes the current flood management program, describes mitigation strategies, and provides a future action plan.

In addition, the SDFCD based on the Act of the State Legislature in 1966 (see SBFCD website) has the legal authority to:

- Establish Flood Control policy
- Establish water quality policy
- Build and maintain recreational facilities within the watercourses of the County of San Diego.
- Purchase land, obtain easements, and build and maintain facilities for the conveyance of storm and flood waters.

- Provide flood warning services to the county.
- Repair and restore affected watersheds within and without the District. ·
- To regulate the discharge of pollutants into District Facilities.
- Provide a water supply to county residents without existing service.
- Operate outside of its jurisdiction to assist with watershed issues within the County of San Diego and in counties and nations with watersheds that drain into the District's jurisdiction.
- Make investigations within and without the District to study local watershed issues.

3.3 History of Flooding

From 1770 until 1952, 29 floods were recorded in the County of San Diego. Between 1950 and 2006, flooding prompted 12 Proclaimed States of Emergency in the County of San Diego. Several very large floods have caused significant damage in the County. The Hatfield Flood of 1916 destroyed the Sweetwater and Lower Otay Dams, and caused 22 deaths and $4.5 million in damages. Most of the deaths were attributed to the failure of Lower Otay Dam. The flood of 1927 caused $117,000 in damages and washed out the Old Town railroad bridge. The floods of 1937 and 1938 caused approximately $600,000 in damages.

Recent serious floods affecting the County occurred during tropical storms Kathleen (1977) and Doreen (1978) and during winter storms in 1980, 1987, 1998, 2005 and 2010. In the 1980 flood, approximately 16-20 inches of rain accumulated over a six week period. This slow moving storm, which was the most severe since the Hatfield Flood of 1916, lead to wide-spread small stream flooding and evacuations of residents in Mission Valley. The San Diego River at Mission Valley peaked at 27,000 cubic feet per second (cfs) and caused $120 million in damage. The following table displays a history of flooding in the County of San Diego, as well as the loss estimation associated with each flood event where available.

Table 3-3: Historical Records of Large Floods in San Diego County

Date	Loss Estimation	Source of Estimate	Comments
1862	Not available	County of San Diego Sanitation and Flood Control	6 weeks of rain
1891	Not available	County of San Diego Sanitation and Flood Control	33 inches in 60 hours
1916	$4.5 Million	County of San Diego Sanitation and Flood Control	Destroyed 2 dams, 22 deaths
1927	$117,000	County of San Diego Sanitation and Flood Control	Washed out railroad bridge Old Town
1937 & 1938	$600,000	County of San Diego Sanitation and Flood Control	n/a
1965	Not available	San Diego Union	6 killed
1969	Not available	San Diego Union	All of State declared disaster Area
1979	$2,766,268	County OES	Cities of La Mesa, Lemon Grove, National City, San Marcos, San Diego and unincorporated areas
1980	$120 million	County of San Diego Sanitation and Flood Control; Earth Times	San Diego river topped out in Mission Valley
Oct – 87	$640,500	State OES	NA
1995	$Tens of Millions	County OES	San Diego County Declared Disaster Area
Source: *Multi-Jurisdictional Hazard Mitigation Plan, San Diego County* (March 2004)			

3.4 Flood Hazard Identification

Regional mapping of the existing flood hazards for the San Diego region has been prepared by FEMA as part for the National Flood Insurance Program (NFIP), which requires each community to identify 100-year recurrence interval flood prone areas as part of adopting floodplain management regulations. The minimum federal flood protection goals and requirements are administered by FEMA as part of the NFIP. The NFIP originally established in 1968 provides low-cost federally subsidized flood insurance to those communities that participate in this program. Participation in the program requires that the community adopt floodplain regulations which meet the requirements of the NFIP defined in *44CFR Chapter 1 Part 59* which include mapping of existing flood hazards.

Hydrologic-hydraulic studies are required to analyze the delineation of the 100-year recurrence interval floodplain limits. The published FEMA flood hazard maps provide an approximation of the regional floodplain limits based on the standards for FMEA alluvial fan hazards. The mapped flood hazards focus on regional flood hazards and do not evaluate localized flooding, particularly in urbanized areas, so there can be areas which may flood in even small storm events but may not be within a mapped flood hazard zone.

FEMA is the federal entity responsible for producing Flood Insurance Rate Maps (FIRMs). The flood risk information presented on the FIRM is based on historic, meteorological, hydrologic, and hydraulic data, as well as open-space conditions, flood-control works, and development within the study area. The FEMA flood hazard zones represents the areas susceptible to the 1% annual chance flood (commonly referred to as the “100-year flood), and the 0.2% annual chance flood

("500-year flood"). The 1% annual chance flood has at least a 1% chance of occurring in any given year. FEMA designates this area as a Special Flood Hazard Area (SFHA) and requires flood insurance for properties in this area as a condition of a mortgage backed by federal funds.

Information found on a flood map includes:

- Common physical features, such as major highways, secondary roads, lakes, railroads, streams, and other waterways
- Special Flood Hazard Areas (SFHAs)
- Base (1% annual chance) Flood Elevation (BFE) depths
- Flood insurance risk zones
- Areas subject to inundation by the 0.2% annual chance (500-year) flood

FIRMs provide the information so that users can:

- Identify SFHAs
- Identify the location of a specific property in relation to the SFHA
- Identify the BFE at a specific site
- Identify the magnitude of flood hazards in a specific area
- Locate regulatory floodways

FIRMs are the mapped product of engineering studies, called Flood Insurance Studies (FISs). The effective date of the first FIS for the Unincorporated Areas of San Diego County was June 15, 1984. (Note: The County has only mapped floodplain in the unincorporated areas of the County of San Diego). Since that time, the FIS for the County has been updated multiple times, the most recent revision being May 16, 2012. The existing published FEMA flood hazard mapping illustrates general characteristics of the floodplain and provides an understanding of the extent of the existing flood potential. It is apparent that there are uncertainties and discrepancies in the flood hazard mapping, particularly where there are dramatic changes in the mapping at local government boundaries where there are not any hydraulic influences. The mapping should be used cautiously because of its approximate nature and it does not necessarily define the magnitude of flooding, but just the approximate extent of the floodplain.

In addition to the FEMA FIRMs, the County of San Diego has developed its own flood maps that account for additional areas of known risk. The County flood maps provide 1% annual chance (100-year) riverine flood elevations for areas beyond those studied by FEMA, and are used in addition to the FIRM in regulating development. The flood hazard information, including FEMA floodplain boundaries and flood zones as well as areas at risk of dam failure, are depicted on the website for SanGIS (http://www.sangis.org). SanGIS is a cooperative endeavor between the City and County of

San Diego. Its GIS data and map creation tools are available free of charge for online use or for purchase for download access and use with other applications.

3.5 Defining Flood Risk

Flood risk can be defined by three different components which include (1) “flood hazard” which is generally the probability of occurrence of a particular flood event, (2) the” exposure” of human activity to the flood which is equated to the flood damage potential, and (3) the specific “vulnerability” or the lack of resistance to damaging/destructive forces. Flood risk can be mathematically calculated as the product of hazard, exposure, and vulnerability. Understanding these definitions is an important foundation in flood management planning. A smaller flood that causes less damage occurs more frequently than a very severe flood that can cause much great damage. However, from a loss prevention standpoint, it may be more beneficial to protect for the more frequent events. The assessment of community vulnerabilities can be evaluated through review of existing codes, plans, policies, programs, and regulations used by local jurisdictions to determine whether existing provisions and requirements adequately address the flood hazards that pose the greatest risk to the community.

Flood Risk – likelihood of consequence from inundation. Identifies the cause and the frequency of the problem (how often)

Flood Exposure – relationship between the flood hazard on the effect on loss of property, life, and environmental resources.

Vulnerability – identifies level of exposure expected (how flooding adversely affects people and property)

Figure 3-2: Different types of flood risk/damage and exposure throughout the County

3.5.1 Flood Event-Specific Factors Influencing Flood Damage

Although there are many issue that effect flood damage, there are several key factors associated with the flood characteristics which influence the amount and severity of the flood damage. In addition, Figure 3-3 provides a general outline of the types of flood losses and the assessment of the type of damage. A description of the primary factors that influence on the severity of flood damage includes the following:

Flood depth: The height flood waters reach is an important consideration affecting flood losses. Structures are more susceptible to damage as flood depths increase. Generally, the coastal plains areas of the County are subject to lower flood depths and more mountainous regions where narrow floodplains and step terrain along the stream corridor prevails are subject to greater flood depths during flood events.

Flood duration: The longer flood waters are in contact with building components (such as structural members, interior finishes, and mechanical equipment), the greater the potential for damage. The duration of flooding is very specific to the nature of an event. However, the structures closest to a flooding source (such as a river, bay, or canal) are more likely to sustain longer durations of flooding and be more vulnerable to flood damage. As flood waters recede, these structures will remain flooded for longer durations than structures located along the edge of the floodplain, increasing the potential for damage.

Velocity: The velocity of flood waters is an important factor impacting potential flooding damage. Flowing water exerts forces on the structural members of a building, increasing the likelihood of significant damage. In addition, flowing waters can increase erosion and scour around the foundation of a structure, which can further increase the vulnerability of a building to flood damage.

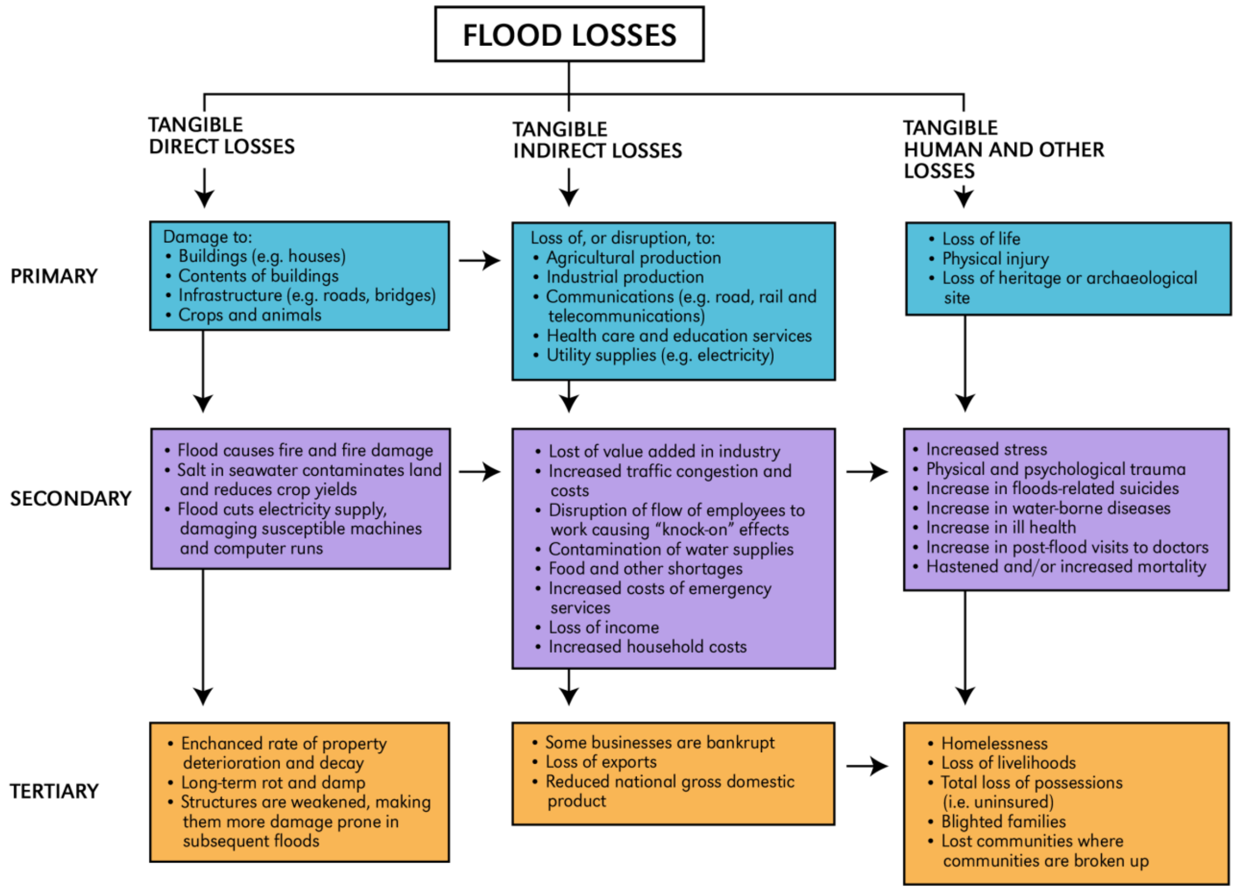

Figure 3-3: Illustration of different types of flood losses and the associated impacts

3.5.2 Repetitive Flood Damage Losses

A "repetitive loss property" is one for which two flood insurance claim payments of at least $1,000 have been paid by the NFIP within any 10-year period since 1978 (e.g., two claims during the periods 1978-1987, 1979-1988, etc.). These properties are important to the NFIP because they cost $200 million per year in flood insurance claim payments. Repetitive loss properties represent only one percent of all flood insurance policies, yet historically they account for nearly one-third of the claim payments (over $4.5 billion to date). Mitigation of the flood risk to these repetitive loss properties will reduce the overall costs to the NFIP as well as to individual homeowners. FEMA programs encourage communities to identify the causes of their repetitive losses and develop a plan to mitigate the losses. Repetitive flood damage loss illustrates areas of an existing recurring chronic flood hazard which should be targeted as a priority to be addressed. Repetitive loss areas and properties should be prioritized for attention and analysis. This "area analysis" should follow FEMA guidelines to determine whether acquisition, elevation, or other flood protection measures are appropriate and feasible for the repetitively flooded buildings. The County is vulnerable to specific "hot spot" areas that have experienced repeated flooding.

3.6 Assessment of Flood Risks

Assessment of the flood risk is a complex problem that can only be solved through interdisciplinary research. In general, a two-step approach is utilized. First it was needed to characterize the flood hazard using a selected set of indicator maps, like the spatial distribution of flow velocity, water height, speed of propagation, duration, etc. The second step was to estimate how the flood hazard indicators interfere with human activities in the flooded area. Agricultural activities will suffer damage in different ways than for instance an industrial zone or an urban area.

An initial assessment of the magnitude of the existing "flood risk" which correlates directly to the potential amount of flood damage can be developed through quantifying encroachment of different landuses within the floodplain. Any area located within 100-year floodplain flood hazard area is considered to be at high risk of flooding. An overlay the landuse plan with the mapped flood hazard zones can be generated. The FEMA flood hazard zone "A" is the 100-year floodplain designation, although there are different types of this flood hazard for insurance purposes. The mapping indicates that the majority of the areas have landuse zoning which is compatible with the floodplain being zoned primarily "open space." However, it is important to note the amounts of other general landuses within the floodplain, particularly the more urban type of uses which would result in more extensive flood damage. The magnitudes of the general landuse designations within the flood hazard zones have been developed utilizing the existing database available. This generalized mapping overlay can be utilized as an effective planning tool as part of the initial plan formulation. The landuse areas which have a high dollar value within flood hazard zones would indicate locations to target and prioritize projects. Other benefits of this mapping assessment include:

- Identification of flooding vulnerable structures based on flood inundation hazards
- Approximate magnitudes of potential flood losses
- Potential critical public lifeline facilities and infrastructure that could be impaired by flooding
- Identification of key transportation facilities, including roadways that could reduce public access and emergency response
- Identification of the different landuses encroaching within the 100-year flood hazard zones as well as quantifying the amount of these areas for different landuse

Figures 4-3, 4-5, 4-7, 4-9, 4-11, 4-13, 4-15, 4-17, 4-19, and 4-21 in Section 4 of this report illustrate the mapped floodplain risk and exposure assessment based on the amount of landuse within the published mapped flood hazard zones. The precise risks to the different landuses would require detailed analyses of different flooding depths for different flood frequencies to determine how risk varies within the floodplain, but this data was not available for this study.

3.6.1.1 Landuse Located within Flood Hazards – City Boundaries

The amount of the different landuses that are within the mapped flood hazard zones for the different major cities within San Diego were quantified and are presented in Table 3-4. This is a planning level assessment in order to provide an indication of the flood hazard risk based on the existing data for landuse within the mapped floodplain. The landuse mapping data is from the County of San Diego through their SanGIS.

Table 3-4: Landuse types located within mapped flood hazard zones based on City boundaries

Carlsbad	Area (acres)
Agriculture	36
Commercial and Services	258
Industrial	13
Open Space and Recreation	706
Residential	84
Transportation, Communications, and Utilities	92
Water	782
Grand Total	**1,970**

Chula Vista	Area (acres)
Commercial and Services	424
Industrial	319
Open Space and Recreation	1,544
Residential	329
Transportation, Communications, and Utilities	565
Water	1,314
Grand Total	**4,494**

Coronado	Area (acres)
Commercial and Services	175
Industrial	187
Open Space and Recreation	159
Residential	143
Transportation, Communications, and Utilities	112
Water	1,948
Grand Total	**2,724**

Del Mar	Area (acres)
Commercial and Services	214
Industrial	3
Open Space and Recreation	89
Residential	45
Transportation, Communications, and Utilities	69
Water	48
Grand Total	**470**

La Mesa	Area (acres)
Commercial and Services	0
Open Space and Recreation	2
Residential	10
Transportation, Communications, and Utilities	6
Grand Total	**18**

Santee	Area (acres)
Commercial and Services	210
Industrial	36
Open Space and Recreation	422
Residential	100
Transportation, Communications, and Utilities	62
Water	45
Grand Total	**874**

El Cajon	Area (acres)
Commercial and Services	304
Industrial	177
Open Space and Recreation	43
Residential	447
Transportation, Communications, and Utilities	430
Grand Total	**1,400**

Encinitas	Area (acres)
Agriculture	24
Commercial and Services	12
Open Space and Recreation	597
Residential	72
Transportation, Communications, and Utilities	62

Water	237
Grand Total	**1,004**

Escondido	**Area (acres)**
Agriculture	3
Commercial and Services	545
Industrial	63
Open Space and Recreation	220
Residential	987
Transportation, Communications, and Utilities	483
Water	76
Grand Total	**3,381**

Imperial Beach	**Area (acres)**
Commercial and Services	41
Industrial	2
Open Space and Recreation	978
Residential	29
Transportation, Communications, and Utilities	22
Water	36
Grand Total	**1,109**

Lemon Grove	**Area (acres)**
Commercial and Services	10
Industrial	24
Open Space and Recreation	2
Residential	1
Transportation, Communications, and Utilities	15
Grand Total	**52**

Solana Beach	**Area (acres)**
Commercial and Services	2
Open Space and Recreation	14
Residential	29
Transportation, Communications, and Utilities	11
Water	2
Grand Total	**57**

National City	Area (acres)
Commercial and Services	213
Industrial	277
Open Space and Recreation	168
Residential	70
Transportation, Communications, and Utilities	253
Water	520
Grand Total	**1,500**

Oceanside	Area (acres)
Agriculture	397
Commercial and Services	519
Industrial	261
Open Space and Recreation	1,760
Residential	1,340
Transportation, Communications, and Utilities	918
Water	95
Grand Total	**5,291**

Poway	Area (acres)
Agriculture	28
Commercial and Services	86
Industrial	14
Open Space and Recreation	344
Residential	379
Transportation, Communications, and Utilities	94
Water	53
Grand Total	**999**

San Diego	Area (acres)
Agriculture	1,653
Commercial and Services	2,318
Industrial	1,532
Open Space and Recreation	9,883
Residential	1,274
Transportation, Communications, and Utilities	2,061
Water	5,170
Grand Total	**23,892**

San Marcos	Area (acres)
Agriculture	13
Commercial and Services	157
Industrial	96
Open Space and Recreation	317
Residential	86
Transportation, Communications, and Utilities	125
Grand Total	**794**

Vista	Area (acres)
Agriculture	0
Commercial and Services	224
Industrial	18
Open Space and Recreation	136
Residential	161
Transportation, Communications, and Utilities	133
Grand Total	**672**

3.6.2 Planning Estimates of Flood Damage Loss Areas

The estimated loss for flood hazards throughout the County, in addition to exposure, was prepared at a planning level to provide guidance with the watershed planning. Loss is that portion of the exposure that is expected to be lost to a hazard. Loss is estimated by referencing frequency and severity of previous hazards. Hazard risk assessment methodologies were applied to flood hazards in the County of San Diego. The procedure adopted integrates GIS mapping data to provide estimates for the potential impact of flood hazards by using a common, systematic framework for evaluation. Average flood damage costs for different landuses based on FEMA guidelines and similar values embedded in to the HAZ-US (FEMA national hazard model). This data included economic and structural data on infrastructure and critical facilities, including replacement value to use in loss estimation assumptions. This approach provides estimates for the potential impact by using a common methodology and database. Uncertainties are inherent in any loss estimation methodology, arising in part from incomplete scientific knowledge concerning natural hazards and their effects on the built environment. Uncertainties also result from approximations and simplifications that are necessary for a comprehensive analysis (such as incomplete inventories, demographics, or economic parameters). However, the results provide a useful planning level tool to identify locations of high value assets within the watershed and prioritizing flood management projects around these locations in order to reduce the potential dollar damage losses.

The data developed for the different levels of flood exposures/risk based on landuses within the mapped flood hazard zones for each of the regional watersheds was used to develop planning level assessment of the potential economic losses or dollar damage. Studies on flood damage estimates illustrate that the dollar damage for residential and commercial structure increases with flood depth. However, this planning level assessment did not differentiate the variation of flood depths within the floodplain. A generalized dollar damage cost was applied to the different landuse categories based upon national information for flood damage. The results of this assessment are illustrated in Figure 3-4 and Figure 3-5. This illustrates some useful trends related to the locations and most susceptible types of flood damage when planning management activities.

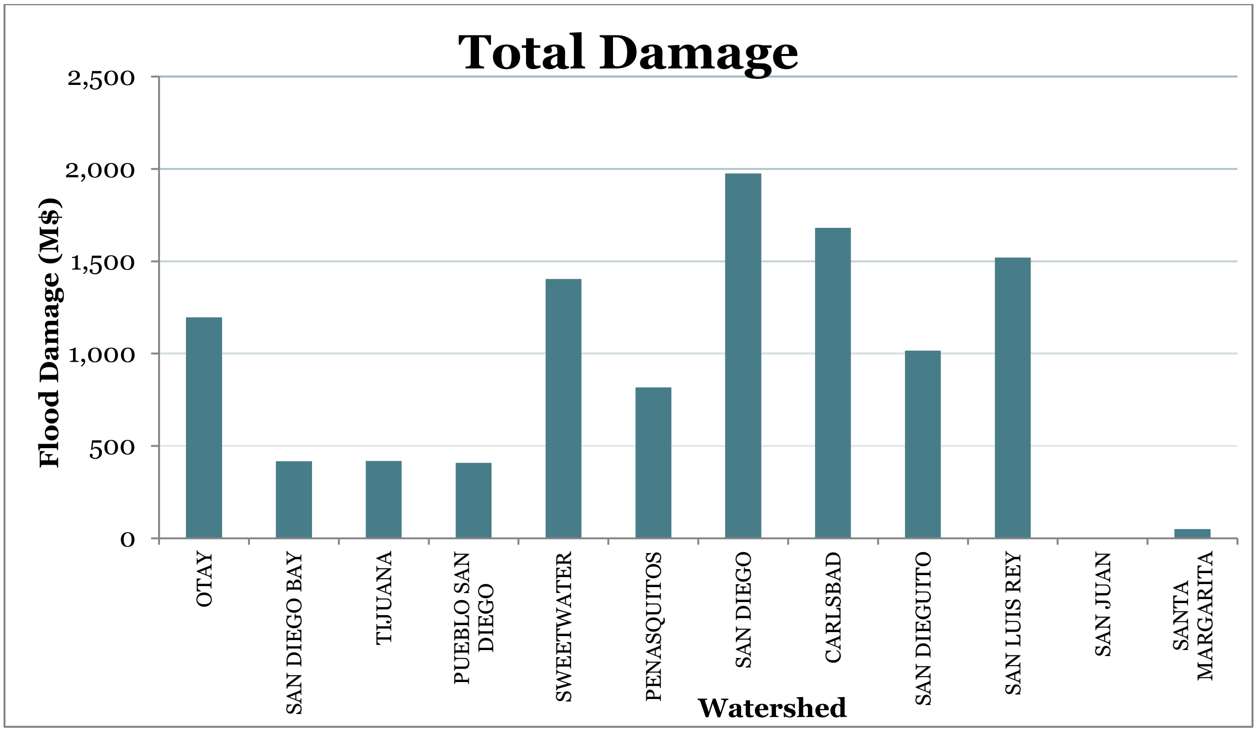

Figure 3-4: Total estimated 100-year approximate dollar flood damage by watershed

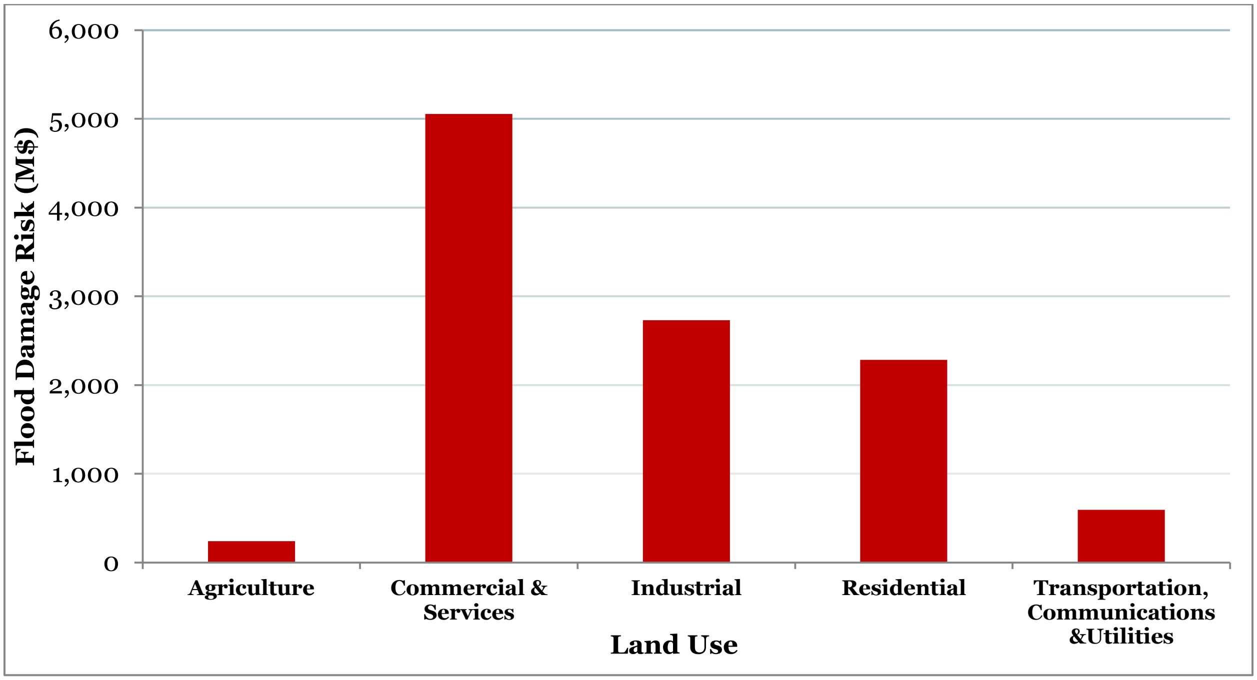

Figure 3-5: Total estimated 100-year flood damage to the different landuse types over all watersheds

3.7 Existing Community Watershed Programs

There are a variety of community-based watershed protection programs that provide a basis for community involvement for the preservation and management of the watershed resources. The community groups provide multiple benefits for the watershed through enhanced monitoring and performing volunteer watershed management projects. The community watershed programs should be an integral component of the watershed management program development and implementation. Table 3-5 provides a select few of the organizations who administer watershed protection programs.

Table 3-5: Examples of Community Watershed Programs

Watershed	Organization	Website
San Diego River	San Diego River Park Foundation	http://www.sandiegoriver.org/index.html
Carlsbad	Batiquitos Lagoon Foundation	http://www.batiquitosfoundation.org/
San Diego River	Friends of Famosa Slough	http://www.famosa-slough.org/
Carlsbad	The Escondido Creek Conservancy	http://www.escondidocreek.org/
Los Penasquitos Creek	Los Penasquitos Lagoon Foundation	http://lospenasuitos.org/
Sweetwater River	Sweetwater River Conservancy	http://www.sweetwaterriverconservancy.org/
Carlsbad	San Elijo Lagoon Conservancy	http://www.sanelijo.org/
Tijuana River	Tijuana River National Estuarine Research Reserve	http://www.trnerr.org/
Los Penasquitos Creek	Friends of Rose Creek	http://www.saverosecreek.org
Santa Margarita River	Santa Margarita River – Friends of the River	http://www.friendsofthe river.org/

4 Regional Watersheds Description

4.1 Regional Watersheds Hydrologic Characteristics

The San Diego IRWM Region is comprised of **11 watersheds** tributary to the Pacific Ocean and is illustrated on Figure 4-1. The Region's watersheds are located either completely within incorporated communities within the County or within undeveloped unmapped areas of the eastern part of the County. The major river systems affecting the unincorporated areas of the county include: Santa Margarita, Otay, San Luis Rey, Sweetwater, San Diego, San Dieguito, and Tijuana. The watersheds are the surface hydrology features or the tributary basin areas corresponding to the regional drainage systems and floodplains. The hydrologic response of these watershed units for rainfall events as well as the channel processes/geomorphology trends, which influence the flooding characteristics which are examined at a regional scale. In addition, different characteristics of the watersheds and floodplains that may limit potential flood management solutions are also explored. The "watershed units" provide a useful method to divide the region and basis for focusing on flood management planning utilizing a regional watershed basis.

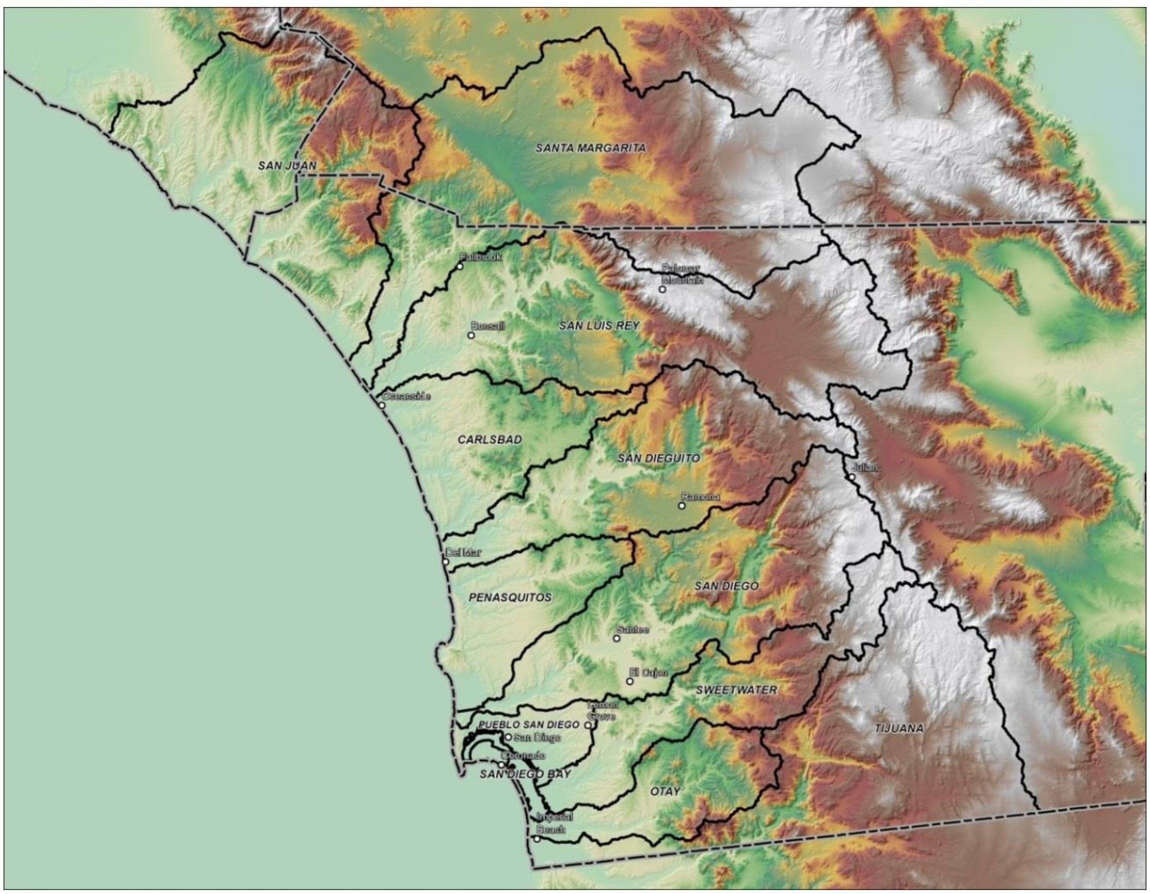

Figure 4-1: Regional delineation of major watershed units utilized for watershed planning

4.1.1 Tijuana River

Figure 4-2: Tijuana River watershed unit with population centers

The Tijuana River watershed encompasses a region of approximately 1,750 square miles on either side of the California – Baja California border. Twenty-seven percent of the watershed area is within California and the river discharges to the Tijuana Estuary and Pacific Ocean on the U.S. side of the international border. Although only 27% of the watershed area is within California, the river discharges to the Tijuana Estuary and Pacific Ocean on the U.S. side of the international border. On the U.S. side of the border, the cities of Imperial Beach and San Diego, and San Diego County have portions of their jurisdictions within the watershed. The cities of Tijuana and Tecate are the most important urban centers on the Mexican side. The current population of the entire watershed is approximately one million people. The cities of Tijuana and Tecate are the most important urban centers on the Mexican side. The major drainages include Cottonwood and Campo creeks in the US, and the Rio Las Palmas system in Mexico. Annual precipitation varies from less than 11 inches to 25 inches farther inland near the Laguna mountains. Runoff is captured by the Morena Reservoir and Barrett Lake on Cottonwood creek. There are 3 dams in the watershed controlling 78% of the area: Morena was built in 1912 and Barrett in 1922. In Mexico, Rodriguez dam was built in 1936. The watershed includes eight hydrological areas, including the Tijuana Valley, Potrero, Barrett Lake, Monument, Morena, Cottonwood, Cameron, and Campo areas.

Table 4-1: Tijuana River watershed unit characteristics and background information

Watershed Characteristics Information	Watershed Unit Area (within County): 467.4 square miles Naturally Occurring Waterways: 549.59 miles Percentage of Free Flowing River Miles: 93 % Percentage of River Miles in Protected Lands: 9 % Number of Dams: 5 Number of Stream Crossings: 407 Average Precipitation per Year: 19.08 inches Percentage Area above 15% Slope: 18.9 % Longest Watershed Flow Path Length: 348,500 feet Maximum Elevation: 5,075 Minimum Elevation: 0 (sea level) Watershed Elevation Difference: 5,075 feet Average Map Slope: 1.46%
Major Water Bodies	Tijuana Estuary, Tijuana River, Cottonwood Creek, Pine Valley, Campo Creek, Barrett Lake, Lake Moreno
Cities in Watershed	Imperial Beach, Tecate, Canyon City, Campo Potrero Rancho Del Campo Barrett Junction Hacienda Del Florasol Cameron Corners Lake Morena Village Live Oak Springs Boulder Oaks Laguna Junction Pine Valley Mt Laguna
River / Creeks Length (ft)	Agua Dulce Creek 7,454 Campo Creek 45,378 Cottonwood Creek 228,415 Dulzura Creek 481 Espinosa Creek 25,651 Grapevine Creek 17,601 Hauser Creek 22,673 Indian Creek 22,116 Kitchen Creek 47,192 La Posta Creek 105,445 Little Potrero Creek 12,213 Lucas Creek 10,205 Miller Creek 39,592 Morena Creek 29,686 Oak Valley Creek 14,214 Oneonta Slough 9,066 Pine Valley Creek 133,940 Potrero Creek 60,075 San Diego City Conduit 55,536 Tecate Creek 6,529 Tijuana River 40,362 Wilson Creek 28,655

4.1.1.1 Water Quality

The Tijuana River watershed is classified as a Category I (impaired) watershed by the State Water Resources Control Board due to a wide variety of water quality problems. These problems are largely a result of non-point agricultural sources on the U.S. side of the border and a large variety of point and nonpoint sources on the Mexican side. The Tijuana Estuary, a National Estuarine Sanctuary that supports a variety of threatened and endangered plants and animals, is threatened by inflows from the Tijuana River containing high concentrations of coliform bacteria, sediment, trace metals (copper, lead, zinc, chromium, nickel, and cadmium), PCBs, and other urban, agricultural, and industrial pollutants. The major problem in the watershed is poor water quality. Although discharges from the Tijuana River account for only a small percentage of total gauged runoff to the Southern California coastal ocean, it contains the highest concentrations of suspended solids and cadmium (Cd), copper (Cu), nickel (Ni), lead (Pb), and zinc (Zn) among the eight largest creeks and rivers in Southern California. Surface water quality has been affected by runoff from Mexico while ground water contamination has occurred as a result of seawater intrusion and waste discharges.

4.1.1.2 Biological / Habitat Natural Resources

The Tijuana estuary is one of the largest and most studied wetlands in the South Coast, and is part of the National Estuarine Research Reserve and National Wildlife Refuge programs. The reserve is home to eight threatened and endangered species, including the Light-footed clapper rail, California least tern, Least Bell's vireo, salt marsh bird's beak, white and brown pelicans, and numerous shorebirds.

4.1.1.3 Watershed Floodplain Hydrology – Major Drainages

Table 4-2: Tijuana River watershed floodplain mapping hydrology – major drainages

Flooding Source / Location	Drainage Area (square miles)	Peak Discharge (cfs)		
		10-year (10% chance)	50-year (2% chance)	100-year (1% chance)
Tijuana River				
At Mouth	1,700	17,000	50,000	75,000

Note: Hydrology Data is based on the FEMA *Flood Insurance Study San Diego County, CA;* May 16, 2012

4.1.1.4 Flood Risk and Exposure Mapping

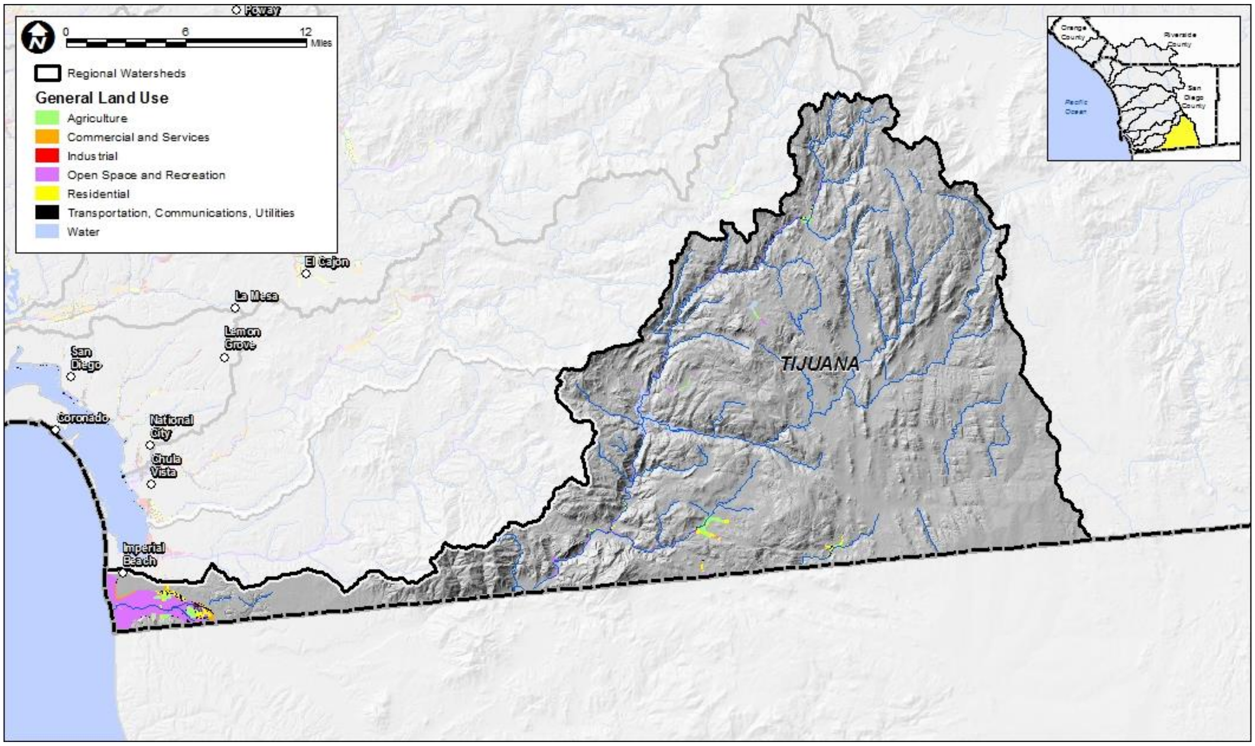

Figure 4-3: Floodplain risks and exposure assessment – landuses within 100-year floodplain for Tijuana watershed unit

Table 4-3: Landuse types located within mapped flood hazard zones for Tijuana watershed unit

TIJUANA	Area (acres)
Agriculture	800
Commercial and Services	188
Industrial	23
Open Space and Recreation	4,758
Residential	852
Transportation, Communications, and Utilities	319
Water	821
Grand Total	**7,761**

4.1.2 Otay River

Figure 4-4: Otay River watershed unit with population centers

The Otay River watershed encompasses approximately 160 square miles in southwest San Diego County and is one of the three county watersheds that discharge to San Diego Bay. The watershed consists largely of unincorporated area, but also includes portions of the cities of Chula Vista, Imperial Beach, Coronado, National City, and San Diego. The predominant land uses in the watershed are open space (67%) and urban/ residential (20%). The major inland hydrologic features, Upper and Lower Otay Lakes, are two water supply reservoirs that also provide important habitat and recreational opportunities.

The current population in the Otay River watershed is approximately 150,000 people. The expected population increase of 88% from 1998 – 2015 is anticipated to substantially increase the volume of urban runoff in the watershed.

Table 4-4: Otay watershed unit characteristics and background information

Watershed Characteristics Information	Watershed Unit Area (within County): 153.7 square miles Longest Watershed Flow Path Length: 148,300 feet Maximum Elevation: 1,888 Minimum Elevation: 0 (sea level) Watershed Elevation Difference: 1,888 feet Average Map Slope: 1.27%
Major Water Bodies	Upper and Lower Otay Reservoirs, Otay River, San Diego Bay
Cities in Watershed	Nestor, Otay Mesa, Palm City, Castle Park, Engineer Springs, Dulzura,
Rivers/Creeks Length (ft)	Dulzura Creek 52,802 Jamul Creek 59,736 Otay River 86,405 Salt Creek 33,431

4.1.2.1 *Water Quality*

The current population in the Otay River watershed is approximately 150,000 people. At the present time, serious water quality problems are limited to the presence of elevated coliform bacteria in the Pacific Ocean receiving waters near Coronado. However, an expected population increase of 88% from 1998 – 2015 will substantially increase the volume of urban runoff in the watershed, and could significantly alter the present water quality status. In the absence of effective watershed-based management, the natural resources of the Otay River watershed may be significantly degraded.

4.1.2.2 *Biological / Habitat Natural Resources*

Approximately 36 square miles of the watershed is part of the Multiple Species Conservation Plan effort that provides habitat for a wide range of endangered plant and animal species. Other important conservation areas within the watershed include the San Diego National Wildlife Refuge, the Rancho Jamul Ecological Reserve, and the vernal pool lands in the region.

4.1.2.3 *Watershed Floodplain Hydrology – Major Drainages*

Table 4-5: Otay watershed floodplain mapping hydrology – major drainages

Flooding Source / Location	Drainage Area (square miles)	Peak Discharge (cfs)		
		10-year (10% chance)	50-year (2% chance)	100-year (1% chance)
Otay River				
At Otay Valley Rd.	122.7	1,200	12,000	22,000
Telegraph Canyon Creek				
At Int. Hwy. 5	7.3	900	2,100	2,800

Note: Hydrology Data is based on the FEMA *Flood Insurance Study San Diego County, CA;* May 16, 2012

4.1.2.4 Flood Risk and Exposure Mapping

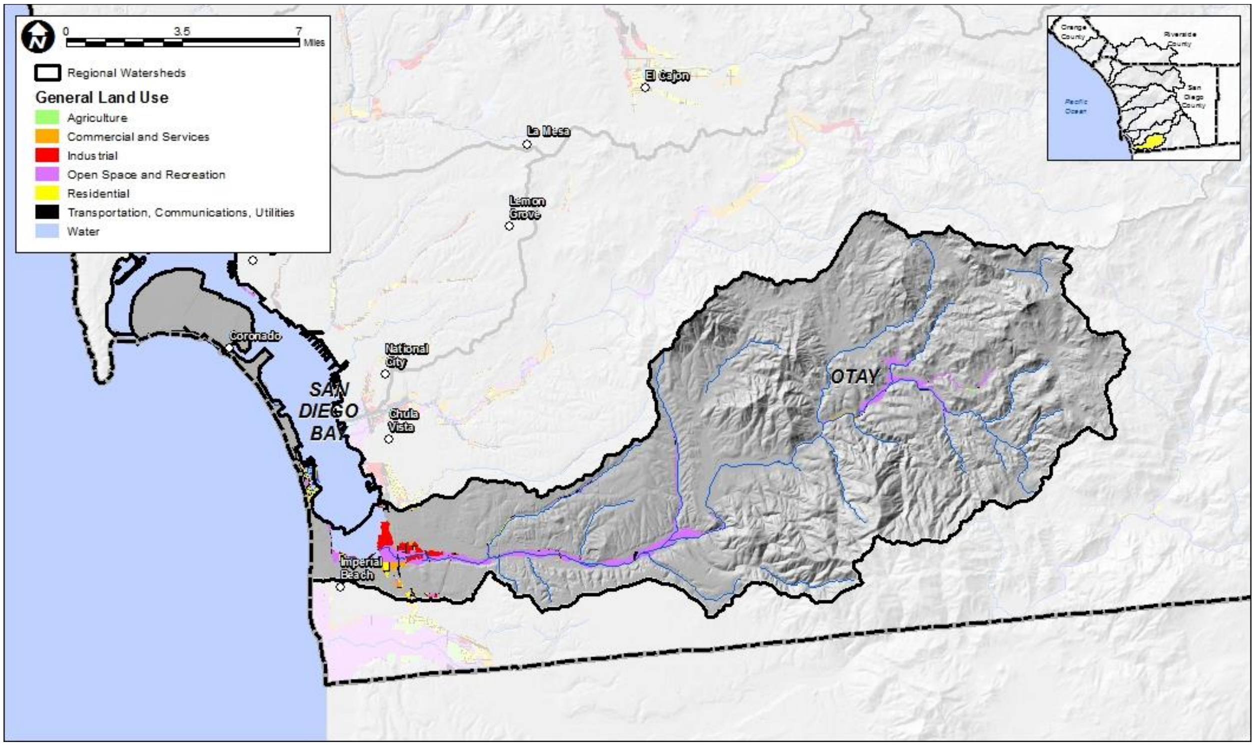

Figure 4-5: Floodplain risks and exposure assessment – landuses within 100-year floodplain for Otay watershed unit

Table 4-6: Landuse types located within mapped flood hazard zones for Otay watershed unit

OTAY	Area (acres)
Agriculture	18
Commercial and Services	170
Industrial	1,238
Open Space and Recreation	2,318
Residential	267
Transportation, Communications, and Utilities	317
Water	61
Grand Total	**4,389**

4.1.3 Sweetwater River

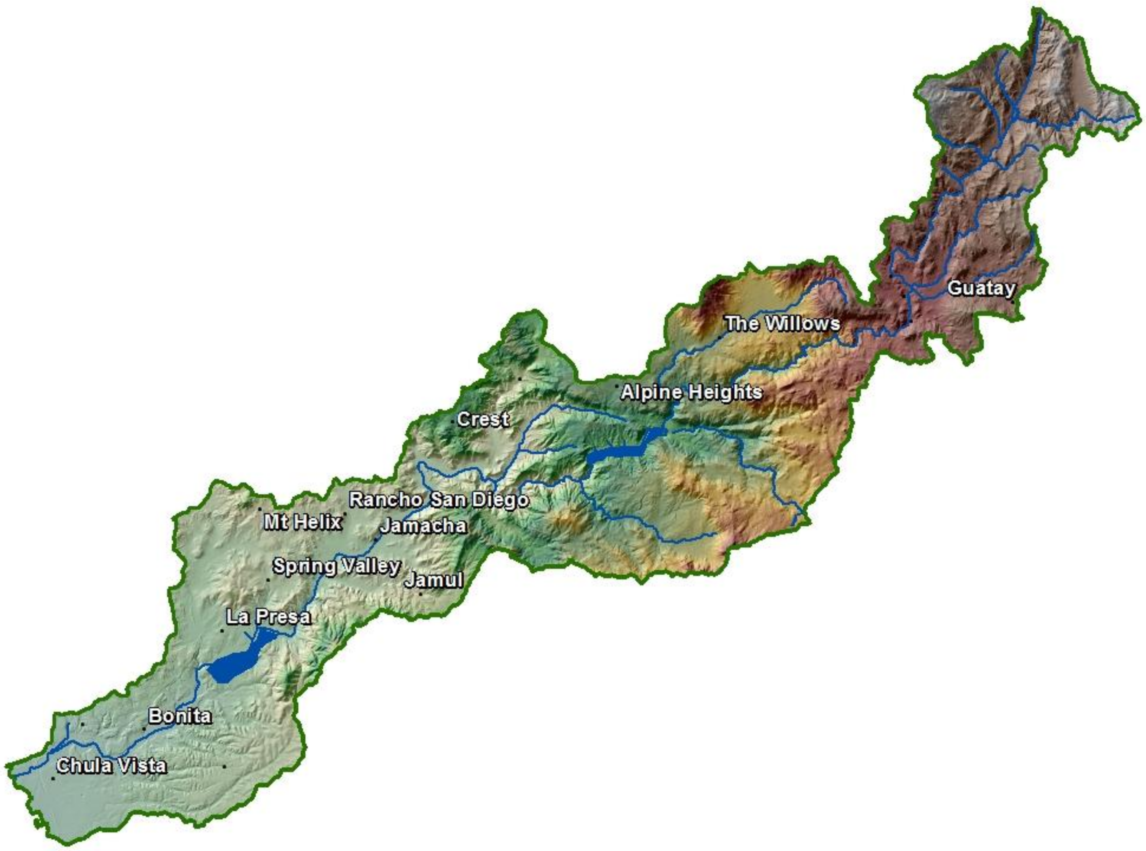

Figure 4-6: Sweetwater River watershed unit with population centers

The Sweetwater River watershed along with the Otay and Pueblo San Diego watersheds combine to form the major watershed tributary to the San Diego Bay area. The Sweetwater River watershed is the largest of the three encompassing 230 of the approximately 415 square mile total. Over 86% of the watershed is within unincorporated jurisdictions. The dominant land uses in the Sweetwater River watershed are urban (29%), open space/ agriculture (22%), and undeveloped (49%). Approximately two-thirds of the land area categorized as urban is composed of residential communities. Approximately 300,000 people currently reside within the Sweetwater River watershed, and this amount is projected to increase to 365,000 by 2015. The most important watershed issues are related to the protection of municipal water supplies, and the protection and restoration of sensitive wetland and wildlife habitats.

The upper watershed includes Cuyamaca Rancho State Park, the unincorporated communities of Pine Valley, Descanso, and Alpine, and the Viejas Indian Reservation. Unincorporated rural and suburban communities characterize the central part of the watershed. The urbanized lower portion of the Sweetwater watershed contains portions of several cities including San Diego, National City, Chula Vista, La Mesa, and Lemon Grove. Of the cities within the watershed, Chula Vista is the most important in terms of land area.

Table 4-7: Sweetwater River watershed unit characteristics and background information

Watershed Characteristics Information	Watershed Unit Area (within County): 229.4 square miles Longest Watershed Flow Path Length: 313,600 feet Maximum Elevation:4,833 Minimum Elevation: 0 (se level) Watershed Elevation Difference: 4,833 feet Average Map Slope: 1.54%
Major Water Bodies	Sweetwater River, Sweetwater Reservoir, Loveland Reservoir, and San Diego Bay
Cities/Population Centers in Watershed	Chula Vista, Rancho Del Ray, Bonita, Lincoln Acres, La Presa, Jamul, North Jamul, Spring Valley, Jamacha Rancho San Diego Mt Helix Crest Alpine Heights Harbison Canyon The Willows Descanso Junction Guatay Descanso Hulburd Grove Morettis Junction Valley Center Ranchita Hidden Meadows Camp Pendleton South San Luis Rey Lake Henshaw San Ysidro La Jolla Amago Bonsall Warner Springs Los Tules Eagles Nest Rincon Birch Hill Pauma Valley San Luis Rey Heights Camp Pendleton North Pala Mesa Village Winterwarm Palomar Mountain Sunshine Summit Pala Fallbrook Rainbow
Rivers / Creek Length (ft)	Arroyo Seco 4,051 Cold Stream 15,642 Descanso Creek 34,725 Harper Creek 28,950 Japacha Creek 10,552

	Juaquapin Creek	13,141
	Lawson Creek	32,326
	North Fork Sweetwater River	31,539
	Paradise Creek	15,399
	Samagatuma Creek	29,426
	Stonewall Canyon	14,259
	Sweetwater River	311,152
	Sycuan Creek	10,893
	Taylor Creek	38,827
	Viejas Creek	49,445

4.1.3.1 Biological / Habitat Natural Resources

Between the headwaters and the outlet to San Diego Bay, the watershed contains a variety of habitat types including oak and pine woodlands, riparian forest, chaparral, coastal sage scrub, and coastal salt marsh. The upper watershed contains large undeveloped areas within the Cleveland National Forest and

4.1.3.2 Watershed Floodplain Hydrology – Major Drainages

Table 4-8: Sweetwater watershed floodplain mapping hydrology – major drainages

Flooding Source / Location	Drainage Area (square miles)	Peak Discharge (cfs)		
		10-year (10% chance)	50-year (2% chance)	100-year (1% chance)
Spring Valley Creek				
Below Confluence w/ Casa de Oro Creek	7.1	1,300	2,600	3,600
Sweetwater River				
Above Sweetwater Reservoir	174	5,600	21,500	29,500
Sweetwater River (At National City)				
At Broadway	219	1,200	21,000	35,000
Sweetwater River (Near Descanso)				
At Japatul Valley Rd. Bridge	41	3,800	14,800	20,300

Note: Hydrology Data is based on the FEMA *Flood Insurance Study San Diego County, CA;* May 16, 2012

4.1.3.3 Flood Risk and Exposure Mapping

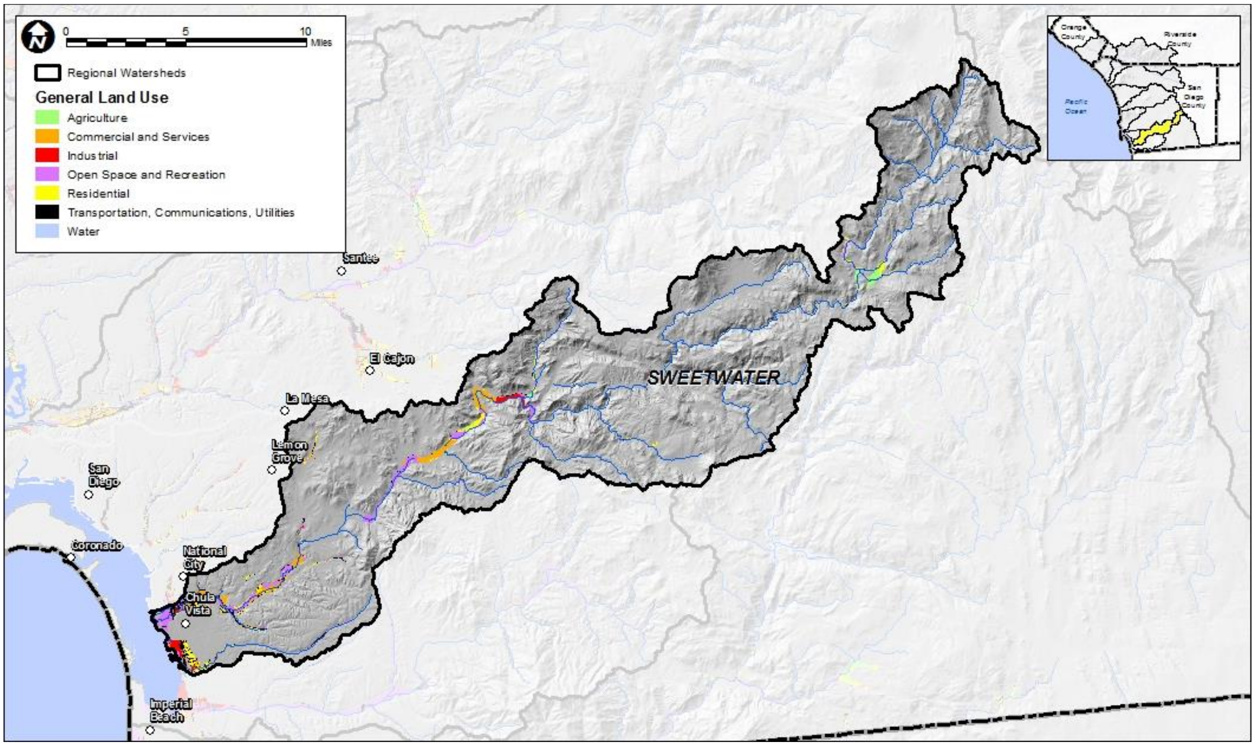

Figure 4-7: Floodplain risks and exposure assessment – landuses within 100-year floodplain for Sweetwater watershed unit

Table 4-9: Landuse types located within mapped flood hazard zones for Sweetwater watershed unit

SWEETWATER	Area (acres)
Agriculture	273
Commercial and Services	1,204
Industrial	371
Open Space and Recreation	1,815
Residential	825
Transportation, Communications, and Utilities	751
Water	97
Grand Total	**5,336**

4.1.4 Pueblo San Diego

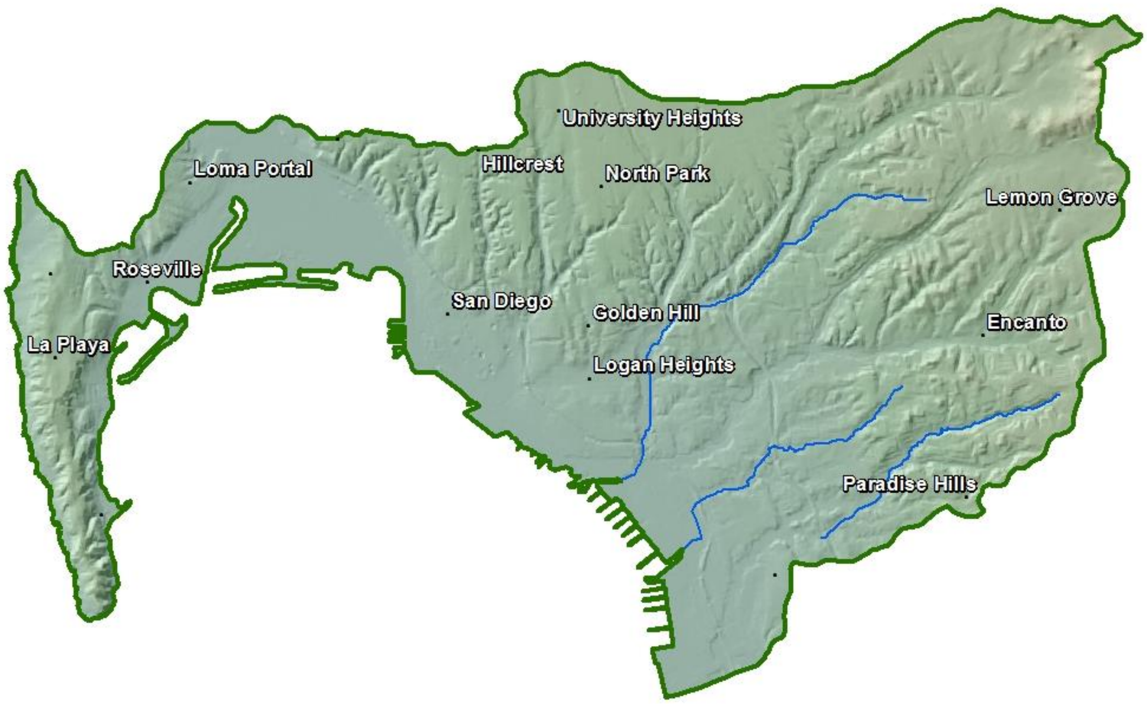

Figure 4-8: Pueblo San Diego watershed unit with population centers

The Pueblo San Diego is the smallest regional watershed unit in San Diego County, encompassing approximately 60 square miles of predominantly urban landscape in the cities of San Diego, La Mesa, Lemon Grove, and National City. The watershed contains the smallest proportion of unincorporated area (0.3%) of the watershed units within the county. The population of the Pueblo San Diego watershed is approximately 500,000 residents, making it the county's most densely populated watershed. Approximately 75% of the watershed is developed. Residential, retail/ office, and industrial land uses account for 45%, 11%, and 10% of the total, respectively. In addition, there are relatively large percentages of land used for transportation corridors and highways. Due to the high level of existing urbanization in the watershed, only small amounts of additional land is projected for development over the next 15 years.

The watershed drainage consists of a group of relatively small local creeks and pipe conveyances, many of which are concrete-lined and drain directly into San Diego Bay.

Table 4-10: Pueblo San Diego watershed unit characteristics and background information

Watershed Characteristics Information	Watershed Unit Area (within County): 58.6 square miles Longest Watershed Flow Path Length: 33,053 feet Maximum Elevation:431 Minimum Elevation: 0 (sea level) Watershed Elevation Difference: 431 feet Average Map Slope: 1.30%
Major Water Bodies	Las Chollas Creek, Switzer Creek, Paleta Creek, and San Diego Bay
Cities in Watershed	National City Paradise Hills Point Loma Logan Heights Encanto La Playa Golden Hill San Diego Roseville Fleetridge Lemon Grove North Park Loma Portal Hillcrest Mission Hills University Heights
Rivers / Creek Length (ft)	Chollas Creek 33,054 Paradise Creek 21,478 Seventh Street Channel 22,300

4.1.4.1 Water Quality

The beneficial uses of the inland surface waters in the Pueblo San Diego watershed are limited to contact (potential use) and non-contact recreation, warm freshwater habitat, and wildlife habitat. The San Diego Bay receiving water supports an extensive array of beneficial uses. The creeks in the watershed are highly impacted by urban runoff, and Chollas Creek and the mouth of the creek in San Diego Bay are listed as 303(d)-impaired water bodies for various trace metals parameters and aquatic toxicity. Five sites in San Diego Bay that are impacted by runoff from the Pueblo San Diego watershed have been identified as hot spots by California's Bay Protection Toxic Cleanup Program.

4.1.4.2 Watershed Floodplain Hydrology – Major Drainages

Table 4-11: Pueblo San Diego watershed floodplain mapping hydrology – major drainages

Flooding Source / Location	Drainage Area (square miles)	Peak Discharge (cfs)		
		10-year (10% chance)	50-year (2% chance)	100-year (1% chance)
Las Chollas Creek				
At Main St.	26.4	4,200	8,000	10,000
Above Confluence w/ South Las Chollas Creek	15.3	3,000	6,000	7,900
At Market St.	12.7	2,700	5,400	7,100
Las Puleta Creek				
At San Diego and AZ	2.8	550	1,200	1,400

Eastern Railroad				
South Las Chollas Creek				
Above Confluence w/ Las Chollas Creek	10.9	2,000	3,900	5,300
Switzer Creek				
At Harbor Dr.	4.3	830	2,200	2,600

Note: Hydrology Data is based on the FEMA *Flood Insurance Study San Diego County, CA;* May 16, 2012

4.1.4.3 Flood Risk and Exposure Mapping

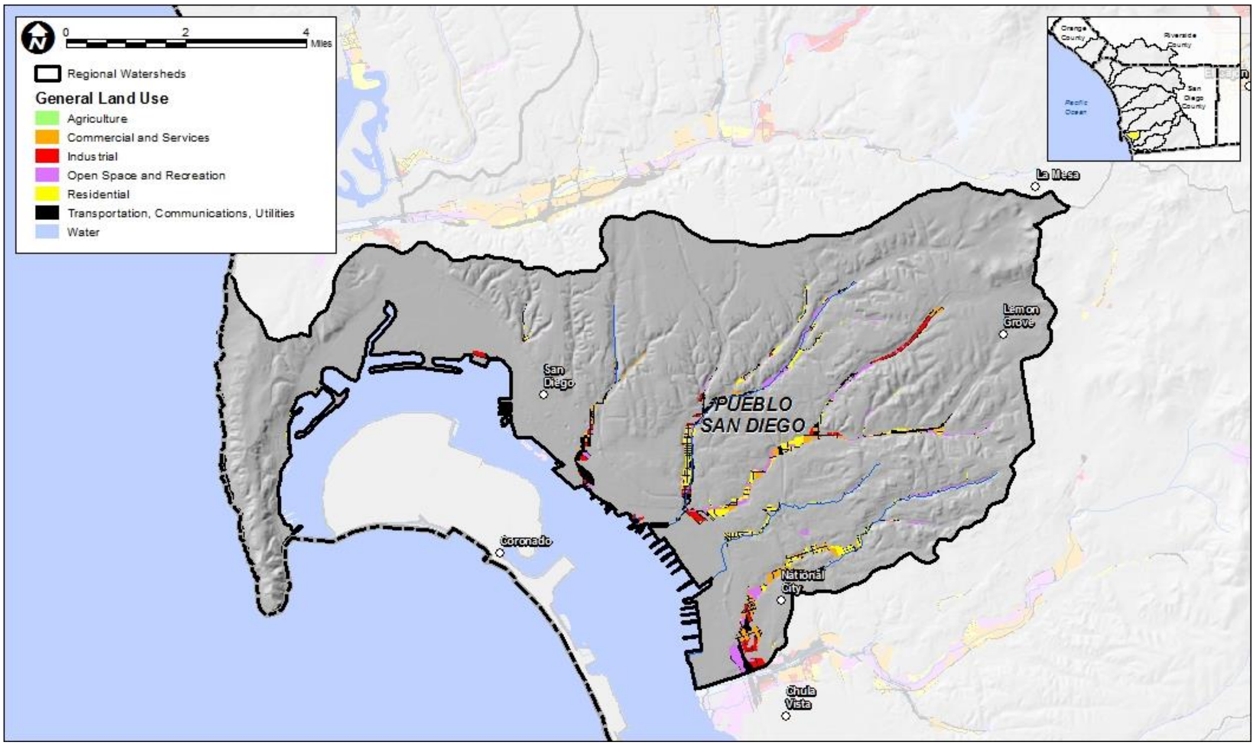

Figure 4-9: - Floodplain risks and exposure assessment – landuses within 100-year floodplain for Pueblo San Diego watershed unit

Table 4-12: Landuse types located within mapped flood hazard zones for Pueblo San Diego watershed unit

PUEBLO SAN DIEGO	Area (acres)
Commercial and Services	217
Industrial	165
Open Space and Recreation	330
Residential	306
Transportation, Communications, and Utilities	555
Water	22
Grand Total	**1,594**

4.1.5 San Diego River

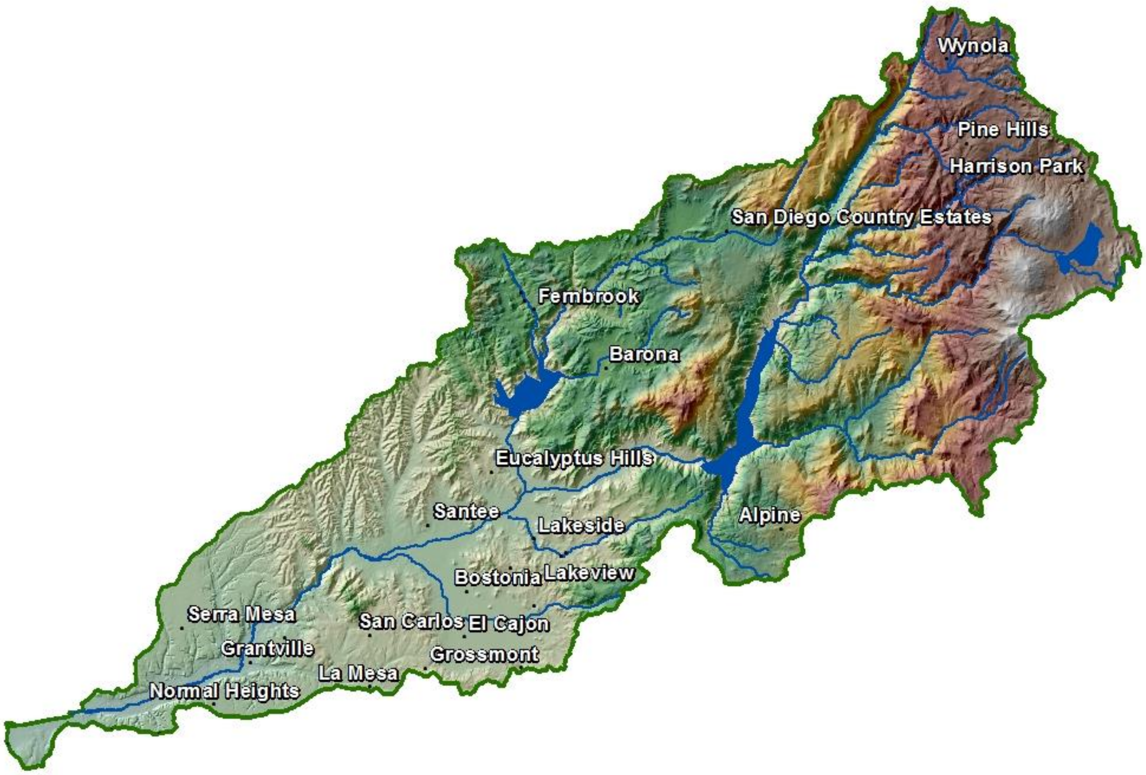

Figure 4-10: San Diego River watershed unit with population centers

With a land area of approximately 440 square miles, the San Diego River watershed is the second largest in San Diego County. It also has the highest population (~475,000) of the County's watersheds and contains portions of the cities of San Diego, El Cajon, La Mesa, Poway, and Santee and several unincorporated jurisdictions. Important hydrologic resources in the watershed include five water storage reservoirs, a large groundwater aquifer, extensive riparian habitat, coastal wetlands, and tidepools. Approximately 58.4% of the San Diego River watershed is currently undeveloped. The majority of this undeveloped land is in the upper, eastern portion of the watershed, while the lower reaches are more highly urbanized with residential (14.9%), freeways and roads (5.5%), and commercial/ industrial (4.2%) land uses predominating.

There are 4 major dams within the San Diego River watershed: El Capitan on the main river; San Vicente, Lake Jennings, and Cuyamaca on tributaries. The reservoirs along the river are major water storage facilities for the San Diego metropolitan area. These reservoirs store water that is primarily from the Colorado River. El Capitan stores local water while Cuyamaca Reservoir stores only local runoff. The annual precipitation ranges from less than II inches along the coast to 35 inches around Cuyamaca and El Capitan reservoir. Other areas including the Cleveland National Forest, Mission Trails Regional Park, and the river flood plain near Lakeside represent three important undeveloped areas that host a wide variety of intact habitats and endangered species. In addition, Famosa Slough, near the mouth of the San Diego River contains extremely productive wetlands habitat. The Famosa Slough is a tidal salt water marsh, located on West Point Loma Boulevard between Nimitz and Sports Arena Boulevards. It receives water via the San Diego River Flood Control Channel.

Table 4-13: San Diego River watershed unit characteristics and background information

Watershed Characteristics Information	Watershed Unit Area (within County): 435.9 square miles Naturally Occurring Waterways: 1736.44 miles Percentage of Free Flowing River Miles: 82 % Number of Dams: 28 Number of Stream Crossings: 2312 Percentage Area above 15% Slope: 14.59 % Longest Watershed Flow Path Length: 260,762 feet Maximum Elevation: 3,668 Minimum Elevation: 0 (sea level) Watershed Elevation Difference: 3,668 feet Average Map Slope: 1.41%
Major Water Bodies	San Diego River, El Capitan Reservoir, San Vicente Reservoir, Lake Murray, Boulder Creek, Santee Lakes
Cities in Watershed	Ocean Beach Normal Heights La Mesa Casa De Oro-Mount Helix Grossmont Grantville El Cajon Allied Gardens San Carlos Serra Mesa Granite Hills Bostonia Winter Gardens Lakeview Johnstown Lakeside Alpine Santee Eucalyptus Hills Barona Fernbrook Shady Dell Irvings Crest San Diego Country Estates Harrison Park Pine Hills Wynola
Rivers / Creek Length	Alpine Creek 12,030 Azalea Creek 10,799 Bailey Creek 11,949

	Boring Creek	6,200
	Boulder Creek	71,041
	Cedar Creek	70,558
	Chocolate Creek	24,606
	Coleman Creek	25,867
	Conejos Creek	58,339
	Daly Creek	3,404
	Dehr Creek	27,621
	Eastwood Creek	7,462
	Forester Creek	62,064
	Isham Creek	17,110
	Jim Green Creek	15,641
	Johnson Creek	14,553
	Kelly Creek	21,973
	King Creek	57,233
	Klondike Creek	16,131
	Little Stonewall Creek	17,513
	Los Coches Creek	48,884
	Mariette Creek	7,305
	Orinoco Creek	27,368
	Padre Barona Creek	34,739
	Ritchie Creek	30,885
	San Diego River	248,403
	San Vicente Creek	141,148
	Sand Creek	35,260
	Sandy Creek	11,533
	Sentenac Creek	12,955
	Sheep Camp Creek	9,916
	Temescal Creek	20,663
	West Branch San Vicente Creek	23,949
	West Fork King Creek	14,942

4.1.5.1 Water Quality

The mouth of the river discharges into the Pacific Ocean at the community of Ocean Beach. Beach postings and closures from elevated levels of coliform bacteria more than doubled between 1996 and 1999 due to urban runoff and sewage spills. Discharge from the San Diego River outlet may also influence water quality in other nearby coastal areas including Sunset Cliffs, Pacific Beach, and Mission Beach. The extensive groundwater resources beneath the San Diego River provide a cost effective and reliable water supply to four local water districts and the City of San Diego. Excessive extraction, increasing total dissolved solids, and MTBE contamination now threatens this resource.

4.1.5.2 Watershed Floodplain Hydrology – Major Drainages

Table 4-14: San Diego River watershed floodplain mapping hydrology – major drainages

Flooding Source / Location	Drainage Area (square miles)	Peak Discharge (cfs)		
		10-year (10% chance)	50-year (2% chance)	100-year (1% chance)
Forester Creek				
At Prospect Ave.	22.7	6,000	11,000	12,450
Murphy Canyon				
Upstream of Friars Rd.	12.1	1,500	2,700	3,500
San Diego River				
At Confluence w/ Murphy Canyon Creek	420	3,100	17,000	36,000
Just Downstream of Confluence of San Vicente Creek	290	2,500	--	31,000
San Vicente Creek				
At Mouth	83	1,400	10,500	16,000

-- Data Not Available

Note: Hydrology Data is based on *Flood Insurance Study San Diego County, CA;* May 16, 2012

4.1.5.3 Flood Risk and Exposure Mapping

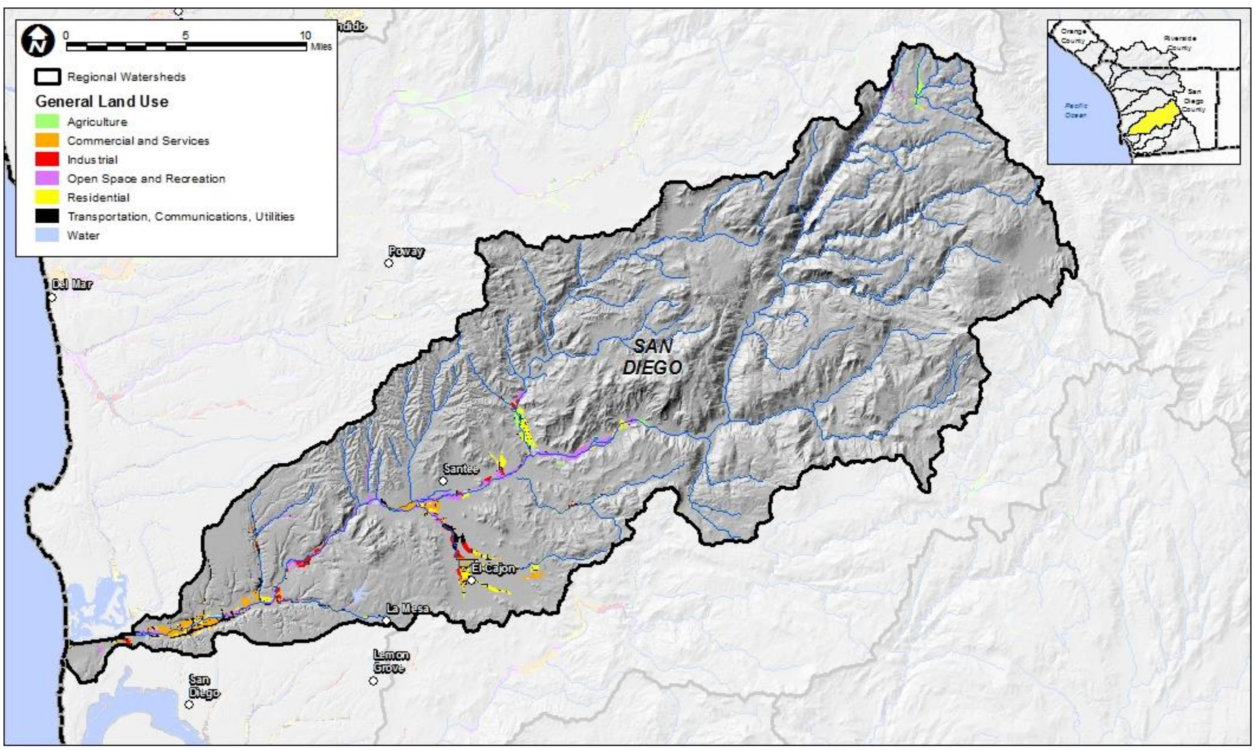

Figure 4-11: Floodplain risks and exposure assessment – landuses within 100-year floodplain for San Diego River watershed unit

Table 4-15: Landuse types located within mapped flood hazard zones for San Diego River watershed unit

SAN DIEGO RIVER	Area (acres)
Agriculture	508
Commercial and Services	1,414
Industrial	600
Open Space and Recreation	2,576
Residential	1,577
Transportation, Communications, and Utilities	1,272
Water	420
Grand Total	**8,367**

4.1.6 Los Peñasquitos Creek

Figure 4-12: Los Peñasquitos watershed unit with population centers

The Los Peñasquitos regional watershed unit is comprised of the Los Peñasquitos Creek watershed, several coastal tributaries, and the Mission Bay watershed. These watersheds drain a highly urbanized region located almost entirely west of Interstate 15 in coastal San Diego County. Collectively and individually, they support a variety of water supply, economic, recreational, and habitat-related beneficial uses. The major receiving waters, Los Peñasquitos Lagoon and Mission Bay, are both fragile systems that support diverse native fauna and flora. Both water bodies are especially sensitive to the effects of pollutants due to restricted or intermittent tidal flushing. The Los Peñasquitos Creek watershed encompasses a land area of approximately 100 square miles including portions of the cities San Diego, Poway, and Del Mar. The watershed is highly urbanized with a population of approximately 400,000 residents. The creek discharges to a 0.6 square mile lagoon that is identified as an impaired water body on the California 303(d) list for sedimentation.

The watershed encompasses 170 square miles, and extends from Poway (inland) to La Jolla. The tributaries of the watershed, Los Peñasquitos Creek and Carmel Creek, low year-round due to development in the watershed. Miramar Reservoir is the major water storage facility within the watershed, and contains Colorado River water. Annual precipitation ranges from less than 8 inches along the coast to 18 inches inland.

Table 4-16: Los Peñasquitos watershed unit characteristics and background information

Watershed Characteristics Information	Watershed Unit Area (within County): 162.1 square miles Longest Watershed Flow Path Length: 111,466 feet Maximum Elevation: 1,684 Minimum Elevation: 0 (sea level) Watershed Elevation Difference: 1,684 feet Average Map Slope: 1.51%	
Major Water Bodies	Los Peñasquitos Creek, Los Peñasquitos Lagoon, Rose Creek, Tecolote Creek, Mission Bay, Miramar Reservoir	
Cities / Population Centers in Watershed	Crown Point, Bay Park, Mission Beach, Linda Vista, Clairemont, Pacific Beach, Bird Rock, La Jolla, University City, Miramar, Mira Mesa, Poway	
Rivers / Creek Length (ft)	Beeler Creek	31,232
	Chicarita Creek	13,095
	Los Peñasquitos Creek	61,229
	Poway Creek	39,098
	Rattlesnake Creek	26,910
	Tecolote Creek	35,928

4.1.6.1 Watershed Floodplain Hydrology – Major Drainages

Table 4-17: Los Peñasquitos watershed floodplain mapping hydrology – major drainages

Flooding Source / Location	Drainage Area (square miles)	Peak Discharge (cfs)		
		10-year (10% chance)	50-year (2% chance)	100-year (1% chance)
Carmel Valley Creek				
Above Confluence w/ Soledad Canyon	15.7	2,100	6,500	9,800

Los Peñasquitos Creek				
Above Confluence w/ Soledad Canyon	58.3	3,700	11,300	16,800
At US Hwy 395	42.7	3,100	10,000	15,400
Poway Creek				
USGS Gage at Cobblestone Creek Rd.	31.2	2,500	8,700	14,000
Rose Canyon Creek				
At Mouth	37	2,700	8,100	12,000
San Clemente Canyon Creek				
Upstream of Confluence w/ Rose Canyon Creek	18.4	1,400	4,200	6,900
Soledad Canyon				
At Mouth	95.5	5,000	15,400	23,000
Tecolote Creek				
At Interstate Hwy. 5	9.29	2,100	3,800	4,900

Note: Hydrology Data is based on the FEMA *Flood Insurance Study San Diego County, CA;* May 16, 2012

4.1.6.2 Flood Risk and Exposure Mapping

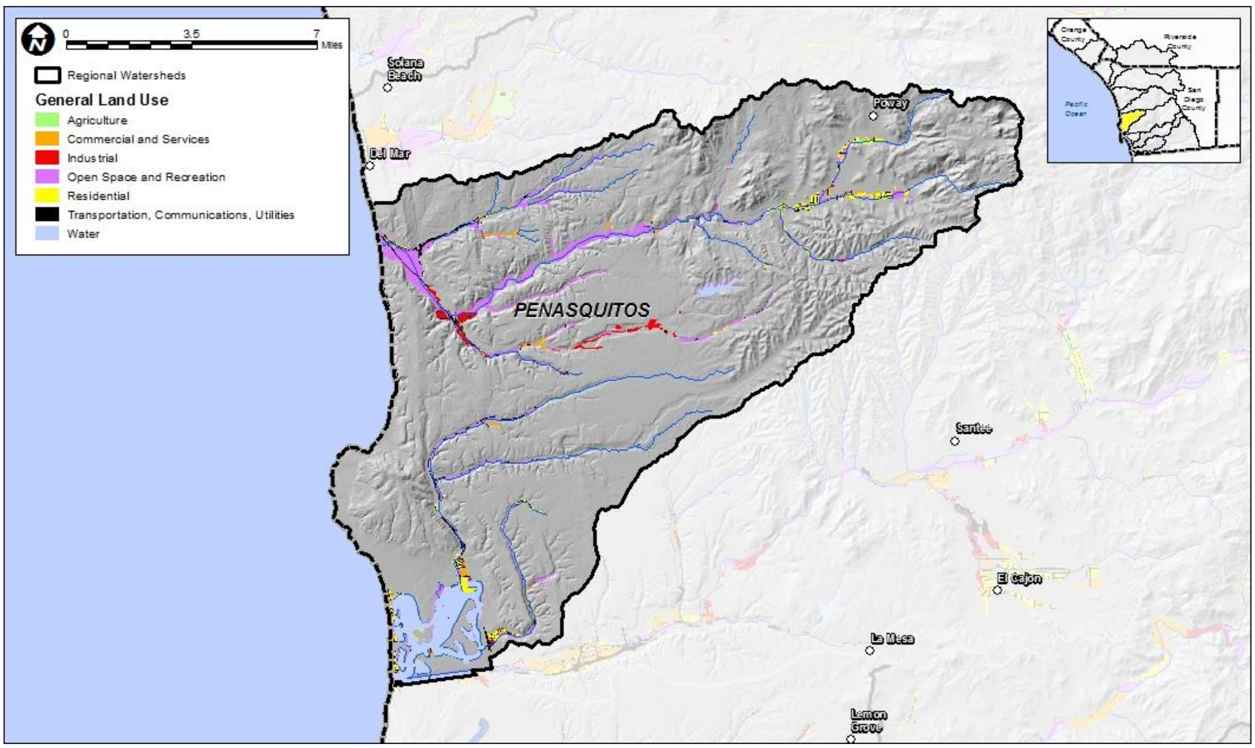

Figure 4-13: Floodplain risks and exposure assessment – landuses within 100-year floodplain for Los Penasquitos watershed unit

Table 4-18: Landuse types located within mapped flood hazard zones for Los Penasquitos watershed unit

LOS PEÑASQUITOS	Area (acres)
Agriculture	38
Commercial and Services	461
Industrial	356
Open Space and Recreation	2,953
Residential	637
Transportation, Communications, and Utilities	629
Water	2,309
Grand Total	**7,382**

4.1.7 San Dieguito River

Figure 4-14: San Dieguito watershed unit with population centers

The San Dieguito River watershed is a drainage area of approximately 346 square miles in west-central San Diego County, 302 of which are behind dams. Lake Hodges (completed in 1919) and Lake Sutherland (completed in 1954) are the two major dams that block the river. Three tributaries join the San Dieguito River below the dam while 2 other small drainages empty directly into the lagoon basin. San Dieguito River flow is intermittent and the riverbed upstream of tidal influence is often dry. The channel is substantially unarmored except for a concrete block revetment along the upper bank. The watershed includes portions of the cities of Del Mar, Escondido, Poway, San Diego, and Solana Beach, and unincorporated San Diego County. In terms of land area, the majority of the watershed (79.8%) is within the unincorporated jurisdiction. The San Dieguito River watershed is presently divided into vacant/undeveloped (54%), parks/open space (29 %), and urban (18%) land uses. Nearly half of the vacant land area is open to future development, most of which is zoned for residential usage. The current watershed population is approximately 125,000 however; this level is projected to increase to over 210,000 residents by 2015.

Table 4-19: San Dieguito watershed unit characteristics and background information

Watershed Characteristics Information	Watershed Unit Area (within County): 346.2 square miles Longest Watershed Flow Path Length: 304,600 feet Maximum Elevation:5,234 Minimum Elevation: 0 Watershed Elevation Difference: 5,234 feet Average Map Slope: 1.72%
Major Water Bodies	San Dieguito River, San Dieguito Lagoon, and Lake Hodges
Cities / Population Centers in Watershed	Rancho Santa Fe Cardiff By The Sea Olivenhain Encinitas Leucadia Escondido Carlsbad Lake San Marcos San Marcos Jesmond Dene South Oceanside Oceanside Twin Oaks Vista
Rivers / Creek Length (ft)	Bear Creek 19,849 Bloomdale Creek 30,505 Dan Price Creek 10,920 Guejito Creek 57,975 Hatfield Creek 54,845 Lusardi Creek 22,472 San Diego Aqueduct 5,848 San Dieguito River 121,820 Santa Maria Creek 92,231 Santa Ysabel Creek 206,095

	Scholder Creek	13,741
	Temescal Creek	53,688
	Wash Hollow Creek	22,135
	Witch Creek	26,994

4.1.7.1 Water Quality

The Pacific Ocean at the mouth of the San Dieguito River is listed as a 303(d)-impaired water body for elevated coliform bacteria. In the absence of a comprehensive watershed planning effort, large-scale future development may exasperate current water quality problems and create additional beneficial use impairments. The San Dieguito Lagoon is especially sensitive to the effects of pollutants and oxygen depletion due to restricted or intermittent tidal flushing.

4.1.7.2 Biological / Habitat Natural Resources

The watershed extends through a diverse array of habitats from its eastern headwaters in the Volcan Mountains to the outlet at the San Dieguito Lagoon and the Pacific Ocean. There are several important natural areas within the watershed that sustain a number of threatened and endangered species. Among these are the 55-mile long, 80,000 acre San Dieguito River Park, the 150 acre San Dieguito Lagoon, and five water storage reservoirs including Lake Hodges, Lake Sutherland, and Lake Poway.

4.1.7.3 Watershed Floodplain Hydrology – Major Drainages

Table 4-20: San Dieguito watershed floodplain mapping hydrology – major drainages

Flooding Source / Location	Drainage Area (square miles)	Peak Discharge (cfs)		
		10-year (10% chance)	50-year (2% chance)	100-year (1% chance)
Hatfield Creek				
At Mouth	20.8	1,700	7,900	13,700
San Dieguito River				
Upstream of Camino Del Mar Bridge	--	5,700	31,400	41,800
Santa Maria Creek (San Pasqual Valley Area)				
At Confluence w/ Santa Ysabel Creek	60	3,200	14,700	19,000
Santa Ysabel Creek				
Lake Hodges at Hodges Dam	290	10,000	48,000	62,000

-- Data Not Available

Note: Hydrology Data is based on the FEMA *Flood Insurance Study San Diego County, CA;* May 16, 2012

4.1.7.4 Flood Risk and Exposure Mapping

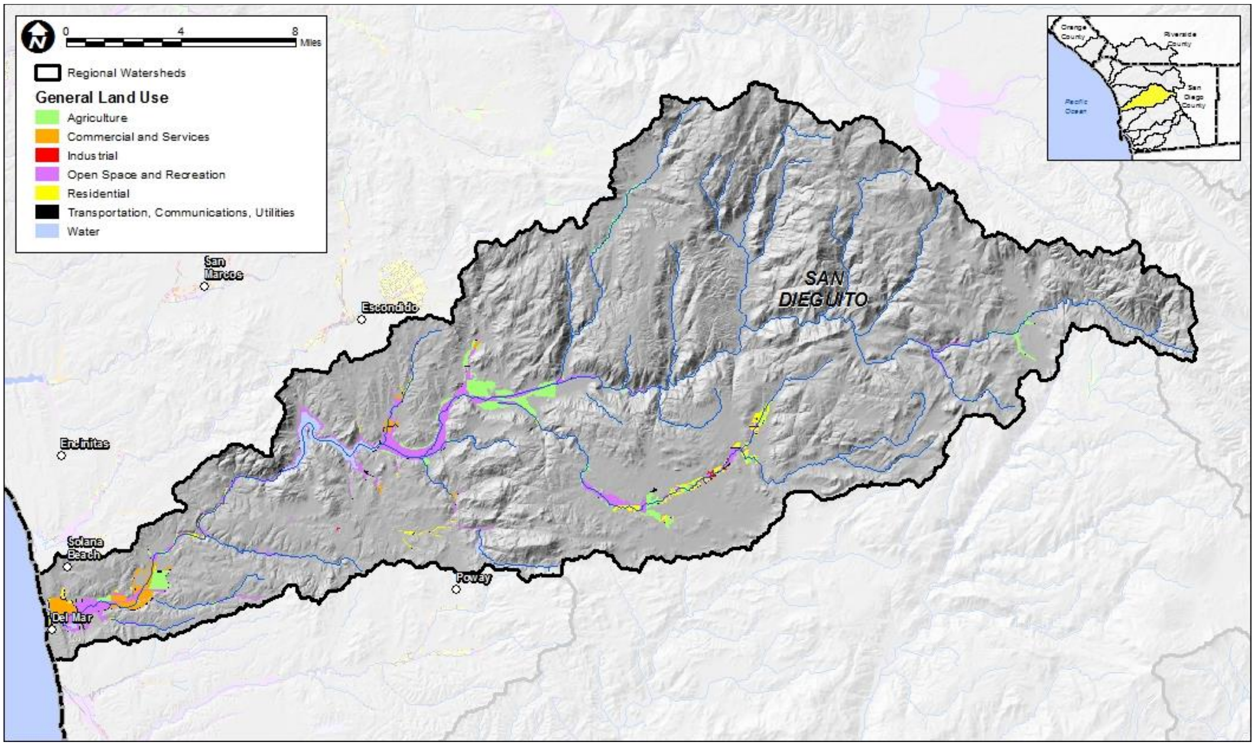

Figure 4-15: Floodplain risks and exposure assessment – landuses within 100-year floodplain for San Dieguito watershed unit

Table 4-21: Landuse types located within mapped flood hazard zones for San Dieguito watershed unit

SAN DIEGUITO	Area (acres)
Agriculture	2,352
Commercial and Services	953
Industrial	44
Open Space and Recreation	4,326
Residential	853
Transportation, Communications, and Utilities	344
Water	993
Grand Total	**9,864**

4.1.8 Carlsbad

Figure 4-16: Carlsbad watershed unit with population centers

The watershed encompasses 210 square miles, and extends from Lake Wohlford to the ocean. The watershed is drained by Buena Vista, Agua Hedionda, San Marcos, and Escondido creeks. The watershed includes the Encinas and Loma Alta hydrological areas. The Buena Vista watershed encompasses 19 square miles while the Escondido creek watershed encompasses 77 square miles and includes the major tributaries of Escondido and La Orilla creeks. The Agua Hedionda creek watershed encompasses 29 square miles. The Loma Alta creek watershed encompasses 20 square miles. The San Marcos creek watershed encompasses 52 square miles. and San Marcos Dam, constructed in 1952, controls approximately 53% of the watershed. The cities of Carlsbad, San Marcos, and Encinitas are entirely within this regional watershed unit. The population of the Carlsbad regional watershed unit is approximately 500,000 residents making it the third most densely populated in San Diego County behind the Pueblo San Diego and the Peñasquitos watershed units. A high percentage of the undeveloped land is in private ownership and the population of the Carlsbad watershed unit is projected to increase to over 700,000 residents by 2015.

The watershed includes four major coastal lagoons: Buena Vista, Agua Hedionda, Batiquitos (at the mouth of San Marcos creek), and San Elijo (at the mouth of Escondido Creek).

Table 4-22: Carlsbad watershed unit characteristics and background information

Watershed Characteristics Information	Watershed Unit Area (within County): 212.1 square miles Longest Watershed Flow Path Length: 141,900 feet Maximum Elevation: 1,841 Minimum Elevation: 0 (sea level) Watershed Elevation Difference: 1,841 feet Average Map Slope: 1.30%
Major Water Bodies	Loma Alta Creek, Buena Vista Creek, Buena Vista Lagoon, Agua Hedionda Creek, Agua Hedionda Lagoon, San Marcos Creek, Batiquitos Lagoon, Escondido Creek, San Elijo Lagoon, and Lake Wolhford
Cities / Population Centers in Watershed	Rancho Santa Fe Cardiff By The Sea Olivenhain Encinitas Leucadia Escondido Carlsbad Lake San Marcos San Marcos Jesmond Dene South Oceanside Oceanside Twin Oaks Vista
Rivers / Creek Length (ft)	Agua Hedionda Creek 68,121 Arroyo Poco 4,657 Buena Creek 25,547 Buena Vista Creek 58,093 Encinitas Creek 24,395 Escondido Canal 6,981 Escondido Creek 138,013 Loma Alta Creek 34,838 San Marcos Creek 64,065 Vista Canal 68,690

4.1.8.1 Water Quality

The Agua Hedionda, Buena Vista, and San Elijo lagoons are experiencing impairments to beneficial uses due to excessive coliform bacteria and sediment loading from upstream sources. These coastal lagoons represent critical regional resources that provide freshwater and estuarine habitats for numerous plant and animal species. Other water bodies in the Carlsbad HU have been identified as impaired on the California 303(d) list for elevated coliform bacteria including several locations in the Pacific Ocean near creek and lagoon outlets.

4.1.8.2 Biological / Habitat Natural Resources

Urban development (and associated flood control activities), sedimentation from agriculture, erosion, eutrophication of lagoon systems, the presence of exotic species in the watershed, water pollution, and general habitat degradation are major threats to the area.

4.1.8.3 Watershed Floodplain Hydrology – Major Drainages

Table 4-23: Carlsbad watershed floodplain mapping hydrology – major drainages

Flooding Source / Location	Drainage Area (square miles)	Peak Discharge (cfs)		
		10-year (10% chance)	50-year (2% chance)	100-year (1% chance)
Agua Hedionda Creek				
At El Camino Real	23.8	--	--	9,850
Buena Vista Creek				
Upstream of Interstate Hwy. 5	20.8	2,000	5,600	8,500
Escondido Creek				
At Interstate Hwy. 5	77.7	3,400	15,500	22,000
San Marcos Creek				
Upstream of San Marcos Dam (Lake San Marcos)	28.1	--	--	15,700

-- Data Not Available

Note: Hydrology Data is based on the FEMA *Flood Insurance Study San Diego County, CA;* May 16, 2012

4.1.8.4 Flood Risk and Exposure Mapping

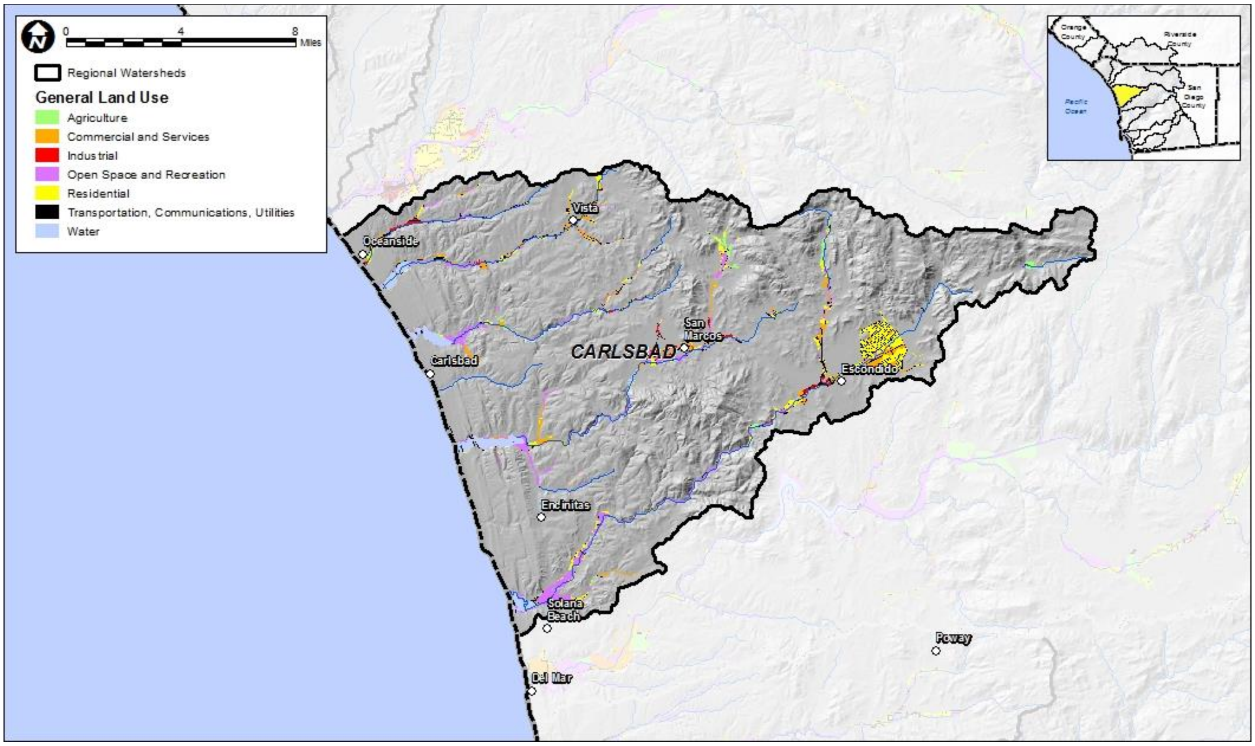

Figure 4-17: Floodplain risks and exposure assessment – landuses within 100-year floodplain for Carlsbad watershed unit

Table 4-24: Landuse types located within mapped flood hazard zones for Carlsbad watershed unit

CARLSBAD	Area (acres)
Agriculture	354
Commercial and Services	1,345
Industrial	271
Open Space and Recreation	2,474
Residential	1,721
Transportation, Communications, and Utilities	1,082
Water	1,217
Grand Total	**8,464**

4.1.9 San Luis Rey River

Figure 4-18: San Luis Rey River watershed unit with population centers

The San Luis Rey River watershed is located east of the City of Oceanside in the northwestern portion of San Diego County. The 558 square mile drainage is the largest watershed affecting the San Diego region. It is bordered to the north by the Santa Margarita River Watershed and to the south by the Carlsbad and San Dieguito River Watersheds. The San Luis Rey River originates in the Palomar and Hot Springs Mountains, both over 6,000 feet above mean sea level, as well as several other mountain ranges along the western border of the Anza Borrego Desert Park. The river extends over 55 miles across northern San Diego County. The river ultimately discharges to the Pacific Ocean near the City of Oceanside. Of the nine major watersheds in the San Diego region, the San Luis Rey is the third largest.

The watershed drains to the Pacific Ocean to the west and is bounded by the Moserate Mountains to the north, the Cleveland National Forest and Camp Pendleton to the northwest, and Escondido, San Diego, and other cities to the south. The basin is roughly 50 miles long by 16 miles wide, and is divided into two drainage areas by Henshaw Dam. The areas above and below the dam encompass

206 and 354 square miles, respectively (USACOE, 1977). Annual precipitation ranges from 12 inches near the coast to approximately 45 inches near the headwaters on Palomar mountain. The watershed is comprised of three hydrological areas: the Lower San Luis, Monserate and Warner Valley areas. Henshaw Dam, built in 1922, controls 36% of the watershed and three small reservoirs. The mouth of the San Luis Rey River is not listed as an impaired water body.

Approximately 92.5% of the San Luis Rey River watershed is located in unincorporated areas of San Diego County. Roughly one-fourth of the land area in the watershed is located west of Interstate 15 including portions of the cities of Oceanside and Vista, the communities of Fallbrook and Bonsall, and the southwestern portion of Camp Pendleton. The land west of I-15 has multiple uses including open space/ undeveloped, residential, commercial/ industrial, and agricultural. East of Interstate 15, most of the land is owned and managed by government agencies (county, state, and federal), special districts, and Native American bands. The predominant land uses are open space/ undeveloped and agricultural. About half (49%) of the land in the watershed is privately owned, 37% is publicly owned, and the remaining 14% consists of six federally recognized Tribal Indian Reservations. In the western half of the watershed, private ownership dominates. Population centers include the City of Oceanside and the unincorporated communities of Fallbrook, Bonsall, and Valley Center. Moving east through the watershed, public lands become increasingly dominant. Over 54% of the land in the watershed is vacant or undeveloped. The next largest land uses in the watershed are residential (15%) and agriculture (14%). Principal agricultural uses include cattle grazing, nurseries, citrus groves, and avocado groves.

Unlike most major rivers in Southern California, the San Luis Rey River has undergone relatively little channelization. The only significant segment of the river that has been channelized is within the City of Oceanside. However, the cumulative impacts of various land use practices in the basin appear to be degrading the river's environmental value. For example, an increased rate of bed erosion attributable to sand mining operations has been observed in the upper reaches of the river.

Table 4-25: San Luis Rey watershed unit characteristics and background information

Watershed Characteristics Information	Watershed Unit Area (within County): 560.0 square miles Area: 495650.48 acres Naturally Occurring Waterways: 961.86 miles Number of Dams: 18 Number of Stream Crossings: 1311 Average Precipitation per Year: 18.82 inches Percentage Area above 15% Slope: 14.64 % Longest Watershed Flow Path Length: 368,400 feet Maximum Elevation:5,593 Minimum Elevation: 0 (sea level) Watershed Elevation Difference: 5,593 feet Average Map Slope: 1.52%
Major Water Bodies	San Luis Rey River and Lake Henshaw
Cities / Population Centers in	Morettis Junction Valley Center Ranchita Hidden Meadows

Table 4-25: San Luis Rey watershed unit characteristics and background information

Watershed	Camp Pendleton South San Luis Rey Lake Henshaw San Ysidro La Jolla Amago Bonsall Warner Springs Los Tules Eagles Nest Rincon Birch Hill Pauma Valley San Luis Rey Heights Camp Pendleton North Pala Mesa Village Winterwarm Palomar Mountain Sunshine Summit Pala Fallbrook Rainbow
Rivers / Creek Length (ft)	Agua Caliente Creek 82,870 Agua Tibia Creek 30,543 Bubble-up Creek 17,923 Buena Vista Creek 43,407 Canada Verruga 13,745 Carrista Creek 34,066 Carrizo Creek 32,895 Cedar Creek 20,057 Doane Creek 12,095 Escondido Canal 66,926 French Creek 17,166 Frey Creek 25,479 Fry Creek 10,298 Gomez Creek 27,805 Hell Creek 24,256 Iron Springs Creek 10,090 Jaybird Creek 11,022 Keys Creek 71,709 Kumpohui Creek 8,556 Lion Creek 13,292 Magee Creek 22,199 Matagual Creek 44,435 Pala Creek 47,683 Paradise Creek 33,155 Pauma Creek 38,597 Pilgrim Creek 52,130

Table 4-25: San Luis Rey watershed unit characteristics and background information

	Plaisted Creek	13,936
	Potrero Creek	30,039
	Prisoner Creek	15,234
	San Diego Aqueduct	74,437
	San Felipe Creek	9
	San Luis Rey River	390,453
	San Ysidro Creek	54,466
	Trujillo Creek	30,379
	West Fork San Luis Rey River	60,762
	Wigham Creek	8,676
	Yuima Creek	29,130

4.1.9.1 Watershed Floodplain Hydrology – Major Drainages

Table 4-26: San Luis Rey watershed floodplain mapping hydrology – major drainages

Flooding Source / Location	Drainage Area (square miles)	Peak Discharge (cfs)		
		10-year (10% chance)	50-year (2% chance)	100-year (1% chance)
Keys Canyon Creek				
Just Downstream of Keys Canyon Creek Tributary (1)	31.58	--	--	22,911
Moosa Canyon Creek				
Near Junction of Moosa Rd. and US Hwy. 395	34.7	2,600[1]	9,000[1]	13,000[1]
Pilgrim Creek				
At Mouth	19	--	--	1,925
San Luis Rey River				
At Mouth	560	6,600	31,000	51,000
Downstream of Confluence w/ Moosa Canyon	355.6	6,200	30,000	48,000
Downstream of Confluence w/ Keys Canyon	252.3	5,000	25,000	41,000

-- Data Not Available

- Note (1) – Flows partially controlled by Turner Dam

Note: Hydrology Data is based on the FEMA *Flood Insurance Study San Diego County, CA;* May 16, 2012

4.1.9.2 Flood Risk and Exposure Mapping

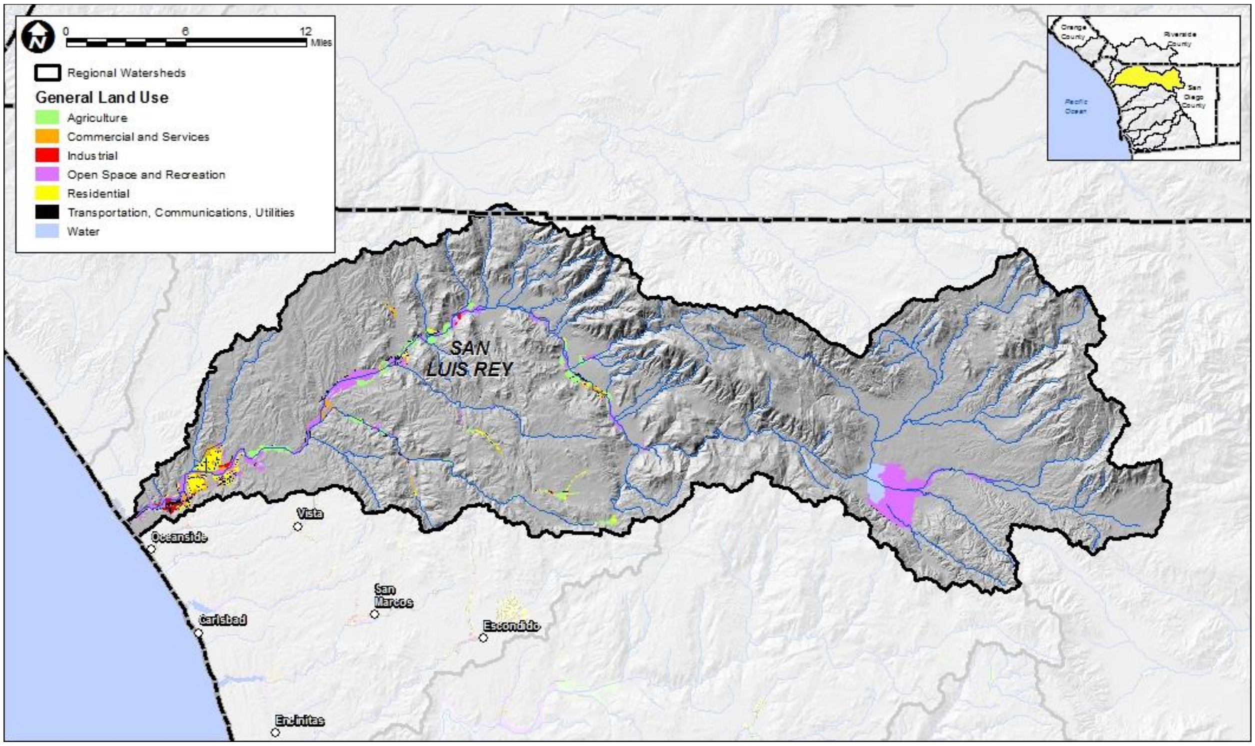

Figure 4-19: Floodplain risks and exposure assessment – landuses within 100-year floodplain for San Luis Rey watershed unit

Table 4-27: Landuse types located within mapped flood hazard zones for San Luis Rey watershed unit

SAN LUIS REY	Area (acres)
Agriculture	2,382
Commercial and Services	917
Industrial	264
Open Space and Recreation	8,262
Residential	1,953
Transportation, Communications, and Utilities	1,159
Water	1,012
Grand Total	**15,950**

4.1.10 Santa Margarita River

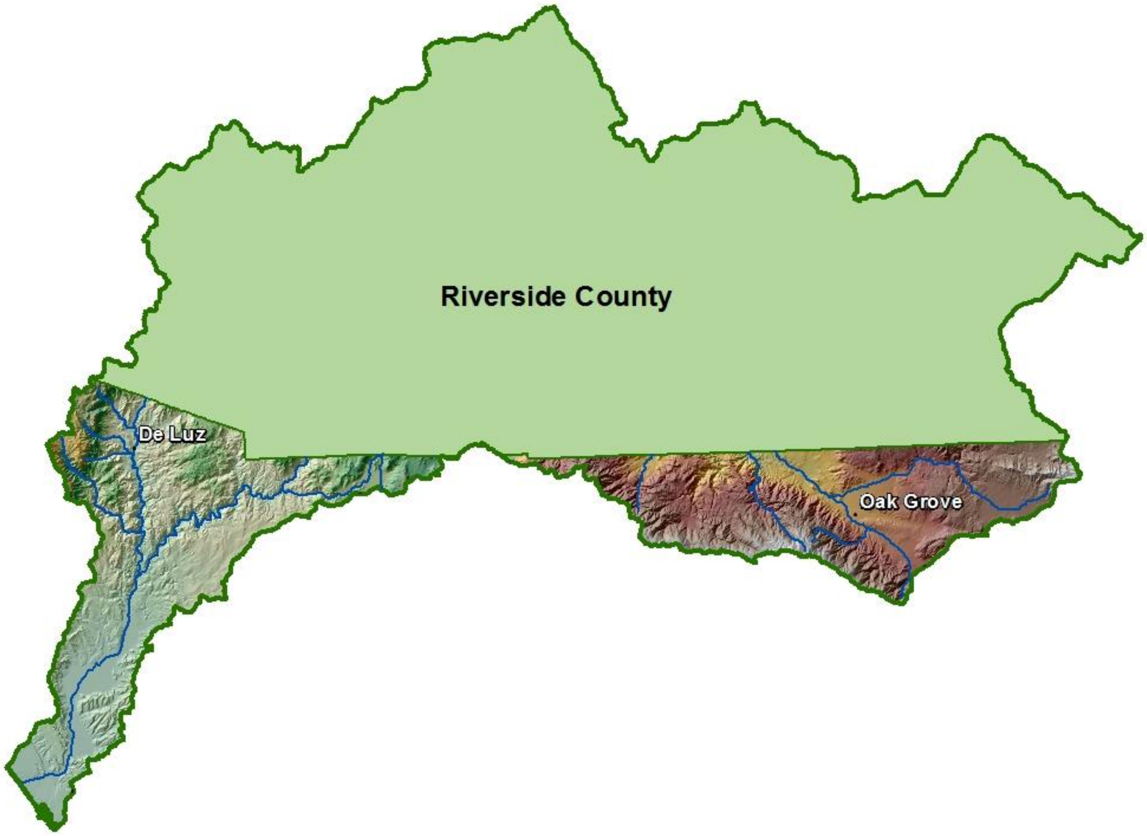

Figure 4-20: Santa Margarita River watershed unit with population centers

The Santa Margarita River watershed encompasses approximately 750 square miles in northern San Diego and southwestern Riverside counties. It is the longest free flowing river in coastal southern California; the channel is braided and supports the most extensive riparian corridor in the county. The watershed is comprised of the following nine hydrologic areas: the Ysidora, Deluz, Murrieta, Auld, Pechanga, Wilson, Cave Rocks, Aguanga, and Oak Groves. This watershed is drained largely by the Santa Margarita River, Murrieta Creek and Temecula River. The precipitation within the watershed ranges from 12 inches on the coast to 45 inches at the headwaters on Palomar Mountain. Twenty-seven miles of free-flowing river exist. Lake O'Neill is out of the River channel but receives much of its water from seasonal river diversions. Two dams are located in the upper watershed along the two streams that join to form the Santa Margarita River. The river is included in the list of impaired water bodies. The watershed contains a variety of nearly intact habitats including chaparral-covered hillsides, riparian woodlands, and coastal marshes. Of the total watershed area, approximately 27% is within San Diego County. The Santa Margarita River is formed near the City of Temecula in Riverside County at the confluence of the Temecula and

Murrieta creek systems. Once formed, the majority of the Santa Margarita River main stem flows within San Diego County through unincorporated areas, the community of Fallbrook, and the Marine Corps Base Camp Pendleton. The lower river and estuary have largely escaped the development typical of other regions of coastal Southern California, and are therefore able to support a relative abundance of functional habitats and wildlife.

The upper watershed basin lies in Riverside County, one of the fastest growing areas in California. In the absence of effective planning measures, this rapid development will likely lead to serious water quality and environmental concerns in the watershed including excessive sedimentation from development and agricultural areas, groundwater degradation and contamination with nitrates and other salts, habitat loss, channelization, flooding and scour (San Diego County Basin Plan).

Table 4-28: Santa Margarita River watershed unit characteristics and background information

Watershed Characteristics Information	Watershed Unit Area (within County): 197.8 square miles (Total 750 sq. mi.) Naturally Occurring Waterways: 1033.46 miles Percentage of Free Flowing River Miles: 92 % Number of Dams: 9 Number of Stream Crossings: 1488 Average Precipitation per Year: 16.07 inches Percentage Area above 15% Slope: 9.38 % Longest Watershed Flow Path Length: 362,900 feet Maximum Elevation: 5,798 Minimum Elevation: 0 (sea level) Watershed Elevation Difference: 5,798 feet Average Map Slope: 1.60%	
Major Water Bodies	Santa Margarita River, Temecula Creek, Murrieta Creek, Santa Margarita Lagoon, Vail Lake, Skinner Reservoir, and Diamond Valley Lake Reservoir	
Cites / Population Centers in Watershed	De Luz, Oak Grove	
Rivers / Creek Length (ft)	Arroyo Seco Creek	51,074
	Cahuilla Creek	98,568
	Camps Creek	15,809
	Chihuahua Creek	66,485
	Cottonwood Creek	64,014
	De Luz Creek	72,850
	Elder Creek	31,991
	Fern Creek	12,724
	Gomez Creek	304
	Hamilton Creek	39,414
	Kolb Creek	17,856
	Murrieta Creek	72,608
	Pechanga Creek	44,567

	Rainbow Creek	30,936
	Rattlesnake Creek	19,357
	Roblar Creek	36,000
	San Diego Aqueduct	18,989
	Santa Gertrudis Creek	66,681
	Santa Margarita River	161,422
	Spring Creek	25,920
	Temecula Creek	180,809
	Tucalota Creek	141,746
	Tule Creek	64,077
	Warm Springs Creek	80,254
	Wilson Creek	86,758

4.1.10.1 Water Quality

Water quality issues focus on sediment, nutrients (especially nitrates), and salts. The Santa Margarita estuary is listed as impaired by the Regional Water Quality Control Board because of being eutrophic. The upper Santa Margarita River is impaired because of phosphorus (San Diego Regional Water Quality Control Board, 2005a).

4.1.10.2 Biological / Habitat Natural Resources

San Margarita River provides diversity of vegetative and aquatic habitats are home to numerous plants and animals, including 500 plant species, 236 bird species, 52 mammal species, 43 reptile species, 26 fish species and 24 species of aquatic invertebrates. The riparian corridor contains the highest density and overall diversity of bird species of any natural area in the south coastal river basin. The Santa Margarita's lush riparian growth supports a substantial percentage of the nation's entire population of the endangered Least Bell's Vireo. This small migratory song bird has been extirpated from 95 percent of its historic breeding range, but has found a home in the Santa Margarita River canyon. The lower portion of the river supports extensive coastal wetlands which provide important habitat for other sensitive and endangered bird species, including the Light-footed Clapper Rail, Belding's Savannah Sparrow and California Least Tern. The Santa Margarita River also supports the largest remaining native population of Arroyo Chub, a small fish which was formerly abundant throughout Southern California. Large runs of coastal steelhead trout have been extirpated from the Santa Margarita, but the river remains one of the few nearly pristine coastal watersheds in which to reintroduce this biologically unique species.

4.1.10.3 Flood Risk and Exposure Mapping

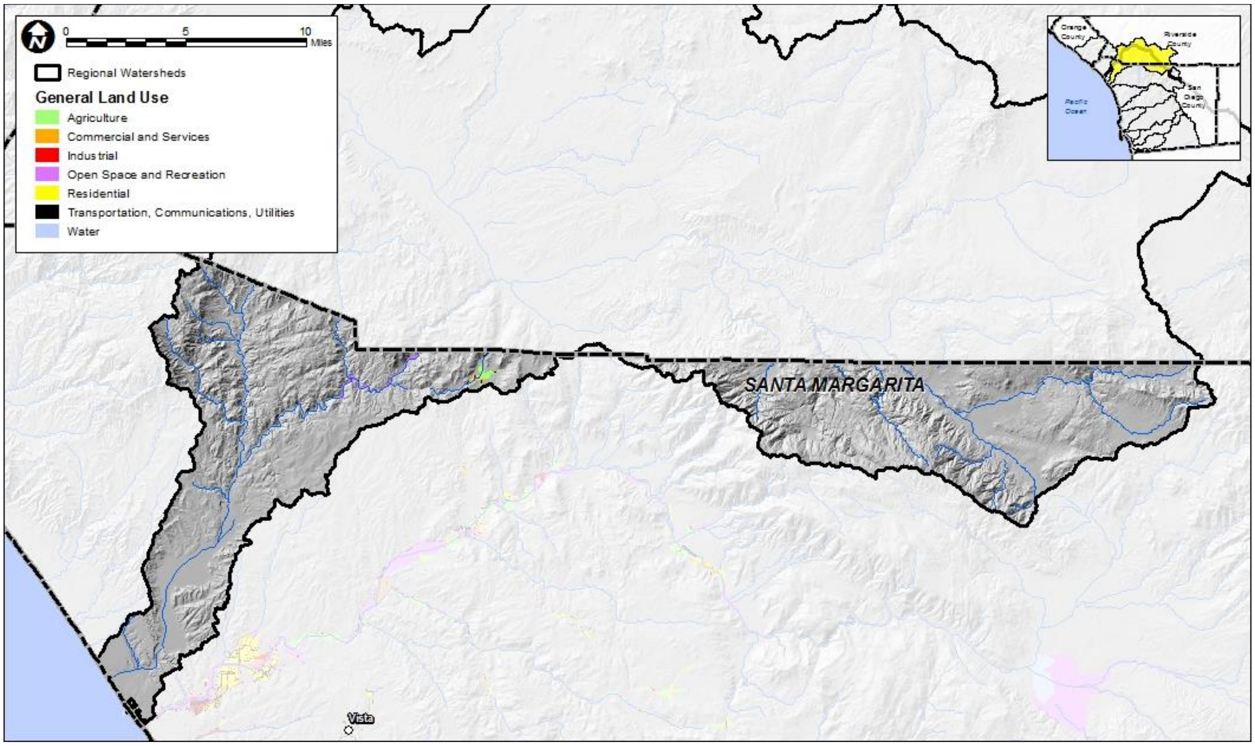

Figure 4-21: Floodplain risks and exposure assessment – landuses within 100-year floodplain for Santa Margarita watershed unit

Table 4-29: Landuse types located within mapped flood hazard zones for Santa Margarita watershed unit

SANTA MARGARITA	Area (acres)
Agriculture	146
Commercial and Services	38
Industrial	4
Open Space and Recreation	273
Residential	42
Transportation, Communications, and Utilities	40
Grand Total	**544**

4.1.11 San Mateo / San Juan

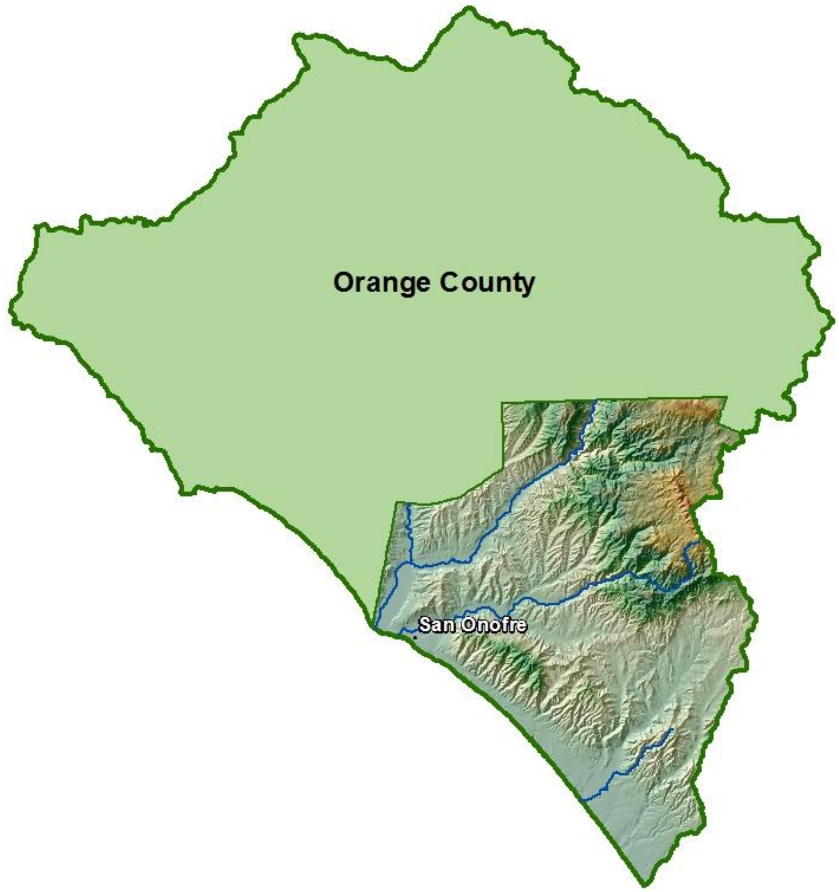

Figure 4-22: San Mateo/San Juan Creeks watershed unit with population centers

The San Mateo watershed unit is located primarily within northern San Diego County and includes the San Onofre watershed, but a portion of the watershed is within the southern portion of Orange County and western portion of Riverside County. San Mateo Creek (133.2 square miles drainage area) flow 22 miles from its headwaters within the Cleveland National Forest to the ocean just south of the City of San Clemente. The watershed lies mostly in undeveloped area of the Cleveland National Forest, the northern portion of Marine Corps Base Camp Pendleton, and ranch lands. The largest tributary of San Mateo Creek is Cristianitos Creek. The confluence is located 3 miles northeast of the San Mateo Creek outlet, near the residence of the largest Marine Corps development within the San Mateo Valley. The Special Area Management Plan (SAMP) for San Juan Creek includes only the portion of San Mateo Creek within Orange County. The watershed is primarily composed of hydrologic soil types C (49%) and D (40%) which indicates that overall the infiltration in the San Mateo watershed is relatively low due to the prominence of poorly infiltrating soils. The estimated 100-year peak discharge for San Mateo Creek at the ocean outlet is approximately 47,530 cfs (PWA, 2001).

Table 4-30: San Mateo/San Juan watershed unit characteristics and background information

Watershed Characteristics Information	Watershed Unit Area (within County): 151.0 square miles Longest Watershed Flow Path Length: 138,508feet Maximum Elevation: 3,340 Minimum Elevation: 0 (sea level) Watershed Elevation Difference: 3,340 feet Average Map Slope: 2.40 %
Major Cities / Population Centers in Watershed	San Onofre
Rivers / Creek Length (ft)	Cristianitos Creek 40,939 San Mateo Creek 138,508

4.1.11.1 Biological / Habitat Natural Resources

Trestles Natural Wetlands Preserve lies between the mouth of the creek and the I-5 Freeway and is wholly within the boundaries of San Onofre State Park. The 160 acre Preserve includes a freshwater lagoon, marshlands and several distinct plant communities including Coastal Sage Scrub, Willow Woodland, Sycamore/Cottonwood and Marsh Wetland. These plant communities are populated with over 219 plant species and provide one of the most diverse habitats in coastal Southern California. Cristianitos and Talega Creeks are known to have the largest population of the endangered Arroyo Toad and provide habitat for other listed species, including the Least Bell's Vireo, California Gnatcatcher, Southwestern Willow Flycatcher and Pacific Pocket Mouse.

4.1.11.2 Flood Risk and Exposure Mapping

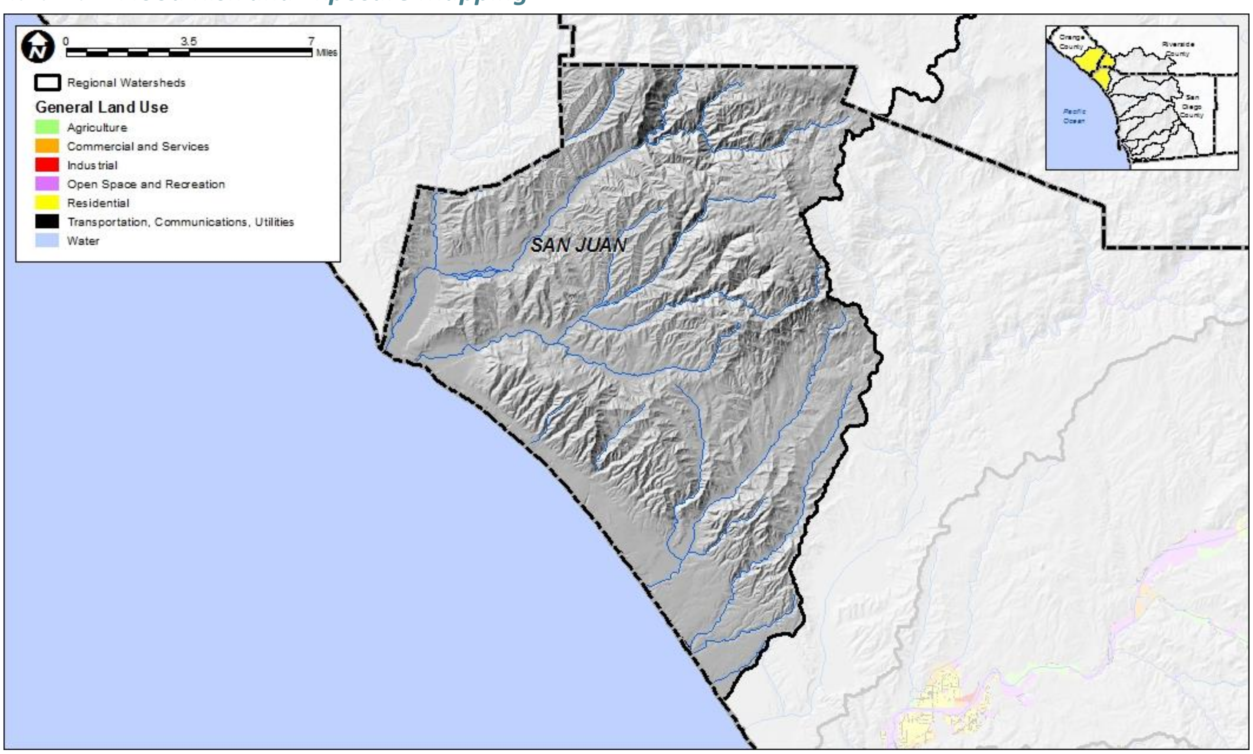

Figure 4-23: Floodplain risks and exposure assessment – landuses within 100-year floodplain for San Juan watershed unit

4.2 Metrologic Conditions / Historic Precipitation

The San Diego IRWM Region climate is classified as subtropical Mediterranean and is a semi-arid environment based on the amount of precipitation. The County of San Diego is an area of great climatic variation with the major rivers and the divide that separates the western- and eastern-draining watersheds. This divide follows the mountain ridgeline and elevations that vary from 3000 to 5000 feet above sea level. Precipitation that falls east of the divide flows down the eastern slope to the Salton Sea Basin, while runoff from precipitation west of the divide flows down the western slope to the Pacific Ocean. Most storms come from the Pacific Ocean toward the mountain ridge. The higher altitude and lower temperature cause the moisture to condense and form rain as it is forced up and over the divide. The north/south lines of equal average annual precipitation vary from west to east which is illustrated on the regional map of the county for the average annual rainfall isopluvials on Figure 3-13. The coast receives an average 10 inches in a year, the mountains over 30 inches, and the eastern valley floor about 3 inches. The major precipitation during the average year (see Figure 3-15) occurs from December to March and in the summer the rainless periods may extend for as long as four months. The historical variation of the total annual rainfall is illustrated on Figure 3-14 which identifies the wet-years, but this does not necessarily correlate directly to flood events since flooding is general associated with large amount of rainfall in a short period of time.

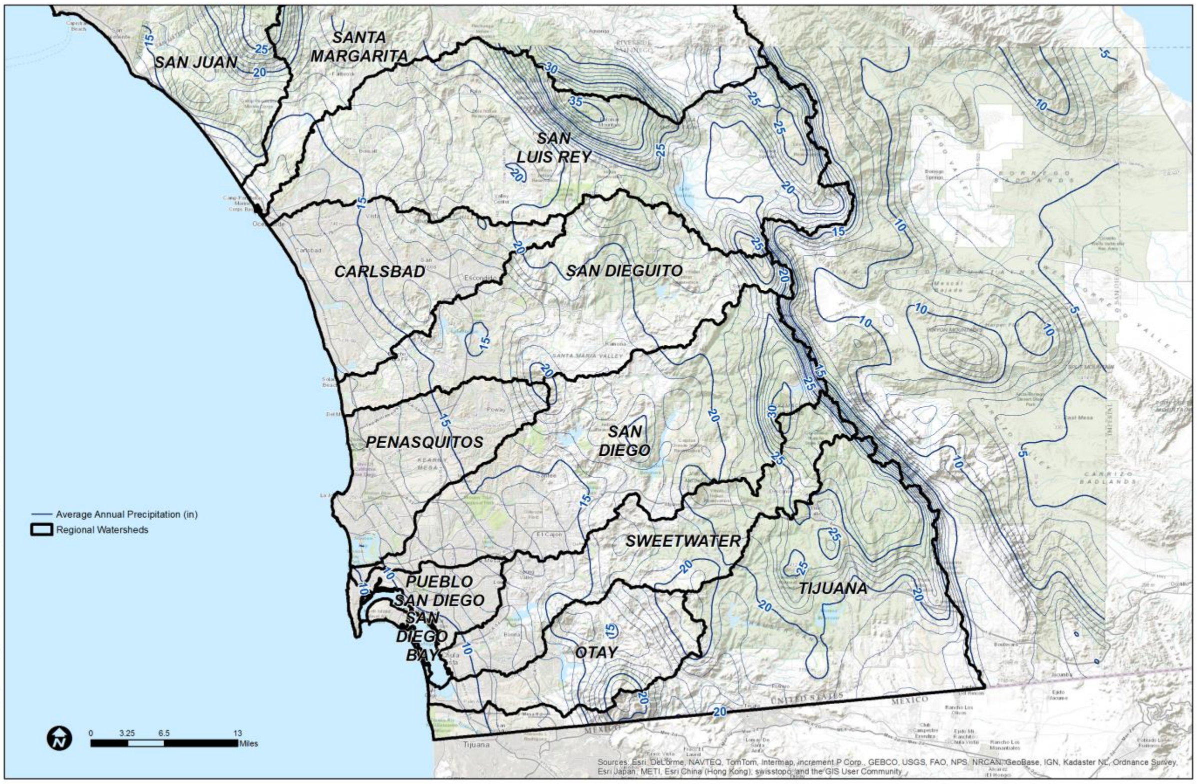

Figure 4-24: San Diego mean annual total precipitation in inches variation across the County illustrating lines of constant rainfall (isopluvials)

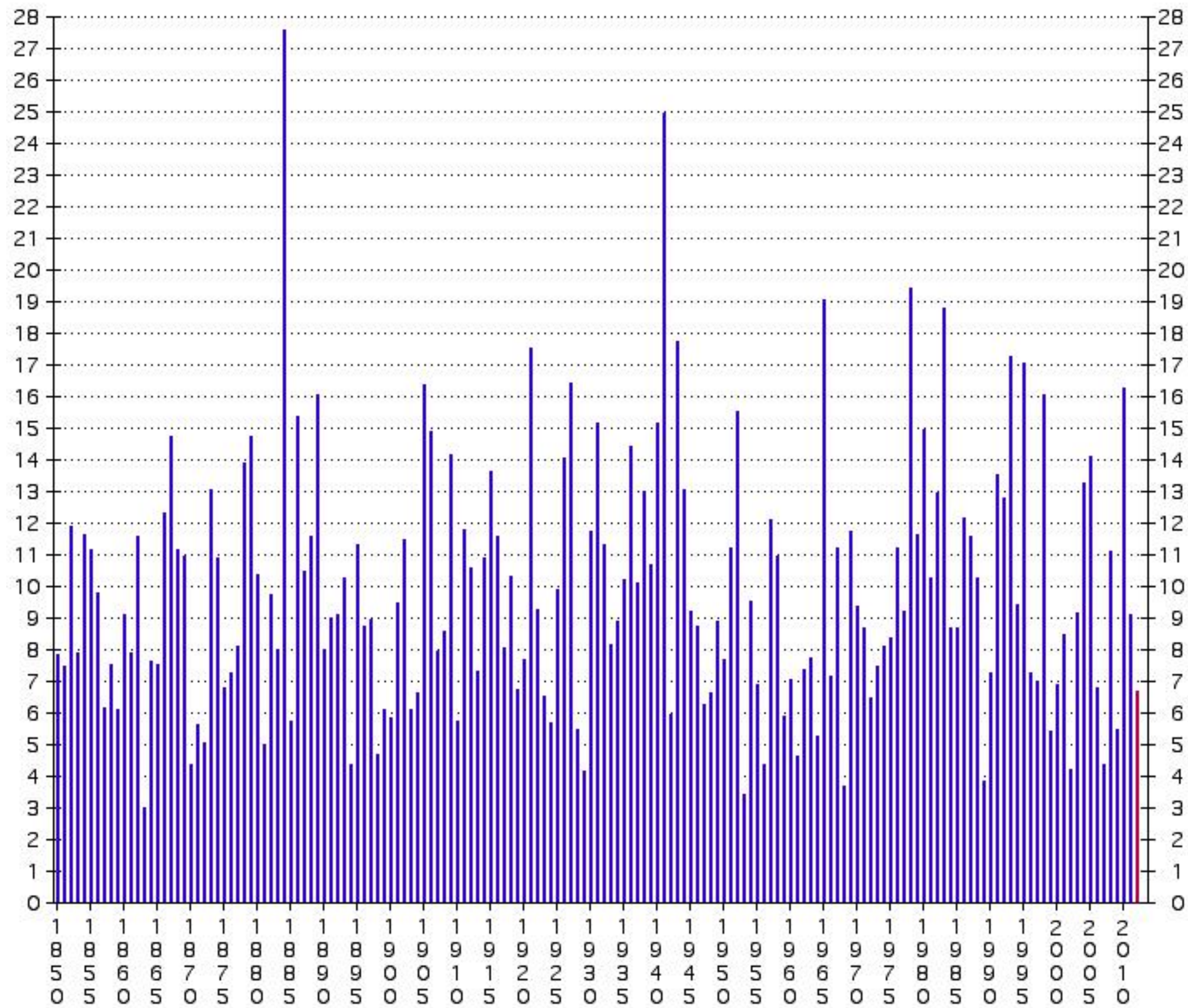

Figure 4-25: Variation of annual rainfall totals in San Diego (Lindbergh Field) from the mid-1800's

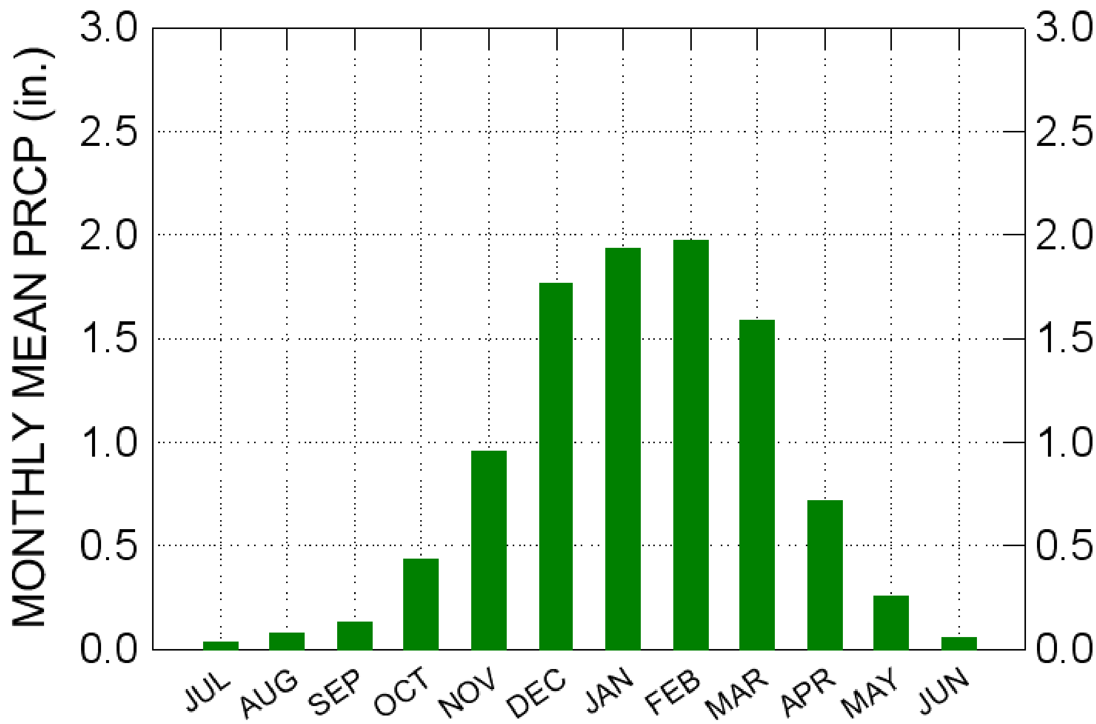

Figure 4-26: Typical month variation of rainfall over the year, noting the months of highest rainfall (Period of record from 1850 to 2010)

4.3 Floodplain Hydrology – Major Regional Flood Sources

The flood hazard mapping generated by FEMA and utilized for the risk/exposure assessment in this study were generated as part of the original FEMA FIS utilized engineering hydrologic analyses methods. A summary of the select larger drainages are provided with each of the regional watershed sections in order to get an understanding of the watershed characteristics and the magnitude of the hydrologic response as part of the watershed planning effort.

5 Integrated Flood Management (IFM) Planning Guiding Principles

5.1 Overview of IFM and Basic Planning Principles

Integrated Flood Management (IFM) is a different approach that deviates from traditional flood protection approaches since IFM combines land and water resources development within a watershed, within the context of IRWM, and with a focus on maximizing the efficient use/net benefit of floodplain while promoting public safety. IFM is a process that promotes an integrated rather than fragmented approach to flood management and recognizes the connection of flood management actions to water resources management, land use planning, environmental stewardship, and sustainability. Flood risk management requires the holistic development of a long-term strategy balancing current needs with future sustainability. Incorporating sustainability means looking for way of working towards identifying opportunities to enhance the performance of the watershed system as a whole. Traditional flood management practices focus on reducing the chance of flooding and flood damages through physical measures intended to store and convey floodwaters away from areas to be protected. Although this approach can reduce the intensity and frequency of flooding, it can also limit the floodplain's natural function and have other unintended consequences. In addition, the traditional approach has typically been reactive or piecemeal in addressing the negative aspects of flooding without looking at the larger watershed processes and riverine ecosystem.

IFM uses various techniques to manage flooding, including structural projects (such as levees), nonstructural measures (such as land use practices), and natural watershed functions. Depending on the characteristics of individual watersheds, various resource management strategies may be used, such as: agricultural land stewardship, conjunctive water management, conveyance, ecosystem restoration, forest management, land use planning and management, surface storage, system reoperations, urban runoff management and watershed management. In recent years, flood managers have recognized the potential for natural watershed features to reduce the intensity or duration of flooding. Natural watershed features include: undeveloped floodplains that can store and slowly release floodwaters and wetlands acting as sponges, soaking up floodwaters, filtering runoff, and providing opportunities for infiltration to groundwater. Natural watershed features also include healthy forests, meadows, and other open spaces that can slow runoff during smaller flood events, reducing peak lows, mudslides, and sediment loads in streams.

5.1.1 Basic Planning Principles of IFM

The following provides basic guiding principles that provide the foundation in planning integrated flood management:

Table 5-1: Basic guiding principles of integrated flood management planning

1. Every flood risk scenario is different: there is no flood management blueprint.
Understanding the type, source and probability of flooding, the exposed assets and their vulnerability are all essential if the appropriate urban flood risk management measures are to be identified. The suitability of measures to context and conditions is crucial: a flood barrier in the wrong place can make flooding worse by stopping rainfall from draining into the river or by pushing water to more vulnerable areas downstream, and early warning systems can have limited impact on reducing the risk from flash flooding.

2. Designs for flood management must be able to cope with a changing and uncertain future.
The impact of urbanization on flood management is currently and will continue to be significant. But it will not be wholly predictable into the future. In addition, in the present day and into the longer term, even the best flood models and climate predictions result in a large measure of uncertainty. This is because the future climate is dependent on the actions of unpredictable humans on the climate – and because the climate is approaching scenarios never before seen. Flood risk managers need therefore to consider measures that are robust to uncertainty and to different flooding scenarios under conditions of climate change.

3. Rapid urbanization requires the integration of flood risk management into regular urban planning and governance.
Urban planning and management which integrates flood risk management is a key requirement, incorporating land use, shelter, infrastructure and services. The rapid expansion of urban built up areas also provides an opportunity to develop new settlements that incorporate integrated flood management at the outset. Adequate operation and maintenance of flood management assets is also an urban management issue.

4. An integrated strategy requires the use of both structural and non-structural measures and good metrics for "getting the balance right".
The two types of measure should not be thought of as distinct from each other. Rather, they are complementary. Each measure makes a contribution to flood risk reduction but the most effective strategies will usually combine several measures – which may be of both types. It is important to identify different ways to reduce risk in order to select those that best meet the desired objectives now – and in the future.

5. Heavily engineered structural measures can transfer risk upstream and downstream.
Well-designed structural measures can be highly effective when used appropriately. However, they characteristically reduce flood risk in one location while increasing it in another. Urban flood managers have to consider whether or not such measures are in the interests of the wider catchment area.

6. It is impossible to entirely eliminate the risk from flooding. Hard-engineered measures are designed to defend to a pre-determined level.
They may fail. Other non-structural measures are usually designed to minimize rather than prevent risk. There will always remain a residual risk which should be planned for. Measures should also be designed to fail gracefully rather than, if they do fail, causing more damage than would have occurred without the measure.

7. Many flood management measures have multiple co-benefits over and above their flood management role.
The linkages between flood management, urban design, planning and management, and climate change initiatives are beneficial. For example, the greening of urban spaces has amenity value, enhances biodiversity, protects against urban heat island and can provide fire breaks, urban food production and evacuation space. Improved waste management has health benefits as well as maintaining drainage system capacity and reducing flood risk.

8. It is important to consider the wider social and ecological consequences of flood management spending.
While costs and benefits can be defined in purely economic terms, decisions are rarely based on economics alone. Some social and ecological consequences such as loss of community cohesion and biodiversity are not readily measureable in economic terms. Qualitative judgments must therefore be made by city managers, communities at risk, urban planners and flood risk professionals on these broader issues.

9. Clarity of responsibility for constructing and running flood risk programs is critical.
Integrated urban flood risk management is often set within and can fall between the dynamics and differing incentives of decision-making at national, regional, municipal and community levels. Empowerment and mutual ownership of the flood problem by relevant bodies and individuals will lead to positive actions to reduce risk.

Table 5-1: Basic guiding principles of integrated flood management planning

10. Implementing flood risk management measures requires multi-stakeholder cooperation. Effective engagement with the people at risk at all stages is a key success factor. Engagement increases compliance, generates increased capacity and reduces conflict. This needs to be combined with strong, decisive leadership and commitment from national and local governments.
11. Continuous communication to raise awareness and reinforce preparedness is necessary. Ongoing communication counters the tendency of people to forget about flood risk. Even a major disaster has a half-life of memory of less than two generations and other more immediate threats often seem more urgent. Less severe events can be forgotten in less than three years.
12. Plan to recover quickly after flooding and use the recovery to build capacity. As flood events will continue to devastate communities despite the best flood risk management practices, it is important to plan for a speedy recovery. This includes planning for the right human and financial resources to be available. The best recovery plans use the opportunity of reconstruction to build safer and stronger communities which have the capacity to withstand flooding better in the future.

5.1.2 General Elements of IFM

An integrated strategy usually requires the use of both structural and non-structural solutions. It is important to recognize the level and characteristics of existing risk and likely future changes in risk. Integrated flood management also includes the recognition that flood risk can never be entirely eliminated and that resilience to flood risk can include enhancing the capacity of people and communities to adapt to and cope with flooding.

The defining characteristic of IFM is integration simultaneously occurring in different forms such as: mix of different strategies, types of mitigation (structural and non-structural), short-term or long-term, and a participatory approach by multiple agency stakeholders within the watershed to decision making. Key elements of IFM would include:

Enhanced Level of Watershed Stakeholder Communication

- Open communication and participation by stakeholders, planners, and decision makes at all levels.
- Public consultation and involvement of watershed stakeholders for decision-making
- Promote coordination/communication across jurisdiction boundaries within the watershed including information management and exchange

Integrate Land and Water Management

- Land use planning and water management combined through coordination authorities to obtain consistency in planning
- Main elements of watershed management (water quantity, water quality, and processes of erosion/sedimentation) should be linked in planning
- Effect of land use changes on the hydrologic cycles should be evaluated and considered

Manage the Water Cycle as a Whole

- Flood management linked with drought management in the effective use of flood water
- Promote multi-benefit solutions that achieve multiple water resource benefits simultaneously

Adopt a Best-Mix of Strategies

- Flood management strategies should involve a combination of complementary strategies
- Formulate a layered strategy based on economic and watershed characteristics that is adaptable to changing conditions
- Appropriate combination of structural and non-structural measures should be evaluated recognizing the different advantage and disadvantages for the most effective plan

Adopt Integrated Hazard Management Approaches

- Flood management should be integrated into the risk management process

5.2 Risk Assessment and Management

Identifying flood risks is an important element in reducing flood damage and prioritizing flood management infrastructure needs. Appropriate assessment of flood risks can help local community government make informed decisions about priorities. The balancing of development needs and risks is essential. Uncertainty and risk management are defining characteristics of choice, and risk management is a necessary component of the development process, essential for achieving sustainable development. The application of a risk management approach provides measures for preventing a hazard from becoming a disaster. Flood risk management consists of systematic actions in a cycle of preparedness, response and recovery. Risk management calls for identification, assessment, minimization of risk, or the elimination of unacceptable risks through appropriate policies and practices. Flood risk management also includes the efforts to reduce the residual risks through such measures as flood-sensitive land-use and spatial planning, early warning systems, evacuation plans, the preparations for disaster relief and flood proofing and, as a last resort, insurance and other risk sharing mechanisms.

5.3 Resource Management Using an Ecosystem Approach

Riverine aquatic ecosystems, including rivers, wetlands and estuaries, provide many benefits to people such as clean drinking water, food, materials, water purification, flood mitigation and recreational opportunities. Variability in flow quantity, quality, timing and duration are often critical for the maintenance of river ecosystems. For example, flooding events serve to maintain fish spawning areas, help fish migration and flush debris, sediment and salt. This is particularly so for regions with dry climates that experience seasonal flooding followed by a period of drought.

Different flood management measures have varying impacts on the ecosystem and at the same time changes in the ecosystem have consequential impacts on the flood situation, flood characteristics and river behavior.

Some flood management interventions adversely impact riverine ecosystems by reducing the frequency of flooding of wetlands that develop around flood plains, which are subject to frequent flooding and owe the large variety of wildlife to this phenomenon. In these situations it is desirable to avoid changes in high frequency floods since to do so would damage the ecosystems that have developed around the existing flood regime. What is desirable is to reduce extreme floods. Thus a tradeoff between competing interests in the river basin is required to determine the magnitude and variability of the flow regime needed within a basin in order to maximize the benefits to society and maintain a healthy riverine ecosystem.

5.4 General Flood Management Opportunities / Constraints

The characteristics of the region provide background into understanding the both potential opportunities as well as constraints for developing potential IFM solutions for the existing flood hazards. Flood management projects are planned and implemented to solve problems reducing risk to public safety and property, meet challenges, and seize opportunities. A problem can be thought of as an undesirable condition, while an opportunity offers a chance for improvement, and constraints limit the ability for implementation. The San Diego IRWM Region includes a wide variety of terrain conditions, as well as geographic features which can generate a range of different types of watershed response. These features include urban development surrounded by rainfall-collecting steep terrain and at the other extreme coastal flooding. The geography, as well meteorological conditions, are conducive to sudden flooding. The semi-arid climate, where the total rainfall is typically concentrated in a few short months, adds to the uncertainty of flood prediction. In addition, the unique issues associated with the watershed conditions also limit the application of even conventional flood management solutions. It is important to identify and recognize the areas within the watershed which have specific unique properties as part of the planning process to assist in the formulation of alternative solutions. This study is utilizing a watershed scale assessment as part of an IFM approach that allows examination of flood hazards and their management in combination with other water resources and environmental restoration on a broad scale.

Based on the characteristics discussed above, the Region’s flood management opportunity/constraints may be divided into four major categories which include: (1) physical conditions, (2) regulatory, (3) landuse, and (4) environmental/biological.

Physical

Different physical features define the types of flooding issues since the topographic features greatly influence the response of the watershed. The nature of the flooding created by the topography also results in different constraints and limits the ability to apply different conventional solutions for the flood hazard mitigation. Table 5-2 illustrates the opportunity and constraints with floodplain management that are associated with "physical features" within the watershed.

Table 5-2: Opportunity / Constraints for regional floodplain management – Physical features

Physical	
Opportunity / Constraint	**Reference**
Hydraulic conveyance limitations of existing roadway and utility crossings	• Identification of hydraulic limitations as potential target areas for fixes that may reduce areas of flooding and sedimentation
Existing facilities and structures located with the floodplain	• Define existing flood risk from existing facilities/uses within the floodplain
Sediment delivery with flood flows from foothill areas	• Excessive sediment delivery causes deposition and will ultimately be deposited at a downstream location with flatter slope • High sediment yields bulk the flood waters and increase depth of flooding
Limited topographic relief/slope that limits hydraulic conveyance in valley areas	• Facility sizes will increase further downstream within the watershed because of the reduced slope
Soils/geology primarily alluvial deposits that are highly erodible	• Channel migration routinely occurs • Erosion hazards for development adjacent to channels
Specialized geographic/geomorphic features which include alluvial fans and coastal plains	• Hydraulic conditions are unique and conventional flood management solutions are not applicable
Topographic features result in steep slopes in the mountains/foothills and extremely flat slopes on the valley floors	• Changes in hydraulic conveyance and sediment delivery because of the change in slopes

Regulatory

The existing regulations related to floodplain management/flood control influence the existing level of flood protection provided to the community. Table 5-3 illustrates the opportunity and constraints with floodplain management that are associated with "regulatory" items within the watershed.

Table 5-3: Opportunity / Constraints for regional floodplain management – Regulatory Elements

Regulatory	
Opportunity / Constraint	**Reference**
No centralized regional flood agency for the entire San Diego region. San Diego County Flood Control District is only responsible for the unincorporated County areas and all other municipalities manage floodplains individually	• Flooding problems within the County area are extremely varied and associated with the different individual watersheds • Comprehensive planning required that reflects the current though process for flood management and the environmental considerations for each of the regional watersheds that will cross over political boundaries
FEMA/NFIP requirements for community floodplain regulations	• NFIP requirements have the most influence on floodplain restrictions
Water quality limitations and restrictions based on the Basin Plan and identified TMDLs	• Water quality restrictions should be implemented as part of the regional planning solution

Landuse

Existing land use and future proposed development should be closely coordinated with the existing mapped flood hazards. Land use restrictions are one of the primary tools for floodplain management in order to reduce flood risks. Table 5-4 illustrates the opportunity and constraints with floodplain management that are associated with "landuse features" within the watershed.

Table 5-4: Opportunity / Constraints for regional floodplain management – Landuse features

Landuse	
Opportunity/Constraints	**Reference**
Various urban/commercial landuse and additional manmade encroachments within the floodplain	• Cost/benefit assessments should be performed to evaluate cost effectiveness of flood control facilities or removing these uses from the floodplain
Limitations of development and landuse restrictions within active flood hazard zones	• Modifications to current General Plan modifying landuses so that they are compatible with the floodplain overlay since many locations have development zoned for floodplain areas

Environmental/Biological

Existing biological resources within the floodplain corridor are an important opportunity to integrate into the regional planning as part of the preservation of these resources. However, in addition to an opportunity these resources can represent constraints in the different types of solutions that can be applied for flood mitigation and may result in additional costs. Table 5-5 illustrates the opportunity and constraints with floodplain management that are associated with "environmental/biological" elements within the watershed.

Table 5-5: Opportunity / Constraints for regional floodplain management – Environmental / Biological

Opportunity/Constraints	Reference
Environmental permitting limitations for activities/structures within the floodplain (i.e. endangered species, etc.)	• Additional costs or limitations on the potential solutions available because of environmental regulatory restrictions
Many existing floodplain corridors have special defined ecological preserve or similar designations because of habitat for sensitive species	• Existing floodplains and streams are valuable biological resources for preservation

6 Formulation Integrated Flood Management Strategies

6.1 Global IFM Management Strategies

IFM includes a broad range of management strategies and can be grouped into four general approaches— (1) Nonstructural Approaches, (2) Restoration of Natural Floodplain Functions, (3) Structural Approaches, and (4) Emergency Management. These approaches and the management actions within them serve as a toolkit of potential actions that local agencies can use to address flood-related issues, and advance IFM throughout the Region's watersheds. These actions range from policy or institutional changes to operational and physical changes to flood infrastructure. Such actions are not specific recommendations for implementation; rather, they serve as a suite of generic management tools that can be used individually or combined for specific application situations. A variety of management actions can be bundled together as part of a single flood management project to provide a multiple benefit outcome related to water resources.

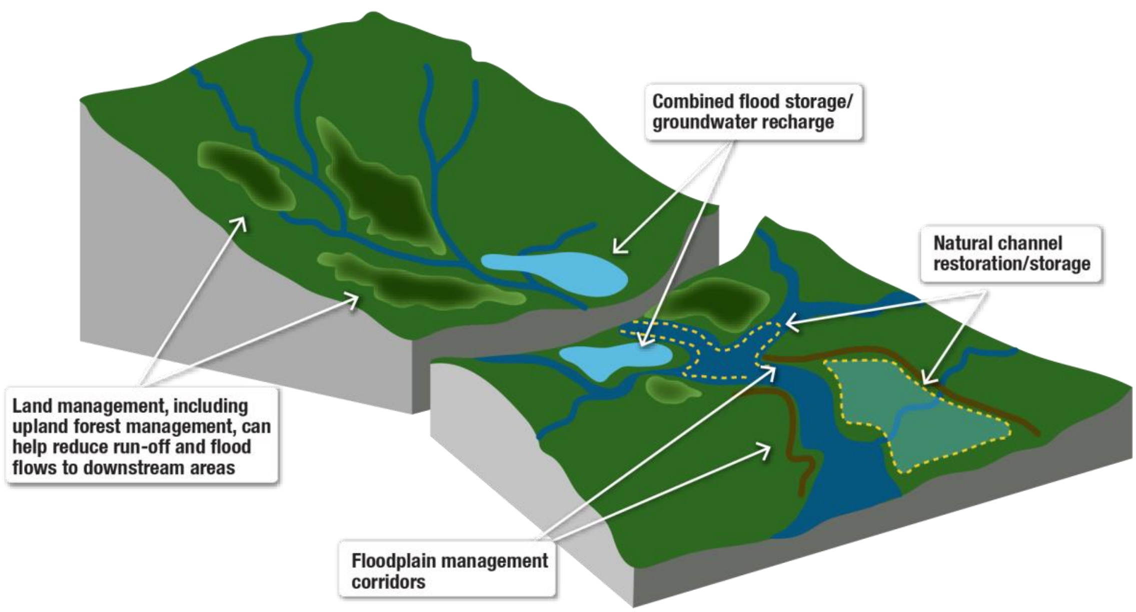

Figure 6-1: Example of IFM strategies applied at different locations on a watershed basis to achieve multiple water resources benefits

6.2 Nonstructural Approaches

6.2.1 Land Use Planning – Floodplain Basis

Land use planning employs policies, ordinances, and regulations to limit development in flood-prone areas and encourages land uses that are compatible with floodplain functions. This can include policies and regulations that restrict or prohibit development within floodplains, restrict size and placement of structures, prevent new development from providing adverse flood impacts to existing structures, encourage reduction of impervious areas, require flood-proofing of buildings, and encourage long-term restoration of streams and floodplains.

6.2.2 Land Use Planning – Watershed Basis

Landuse controls on a watershed basis provide the opportunity to assist in controlling the response of the watershed and influence or correct potential problems through non-structural means. In addition, land use planning and regional water management can be coordinated between land management and water management authorities to achieve consistency and maximum benefits. Landuse impacts different elements of the watershed including water quantity, water quality, and the processes of erosion/deposition. It is important to understand these linkages between landuse and the watershed functions in order to develop collaboration to improve the watershed performance on a regional basis.

6.2.3 Floodplain Management

Floodplain management generally refers to nonstructural actions in floodplains to reduce flood damages and losses. Floodplain management actions include:

- **Floodplain Mapping and Risk Assessment –** Floodplain mapping and risk assessment serve a crucial role in identifying properties that are at a high risk to flooding. Accurate, detailed maps are required to prepare risk assessments, guide development, prepare plans for community economic growth and infrastructure, utilize the natural and beneficial function of floodplains, and protect private and public investments. Development of needed technical information includes topographic data, hydrology, and hydraulics of streams and rivers, delineation of areas subject to inundation, assessment of properties at risk, and calculation of probabilities of various levels of loss from floods.
- **Land Acquisitions and Easements** – Land acquisitions and easements can be used to restore or preserve natural floodplain lands and to reduce the damages from flooding by preventing urban development. Land acquisition involves acquiring full-fee title ownership of lands from a willing buyer and seller. Easements provide limited-use rights to property owned by others. Flood easements, for example, are purchased from a landowner in exchange for perpetual rights to periodically flood the property when necessary or to prohibit planting certain crops that would impede flood flows. Conservation easements can be used to protect agricultural or wildlife habitat lands from urban development. Both land acquisitions and easements generally involve cooperation with willing landowners. Although acquisition of lands or easements can be expensive, they can reduce the need for

structural flood improvements that would otherwise be needed to reduce flood risk. Maintaining agricultural uses and/or adding recreational opportunities where appropriate provide long-term economic benefits to communities and the State.

- **Building Codes and Flood-proofing** – Building codes and flood-proofing include specific measures that reduce flood damage and preserve egress routes during high- water events. Building codes are not uniform; they vary across the state based on a variety of factors. Example codes could require flood-proofing measures that increase the resilience of buildings through structural changes, elevation, or relocation and the use of flood resistant materials.
- **Retreat** – Retreat is the permanent relocation, abandonment, or demolition of buildings and other structures. Retreat can be used in a variety of settings from floodplains to coastal areas. In coastal regions, this action would allow the shoreline to advance inward, unimpeded in areas subject to high coastal flooding risks, high erosion rates, or future sea level rise. Integrating recreation uses into retreat areas along the shoreline provides economic uses for these buffer lands.
- **Flood Risk Awareness (Information and Education)** – Flood risk awareness is critical because it encourages prudent floodplain management. Flood hazard information is a prerequisite for sound education in understanding potential flood risks. If the public and decision makers understand the potential risks, they can make decisions to reduce risk, increase personal safety, and expedite recovery after floods. Effective risk awareness programs are critical to building support for funding initiatives and to building a connection to the watershed.
- **Flood Insurance** – Flood insurance is provided by the Federal government via the NFIP to communities that adopt and enforce an approved floodplain management ordinance to reduce future flood risk. The NFIP enables property owners in participating communities to purchase subsidized insurance as a protection against flood losses. If a community participates in the voluntary Community Rating System and implements certain floodplain management activities, the flood insurance premium rates are discounted to reflect the reduced flood risks

6.2.4 Restoration of Natural Floodplain Functions

This strategy recognizes that periodic flooding of undeveloped lands adjacent to rivers and streams is a natural function and can be a preferred alternative to restricting flood flows to an existing channel. The intent of natural floodplain function restoration is to preserve and/or restore the natural ability of undeveloped floodplains to absorb, hold, and slowly release floodwaters, to enhance ecosystem, and to protect flora and fauna communities. Natural floodplain conservation and restoration actions can include both structural and nonstructural measures. To permit seasonal inundation of undeveloped floodplains, some structural improvements (e.g., weirs) might be needed to constrain flooding within a defined area along with nonstructural measures to limit development and permitted uses within those areas subject to periodic inundation. Actions that support natural floodplain and ecosystem functions include:

- **Promoting Natural Hydrologic, Geomorphic, and Ecological Processes –** Natural hydrologic, geomorphic, and ecological processes are key components of promoting natural floodplain and ecosystem functions**.** Human activities (including infrastructure such as dams, levees, channel stabilization, and bank protection) have modified natural hydrological processes by changing the extent, frequency, and duration of natural floodplain inundation. These changes disrupt natural geomorphic processes such as sediment erosion, transport, and deposition, which normally cause channels to migrate, split, and rejoin downstream. These natural geomorphic processes are important drivers in creating diverse riverine, riparian, and floodplain habitat to support fish and wildlife, and in providing natural storage during flood events. Restoration of these processes might be achieved through setting back levees, restoring channel alignment, removing unnatural hard points within channels, or purchasing lands or easements that are subject to inundation.
- **Protecting and Restoring Quantity, Quality, and Connectivity of Native Floodplain Habitats –** Quantity, quality, and connectivity of native floodplain habitats are critical to promote natural floodplain and ecosystem functions**.** In some areas, native habitat types and their associated floodplain have been lost, fragmented, and degraded. Lack of linear continuity of riverine, riparian habitats, or wildlife corridors, impacts the movement of wildlife species among habitat patches and results in a lack of diversity, population complexity, and viability. This can lead to native fish and wildlife becoming rare, threatened, or endangered. Creation or enhancement of floodplain habitats can be accomplished through setting back levees and expanding channels or bypasses, or through removal of infrastructure that prevents flood flows from entering floodplains. Coastal wetlands have been severely reduced, resulting in a loss of habitat for freshwater, terrestrial, and marine plant species. Restoration of these habitats could provide a buffer against storm surges and sea level rise.
- **Invasive Species Reduction –** Minimizing invasive species can help address problems for both flood management and ecosystems. Invasive species can reduce the effectiveness of flood management facilities by decreasing channel capacity, increasing rate of sedimentation, and increasing maintenance costs. Nonnative, invasive plant species often can out-compete native plants for light, space, and nutrients, further degrading habitat quality for native fish and wildlife. These changes can supersede natural plant cover, eliminate, or reduce the quality of food sources and shelter for indigenous animal species, and disrupt the food chain. Reductions in the incidence of invasive species can be achieved by defining and prioritizing invasive species of concern, mapping their occurrence, using BMPs for control of invasive species, and using native species for restoration projects.

6.3 Structural Approaches

Structural approaches to flood management include flood infrastructure, reservoir and floodplain storage and operations, and operations and maintenance (O&M).

6.3.1 Flood Infrastructure

Flood infrastructure varies significantly based on the type of flooding. There are many alternative components that can be applied to correct flood control deficiencies. These components can be used individually or in different combinations with other available alternative components. The alternative structural flood control infrastructure solutions that are available to select from for any type of flood control problem are limited to three major categories of solutions from which the individual components will generally fall within one of these categories and include (1) conveyance oriented, (2) storage, and (3) diversion. The major categories of structural solutions can be further expanded to define additional classifications of the primary components which include: (1) flow redirection, (2) structural rigid revetments, (3) other structural techniques, (4) biotechnical techniques, (5) channel geometry, (6) channel alignment, (7) diversion, (8) storage, and (9) other techniques. Flood infrastructure can include:

- **Levees and Floodwalls –** Levees and floodwalls are designed to confine flood flows by containing waters of a stream or lake. Levees are an earthen or rock berm constructed parallel to a stream or shore (or around a lake) to reduce risk from all types of flooding. Levees could be placed close to stream edges, or farther back (e.g., a setback levee). Ring levees could be constructed around a protected area, isolating the area from potential floodwaters. A floodwall is a structural reinforced-concrete wall designed and constructed to hold back floodwaters. Floodwalls have shallow foundations or deep foundations, depending on flood heights and soil conditions. Although Levees and Floodwalls are structural flood management approaches, they are not recommended. Due to strict FEMA regulations and intensive maintenance requirements, other alternatives are preferred within the County of San Diego.
- **Channels and Bypasses –** Channels and bypasses convey floodwaters to reduce the risk of slow rise, flash, and debris- flow flooding. Channels can be modified by deepening and excavating the channel to increase its capacity, or lining the streambed and/or banks with concrete, riprap, or other materials, to increase drainage efficiency. Channel modifications can result in increased erosion downstream and degradation of adjacent wildlife habitat, and often the modifications require extensive permitting. Bypasses are structural features that divert a portion of flood flows onto adjacent lands (or into underground culverts) to provide additional flow-through capacity and/or to store the flows temporarily and slowly release the stored water.
- **Retention and Detention Basins** – Retention and detention basins are used to collect stormwater runoff and slowly release it at a controlled rate so that downstream areas are not flooded or eroded. A detention basin eventually drains all of its water and remains dry between storms. Retention basins have a permanent pool of water and can improve water quality by settling sediments and attached pollutants.
- **Culverts and Pipes** – Culverts and pipes are closed conduits used to drain stormwater runoff. Culverts are used to convey stream-flow through a road embankment or some other type of flow obstruction. Culverts and pipes allow stormwater to drain underground instead of through open channels and bypasses.

- **Shoreline Stabilization, and Streambank Stabilization** – Shoreline stabilization reduces risk to low-lying coastal areas from flooding. Coastal armoring structures are typically massive concrete or earthen structures that keep elevated water levels from flooding interior lowlands and prevent soil from sliding seaward. Shoreline stabilization reduces the amount of wave energy reaching a shore or restricts the loss of beach material to reduce shoreline erosion rates. Types of shoreline stabilization include breakwaters, groins, and natural or artificial reefs. Streambank stabilization protects the banks of streams from erosion by installing riprap, matting, vegetation or other materials to reduce erosion.
- **Debris Mitigation Structures** – For debris and alluvial flooding, debris fences and debris basins separate large debris material from debris flows, or the structures contain debris flows above a protected area. These structures require regular maintenance to periodically remove and dispose of debris after a flood. Deflection berms (or training berms) can be used to deflect a debris flow or debris flood away from a development area, allowing debris to be deposited in an area where it would cause minimal damage.

6.3.2 Reservoir and Floodplain Storage and Operations

Reservoir and floodplain storage provide an opportunity to regulate flood flows by reducing the magnitude of flood peaks occurring downstream. Many reservoirs are multipurpose and serve a variety of functions, including water supply, irrigation, habitat, and flood control. Reservoirs collect and store water behind a dam and release it after the storm event. Floodplain storage occurs when peak flows in a river are diverted to adjacent off-stream areas. Floodplain storage can occur naturally when floodwaters overtop a bank and flow into adjacent lands, or storage can be engineered using weirs, berms, or bypasses to direct flows onto adjacent lands.

- **Storage Operations –** Storage operations can reduce downstream flooding by optimizing the magnitude or timing of reservoir releases, or through greater coordination of storage operations. Coordination can take the form of formal agreements among separate jurisdictions to revise reservoir release operations based on advanced weather and hydrology forecasts, or it can simply involve participation in coordination meetings during flood emergencies.
- **Groundwater Recharge** – In some areas, opportunities may exist to provide recharge to the aquifer in order to capture surface water sources which would normally discharge to the ocean can enhance the water supplies. In addition, the opportunities for flood storage should be coordinated with recharge opportunities to ensure that these are located where optimum benefits occur, including recharge capabilities.

6.3.3 Operations and Maintenance

Operation and maintenance (O&M) is a crucial component of flood management. O&M activities can include inspection, vegetation management, sediment removal, management of encroachments and penetrations, repair or rehabilitation of structures, or erosion repairs. Because significant flood infrastructure constructed in the early to mid-twentieth century are near or have exceeded the end of their expected service lives, adequate maintenance is critical for this flood infrastructure to continue functioning properly.

6.4 Flood Emergency Management

Flood emergency management includes the following preparedness, response, and recovery activities:

- **Flood Preparedness** – Flood preparedness consists of the development of plans and procedures on how to respond to a flood in advance of a flood emergency, including preparing emergency response plans, training local response personnel, designating evacuation procedures, conducting exercises to assess readiness, and developing emergency response agreements that address issues of liability and responsibility.
- **Emergency Response** – Emergency response is the aggregate of all those actions taken by responsible parties at the time of a flood emergency. Early warning of flood events through flood forecasting allows timely notification of responsible authorities so that plans for evacuation of people and protection of property can be implemented. Emergency response includes flood fighting, emergency evacuation, and sheltering. Response begins with, and might be confined to, affected local agencies or operational areas (counties). Depending upon the intensity of the event and the resources of the responders, response from regional, State, and Federal agencies might be required.
- **Post-Flood Recovery** – Recovery programs and actions include restoring utility services and public facilities, repairing flood facilities, draining flooded areas, removing debris, and assisting individuals, businesses, and communities to protect lives and property. Recovery planning could include development of long- term floodplain reconstruction strategies to determine if reconstruction would be allowed in flood-prone areas, or if any existing structures could be removed feasibly. Such planning should review what building standards would be required, how the permit process for planned reconstruction could be improved, funding sources to remove existing structures, natural habitat restoration, and how natural floodplains and ecosystem functions could be incorporated.

6.5 Application of Common IFM Strategies

The value of using an IFM approach within the watershed is in the results—improved public safety, enhanced environmental stewardship, and statewide economic stability. Localized, narrowly focused projects are not the best use of public resources and might have negative unintended consequences in nearby regions. The IFM approach can help deliver more benefits at a faster pace using fewer resources than what is possible from single-benefit projects. Table 6-1 provides examples of different recommended IFM strategies to assist in formulating alternatives within the different watersheds in order to produce high-value multi-benefit projects.

Table 6-1: Examples of applications of different IFM strategies and approaches

1. Increase hydraulic conveyance capacities and remove flow restrictions
2. Provide flood relief structures or bypass system to reduce downstream flows

Table 6-1: Examples of applications of different IFM strategies and approaches

3. Construct setback levees to preserve natural floodplain vegetation corridor
4. Preservation of natural active washes and floodplain corridors
5. Clearing of debris and snags within channel systems
6. Watershed and floodplain vegetation management plan including current levee requirements
7. Streambank stabilization to reduce sedimentation downstream
8. Update O&M procedures and methods to reflect other functions in the flood management system including ecosystem functions
9. Acquire floodplain areas to reduce flood damages and preserve natural floodplain corridors / ecosystem values
10. Sediment deposition removal projects to enhance hydraulic capacity and maintain fluvial processes
11. Update local flood management plans and coordinate with landuse planning
12. Designate additional floodways based on current hydraulic and hydrologic conditions
13. Encourage compatible landuse with flood management system and floodplain
14. Mange urban stormwater runoff to natural floodplain to reduce the potential for “hydromodification” impacts including flooding and stream stability
15. Improved accuracy of floodplain mapping/delineation, including urban areas, as well as better assessment of flood risks
16. Increased public information on floodplain hazards through access to floodplain hazard delineation with GIS tools on web based applications
17. Increased awareness and participation of FEMA Community Rating System (CRS) for flood insurance rate adjusting program
18. Identify locations and structures which have repetitive flood damage losses and eliminate
19. Land use planning and decision-making should be based on a more accurate assessment of flood risk from multiple hazards (i.e. influence of wildfires on flooding)
20. Construct new or enlarge existing temporary floodplain storage to attenuate peak flooding downstream
21. Increase flood control allocation by expanding existing or building new off-stream storage.
22. Implement advanced weather- forecast-based operations to increase reservoir management flexibility on a watershed basis such as with the County ALERT Network
23. Manage runoff through watershed management. Runoff from watershed source areas increases, in varying extents, due to increases in impermeable surfaces in developed areas, soil compaction from agriculture, reductions in vegetative cover, incision of stream channels, and losses of wetlands. Runoff flood
24. Remove unnatural hard points in or on the banks of streams (such as bridge abutments, rock revetment, dikes, limitations on channel boundaries, or other physical encroachments into a channel or waterway) can affect the hydraulics of river channels, constraining dynamic natural fluvial geomorphologic processes of erosion.
25. Develop hazardous waste and materials management protocols to identify, contain, and remediate potential water quality hazards within floodplains
26. Operate reservoirs with flood reservation space to more closely approximate natural flow regimes
27. Reduce the incidence of invasive species in flood management systems
28. Remove barriers to fish passage
29. Encourage natural physical geomorphic processes, including channel migration and sediment transport
30. Floodplain and watershed improve the quality, quantity, and connectivity of wetland, riparian, woodland, grassland, and other native habitat communities
31. Develop regional advanced mitigation strategies and promote networks of both public and private mitigation banks to meet the needs of flood and watershed infrastructure projects.
32. An effective and sustainable flood/watershed management system encompass critical habitat and migration corridors through integration of public safety, water supply, and ecosystem function—managing flood infrastructure as a system
33. Coordinate flood response planning and clarify roles and responsibilities of the different flood management agencies/entities related to flood preparedness and emergency response
34. Use Building Code amendments to reduce consequence of flooding

Table 6-1: Examples of applications of different IFM strategies and approaches

35. Encourage multi- jurisdictional and regional partnerships on flood planning and improve agency coordination on flood management within watersheds to provide system wide planning

6.6 Detailed Application of IFM Strategies

A more detailed assessment was developed for commonly utilized IFM strategies that are applicable to the County. A variety of the different specific strategies or projects were generalized or lumped to ten different types of strategies or applications that could be utilized in Southern California. A series of fact sheets were developed for the different generalized application in order to assist in the guidance and formulation of specific projects.

Strategy Application No.1 - Watershed Management Planning

IFM Objectives / Principles:

- Landuse planning
- LID policies
- Natural resource preservation
- Sustainable development
- Water quality
- Runoff management

Description of Representative Actions / Elements:

Apply core underlying watershed management planning guidelines in developing the proposed strategies and infrastructure for future development. These guidelines would ensure that development (i) mimics existing runoff and infiltration patterns within the project area, (ii) does not exacerbate peak flow rates or water volumes within or downstream of the project area, (iii) maintains the geomorphic structure of the major tributaries within the project area, (iv) maintains coarse sediment yields, storage and transport processes, and (v) uses a variety of strategies and programs to protect water quality. The principles refine the planning framework and identify key physical and biological processes and resources at both the watershed and sub-basin level. The Watershed Planning Principles focus also on the fundamental hydrologic and geomorphic processes of the overall watersheds and of the sub-basins. These principles can be utilized to guide the initial planning of the development program relative to watershed resources and to minimize impacts thereto through careful planning by integrating the initial baseline technical watershed assessments. Non-structural watershed protection planning principles would include minimization of impervious areas/preservation of open spaces, prioritization of soils for development and infiltration, and establishment of riparian buffer zones. Examples of watershed planning principles that can be used include:

Principle 1 – Recognize and account for the hydrologic response of different terrains at the sub-basin and watershed scale.

Principle 2 – Emulate, to the extent feasible, the existing runoff and infiltration patterns in consideration of specific terrains, soil types and ground cover.

Principle 3 – Address potential effects of future land use changes on hydrology.

Principle 4 – Minimize alterations of the timing of peak flows of each sub-basin relative to the mainstem creeks.

Principle 5 – Maintain and/or restore the inherent geomorphic structure of major tributaries and their floodplains.

Principle 6 – Maintain coarse sediment yields, storage and transport processes.

Principle 7 – Protect water quality by using a variety of strategies, with particular emphasis on natural treatment systems such as water quality wetlands, swales and infiltration areas and application of Best Management Practices within development areas to assure comprehensive water quality treatment prior to the discharge of urban runoff into the floodplain corridor

Potential Benefits:

- Integrated land planning process with watershed functions
- Managed runoff from development and commercial watershed activities
- Maintain natural runoff process
- Minimize long term maintenance costs within floodplain

Strategy Application No.2- Floodplain Management

IFM Objectives / Principles:

- Integrated landuse planning
- Natural floodplain corridor preservation
- Sediment management / stream stability
- Natural streambed groundwater recharge

Description of Representative Actions / Elements:

Facilitating improved alignment and coordination between land use and flood management would result in better understanding of flood risk and potential impacts to proposed developments, as well as improved decision making. Specifically, flood risk information has the potential to influence land use policy decisions related to developing and expanding communities within a floodplain, which would result in reductions to flood damage claims and long-term O&M costs on projects. At the planning stage, additional measures might be incorporated into the initial proposed projects that could provide community benefits, such as setback areas that act as greenways or trails, and greatly reduce the need to retrofit or replace undersized infrastructure in the future. Too often, regional and land use policymakers realize flood risk and economic losses only after a damaging flood event. Some of the additional actions associated with this item include defining increased floodways to limit development along the floodplain fringe, floodplain retreat through purchase of properties within the floodplain, ensuring that different landuses are compatible with the floodplain risks.

Potential Multiple Water Resource Benefits:

- Reduction in flood damage subsidies to chronic flood locations

Strategy Application No.3 – Stream Stabilization

IFM Objectives / Principles:

- Sediment control
- Increased floodplain capacity
- Water quality
- Reduce sediment deposition downstream

Description of Representative Actions / Elements:

Channel erosion, with substantial stream incision can be a large contributor of sediment to downstream receiving waters and deposition in portions of channels that reduce flood capacity. In addition, increased sediment transport will bulk the runoff flows in the channel and further diminish the flood conveyance capacity. Watershed based regional studies/investigations of the fluvial processes and watershed sediment yields as well as geomorphic assessments/monitoring can evaluate those critical locations within the watershed that require stabilization. Stream erosion and sedimentation adversely impact water quality beneficial uses of both the stream and the receiving waters, and sediment TMDL. Stabilization of the natural alluvial channel system to eliminate future erosion of the streambed and streambank will assist in critical channel areas as a major sediment source as well as disrupting the loss of vegetative habitat within the floodplain. Detailed streambed stability assessments provides part of the technical support for the evaluation of the benefits of and opportunities for alternative stream stabilization / restoration techniques to ensure that the natural geomorphic and fluvial process are maintained in balance.

Potential Benefits:

- Minimize maintenance in floodplains
- Reduce long term operations costs
- Reduce apparent peak discharge through reduced sediment bulking
- Reduce loss of land
- Improve recharge in streambed
- Reduce sediment deposition in riverine /estuarine habitat areas

Strategy Application No. 4 – Watershed Sediment Control / Erosion Management

IFM Objectives / Principles:

- Landuse planning
- Development sustainability
- Water quality enhancement

Description of Representative Actions / Elements:

Soil is considered a water pollutant because it can significantly affect water used for public consumption, recreation and habitat. Therefore, the most effective way to control soil erosion is at its source. Erosion control best management practices (BMPs) are required on all land disturbance sites to provide a defense against soil erosion in addition to different commercial activities within the watershed. Watershed planning implementing and requiring different BMPs can be applied as well as the modification of these commercial activities to minimize sediment disturbances. There are also natural areas which may be de-stabilized and be a significant sediment source which require specialized treatments to reduce the amount of sediment production.

Potential Benefits:

- Receiving waters improved water quality
- Reduce flooding through reduced sediment bulking of flows
- Reduction of sediment deposition in undesirable locations within floodplain

Strategy Application No.5 – Multi-Function Flood Storage / Recharge Basins

IFM Objectives / Principles:

- Flood reduction
- Groundwater recharge
- Stormwater recycling / alternative water source

Description of Representative Actions / Elements:

Regional watershed evaluation and planning to provide flood peak flow attenuation through either off-channel or adjacent in-channel temporary flood volume storage. The reduction in peak flow rates will minimize downstream flooding in addition the stored flood runoff volumes can be recharged into the aquifer to enhance groundwater supplies. Coordination with groundwater management agencies should be performed on a watershed basis to determine the optimum location to ensure that maximum recharge can be provided to the aquifer since different areas of the watershed may not provide any benefit to groundwater supplies. Coordination of both groundwater and flood benefits is necessary as part of advance planning with multiple agencies. In addition, floodplain enlargement can result in increased habitat corridors as well as the in-channel flood storage capabilities.

Potential Benefits:

- Reduced flooding downstream
- Stormwater recycling and additional water source capture

Strategy Application No.6 – Urban Water Quality Treatment / Retention	
IFM Objectives / Principles: • Water reuse / recycling • Groundwater recharge • Natural floodplain protection • Stream stabilization • Water quality treatment • Urban flood management	
Description of Representative Actions / Elements: Management of urban stormwater runoff and the associated water quality as well as increased runoff quantities impacting the natural floodplain corridors which result in a variety of impacts, not just increased flooding. Projects involving the capture of non-stormwater flows provide an opportunity for recycling this water source which was a waste-stream in the past	
Potential Benefits: • Improved water quality and reduce impact to downstream receiving waters • Restore natural floodplain functions • Reduce impacts of urban hydromodification	

Strategy Application No. 7 – Floodplain Habitat Corridor Preservation / Buffer

IFM Objectives / Principles:

- Vegetation buffer
- Habitat preservation
- Stream corridor stabilization

Description of Representative Actions / Elements:

Wetlands and floodplain vegetation can provide a hydrologic buffer to the watershed response through reduced velocity and increased time of watershed. The watershed vegetation can buffer the intensity of rainfall events and the corresponding watershed response which will reduce the flooding downstream. The preservation of natural vegetation reduced water flow connectivity by interrupting surface flows of water, for example, by water storage or planting buffer strips of grass or trees.

Potential Benefits:

- Reduction of streambank/streambed erosion through natural protection
- Enhanced wildlife habitat benefits
- Natural water quality biological uptake benefits

Strategy Application No. 8 - Enhanced Floodplain Storage / Recharge	
IFM Objectives / Principles: • Floodplain preservation • Flood storage / groundwater recharge • Peak flow reduction • Flooding reduction • Maintain natural hydrologic processes	
Description of Representative Actions / Elements: Creative use of the floodplain to provide temporary in-channel storage to reduce peak flow rates downstream. The identification of potential flood storage within the floodplain involves integrating wetland and floodplain natural and beneficial functions into floodplain management planning. Integrate the protection and restoration of floodplain and wetland natural and beneficial functions into comprehensive land use planning, watershed planning, and floodplain management planning effort. Protection of floodplain and wetland vegetation to erosion is particularly important for high velocity areas	
Potential Benefits: • Enhanced groundwater supplies • New water source • Habitat enhancement and increased corridor	

Strategy Application No. 9 - Coordination between programs/agencies for water management and flood management planning.	
IFM Objectives / Principles: • Communication between agencies within watershed • Watershed planning guidance / regulations • Enhanced water supplies • Water management	
Description of Representative Actions / Elements: Improving coordination between regional water management and flood management planning is a key strategy to increase implementation of IWM projects. Existing planning groups and forums should be utilized to the extent possible. By coordinating water and flood management planning with balanced representation, a common understanding of flood management, water supply, water quality, environmental stewardship, public safety, and economic sustainability factors would be developed. Where possible, policy changes that promote this holistic approach to IWM should be proposed and sponsored (for example, changes to existing IRWM legislation). In addition, coordination in watershed planning process provides the opportunity to optimize the benefits of joint-use regional facilities to maximize water resources as well as flood mitigation benefits.	

Potential Benefits:

- Maintaining natural watershed response
- Increased groundwater replenishment
- Reduced flood damage
- Reduction in flood maintenance

Strategy Application No. 10 - Watershed / floodplain information management and data exchange

IFM Objectives / Principles:

- Communication between agencies within watershed
- Community involvement
- Increased watershed monitoring

Description of Representative Actions / Elements:

Improving the watershed database to ensure that different watershed stakeholders have access to the different available information and studies being performed. The sharing and the exchange of data, information, knowledge among experts, general public, policy makers, and floodplain managers in a most transparent manner is essential for comprehensive planning and effective management. Significant studies and mapping information are being performed within the watershed on an individual basis with single users or sole functions, but could become a valuable asset is shared with other users as well as saving significant costs. Fragmentation of data is common and providing a common data repository as well as manager provides the technical foundation for comprehensive planning.

Potential Benefits:

- Improved tracking and monitoring of watershed characteristics
- Reduction in data acquisition
- Enhanced community involvement in watershed, include active participation in data collection

7 Watershed Management Planning Recommendations and Guidelines

7.1 Watershed Level Planning Procedures

Effective IFM planning should be conducted at a regional scale in order to study the cause and effect of solutions through a system-wide approach. Although each watershed plan emphasizes different issues and reflects unique goals and management strategies, some common features are included in every watershed planning process. The watershed planning process is iterative, holistic, geographically defined, integrated, and collaborative. A holistic watershed planning approach usually provides the most technically sound and economically efficient means of problems and is strengthened through the involvement of stakeholders that might have broader concerns than just flood mitigation.

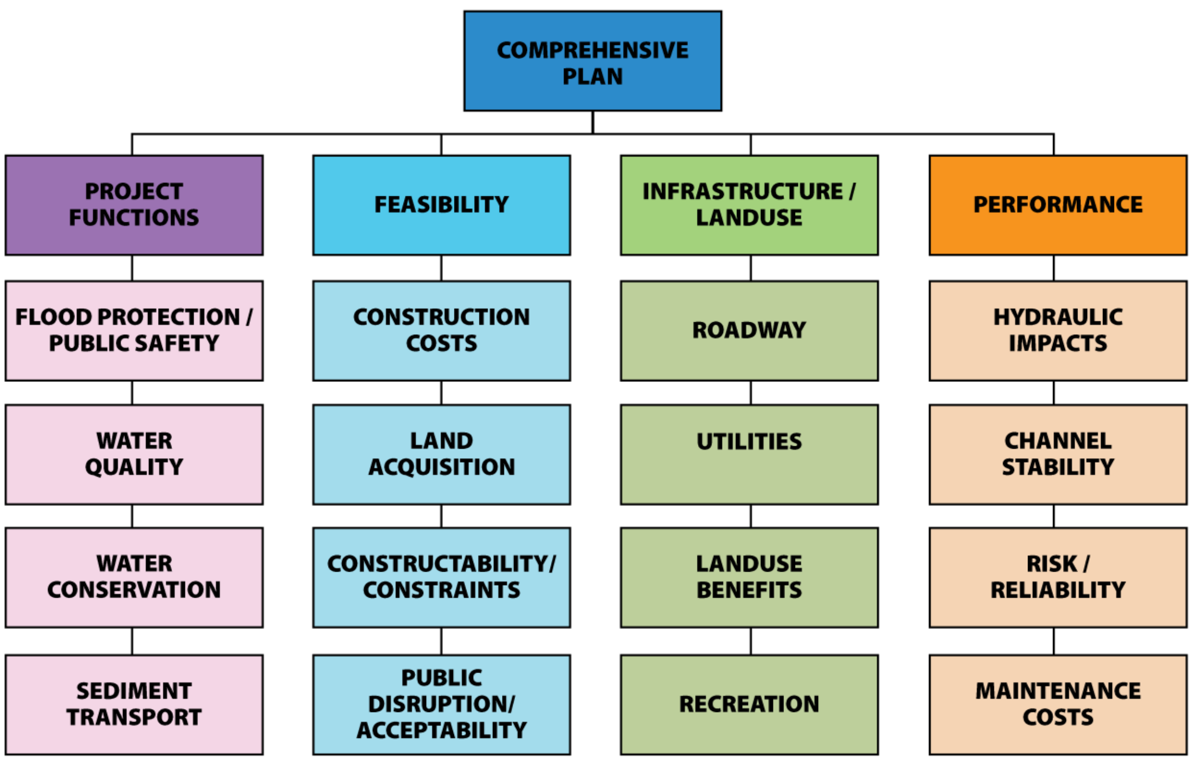

Figure 7-1 – Comprehensive watershed planning involves multiple objectives with an integrated approach to ensure that maximum benefits are achieved

Watershed flood management planning is a specialized discipline of planning that deals with floodplain management and implementation of flood protection systems and facilities to correct existing deficiencies or flooding problems. Flood management planning requires integrating a wide range of disciplines to ensure success of the plan and detailed understanding of the physical processes and system functions so that the "cause" can be effectively treated rather than the "symptom." The typical approach is an integrated planning process which evaluates multiple technical factors and evaluates multi-purpose objectives as part of the plan formulation program.

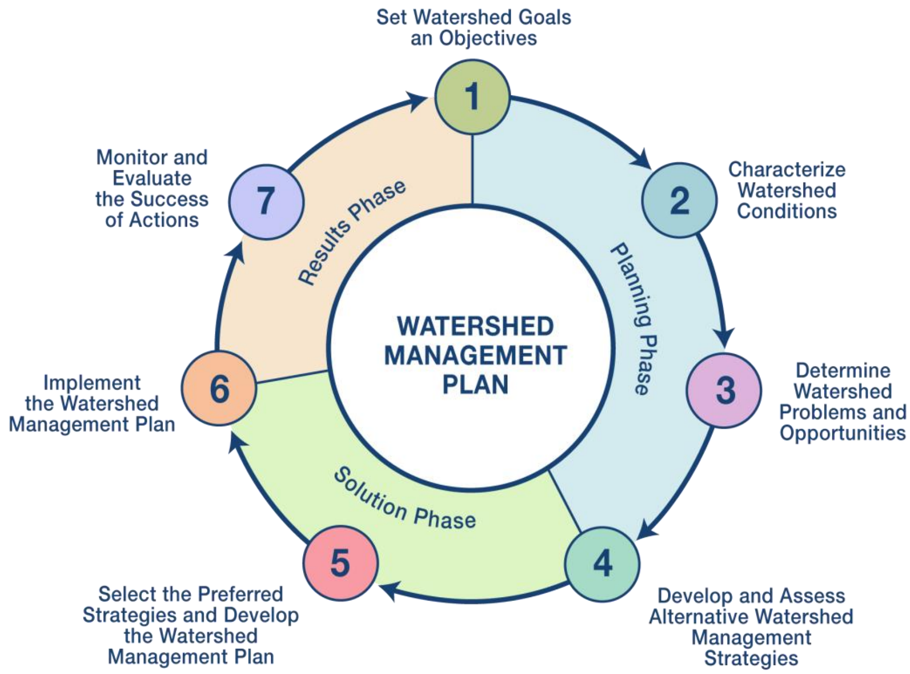

Figure 7-2 – Overview of the typical comprehensive watershed planning process involving sequential plan formulation

The general flood control planning and plan formulation process consists of a series of tasks:

Step 1 – Define Objectives and Criteria: Selection of an appropriate flood control solution requires identifying all the objectives associated with the project, since most projects will have multiple objectives, many which may be in conflict with each other. Objectives should be stated in terms of the desired outcome to be achieved and should not include the method in the objective. Design criteria are a key to establishing understood expectations for implementing a solution and are specific, measurable attributes of project components developed to meet objectives.

Step 2 – Prepare Data Inventory: Develop a database to provide a suitable technical foundation that defines the physical attributes of the system and the constraints. The data and information obtained during the inventory provides the factual basis for all future assessments and analyses.

Step 3 – Baseline Assessments and Analysis: Developing a baseline understanding of the existing conditions is essential through the application of different engineering analysis and modeling techniques.

Step 4 - Identify Problems and Opportunities: Determine the potential problems and identify the corresponding cause/source of the problem or failure mechanism.

Step 5 – Alternatives Plan Formulation: Develop a range of conceptual alternative approaches and solutions which will serve as a toolkit to draw from in order to formulate the different "systems" alternative plans. The systems can incorporate naturalized solutions and minimize impacts to environmental constraints. Plans should develop conceptual projects and should align the proposed facilities for each alternative utilizing different IFM strategies, including structural and non-structural approaches. The alternative formulation process will conceptually identify the range of potential alternative that can be screened to the most feasible alternatives.

Step 6 – Forecasts Analysis / Impacts & Risk Assessment: Prepare "planning level" assessment and analyses, which include conceptual facility hydraulic/hydrologic sizing and assessments of facility hydraulic operation or modifications of floodplain/flood hazards. The engineering analysis should be performed to sufficient level of detail in order to develop approximate construction costs of facilities and assess potential impacts, both to the floodplain and other impacts such as encroachments to biological corridors or integrating environmental habitat restoration and preservation as a key element. An initial assessment of the risk for failure of the solution is evaluated in relation to the return period of flood events, particularly if "soft" solutions or management vs. structural solutions are implemented.

Step 7 – Feasibility and Screening Analysis: A feasibility analysis is performed to screen the number of conceptual alternatives to select the recommended alternative which meets the project objectives. The screening process allows for promising alternatives to be evaluated in more detail while inferior alternatives are excluded from further evaluation. This process will qualify the alternatives different levels of feasibility in order to rank the alternatives. The "feasibility" evaluation addresses the (1) economic suitability, (2) constructability, (3) acceptability so that many of the conceptual alternatives can be eliminated from further investigation. A decision matrix can be utilized for the assisting in the screening of the flood control alternatives which identify the (1) advantages, (2) disadvantages, (3) preliminary construction costs, (4) design constraints, (5) physical constraints, (6) implementation requirements, (7) flood protection, and (8) economic factors including intangible costs. The alternatives are weighted and ranked through this process to identify the most suitable alternatives. A typical decision matrix presents the alternatives comparison based upon the degree of satisfying the various multiple watershed objectives in order to facilitate the decision making process for the recommended alternative.

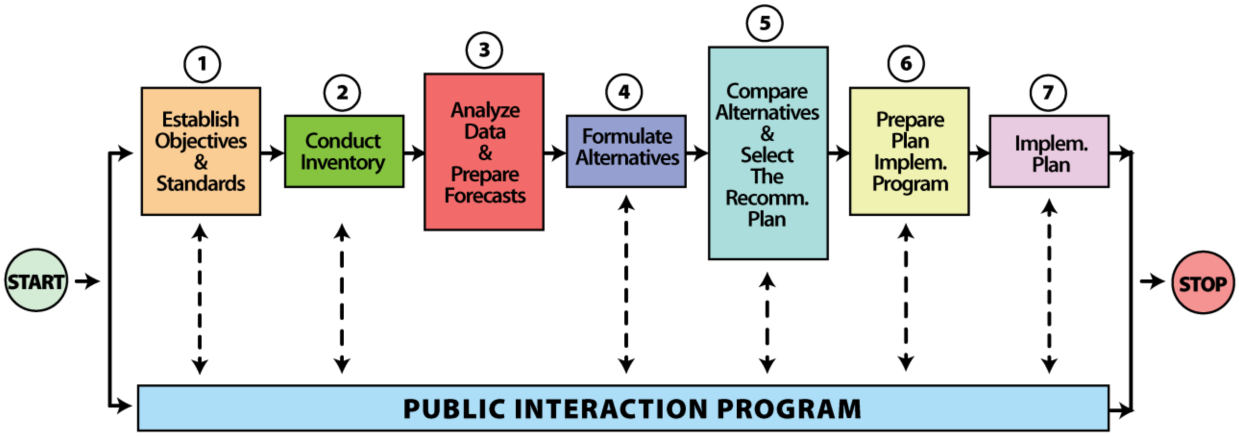

Figure 7-3 – General work flow of the watershed planning process. which includes stakeholder interaction as key element throughout the process

7.2 Specialized GIS Watershed Floodplain Management Planning Tool

The actual implementation of different IFM strategies for specific project should ensure that (1) the maximum number of benefits are achieved, (2) optimum location within the watershed to achieve the maximum flood benefits is identified, (3) multiple flood hazard issues are addressed, and (4) the focus on different water resources objectives is achieved. In order to assist in developing these projects on a watershed basis, a watershed planning tool has been developed to define locations within the watershed or floodplain that would potentially achieve multiple water resources benefits. This guidance document is intended to be used as background in the planning to identify the range of these different types of projects for implementation using multiple IFM strategies. However, the intent of this document is not to limit the range of specific strategies. These potential projects depend in part on the lead agency or entity promoting the particular subwatershed facility plan implementation and many other influential factors such as timing and opportunity. The objective in developing this initial planning tool is to provide as much flexibility as possible in order to allow responding to potential implementation/funding opportunities that may be available in the future that will allow the construction of different facilities. A feature of this planning is to identify feasible alternative regional and subregional facility locations based on specific feasibility selection screening criteria. The results of the alternative screening exercise based on feasibility of opportunities does not preclude the use of additional alternative sites in the future, as other different types of opportunities may be presented since the feasibility screening was based on a specific set of criteria.

The GIS IFM watershed planning tool evaluated different types of “opportunities” that define water resource benefits and IFM planning principles. From a watershed planning and implementation perspective it is useful to consider the “opportunities” for the implementation of regional and subregional facilities to complement or as an alternative to floodplain management approaches utilizing IFM and the associated planning principles. The series of "opportunities" in GIS mapping layers that were considered in the initial development of this planning tool included: (1) floodplain areas, (2) highly permeable soils (hydrologic soil type A), (3) groundwater basins, (4) riparian vegetation or sensitive habitat area, and (5) high sediment producing watershed areas. These initial mapping layers were overlaid to determine the locations where multiple occurrences of these five criteria occurred and were considered "opportunities." The more opportunities at a particular location then the more there was the possibility of achieving multiple flood management and water resources benefits. For example, in-stream groundwater recharge locations would be possible at location where there is (1) wide floodplain area, (2) permeable soil, and (3) groundwater basin in order to maximize the benefits to the aquifer.

In the future, additional screening criteria can be added to the tool as well as additional features such as evaluating the amount of tributary watershed area to assess the potential benefit or understand facility sizing. The tool provides planning level information to assist in evaluating potential IFM features within the watershed to increase the benefits. Figures 7-4 thru 7-9 illustrate the use of the planning tool with mapped IFM opportunity ranking that was conducted for this planning study on the different watershed units.

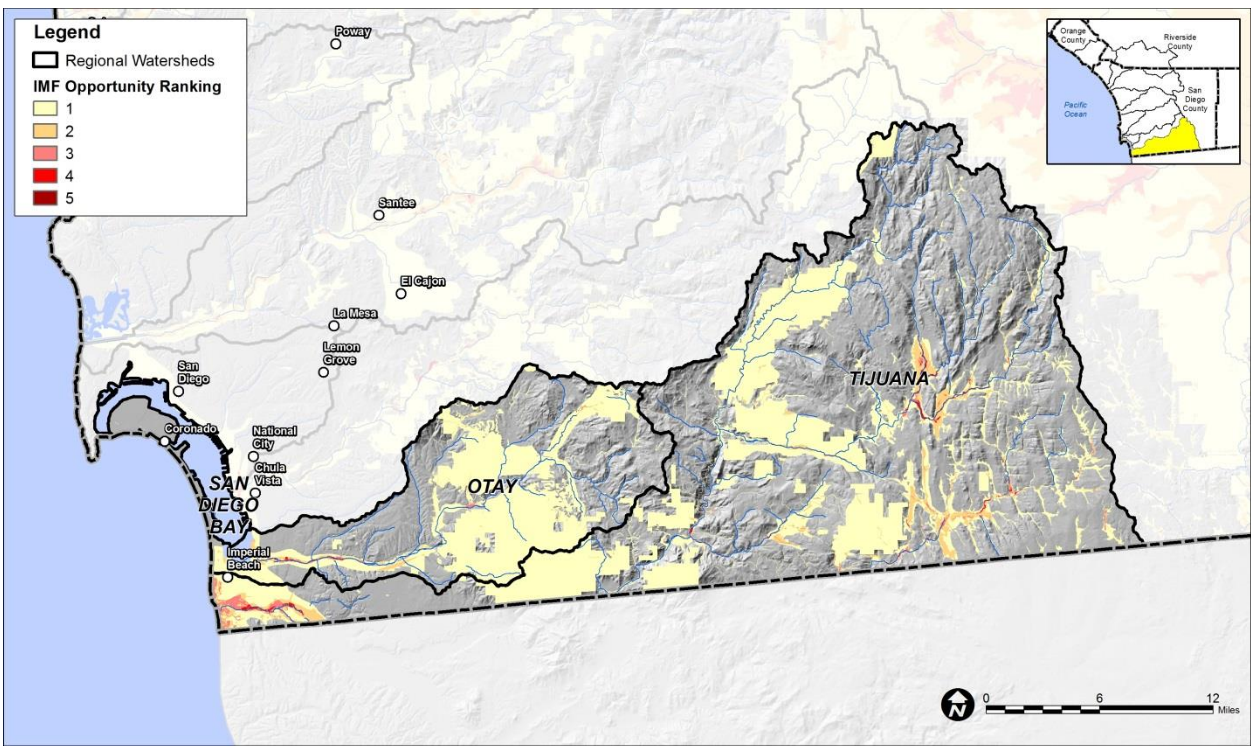

Figure 7-4: IFM opportunity ranking for application of IFM on the Otay and Tijuana River watershed unit

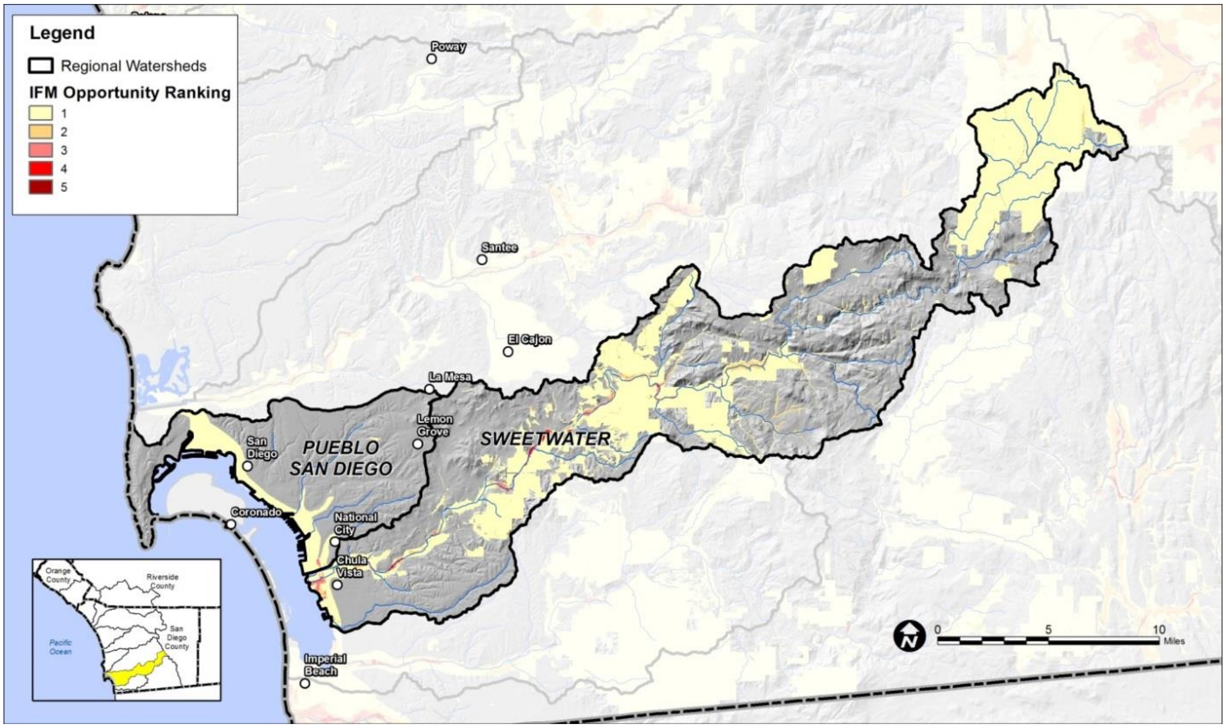

Figure 7-5 IFM opportunity ranking for application of IFM on the Pueblo and Sweetwater River watershed unit

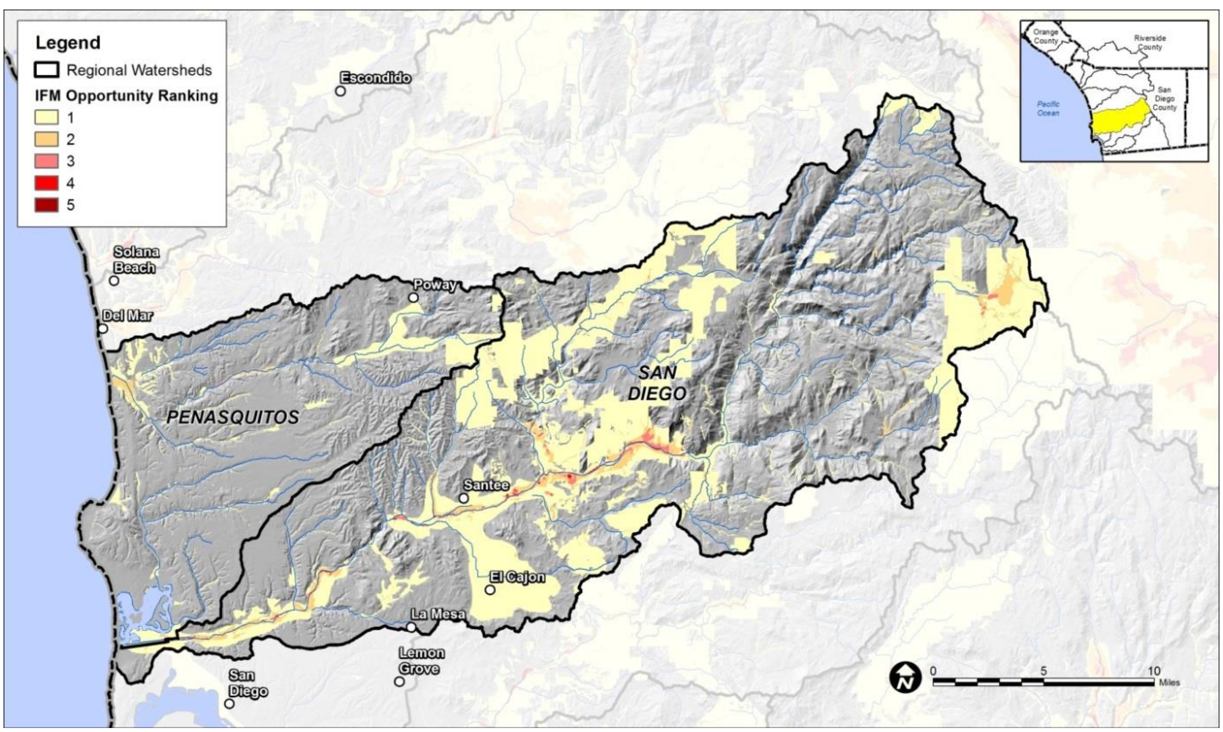

Figure 7-6: IFM opportunity ranking for application of IFM on the Peñasquitos and San Diego River watershed unit

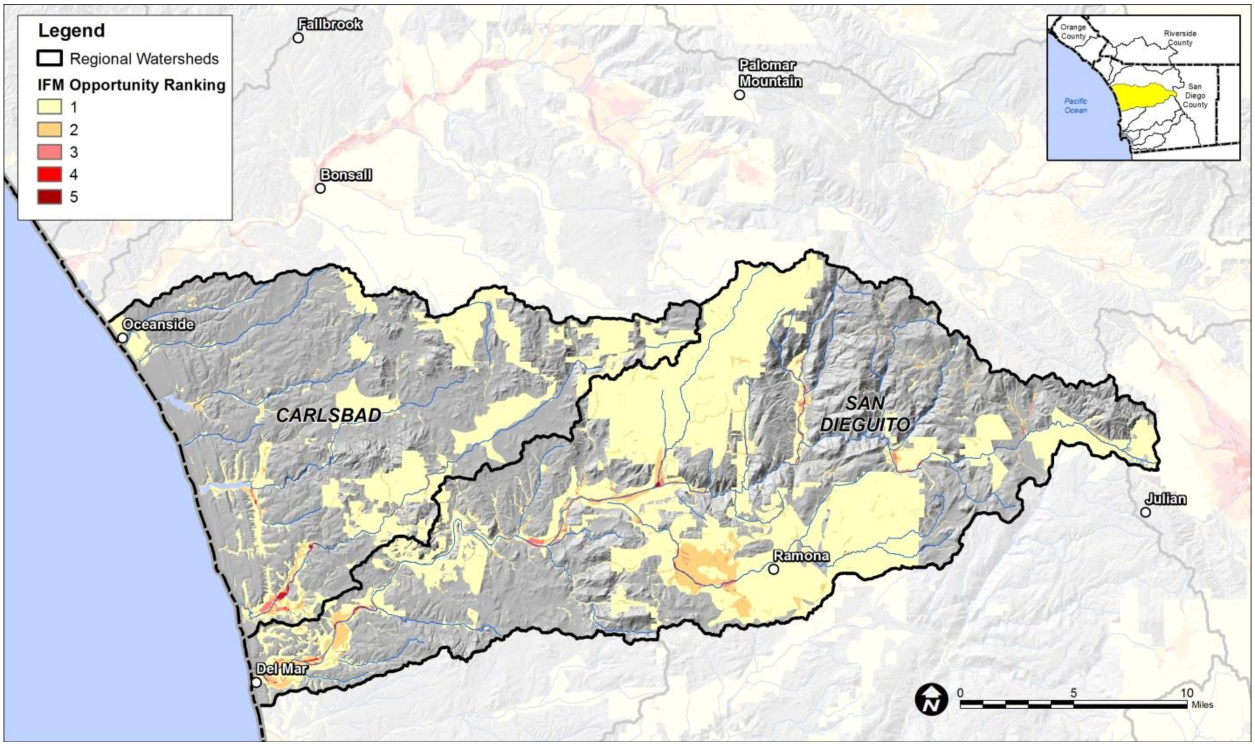

Figure 7-7: IFM opportunity ranking for application of IFM on the Carlsbad and San Dieguito watershed unit

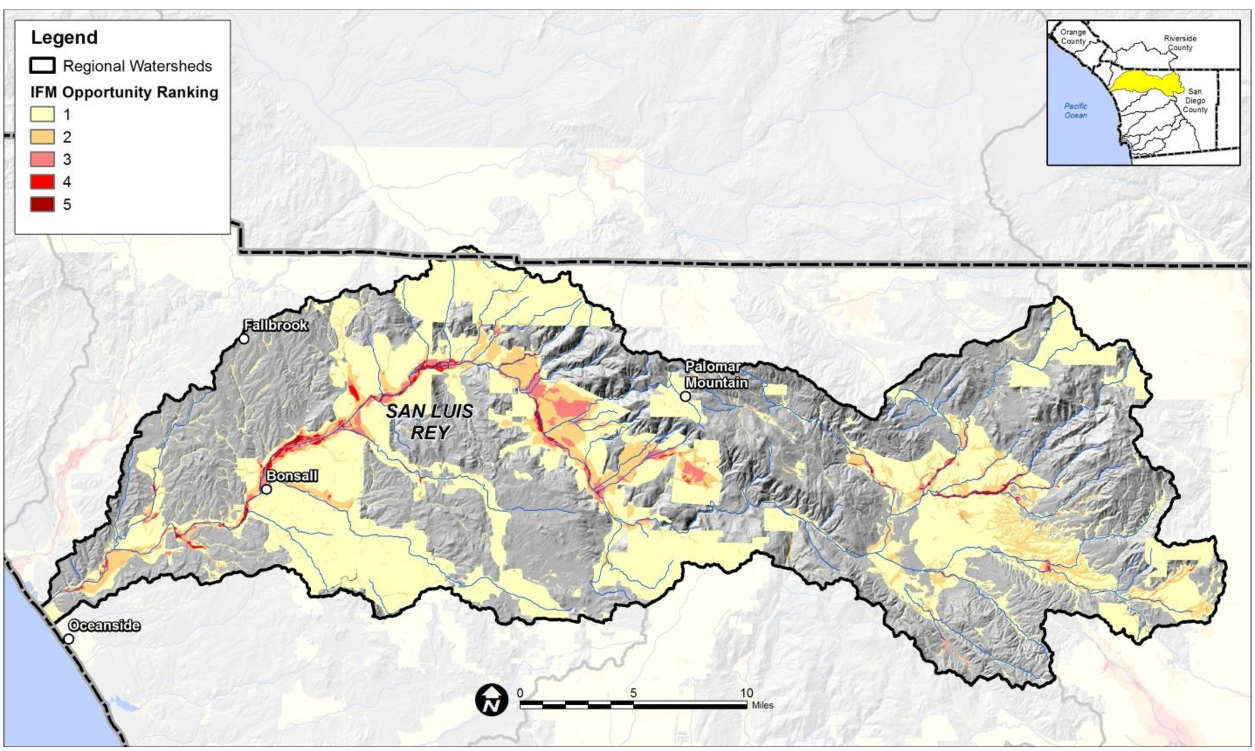

Figure 7-8: IFM opportunity ranking for application of IFM on the San Luis Rey watershed unit

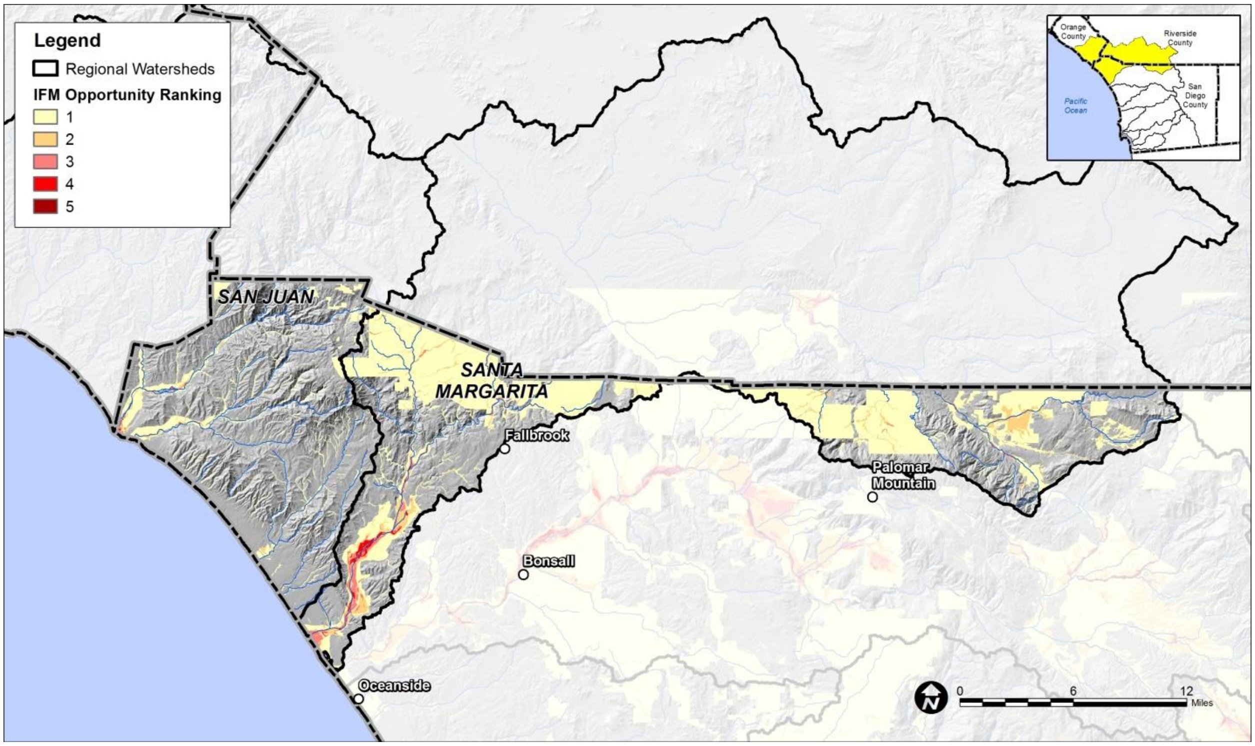

Figure 7-9: IFM opportunity ranking for application of IFM on the Santa Margarita and San Juan/San Mateo watershed unit

7.3 Communication Process – Watershed/Floodplain Managers Forum

The San Diego IRWM Region is unique with regards to floodplain management administration as compared to other areas within the state. There is not a single agency which administers and coordinates the floodplain management activities throughout the County. The SDFCD has the responsibility for areas within the unincorporated areas of the county, while the other 18 cities within the IRWM Region are responsible for the floodplain management within their municipal boundary. The fragmentation of floodplain management responsibility makes watershed scale planning more difficult.

It is recommended that a Watershed/Floodplain Managers Forum be established that promotes the collaboration with the different floodplain managers as well as coordinating with the other water resource agencies in order to implement IFM strategies. This forum would assist in define the framework and process for different levels of communication of the different levels of flood managers and watershed stakeholders. The process will define different strategies and media for communication and disseminating of information or updating of management activities as well as planning. In addition, the forum can engage the different managers and stakeholders through workshops in order to provide participation in the plan development. This working forum is a critical element that should continue into the future after the initial plan structure has developed with this contract. It can be used as an annual or more frequent vehicle for communication and collaboration to ensure effective watershed planning.

7.4 Project Plan Formulation

The initial project formulation process should provide numerous alternative general concepts or approaches that cover an entire range or spectrum of available potential solutions. The range of alternatives generated from this process should be of sufficient extent that it would satisfy an alternative analysis as part of the environmental documentation or regulatory permitting. These different options are developed through the application of a variety of available conventional tools and flood protection techniques that can be developed into different creative and effective solutions.

Conceptual design solutions are developed through an in-depth understanding of the problems and fundamental hydraulic/hydrologic processes. A hierarchy of design components is pieced together utilizing the engineering "toolbox" to develop creative alternatives that provide the desired hydraulic/hydrologic function. Techniques are selected with respect to the hydraulic conditions and fulfilling the objectives/design criteria. The intent of this process is to ensure that novel and innovative solutions are generated rather than focusing on routine alternatives.

An integral component is application of different techniques as part of these solutions that embrace the natural river function/ecology and preservation/enhancement of these resources. An important first step in formulating alternative plans is the process of creating measure of performance of evaluating each alternative since the performance measures often assist in defining potential alternatives. The performance measure must be easily understood and directly related to the planning objective. For example for the flood protection evaluation the change in water surface elevation within the floodplain will be a clear indicator of the alternative performance related to that particular primary objective.

7.5 Project Review and Screening Process

There are many unique challenges associated with the selection and prioritization of watershed projects in order to ensure that the correct or optimum is selected that provides the maximum benefits while addressing multiple watershed objectives, or ensuring the needs of all the watershed stakeholders are adopted. It is desirable to have a planning tool to assist in the alternative screening process which can provide guidance in understanding the relative importance of many different objectives through a numerical weighting scale which can be used in ranking alternatives in forming the decision nexus.

A useful technique where multiple objectives are evaluated in making a decision in the selection of many different alternatives is known as the Analytical Hierarchy Process (AHP). The main advantage to the masterplan process is its ability to rank choices in order of their effectiveness in meeting conflicting objectives. The essence of this process is to construct a matrix expressing the "relative" values of a set of different objectives or attributes. A pairwise comparison or numerical ranking is performed for each different combination of two different objectives, say cost vs. environmental protection, in order to form the matrix. The AHP involves calculating the eigenvector for the matrix which can be performed applying a relatively simplified mathematical process which otherwise would be rather daunting. (Note: an "eigenvector" of a square matrix that when multiplied by another non-zero vector yields the eigenvector multiplied by a single number) AHP is an effective tool to objectively numerically rank and prioritize projects when faced with numerous projects and multiple competing objectives on a planning basis.

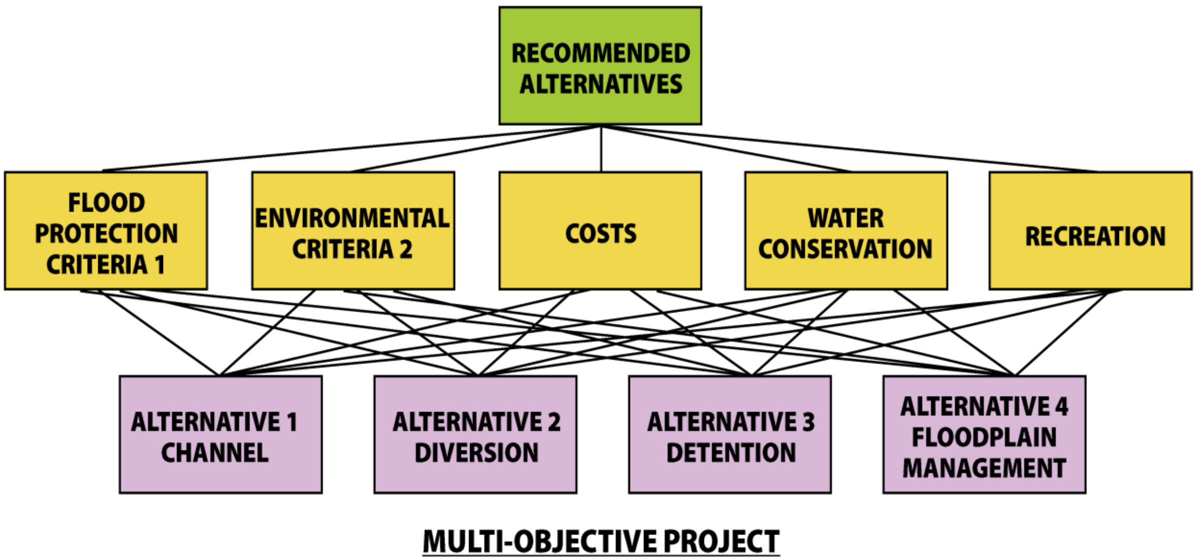

Figure 7-10: Complexity of evaluating multiple projects with different objectives which requires specialized planning tool such as AHP

7.6 Recommended Actions

This study is intended to identify a general framework for the application of an integrated flood management approach throughout the County on a regional basis that will ensure maximizing water resources benefits. General principles and strategies are also provided as guidance to assist in watershed planning. IFM combines land and water resources development in a floodplain, within the context of IRWM with a view to maximize the efficient use of the floodplains and minimize loss of property and life.

Flood management practices have evolved from single purpose projects to a more holistic water resources management approach focusing on a watershed perspective. Using an IFM approach provides significant benefits including high-value multi-benefit projects, which the community can leverage through broader access to funding sources. This report is intended as a "guidance document" to facilitate an integrated water resources approach to flood management. This assessment is based on readily available information to perform planning level risk assessment in order to provide high level recommendations. Based on the findings, the following actions are recommended to advance the use of IFM on a county-wide basis for development of flood management solutions:

1. **Increase collaboration/communication of agencies responsible municipal and regional floodplain management which will increase effectiveness of flood management**
   - Develop framework and process for different level of communication for floodplain managers
   - Provide basis for regional working forum (Watershed/Floodplain Managers Forum) of floodplain managers that allows increased collaboration and future regular meetings
   - Provide basis for a regional work-group forum of floodplain managers and watershed stakeholders that allows increased collaboration and future regular meetings. Utilize existing industry forums or planning groups such as the Floodplain Mangers Association to establish these initial working groups.
2. **Improve understanding and accuracy of regional and local flood risks on a watershed basis**
   - Develop understanding of the different types of flooding from both regional level and local level and include specific flood problems for the different areas as well inventory of common "hot spots" of chronic problems
   - Provide methodology to define the magnitude of flood risks to better prioritize the level of flood risk which integrates potential flood damage
   - Review common recurring flood damage losses and evaluate the sources of these flood problems
3. **Develop regional watershed database to assist in flood management planning that will provide a data exchange of information for all watershed stakeholders as well as sharing of information between public agencies to foster collaboration**
   - Ensure that different watershed stakeholders have access to the different available information and studies being performed
   - Develop community based watershed groups to provide monitoring of floodplains and reduce costs of performing these services while increase the active field database
   - Collect and compile watershed mapping information related to flood hazards and watershed information in a GIS format as well as developing a schema for managing the data to benefit future watershed planning
   - Develop an updated GIS database of all the different flood control and flood management infrastructure
4. **Develop watershed based planning, which includes collaboration with all the different stakeholder groups to minimize conflicts and define specific watershed goals**
   - Develop understanding of the different priority goals of the watershed stakeholders based on the common recurring flooding issues/problems/hazards

- Involve environmental groups and agencies in the planning process as well as develop an understanding of additional environmental resources

5. **Initiate understanding and awareness of "integrated flood management" (IFM) for agencies and the community**
    - Prepare educational material and information on background of IFM to encourage better understanding of the required thought process
    - Provide examples of IFM projects to assist in understanding how to apply and the basis of the key planning principles which are different from conventional watershed planning
6. **Identify applicable IFM strategies on a watershed basis that can be utilized within the County to assist agency's understanding on how IFM can be implemented given the nature of the types of flood hazards within the County**
    - Define common types of IFM strategies which integrate different planning principles through different scales (1) watershed level, (2) city level, and (3) neighborhood/local level for the semi-arid climate
    - Develop regional mapping of both opportunities and constraints related to integrated flood management
    - Develop a specialized GIS based tool which assists in the defining locations of IFM projects at a regional scale and can provide maximum multiple benefits and provides method for prioritizing flood management projects
7. **Develop watershed planning guidance program implementing IFM through different land planning regulations and collaboration with agencies during the development planning process**
    - Develop watershed planning process framework with key planning principles for implementing IFM that focuses on linking sustainability, water resource management, and landuse planning to flood management and the entire hydrologic cycle
    - Prepare guidance on integrating "landuse planning" as central element of IFM and define how it can be utilized for different type of floodplain hazards issues
    - Develop overall guidance document that provides stakeholders the basis for watershed planning with IFM