Loss Avoidance Study

Southern California Flood Control Mitigation
Part One: General Overview

April 2007

FEMA

Federal Emergency Management Agency
U.S. Department of Homeland Security
500 C Street, Southwest
Washington, DC 20472

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Each year, natural disasters produce tens of billions of dollars in direct damages to the built environment and as much or more in indirect damages and economic losses. As the nation's population continues to grow and migrate to hazard-prone regions, disaster related losses continue to escalate. In response, mitigation actions to reduce or eliminate long-term risk to life, property, and infrastructure are being taken in communities around the country.

In Southern California, tens of millions of dollars have been invested in mitigation projects in an effort to reduce the region's risk to flood hazards. The projects analyzed in this study were funded as a result of presidential disaster declarations between 1992 and 1995. Various post-project flooding events provided an opportunity for the projects to be evaluated and assess the project's effectiveness.

Several individuals made up the Loss Avoidance Team for this study. John Rowden and David Kennard envisioned the need for this study following the 2005 disaster declarations in Southern California. Shabbar Saifee and L. Gina White led the effort to define the scope of the study, collect data, guide the analysis, and develop the report. Daniel Powell and Dennis Quan provided technical expertise and were instrumental in collecting data for the analysis. Alan Springett provided technical support and review of the analysis and draft documents. Christina Finch and Robert Patten provided GIS, graphics design and technical writing support throughout the process. URS participated in data collection, completed the analysis and aided report development.

FEMA Region IX would like to take this opportunity to thank the State of California for their participation and support throughout the study. Special thanks is extended to the local governments in Los Angeles, Orange, Riverside, San Bernardino, Santa Barbara, San Diego, and Ventura counties who spent many hours assisting the Loss Avoidance Team in data collection and whose participation in the study was tireless.

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Section One:

Introduction

1.1 Background

Mitigation is defined as any sustained action to reduce or eliminate long-term risk to people and property from hazards and their effects. It is an activity that is practiced within numerous federal, state and local entities and is identified as one of the primary missions of the Federal Emergency Management Agency (FEMA). Through three nationwide programs – the Hazard Mitigation Grant Program (HMGP), the Pre-Disaster Mitigation Program (PDM), and the Flood Mitigation Assistance Program (FMA) – FEMA annually provides states and communities with substantial financial assistance for projects to reduce or eliminate risks of natural hazards. In California alone, multiple entities have contributed more than $1.4 billion to reducing or eliminating long-term risks through mitigation activities.

With this type of investment, policy makers take great interest in the effectiveness of mitigation. In response a study was performed by the Multihazard Mitigation Council (MMC) under the direction of FEMA. The MMC Study: *NATURAL HAZARD MITIGATION SAVES: An Independent Study to Assess the Future Savings from Mitigation Activities* indicated that natural hazard mitigation saves an average of $4 for every $1 of investment (MMC, 2005). However, the MMC study used methods that assess project effectiveness for probabilistic events. While this provides a theoretical measure of effectiveness, it does not demonstrate the effectiveness of mitigation projects for reducing or eliminating damage during actual hazard events.

The MMC determined that natural hazard mitigation saves an average of $4 for every $1 invested.

To determine the effectiveness of mitigation during actual events, FEMA developed loss avoidance methodology which is based on the analysis of actual events. By conducting this analysis, FEMA (or any project sponsor) can quantitatively assess the benefits of the project in terms of its actual performance. Such results demonstrate the effectiveness of the project and can be used to promote the value of investing in mitigation measures.

1.2 Purpose

The purpose of this study is to verify potential effectiveness and document economic performance of structural flood control mitigation projects in Southern California. In doing so, this study will answer the question "how much damage could have occurred from a storm event if the flood control mitigation project had not been in place?" Further, the study will provide comprehensive documentation of "losses avoided" (damages avoided or benefits) utilizing quantitative methods. The methods incorporated will provide a reproducible and verifiable methodology so that results of this study are meaningful and defensible.

Often verifiable tools utilized in loss avoidance analyses include tools such as Hazards U.S. – Multihazard (HAZUS-MH) or the FEMA Benefit-Cost Analysis (BCA) Modules. HAZUS-MH is primarily a planning tool that estimates damages in general terms (census block) for existing site conditions. On the other hand, BCA provides a more narrowed focus and requires specific assumptions in order to determine the cost effectiveness of the project. Both HAZUS-MH and BCA are tools that look into the future. They are completed prior to project funding and prior to project construction. The most visible use of these tools was by the MMC during the completion of the MMC Study: *NATURAL HAZARD MITIGATION SAVES: An Independent Study to Assess the Future Savings from Mitigation Activities.*

Terminology

Two different scenarios are required for a loss avoidance study. The first is the existing project and will be identified as the Mitigation Project Complete (MP_C). The second is to determine how the area would respond without a project in place, or Mitigation Project Absent (MP_A).

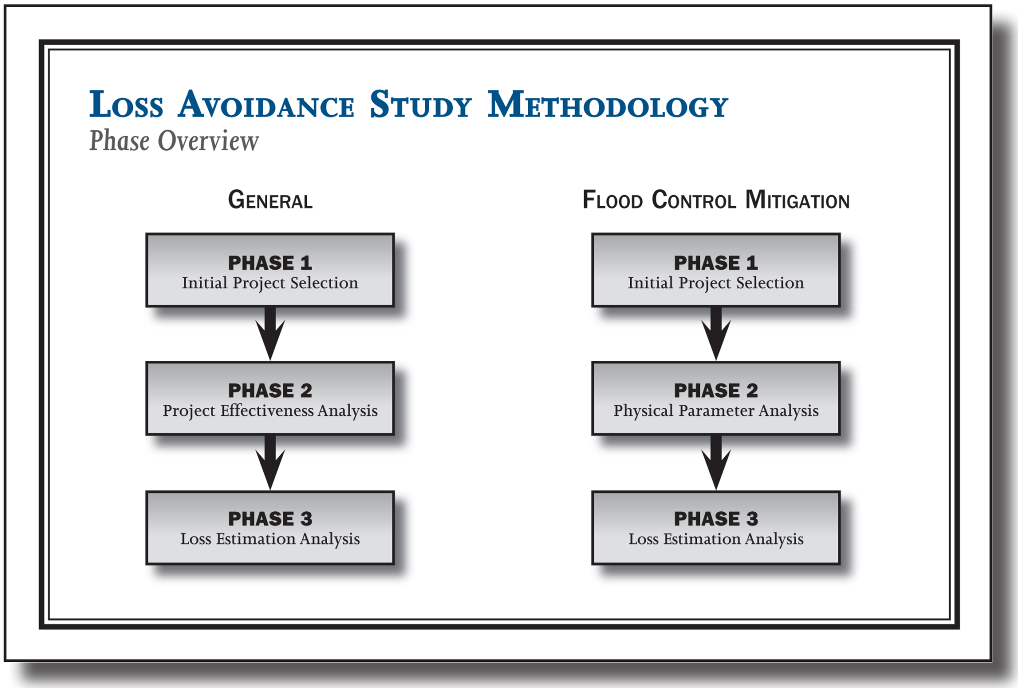
In contrast to the previously mentioned tools, this loss avoidance study provides an alternative methodology for project analysis. Its approach quantifies losses avoided of completed mitigation projects using actual post-construction storm events for two separate scenarios, Mitigation Project Absent (MP_A) and Mitigation Project Complete (MP_C). This approach provides a comprehensive and detailed methodology that can be utilized as a template for additional studies throughout the nation in order to show the impact of mitigation programs and the importance of these programs in reducing damages.

This report is divided into two parts. Part One presents an overview of the loss avoidance study methodology and describes its application to small flood control projects. Additionally, it summarizes the application of the methodology to flood control mitigation projects in Southern California and the results of that study. Finally, it describes considerations and recommended practices that were identified during the completion of the Southern California Study. Part Two provides detailed documentation of the methodology implemented during the Southern California Study and can be used as guidance for the preparation of future loss avoidance studies for flood control mitigation projects. The appendices to Part Two describe the specific application of the methodology to the six Phase 3 projects in the Southern California study detailed herein.

1.3 Loss Avoidance Methodology Overview

Figure 1.1 illustrates the phases of the general methodology for loss avoidance studies and the methodology specific to flood control mitigation projects. While Phase 1 and Phase 3 would be the same regardless of the type of mitigation project or type of disaster being

Figure 1.1



evaluated, Phase 2 would vary depending on the type of disaster and project. This study specifically focuses on the methodology utilized when assessing flood control mitigation projects. Figure 1.2 illustrates this methodology in more detail.

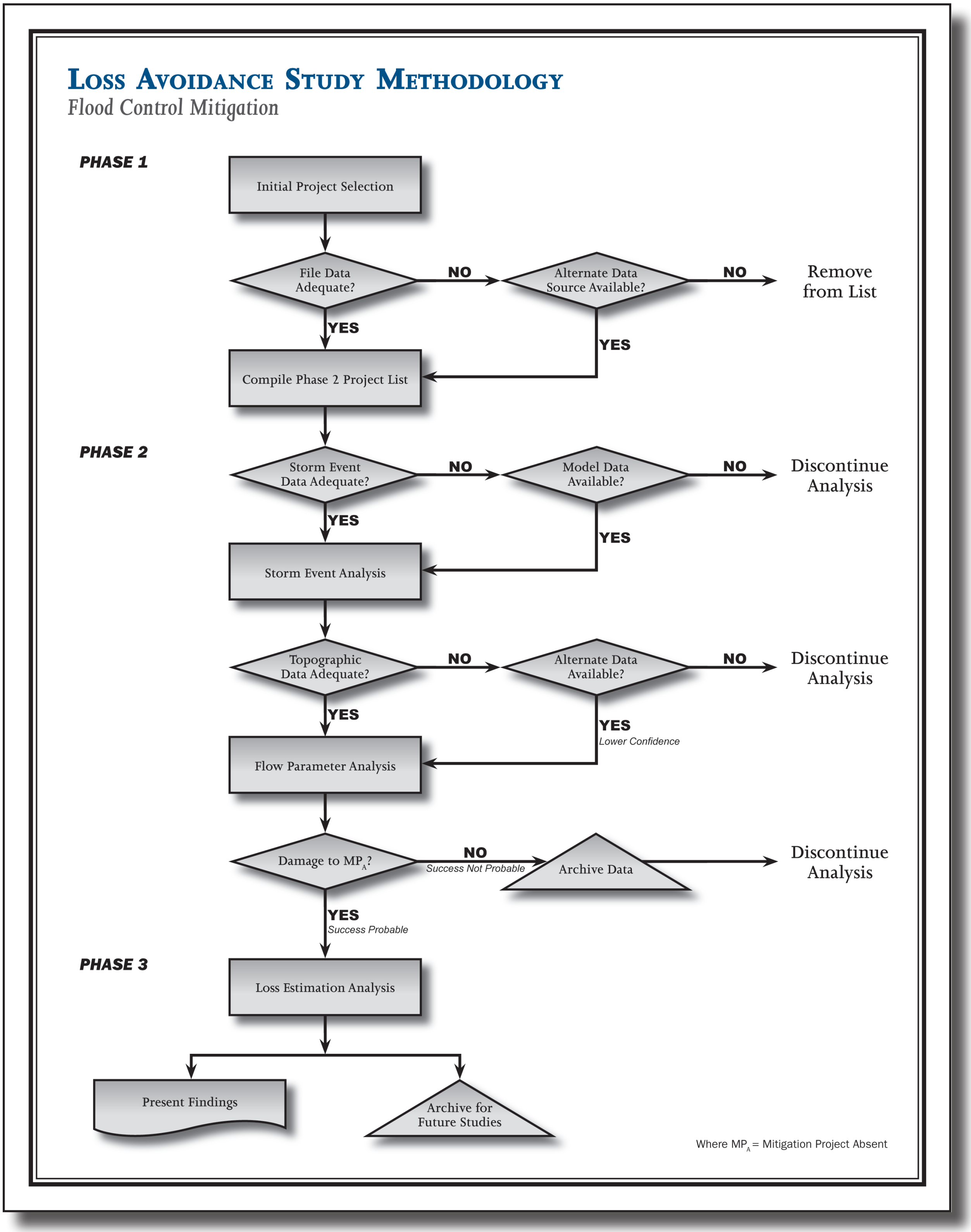
Phase 1 focuses on the selection of initial projects and the development of the initial project list. First, projects are selected based on parameters established for the study. This initial selection of projects is then screened based on the availability of data necessary to complete the study. This process determines the projects that will be placed on the initial project list and will advance to the analysis phases of the study.

As previously indicated, the purpose of the Southern California Loss Avoidance Study is to verify the effectiveness and document economic performance of structural flood control mitigation projects in Southern California. Although the projects reviewed for inclusion in the initial list of projects were funded by FEMA through the HMGP, this type of study can be implemented for any mitigation project regardless of funding source. Several parameters were established to guide the selection of projects for the initial list: projects had to be flood control mitigation projects, had to have a construction completion date prior to 2005, and had to be located in a county designated under 1577-DR-CA or 1585-DR-CA. Utilizing these parameters, 37 projects located in seven Southern California counties were selected for review and inclusion in the initial list of projects. From this selection, 17 projects were selected for further analysis based on the type of data available.

Hazard Mitigation Grant Program (HMGP)

The HMGP is authorized by the Robert T. Stafford Disaster Relief and Emergency Assistance Act, and is administered by FEMA to provide funding for eligible mitigation activities following a presidential disaster declaration. The intent of the program is to prevent or reduce losses and protect life and property during future disasters. State, local, and tribal governments, and some private non-profit organizations, are eligible applicants for HMGP funds.

Figure 1.2


Loss Avoidance Study Methodology
Flood Control Mitigation
PHASE 1
Initial Project Selection
File Data Adequate?
NO
Alternate Data Source Available?
NO
Remove from List
YES
YES
Compile Phase 2 Project List
PHASE 2
Storm Event Data Adequate?
NO
Model Data Available?
NO
Discontinue Analysis
YES
YES
Storm Event Analysis
Topographic Data Adequate?
NO
Alternate Data Available?
NO
Discontinue Analysis
YES
YES
Lower Confidence
Flow Parameter Analysis
Damage to MPA?
NO
Success Not Probable
Archive Data
Discontinue Analysis
YES
Success Probable
PHASE 3
Loss Estimation Analysis
Present Findings
Archive for Future Studies
Where MPA = Mitigation Project Absent

The second phase of the methodology includes multiple analyses to determine if there were avoided losses to measure since the project's completion. As the analyses are completed projects are eliminated from further evaluation based on data availability and analytic results.

To fully analyze flood control mitigation projects a Storm Event Analysis and Flow Parameter Analysis is completed as the second phase of the methodology. During these analyses an estimate is made of the depth and extent of inundation from an actual storm event(s) that occurred since project completion. The first task for Phase 2 is to determine if there are recorded precipitation event(s) of a size to have caused damages if the mitigation project had not been constructed. The second task is to map the MP_A and MP_C damages for the event(s). In order to compare the area inundated by flooding from the event, detailed topographic data for the area affected in both scenarios is required. This flood boundary limit is used to estimate the number and types of structures and facilities flooded.

As a result of the Phase 2 analyses for the Southern California Loss Avoidance Study several projects were eliminated from the study. Seven were eliminated from consideration based on lack of data and four were eliminated based on analysis results that indicated no damage from the MP_A event. This resulted in six projects advancing to Phase 3 of the study for Loss Estimation Analysis.

The final phase of the methodology is the Loss Estimation Analysis. There are two steps to this phase. First an economic evaluation of the projects is completed for the two scenarios, MP_A and MP_C. The difference between the two scenarios is calculated and losses avoided (LA) are determined. Secondly the return on investment (ROI) is assessed by computing the difference between project investment (PI) and LA.

In Phase 3 of the Southern California Loss Avoidance Study the remaining six projects were analyzed for flood damage loss. During this analysis, losses were estimated using the relationship between the type of structure or facility flooded, the depth and duration of the flood event impacting that structure, and the damage amount (in dollars) for both the MP_A and MP_C scenarios. The calculations included physical damage costs, loss of function costs, and emergency management costs. Once the MP_A and MP_C damages were estimated, the difference between the two scenarios was calculated to assess the losses avoided. The total LA for the projects analyzed in the Southern California Loss Avoidance Study was $7,309,402 with an average ROI of 37%.

The total losses avoided for the six projects analyzed in this study was $7,309,402 which yielded an average return on investment of 37%.

Section Two:

Phase 1 - Project Selection

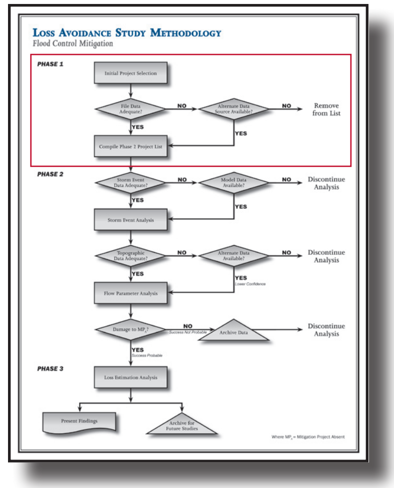
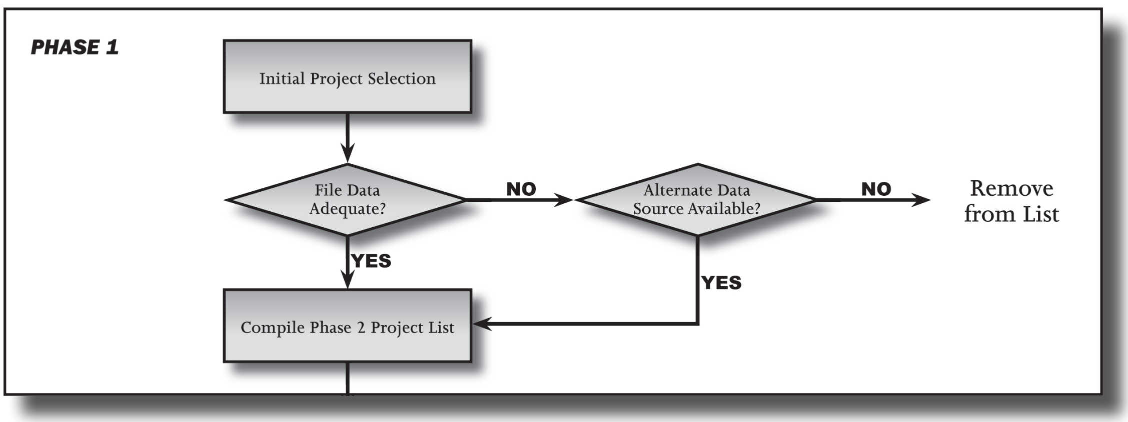


Figure 1.2 provides a detailed illustration of each of the methodology phases for flood control mitigation projects. Section Two provides a full synopsis of the process for Phase 1 as illustrated in that figure. This section will utilize examples from, and provide summaries of, the Southern California Loss Avoidance Study in an effort to better illustrate the process.

There are two tasks completed as a part of Phase 1 in order to develop an initial project list:

1. **Identifying a list of candidate mitigation projects** and
2. **Eliminating projects based on available data** as illustrated in Figure 2.1.

Figure 2.1



2.1 Initial Project Selection

The initial project selection is based on parameters established by the organization conducting the loss avoidance study, including but not limited to area of interest, hazard type, project type, and project baseline. The area of interest may vary greatly from study to study. For example, the area of interest could be a single community, a region within a state, or a watershed. Because of the extreme variance of the area of interest, it should be clearly defined by the organization considering the study prior to project selection.

Projects may also be screened by general hazard type and project type. Care should be taken, to avoid accidentally removing a multihazard project from consideration. For example, a dam may have been mitigated for earthquake hazards, yet part of the project may have been to increase overall capacity to lower pressure on the dam face while retaining reservoir capacity. This would increase the amount of water the dam could hold for a temporary period, reducing flash flood risk.

Some of the projects on the initial project list may not have adequate information in project files to proceed to Phase 2. Since the inception of mitigation programs, FEMA and other contracting agencies have had different long-term data storage requirements. Basic information, such as the original funding application and financial reports, are routinely kept in FEMA files. However, detailed engineering design drawings and digital data are not often kept in the same files. As a result, the Loss Avoidance Team may be required to utilize other resources, such as local governments or contracting consultants to retrieve the information. If the necessary information is not in the FEMA file and not available through other resources, the list of all possible projects that could be included in a loss avoidance study may be reduced due to the lack of available information.

2.2 Southern California Study: Project Selection

FEMA Region IX and the California Office of Emergency Services (OES) initiated the Southern California Loss Avoidance Study following the flooding that occurred during December 2004, January 2005, and March 2005, leading to Presidential Disaster Declarations 1577-DR-CA and 1585-DR-CA in Southern California. The scope of work for this study required the identification of six to eight projects in Southern California that could proceed through all three phases of the study. Officials noted that the flood losses from the 1577-DR-CA and 1585-DR-CA events were less than the 1995 California Winter Storms (1044-DR-CA and 1046-DR-CA). Additionally they believed that the flood control mitigation implemented since the early 1990s was responsible for the reduction of out-of-bank flooding and the reduction in damages. As a result, the parameters established for this loss avoidance study included:

1. **Area of Interest** - Southern California counties designated in 1577-DR-CA or 1585-DR-CA,
2. **Hazard Type** - flood or multihazard (including flood),
3. **Project Type** - structural flood control mitigation projects, and
4. **Baseline** - project construction completion date prior to 2005.

The initial project selection seen in Table 2.1 included a total of 37 projects. These projects were located in Los Angeles, Orange, Riverside, San Bernardino, San Diego, Santa Barbara, and Ventura counties and were funded through HMGP under disasters 0935-

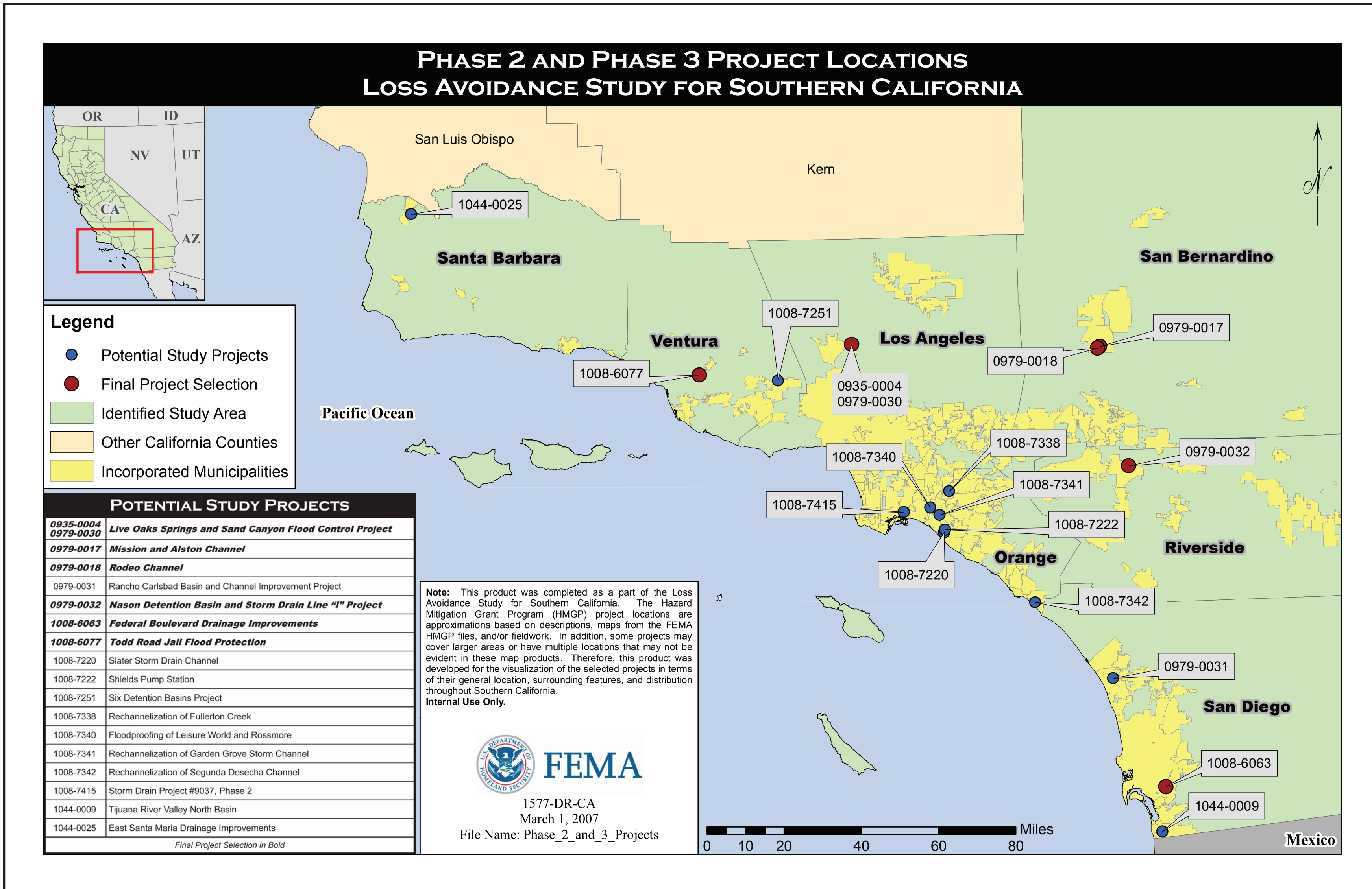
DR-CA, 0979-DR-CA, 1008-DR-CA, 1044-DR-CA, and 1203-DR-CA.

Following the initial project selection a review of the FEMA HMGP project files was completed in order to identify the data that had to be collected from alternate resources. Contacting alternate sources for hydrologic data, hydraulic data, and engineering drawings was necessary for all 37 projects. This task proved difficult for the Southern California Study as many local officials and engineering firms did not maintain digital files as needed. Seventeen of the 37 projects advanced to Phase 2 for a Physical Parameter Analysis following this data collection process. Upon completion of Phase 1 and Phase 2, six projects advanced to Phase 3 analysis (see Table 2.1 and Figure 2.2).

Table 2.1

Project List					
County	Disaster and Project Number	Project Name	Phase 1	Phase 2	Phase 3
Los Angeles	0935-0004 0979-0030	Live Oaks Springs and Sand Canyon Project			
	0979-0022	Western Avenue Storm Drain			
	0979-0023	Grand Avenue Storm Drain			
	1008-6056	23rd Place Storm Drain			
	1008-7003	Mainview Drain			
	1008-7415	Long Beach Storm Drain Project #9037			
Orange	0935-0008	Flounder Pump Station Upgrade			
	0935-0009	Flounder Pump Station Controls			
	0979-0013	E01 P25 Storm Drain			
	1008-7219	Corsican Storm Drain Improvement			
	1008-7220	Slater Storm Drain Channel			
	1008-7222	Shields Pump Station			
	1008-7338	Fullerton Creek Rechannelization			
	1008-7340	Rossmoor (Leisure World) Floodproofing			
	1008-7341	Bolsa Chica Rechannelization			
	1008-7342	Segunda De Schecha Rechannelization			
	1008-7844	Serrano Creek Erosion Control			
	1008-7845	Serrano Creek Erosion Control			
Riverside	0935-0005	Pipeline Avenue Storm Drain			
	0979-0032	Nason Detention Basin			
San Bernardino	0979-0009	Dry Well Installation			
	0979-0010	Middle School Detention Basin			
	0979-0011	Rimrock Detention Basin			
	0979-0017	Mission and Alston Channel			
	0979-0018	Rodeo Channel			
San Diego	0979-0003	Troy Street Culvert			
	0979-0004	Harbison Avenue Storm Drain			
	0979-0031	Ranchero Carlsbad Basin and Channel			
	1008-6063	Federal Boulevard Drainage Improvements			
	1044-0009	Tijuana River North Berm			
Santa Barbara	1044-0024	Via Regina Interceptor Channel			
	1044-0025	East Santa Maria Project			
	1203-4443	Veloz Drive RCB Culvert Replacement			
Ventura	0935-0003	Amlit Way Storm Drain			
	1008-6077	Flood Protection for Todd Road Jail Facility			
	1008-7251	Simi Valley Detention Basins			

Figure 2.2



POTENTIAL STUDY PROJECTS

0935-0004 0979-0030	***Live Oaks Springs and Sand Canyon Flood Control Project***
0979-0017	***Mission and Alston Channel***
0979-0018	***Rodeo Channel***
0979-0031	Rancho Carlsbad Basin and Channel Improvement Project
0979-0032	***Nason Detention Basin and Storm Drain Line "I" Project***
1008-6063	***Federal Boulevard Drainage Improvements***
1008-6077	***Todd Road Jail Flood Protection***
1008-7220	Slater Storm Drain Channel
1008-7222	Shields Pump Station
1008-7251	Six Detention Basins Project
1008-7338	Rechannelization of Fullerton Creek
1008-7340	Floodproofing of Leisure World and Rossmore
1008-7341	Rechannelization of Garden Grove Storm Channel
1008-7342	Rechannelization of Segunda Desecha Channel
1008-7415	Storm Drain Project #9037, Phase 2
1044-0009	Tijuana River Valley North Basin
1044-0025	East Santa Maria Drainage Improvements

Final Project Selection in Bold

Note: This product was completed as a part of the Loss Avoidance Study for Southern California. The Hazard Mitigation Grant Program (HMGP) project locations are approximations based on descriptions, maps from the FEMA HMGP files, and/or fieldwork. In addition, some projects may cover larger areas or have multiple locations that may not be evident in these map products. Therefore, this product was developed for the visualization of the selected projects in terms of their general location, surrounding features, and distribution throughout Southern California.
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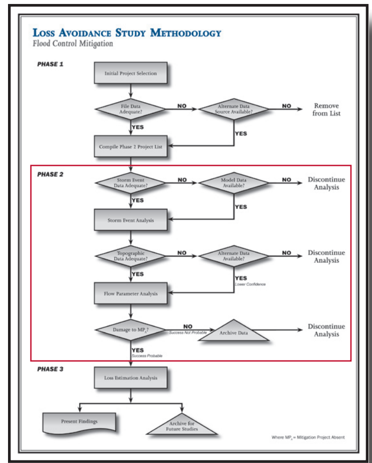
Section Three:

Phase 2 - Physical Parameter Analysis

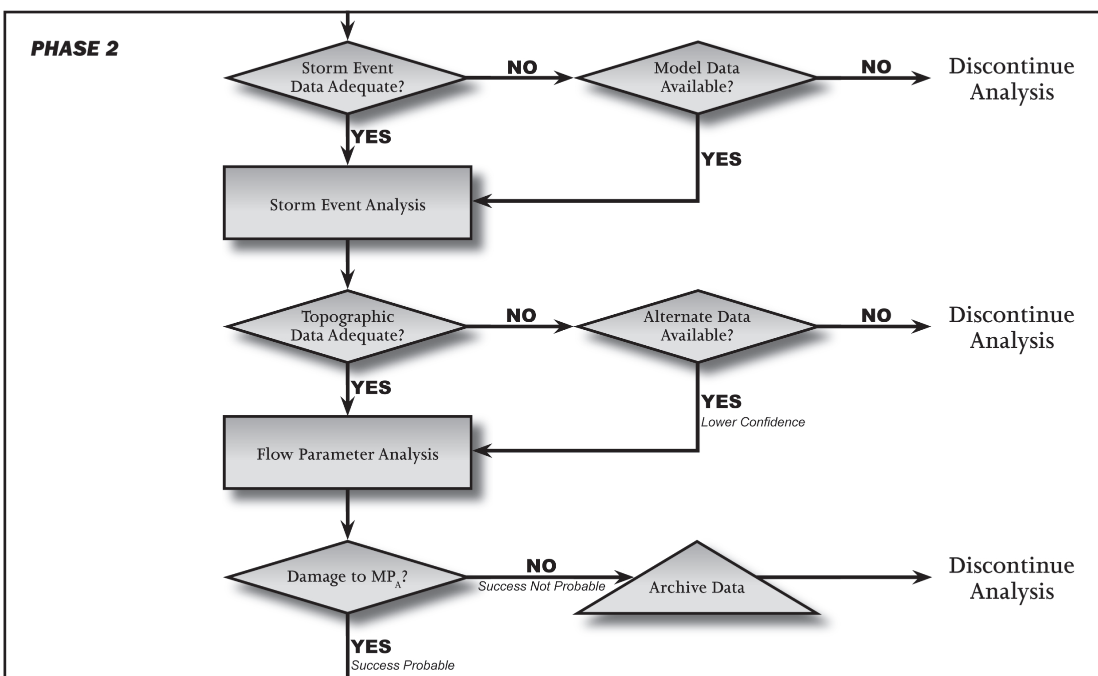


Section Three provides a full synopsis of the process for Phase 2, the Physical Parameter Analysis, as illustrated in Figure 3.1. This section utilizes examples from, and provides summaries of, the Southern California Loss Avoidance Study in an effort to better illustrate the process.

During Phase 2 the physical parameter for the storm event(s) of interest is determined for both the MP_A and MP_C scenarios. There are two major tasks in Phase 2 that must be completed when analyzing flood control mitigation projects.

1. **Storm Event Analysis** to determine rainfall amounts,
2. **Flow Parameter Analysis** which includes:
   - **Hydrologic Modeling** to determine runoff amounts,
   - **Hydraulic Modeling** to determine flood depths, and
   - **Flood Boundary Analysis** to identify and map inundation boundaries.

Figure 3.1



3.1 Storm Event Analysis

A loss avoidance study to analyze flood mitigation projects uses recorded storm events to evaluate the effectiveness of the projects. Data for a Storm Event Analysis can vary in confidence based on the type of data and the data source. As illustrated in Figure 3.2 the best available data to complete the Storm Event Analysis is stream or rainfall gage records for the watershed in which the mitigation project is located, where as general precipitation data in a similar watershed has a lower confidence. The most direct method to estimate the peak runoff is from a stream gage located on the project area reach. For larger watersheds, a rainfall distribution model may be necessary to determine the average rainfall amount for several gages. If stream gage data is not available, then a hydrologic analysis is used to estimate the peak runoff from storm event rainfall data. If rainfall or stream gage data for the project of interest cannot be found, then that project is removed from the Phase 2 project list.

Figure 3.2

3.1.1 Southern California Study: Storm Event Analysis

In the Southern California Study only one of the projects analyzed in Phase 2 had stream gage data for the reach of interest. The runoff for all the other project sites was estimated from rainfall data. The county-based Automated Local Evaluation in Real Time (ALERT) systems and the National Weather Service (NWS) were the primary sources for the rainfall data. In general, the ALERT system has more extensive gages throughout this region and was the best available data source for most of the project sites. However, since ALERT is used primarily for real-time flood forecasting, the availability of long-term ALERT data was limited. For those projects with inadequate ALERT data, long-term weather data from the NWS, or state and local sources, were used.

3.2 Hydrologic Analysis

A hydrologic analysis estimates the amount of runoff from precipitation data. The peak amount of runoff is measured in units of volume per time, such as cubic feet per second. Another important measure of runoff is total volume, which is important information for designing detention structures, such as ponds and lakes. Depending on the complexity of the hydrologic network upstream of the project site, several different types of hydrologic models may be needed to accurately predict how runoff is routed through the watershed during a storm.

Data required for a hydrologic analysis can be extensive. Typically, hydrologic models use Geographic Information System (GIS)-based datasets for land cover, soils, stream and drainage networks, and rainfall distribution. Ideally, the project files would contain the hydrologic models (in digital form) that are representative of the runoff that would occur in the project area for both MP_A and MP_C. Flood control projects alter the drainage network and/or storage capacity in the watershed upstream of the structure. Although the upstream watershed runoff volume is the same, there will be modifications in how flow reacts to project alterations. Flow may move through the watershed faster or slower than pre-project. In all design flood events, flow downstream of the flood control project should be reduced in volume for identical time periods compared to pre-project conditions. This will not be the case for volumes of flow lesser than the control structure's threshold value. Each flood control structure has a volume of flow that it is supposed to contain (i.e. flow greater than the 10-year event and lesser than the 100-year event). For events lesser than the 10-year level (identified threshold value for this example), there may be increased flow throughout the downstream area due to changes in the flow character of the upstream watershed. During project planning, care should have been taken to ensure that the project threshold flow would not create hazards downstream.

If an existing hydrologic model cannot be found or data is not available to produce a new hydrologic model, then alternate models like those developed by agencies such as the United States Geologic Survey (USGS) or the National Resources Conversation Service (NRCS) can be used. Although this is not direct empirical evidence, these models have been developed from such evidence and usually have upper and lower bounds error levels provided. As a result an upper and lower bounds analysis would be completed for the loss avoidance study.

Hydrologic Analysis Data Sources

Mitigation Project Data:

- HMGP Project Files
- FEMA Databases
- Construction Drawings and Specifications
- GIS Data (Aerial Photography and Political Boundary Mapping)

Hydrologic Modeling Data:

- HMGP Project Files
- Pre- and Post-Construction Hydrology Design and Model Reports
- Local Drainage Plans
- NOAA Design Storm Maps
- FEMA Data (FIRM, DFIRM, FIS, LOMC)
- GIS Data (Streams, Rivers, Watersheds, Land Cover, and Soils)

Two projects were removed from the Phase 2 project list because there was insufficient information available to model the complex upstream drainage network.

- 1008-7340 Rossmore (Leisure World) Flood Proofing
- 1044-0025 East Santa Maria Project

3.2.1 Southern California Study: Hydrologic Analysis

Hydrologic analyses were conducted for most of the projects evaluated in Phase 2 of this case study. The HMGP files did not contain detailed project design or construction information. As a result, local communities provided the information for the study. Access to this data was limited and often only available in hardcopy formats. However, many of the project analyses used county-specific hydrologic models that were still available. Therefore, when the required information about the watershed and drainage network upstream from the project site was available, a hydrologic model was created for the project site.

Hydraulic Analysis Data Sources

Topographic Data:

- Digital Elevation Data (Contours, LIDAR, and TIN)
- NOAA IfSAR Data
- USGS Topographic Mapping
- Paper Drawing Contours

Hydraulic Modeling Data:

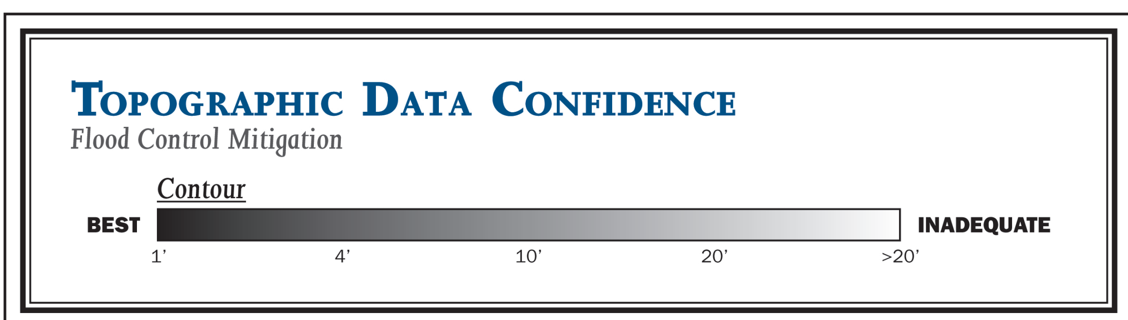
- HMGP Project Files
- Pre- and Post-Construction Hydrology Design and Model Reports
- Local Drainage Plans
- NOAA Design Storm Maps
- FEMA Data (FIRM, DFIRM, FIS, LOMC)
- GIS Data (Streams, Rivers, Watersheds, Land Cover, and Soils)

3.3 Hydraulic Analysis

Hydraulic analyses use the runoff determined by the hydrologic model to estimate the water surface (flood) elevation for a series of cross-sections that represent the area impacted by flooding. The cross-sections show the profile of the stream channel and the stream banks along the area of interest. Detailed topographic data is required to determine the elevations needed for both pre- and post-construction hydraulic models. As illustrated in Figure 3.3 the confidence of the topographic data varies depending upon the contour intervals. One to four foot contour intervals is the best data to have when completing a loss avoidance study. However, if contour intervals up to 10 feet are available, they can be interpolated to four feet or less which increases its resolution. Confidence in the data is drastically decreased if contour levels are greater than 10 feet.

Hydraulic models also require detailed information about structures that modify flow, such as bridges and culverts. Additional data requirements for hydraulic analyses include stream bank roughness conditions, boundary conditions, and hydraulic flow parameters. The results of a hydraulic analysis are estimated flood depths at each of the modeled cross-sections.

Figure 3.3



Ideally hydraulic models would be available for both the pre- and post-construction conditions for each project. If these models are not available, new models must be created using available data. Like the hydrologic models, if an existing hydraulic model cannot be found or data is not available to produce a new model, then that project is removed from the Phase 2 project list and no further analyses are conducted.

Five projects that did not have sufficient topographic data to create hydraulic models were eliminated from the Phase 2 project list.

- 1008-7220 Slater Storm Drain Channel
- 1008-7222 Shields Pump Station
- 1008-7338 Fullerton Creek Rechannelization
- 1008-7342 Segunda De Schecha Rechannelization
- 1008-7415 Long Beach Storm Drain Project

After the Hydraulic Analysis, two projects indicated no out-of-bank flooding and were removed from the project list.

- 1008-7341 Bolsa Chica Rechannelization
- 1044-0009 Tijuana River North Berm

3.3.1 Southern California Study: Hydraulic Analysis

Most of the project files did not include hydraulic models that described the pre- and post-construction hydraulic conditions of the floodplain. Most often the hydraulic information included in the project file was for the flood control structure only and not the floodplain (i.e., storm sewer hydraulic model). If topographic data was available new hydraulic models were created by extracting cross-section elevations from the topography.

3.4 Flood Boundary Analysis

The final step in Phase 2 is to map the flood inundation boundary using the results of the hydraulic analysis. GIS- or Computer-Assisted Drafting and Design (CADD)-based tools are used to add the flood depths to each of the cross-sections (estimated from the hydraulic model) and interpolate a flood boundary between cross-sections. The floodplain inundation boundary, in conjunction with aerial photography and asset mapping, shows the structures or other assets that would have been flooded and at what depth, for both MP_A and MP_C scenarios. The results of the Physical Parameter Analysis validate either continuation or discontinuance of project analysis. Projects that do not indicate any out-of-bank flooding MP_A from the storm event analyzed are eliminated.

Flood Boundary Analysis Data Sources

Topographic Data:

- Digital Elevation Data (Contours, LIDAR, and TIN)
- NOAA IfSAR Data
- USGS Topographic Mapping
- Paper Drawing Contours

Flood Boundary Analysis Data:

- HMGP Project Files
- FEMA Data (FIRM, DFIRM, FIS, LOMC)
- GIS Data (Streams, Rivers, Watersheds, Land Cover, and Soils)

3.4.1 Southern California Study: Flood Boundary Analysis

The flood inundation boundaries were determined using the estimated water surface elevations from the hydraulic model results and locating them on available topographic maps. Because there was no inundation from the event analyzed with the MP_C, the boundaries illustrate where damage would have occurred for the MP_A. The Flood Boundary Analysis was completed for eight of the Phase 2 projects. The results of the Flood Boundary Analysis indicated six projects would have had inundation with resulting damages from the storm event analyzed MP_A. A summary of the Phase 2 analysis for the final six projects is provided in Table 3.1 and the locations are illustrated in Figure 2.3. These six projects advanced to Phase 3 for the Loss Estimation Analysis.

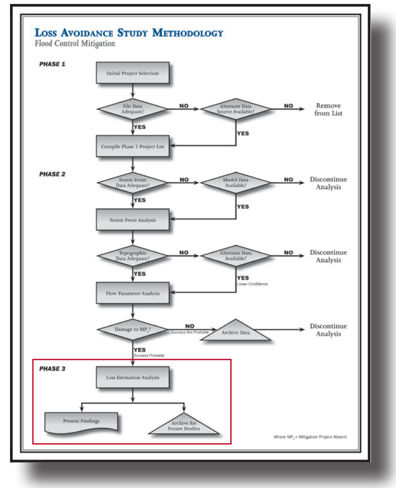
After the Flood Boundary Analysis, two projects indicated no MP_A inundation and were removed from the project list.

- 0979-0031 Ranchero Carlsbad Basin and Channel
- 1008-7251 Simi Valley Detention Basins

Table 3.1

Project Analysis Summary

General Project Information				Phase 2 and Phase 3 Results	
Project Name	Community	County	Project Type	Phase 2 Physical Parameter Analysis	Phase 3 Loss Estimation Analysis
Live Oaks Springs and Sand Canyon Project	Santa Clarita	Los Angeles	Detention Basin and Channel Rerouting	*Storm Event Analysis:* February 12, 2003, Event from Los Angeles County Fire Department Data *Hydrologic Analysis:* Modified version of model in project files *Hydraulic Analysis:* New model based on topographic data *Flood Boundary Analysis:* Mapping based on hydraulic model results and topographic data	*Primary Loss Categories:* Residential Structural Damage, Road Closure
Mission and Alston Channel	Hesperia	San Bernardino	Detention Basin, Channel Improvements (with storm drain pipe), and Improved Outlet	*Storm Event Analysis:* February 23, 1999, Event from San Bernardino County ALERT Data *Hydrologic Analysis:* Modified version of model in project files *Hydraulic Analysis:* New model based on topographic data *Flood Boundary Analysis:* Mapping based on hydraulic model results and topographic data	*Primary Loss Categories:* Residential Structural Damage, Extensive Road Closures
Rodeo Channel	Hesperia	San Bernardino	Channel Improvements and New Storm Drain Outlet Pipe	*Storm Event Analysis:* February 23, 1999, Event from San Bernardino County ALERT Data *Hydrologic Analysis:* Modified version of model in project files *Hydraulic Analysis:* New model based on topographic data *Flood Boundary Analysis:* Mapping based on hydraulic model results and topographic data	*Primary Loss Categories:* Residential Structural Damage, Extensive Road Closures
Nason Detention Basin	Moreno Valley	Riverside	Detention Basin and New Storm Drain Pipe	*Storm Event Analysis:* March 16, 2003, Event from Riverside County ALERT Data *Hydrologic Analysis:* Modified version of model in project files *Hydraulic Analysis:* New model based on topographic data *Flood Boundary Analysis:* Mapping based on hydraulic model results and topographic data	*Primary Loss Categories:* Residential Structural Damage, Road Closure, Business Interruption
Federal Boulevard Drainage Improvements	Lemon Grove	San Diego	New Storm Drain Pipes and Street Curb Inlets	*Storm Event Analysis:* February 23, 2004, Event from San Diego County ALERT Data *Hydrologic Analysis:* Modified version of model in project files *Hydraulic Analysis:* New model based on topographic data *Flood Boundary Analysis:* Mapping based on hydraulic model results and topographic data	*Primary Loss Categories:* Business Structural Damage, Road Closure, Business Interruption
Flood Protection for Todd Road Jail Facility	Santa Paula	Ventura	Channel Armoring	*Storm Event Analysis:* January 10, 2005, Event from Ventura County ALERT Data *Hydrologic Analysis:* Modified version of model in project files *Hydraulic Analysis:* New hydraulic and stream erosion models based on topographic data *Flood Boundary Analysis:* Mapping based on hydraulic model results and topographic data	*Primary Loss Categories:* Channel Erosion Damage, Road Closure, Prison Operations Interruption



Section Four:

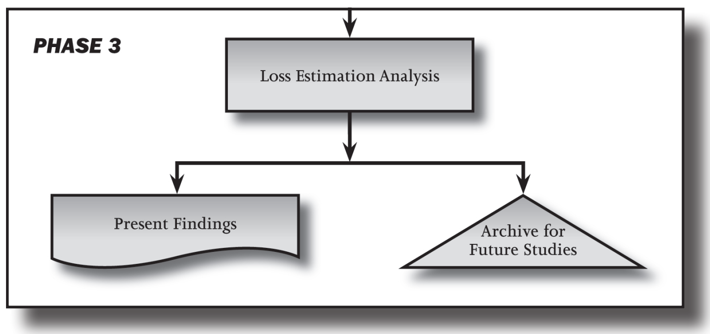
Phase 3 - Loss Estimation Analysis

The final phase of a loss avoidance study is to estimate the amount of losses that were avoided based on the effectiveness of the mitigation project during the modeled storm event. Section four will provide a full synopsis of the process for Phase 3, the Loss Estimation Analysis. The methodology is illustrated in Figure 4.1. Examples are given from the Southern California Loss Avoidance Study to better illustrate the process.

There are two major tasks in Phase 3 that must be completed:

1. **Calculating losses avoided** and
2. **Calculating return on investment**.

Figure 4.1



4.1 Calculating Losses Avoided

Calculating losses avoided requires knowledge of damages MP_A and MP_C. Figure 4.2 illustrates the formula utilized to compute losses avoided.

Figure 4.2

Loss Estimation Analysis

$$MP_A - MP_C = LA$$

Where **MP_A** = Mitigation Project Absent
Where **MP_C** = Mitigation Project Completed
Where **LA** = Losses Avoided

4.1.1 Formulating MP_A and MP_C Damages

For each of the Phase 3 projects selected for the Loss Estimation Analysis, the following information was determined as part of Phase 2 of the loss avoidance study:

- The most extreme post-construction storm event analyzed either caused damages or would have caused damages using MP_A and MP_C scenarios.
- The number and type of assets impacted by the storm event being analyzed for both MP_A and MP_C scenarios.
- The flood depth at each impacted asset estimated from the hydraulic analysis.

The result of this information is a list of impacted assets and the depth of the flooding at each asset for each project, for both MP_A and MP_C scenarios. It is assumed that the damages from the flood event MP_C (in dollars) would be available from the community directly (these are the damages, if any, for the right side of the equation).

Estimated flood depths MP_A provide the basis for the damages on the left side of the equation. Asset damage estimates were based on flood depth-damage relationships published nationally or estimated from more relevant local information. The type of depth-damage information used is dependent upon the type of asset. For example, the depth-damage curve for a residential structure is dependent upon the type of construction, number of floors, and the square footage.

4.1.2 Loss Categories

As illustrated in Table 4.1 asset damages such as structural, infrastructure, and displacement costs are divided into loss categories. Loss categories generally include physical damage, loss of function, and emergency management costs.

Physical Damage Data Sources

- Depth-damage curves obtained from HAZUS-MH or USACE
- Insurance information
- HMGP or FMA project files and BCA's
- Public assistance program project worksheets for permanent repair work
- Historical flood damage information

Physical Damage is damage that occurs directly to assets such as buildings, contents, and roads and bridges. The types of physical losses resulting from a given flood event vary based on the land use and the flood area. Flooding in residential areas tends to result in structure and contents damage. Flooding in industrial areas could result in extensive infrastructure and environmental damage. Flooding in commercial areas, such as downtown areas, could result in a wide variety of impacts due to the mixed usage of the area. To ensure that the results of the loss avoidance study are meaningful, detailed data regarding land use must be obtained using aerial photographs, community tax and parcel data, or GIS-based land use information.

Table 4.1

LOSS ESTIMATION CATEGORIES AND TYPES

Loss Category	Loss Types
Physical Damage	Structure Contents Roads and Bridges Infrastructure Landscaping Environmental Impacts Vehicles/Equipment
Loss of Function	Displacement Expense Loss of Rental Income Loss of Business Income Lost Wages Disruption Time for Residents Loss of Public Services Economic Impact of Utility Loss Economic Impact of Road/Bridge Closure
Emergency Management	Debris Cleanup Governmental Expense

Established depth-damage relationships for different asset types, such as buildings of varying construction types and building contents, are a common source of information for determining physical destruction caused by hazards. These relationships, which have been developed by FEMA, the United States Army Corps of Engineers (USACE), and other agencies using observed data from historical events, generally identify the percentage of damage that is likely to occur at certain intervals (i.e. flood depths).

The flood depth-damage relationships are either nationally published estimates or are estimated from local damage information. The specific depth-damage relationship used for the analysis is dependent upon the characteristics of the given asset. For example, the depth-damage curve for a residential structure is dependent upon the type of construction, number of floors, and square footage. Additional data for assets can be collected from a follow-up field visit for specific information on the assets impacted, as shown by the Flood Boundary Analysis conducted during Phase 2.

Loss of Function damages are those damages that occur indirectly because of the damage to an asset. These damages can vary extensively depending upon the type of asset damage. For example indirect costs associated with damage to a residence could be costs associated with moving to another residence while flooding

Loss of Function Data Sources

- Factors used in HAZUS-MH for loss of function calculations
- FEMA BCA loss of function calculations
- Highway mapping and traffic counts
- Utility and infrastructure use information
- Historical flood damage information

subsides and repairs occur. Indirect costs associated with damages to a business could be lost business, temporary relocation to another structure, and lost wages for employees. Indirect costs resulting from damages to public facilities could be maintenance of critical public services, such as police and fire departments. Indirect costs associated with road damages could be costs due to traffic rerouting while road repairs are being completed.

Most methods used to calculate loss of function quantify the stoppage or delay in delivery of services, in terms of days or units of delivery (i.e. kilowatt hours for electrical service). These estimates are typically based on the amount of destruction to the physical asset, so the physical damages must be estimated before the loss of function estimates can be calculated. For example, residential displacement time can be estimated based on the percent of damage to the residence – that is, the displacement time increases with the severity of damage to the structure.

As with depth-damage relationships, published relationships between flood depth and duration and loss of function costs can be used to identify these costs. For example, loss of function calculations can be found in FEMA's BCA modules and HAZUS-MH. For specialized loss of function costs, such as those associated with critical facilities, communities may provide costs from past events that demonstrate the impact of the event.

Emergency Management Data Sources

- Public assistance program project worksheets for emergency work
- Interviews with local public safety officials
- Historical flood damage information

Emergency Management costs are those costs related to local, state, and federal government response to, and recovery from, hazard events. These estimates are primarily obtained from historic damage records, such as project worksheets prepared by FEMA. Since many of the projects evaluated affect small areas, there may be little difference between MP_A and MP_C scenarios for emergency management costs. Like loss of function costs, these estimates are dependent upon the results of the physical damage estimates. For example, the community will experience costs for ensuring public safety, evaluating the road damage, developing a repair plan, and managing the rerouting during repair. Care should be taken to ensure these costs should not be doubly counted as part of the physical damage costs.

4.1.3 Southern California Study: Calculating Losses Avoided

The six projects that advanced to Phase 3 are summarized in Table 3.1, and their locations are shown on Figure 2.3. It is important to note that five of the project sites did not actually experience any out-of-bank damage during the event being analyzed. As a result, the flood mitigation project was completely effective for that event, and no actual damages (zero dollars) accrued for five of the projects. The Todd Road Jail Facility had minor out-of-bank flooding and experienced minor damage to the channel armoring which led to MP_C damages. All of the projects experienced MP_A damage conditions. Some of the areas evaluated had residential structure damages and all had road closure issues.

- Regarding the Live Oaks Springs and Sand Canyon, Nason Detention Basin, and Federal Boulevard Drainage Improvement projects, when larger events occurred, the roadway became the overflow channel, flooding structures along the roads and requiring the rerouting of traffic to neighboring roads.
- Two projects (Rodeo Channel and Mission and Alston Channel projects) experienced flooding through a residential neighborhood involving a number of structures and roadways.
- The hydraulic models for the Todd Road Jail Facility project showed minor out-of-bank MP_C flooding and indicated some in-stream bank erosion.

The types of damages (losses) that were estimated for each of the six projects included in this phase of the study are shown on Table 4.1.

Part of the data collection for this analysis included a final field visit to the six project sites. This visit focused on the assets, shown by the inundation boundary, to be at risk from MP_A flooding. Photos of each asset that would have been impacted were taken, and the type and condition of the asset was noted.

Avoided losses were calculated for each of the loss types listed in Table 4.1. The detailed depth-damage relationships in FEMA HAZUS-MH for different residential and commercial construction types were used for the structural and contents damages and displacement. The traffic delay cost methodology from FEMA Benefit-Cost guidance documents was used for the loss of function costs (flooded roads). The HMGP project files were used to estimate other loss types by noting the date of the original damage and the flood depth that caused the damage. The damages were calculated by interpolating the previous data and converting the result into 2006 dollars. Details on the specific methods used for each project analyzed in Phase 3 are included in Part Two of the study report.

As noted above, with the exception of the Todd Road Jail Facility, there were no actual MP_C damages from the storm events analyzed. Therefore, the MP_C was \$0.00. The benefits are then the damages that would have occurred from a storm event MP_A. The results of the avoided losses for each type of damage for the projects analyzed in Phase 3 are summarized in Table 4.2 by loss category. Part Two of

Table 4.2

Loss Estimation Analysis Results

General Project Information				Results by Loss Category						Losses Avoided Total
				MP_A Scenario Damages			MP_C Scenario Damages			
Project Name	Community	County	Project Type	Physical Damage Subtotal	Loss of Function Subtotal	Emergency Management Subtotal	Physical Damage Subtotal	Loss of Function Subtotal	Emergency Management Subtotal	
Live Oaks Springs and Sand Canyon	Santa Clarita	Los Angeles	Detention basin and channel rerouting	$167,920	$512,856	$11,079	$0	$0	$0	**$691,855**
Hesperia Projects: Mission and Alston Channel and Rodeo Channel	Hesperia	San Bernardino	**Mission and Alston Channel:** Detention basin, channel improvements (with storm and drain pipe), and improved outlet **Rodeo Channel:** Channel improvements and new storm drain outlet pipe	$4,452,784	$244,133	$725,996	$0	$0	$0	**$5,422,913**
Nason Detention Basin	Moreno Valley	Riverside	Detention basin and new storm drain pipe	$178,100	$78,093	$4,511	$0	$0	$0	**$260,704**
Federal Boulevard Drainage Improvements	Lemon Grove	San Diego	New storm drain pipes and street curb inlets	$507,483	$220,568	$3,093	$0	$0	$0	**$731,144**
Flood Project for Todd Road Jail Facility	Santa Paula	Ventura	Channel armoring	$251,720	$0	$27,969	$69,213	$0	$7,690	**$202,786**
			Total	**$5,558,007**	**$1,055,650**	**$772,648**	**$69,213**	**$0**	**$7,690**	**$7,309,402**

the study report includes the detailed loss calculations for each loss type. Based on these results, the total amount of damages avoided from one event for these six projects is approximately $7,309,402 with the most significant amount of losses avoided being in the physical damage category.

For the events analyzed in Southern California, five of the projects evaluated were *completely effective*, resulting in *no damages*.

4.2 Calculating ROI

The final task in determining losses avoided is to calculate the return on investment. Care should be taken to remember the results on a per project basis could vary depending upon the number of events being analyzed for each project and the level of MP_A damage. Figure 4.3 provides an illustration of the formula utilized in calculating return on investment.

Figure 4.3

Return on Mitigation Investment

$$\frac{\$\,LA}{\$\,PI} = \%\,ROI$$

Where **LA** = Losses Avoided
Where **PI** = Project Investment
Where **ROI** = Return on Investment

The bottom portion of the equation is the total investment for the project being calculated. It is important to remember that project investment does not represent the federal investment alone. Rather, it is the total investment for the project from all parties involved. Care should be taken to insure the investment total is representative of the project area only and does not include work outside the identified project bounds.

4.2.1 Southern California Study: Calculating ROI

All of the projects analyzed in the Southern California Study utilized multiple sources of funding. The total project investment ranged from a few hundreds of thousands of dollars to millions of dollars.

Table 4.3 illustrates the amount of investment and provides details on the percent of ROI for each individual project. The total investment for the six projects that advanced to Phase 3 was $19,575,932 and the average ROI was 37%.

The Federal Boulevard Drainage Improvements project yielded the highest ROI with approximately 118%. As a result, the investment in the project was fully recovered with one event. The Hesperia and the Todd Road Jail Facility projects also yielded a higher than average ROI. However the Live Oaks Springs and Sand Canyon and the Nason Detention Basin projects were determined to have a lower than average ROI with the Nason Detention Basin project yielding a 4% ROI.

All projects included in the Southern California Loss Avoidance Study were completed within the last five to 10 years. Since their completion the projects were impacted by only one storm event that caused inundation. If similar events occur during the next 10 to 20 years, the ROI will likely exceed 100%. As a result, project investment could be fully recovered well within the intended lifespan of the projects.

Table 4.3

Return on Mitigation Investment

General Project Information			Results by Loss Category			Losses Avoided Total	Project Investment Adjusted for 2006 Dollars	Current ROI
Project Name	County	Date of Project Completion	Physical Damage Subtotal	Loss of Function Subtotal	Emergency Management Subtotal			
Live Oaks Springs and Sand Canyon	Los Angeles	**07/17/2002**	$167,920	$512,856	$11,079	**$691,855**	**$6,436,509**	**10.75%**
Hesperia Projects: Mission and Alston Channel and Rodeo Channel	San Bernardino	**11/21/1997 and 08/14/1995**	$4,452,784	$244,133	$725,996	**$5,422,913**	**$6,251,954**	**86.74%**
Nason Detention Basin	Riverside	**01/14/2003**	$178,100	$78,093	$4,511	**$260,704**	**$5,957,151**	**4.38%**
Federal Boulevard Drainage Improvements	San Diego	**04/17/2002**	$507,483	$220,568	$3,093	**$731,144**	**$621,619**	**117.62%**
Flood Project for Todd Road Jail Facility	Ventura	**12/14/2001**	$182,507	$0	$20,279	**$202,786**	**$308,699**	**65.69%**
		Total	**$5,488,794**	**$1,055,650**	**$764,958**	**$7,309,402**	**$19,575,932**	**37.34%**

Section Five:
Considerations and Recommended Practices

The Southern California Study yielded findings that are of potential value to future loss avoidance studies. Many of these findings could be incorporated into the planning and implementation of mitigation projects so that loss avoidance studies can be completed more efficiently once those projects are constructed. Section Five provides a discussion about considerations and recommended practices that were developed based on the findings of the study. These considerations and recommended practices are grouped under two separate categories: Data and Analysis.

5.1 Data

Multiple types of data were collected for each phase of the analysis and different challenges were experienced with each type of data (see Table 5.1). In working through these challenges a list of considerations and recommended practices were developed that address data collection and long-term storage.

5.1.1 Data Available from HMGP Project Files

HMGP project files typically contain basic information about a project, including funding applications, financial reports, and basic engineering design information. Additionally, many older reports only include hard copies and not the original digital input and output model files. However, detailed engineering drawings and design reports are needed for a Physical Parameter Analysis. To support future loss avoidance studies, state and federal officials should require that the digital files created throughout the project design and construction process, including hydrologic and hydraulic modeling and topographic data, be stored with the project files or retained in searchable archives.

5.1.2 Planning Data Collection

Data not available from project files must be collected from other sources. These sources may include local governments; state and federal agencies; and private companies, such as engineering and mapping firms. The older the project, the less likely it is that the original agencies and firms involved with the project have retained detailed information. In addition, data such as topographic or community parcel data may require a special data release that may take a significant period of time to process through local government channels. Therefore, the data collection process should have a clearly identified plan and priority list for different datasets.

Table 5.1

Data Collection Summary		
Data Type	**Description**	**Challenges**
Project Data	Background information for each project, including HMGP project files, Construction Drawings and Plans, GIS data and aerial photography	Completeness of project files; coordination with multiple data sources
Topographic Data	Data describing the terrain for each project area - gathered from paper files of site plans and in GIS and CADD digital formats	Data availability especially for pre-project conditions, data detail (contour interval), aerial extent of data (often did not include downstream areas)
Storm Event Data	Rainfall or stream gage data describing severity of storm events	Completeness of data for post-construction time period, different data collection intervals, lack of stream gages
Flow Parameter Data	Data required to conduct hydrologic modeling, hydraulic modeling, and flood boundary analysis	***Hydrologic***: Availability of model input and output files ***Hydraulic:*** Lack of models for the downstream reaches affected by flooding ***Flood Boundary:*** Lack of topographic data to produce detailed inundation boundaries
Field Data	Information gathered from site visits including photography and structure data	Visit final projects for structure information after completion of inundation mapping
Asset Data	Data used to determine value of different assets affected by flooding, including structure replacement values, road repair costs, and traffic count data	Have completed inundation analysis to determine specific at-risk locations where asset data would be required for analysis

5.1.3 Availability of Storm Event Data

Southern California is a highly populated area, sensitive in the extreme to storms. Accordingly, multiple sources were identified for the data necessary to complete a Storm Event Analysis. It is highly unlikely that areas more rural in nature will have appropriate data availability. Analysis methods that use modeling of precipitation over a wide area may be required for rural areas.

5.1.4 Availability of Topographic Data

Topographic data with the vertical resolution and format suitable for computer modeling is often difficult to obtain. During the Southern California Study, obtaining such data for the pre-construction MP_A scenario proved difficult, and resulted in the elimination of a number of projects from further consideration. Topographic data should have detailed contours of four feet or less. If this data is not available and interpolation of the available data is not possible then the project should be removed from the project analysis list.

5.1.5 Data Collection Archive

The data collected and the analyses completed for any project in a study should be maintained and easily accessible once the project has been removed from the study or once the study has been completed. Care should be taken to remember that projects may be a part of more than one study and maintaining the information collected and analyzed could greatly reduce the cost of future studies of which the project is a part.

5.2 Analysis

The study consisted of various types of analysis and modeling. The challenges experienced when completing these tasks assisted in the LAT identifying processes and methods that can improve the efficiency of future loss avoidance studies.

5.2.1 Damage Thresholds

Where the Southern California Loss Avoidance Study focused heavily on the most significant storm event, future studies should consider identifying and analyzing the threshold storm event and use it as a filter to determine if a project moves forward in the analysis. Establishing a threshold will assist in determining if the project had post-construction impact by more than one event, thereby, having more significant losses avoided and potentially having a total return on investment. Additionally, this practice will assist in establishing parameters for the projects participation in future studies which will greatly assist in reducing the cost of the future studies.

5.2.2 Evolving Computer Models

The computer models used for hydrologic, hydraulic, and flood boundary analyses evolve over time. Any analysis conducted for a loss avoidance study should electronically store the properly formatted input and output files for the particular model used in the analysis. The input and output information should be stored in "common" formats, such as spreadsheets or text files. This will aid future studies that may not have the original models available and will need to create new models. This type of data storage especially applies to any mapping or digital drafting and design data that are in a special format.

5.2.3 Use of Methods Based on National Data

Many of the methods currently available for calculating flood damages for certain features, such as infrastructure, are usually obtained from regional or national averages. If the project files contain actual damage amounts from past events, the loss avoidance study should make use of these locally-based values. The damage estimates can be scaled or interpolated from these actual damage amounts and converted to current dollars. However, care must be taken that local inflationary or deflationary factors are still applicable.

Acronyms:

ALERT
Automated Local Evaluation in Real Time

BCA
Benefit-Cost Analysis

CADD
Computer-Assisted Drafting and Design

DFIRM
Digital Flood Insurance Rate Map

FEMA
Federal Emergency Management Agency

FIRM
Flood Insurance Rate Map

FIS
Flood Insurance Study

FMA
Flood Mitigation Assistance

GIS
Geographic Information System

HAZUS-MH
Hazards U.S. – Multihazard

HMGP
Hazard Mitigation Grant Program

IfSAR
Interferometric Synthetic Aperture Radar

LA
Losses Avoided

LIDAR
Light Detection and Ranging (system)

LOMC
Letter of Map Change

MMC
Multihazard Mitigation Council

MP_A
Mitigation Project Absent

MP_C
Mitigation Project Complete

NOAA
National Oceanic and Atmospheric Administration

NRCS
National Resources Conservation Service

NWS
National Weather Service

OES
California Office of Emergency Services

PDM
Pre-Disaster Mitigation

PI
Project Investment

ROI
Return on Investment

TIN
Triangulated Irregular Network

USACE
United States Army Corps of Engineers

USGS
United States Geological Survey

References and Resources:

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RSMeans. *Residential Cost Data*, Kingston, MA 2006.

Resources

FEMA Flood Insurance Studies and Map Revision Files:
http://msc.fema.gov/

FEMA Hazard Mitigation Grant Program:
http://www.fema.gov/government/grant/hmgp/

FEMA Public Assistance Program:
http://www.fema.gov/government/grant/pa/index.shtm

NOAA Radar Data:
http://www.csc.noaa.gov/crs/rs_apps/sensors/ifsar.htm

National Weather Service Rainfall Data:
http://www.weather.gov/climate/local_data.php?wfo=lox

Orange County ALERT Rainfall Data:
http://www.ocgov.com/pfrd/envres/Rainfall/intro.asp

State of California Department of Water, Resources Gages:
http://www.water.ca.gov/nav.cfm?topic=Public_Safety&subtopic=Flood_Emergency_Information

USGS Stream Gage Data:
http://waterdata.usgs.gov/nwis/rt

USGS Topographic Mapping:
http://topomaps.usgs.gov/