APPENDIX L

Mariposa Lakes Off-Site Regional Hydrologic Investigation

PACIFIC ADVANCED CIVIL ENGINEERING, INC.

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August 8, 2006 #8013E

City of Stockton
c/o David Wade
Wade & Associates
7777 Campus Common Dr., Suite 200
Sacramento, CA 95825

Re: Responses to the City of Stockton comments on the Mariposa Lakes Off-site Regional Hydrologic Investigation, First Submittal (4/7/06)

Dear Mr. Wade:

Pacific Advanced Civil Engineering, Inc. (PACE) is pleased to provide the following responses to the City of Stockton and Peterson, Brustad, and Pivetti, Inc. review comments for the above-referenced hydrology study. Both the comments and responses from PACE are as follows:

a. *Need engineer's stamp on the fly sheet*

PACE response:
Noted.

b. *Exhibit 3 doesn't correlate with Appendix A. At highway 99, Appendix A (from the County Hydrology Manual) shows mean annual precipitation of 14.5", versus 13" on Exhibit 3. A spot check at Farmington Dam shows Exhibit 3 in error as well. This will cause an underestimation of flood flows.*

PACE response:
Exhibit 3 does not match exactly with Appendix A. Appendix A is a Mean Annual Precipitation map for San Joaquin County Hydrology Manual. It covers San Joaquin County only. The contributing watershed area upstream of the Mariposa Lakes development site includes portions of three counties, San Joaquin County, Stanislaus County, and Calaveras County. Therefore, a lager data set was required than what is available in the Hydrology Manual.

PACE identified and compared two California State rainfall maps, both available in GIS format from the California Spatial Information Library (http://gis.ca.gov/). The first map uses rainfall data from over 800 rainfall gages throughout California from 1900-1960, and the second uses data from 1961-1990. The rainfall map from the Hydrology Manual was superimposed on top of each of the two USGS datasets, and it was decided to use the dataset from 1961-1990. Though this period of record is smaller (30 years as opposed to 61 years), many of the larger storm events and wet years occurred in the period from 1961-1990. So to be conservative, we chose to use more recent rainfall dataset. By using these larger rainfall values, runoff flow rates increased

considerably.

Between the April 7 submittal and this report, peak flow rates on Duck Creek at the Mariposa Lakes project boundary increased from 393 cfs to 1095 cfs. Peak flow rates on North Little Johns Creek increased from 485 cfs to 1096 cfs. Although there were many changes made to the hydrologic model, including changes to the unit hydrographs, rainfall distributions, and changes to the channel routing parameters, using the new rainfall map (1961-1990) was the most significant change between the previous submittal and this report. Peak flow rates for the April 7 submittals were approximately 20-30% smaller than modeling results from Ensign and Buckley in 1993. Results in this report are approximately 80-100% more than the Ensign and Buckley numbers.

A 30-year rainfall record is a relatively small dataset. Extremely large rainfall totals in just a few of the 30 years of record can dramatically effect the mean annual precipitation values. It is recommended that additional discussion take place regarding the use of the 1961-1990 data.

c. 24-hour storms were used. Need to use overall time of concentration to assign critical storm duration for each basin.

PACE response:
The critical storm duration was developed for the Duck Creek and North Little Johns Creek watersheds. Time of concentration was computed for each regional watershed upstream of the Mariposa Lakes project boundary. The Tc for Duck Creek was computed to be 47.3 hours, while the Tc for North Little Johns Creek was 117.0 hours. Because most of the North Little Johns Creek watershed is located upstream of Farmington Dam, and because the larger flood hazard is presented by runoff from the Duck Creek watershed, the Duck Creek Tc of 47.3 hour is the more important of the two. Therefore, a 48-hour 100-year storm was developed and modeled as part of this report. The statistical analysis used to derive the 48-hour rainfall depths and distributions is detailed in Section 5.1 of this report.

d. NRCS rainfall distribution was used. Should have used the procedure in the Hydrology Manual.

PACE response:
48-hour rainfall distributions were developed using the procedures specified in the Hydrology Manual. A detailed discussion of how these distributions were developed can be found in Section 5.1 of this report.

e. Salt Springs Valley Reservoir was ignored, which will give conservatively high peak flow estimates. No need to make changes, but improvements may be oversized.

PACE response:
Noted.

f. SCS unit hydrograph was used. Should have used the procedure in the Hydrology Manual.

PACE response:
Unit hydrographs were developed based on the methods specified in the Hydrology Manual. The

USACE equation was used to develop lag times, and Valley and Foothill S-graphs were used to develop unit hydrographs specific to each sub-basin. Unit hydrographs were entered into HEC-1 using UI cards. A more detailed discussion of unit hydrographs can be found in Section 5.3 of this report.

g. *Storage method of channel routing was used. Should have used the procedure in the Hydrology Manual.*

PACE response:
The routing method was changed from Storage Method to Convex Method (RV card in HEC-1), as specified in the Hydrology Manual. A detailed discussion of the development of the RV card can be found in Section 6.1.

h. *Channel and overbank friction factors of 0.03 and 0.035 were used, which are low for these channels. The result will be conservatively high peak flow estimates. No need to make changes for the hydrologic analyses, but more realistic numbers should be used for yet-to-be-completed hydraulics. However, if realistic friction factors results in overbank flows wich leave one stream for another, the inter-basin overflow should be reflected in the analysis. This topic should be explored and discussed in the text and analysis.*

PACE response:
Channel friction factors (Manning's roughness coefficient, *n*) were adjusted. Because the routing method was changed from storage routing to convex routing, only one roughness coefficient is used for the channel and overbank areas. All sub-basins were divided into two different stream types, Valley and Foothill. Streams above elevation 500 were considered Foothill channel types, and streams below 500 feet were considered Valley channel types. Valley channels were assigned a roughness coefficient of 0.04 and Foothill channel types were assigned a roughness coefficient of 0.045. It should be noted that the same channel distinctions and friction factors were also used in developing the UI cards. More discussion of PACE's methodology can be found in Section 5.3 and 6.1.

i. *The report states that Farmington Reservoir stores all inflows until the peak flow from Duck Creek Passes, and then Farmington releases begin. Need to verify that full-time manned operation of Farmington exists during the rainy season.*

PACE response:
The Channel Maintenance unit of the Department of Public Works was contacted, and they report that the USACE operates the Farmington Reservoir and gate operations during the rainy season.

j. *Gate settings at Duck Creek and Little Johns Creek diversions are very important to understand. Need to verify County policies for rainy season gate settings.*

PACE response:
True, gate settings at the two diversion sites are very important. Channel Maintenance personnel were contacted. They stated there is no written County policy on gate settings. Both diversions have operated without any changes to gate settings for over 20 years.

k. *Comparison of peak flood flows with Ensign & Buckley study shows PACE numbers 20-30% less. This could be due to errors in application of the Hydrology Manual, but PACE should attempt to explain the differences, or use the higher estimates for design purposes. PACE should also attempt to compare/calibrate unregulated portions of the subbasins to hydrologically-similar stream gages, or other regression equations for design floods established by DWR or USGS.*

PACE response:

Response to Comment B addresses the Ensign and Buckley report. Our new peak flow rates are now much larger than those computed in the Ensign & Buckley report. The problem comparing with the Ensign and Buckley report is that there is very little technical discussion of the hydrologic or geometric parameters they used to compute their results. There is no discussion in their report of the diversion structures that play such an important role in evaluating large flood events. Therefore, the Ensign and Buckley report should be considered, but without knowing more about their methodology it is difficult to compare with current simulations.

l. Report needs to discuss hydrology from FEMA studies.

PACE response:
It is recognized that a Conditional Letter of Map Revisioin (CLOMR) will be required upon completion of a rough grading plan for the entire site. Later during construction, a Letter of Map Revision (LOMR) will be required. The analysis contained in this report is a regional off-site hydrologic investigation and is not an attempt to study the floodplain and channel hydraulics through the project site. The floodplain study, which will include surveyed channel cross-sections, various detailed HEC-RAS hydraulic models, and will evaluate FEMA floodplain zones and how they will change in a developed condition, will be contained in a future report.

m. *Report only covered hydrology. Subsequent submittals need to cover detailed layouts, hydraulics, performance of project features, hydraulic impacts to upstream and/or downstream properties, and impacts to floodplains.*

PACE response:

Additional submittals include the "Master Drainage Plan- Part A- Description of Stormwater Facilities," which discusses the performance of manmade lakes, detention basins, stormwater BMPs, and restored stream channels, and the "Master Drainage Plan- Part B- Numerical Modeling of Stormwater Facilities," which is a more thorough numerical analysis of the regional flood control features, including hydraulic impacts to upstream and downstream properties.

Sincerely,
PACIFIC ADVANCED CIVIL ENGINEERING, INC.

Blaine K. Jones
Hydrologist

Technical Summary

MARIPOSA LAKES
OFF-SITE REGIONAL HYDROLOGIC INVESTIGATION

August 8, 2006

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Table of Contents

1 Introduction 1
1.1 General Watershed Description 1
1.2 Study Objectives 1
1.3 Analysis Approach 1
2 Previous Studies 1
2.1 United States Army Corps of Engineers (USACE) 1
2.2 Other Reports 2
3 Watershed Description and Characteristics 2
3.1 Physiography/Topology 2
3.1.1 Duck Creek 2
3.1.2 North Little Johns Creek 3
3.1.3 Branch Creek 3
3.2 Hydrometeorological Characteristics 3
3.2.1 Historical Rain Gage Data 3
3.2.2 Historical Stage Gage Data 5
3.3 Geology/Soils 7
3.4 Land Use/Vegetation 8
3.5 Structures Affecting Runoff 11
3.5.1 Farmington Flood Control Reservoir 11
3.5.2 Salt Springs Valley Reservoir 11
3.5.3 Duck Creek Diversion 11
3.5.4 Little Johns Creek Diversion 13
4 Hydrologic Analysis Tools 16
4.1 WMS 16
4.2 HEC-1 16
4.3 GIS Data 16
5 Hydrologic Modeling Parameters 17
5.1 Rainfall and Precipitation 17
5.2 Losses 20
5.3 Unit Hydrographs 20
6 Hydraulics, Routing and Structures 21
6.1 Channels 21
6.2 Reservoirs 21
6.3 Diversions 22
6.3.1 Duck Creek Diversion 22
6.3.2 Little Johns Creek Diversion 23
7 Watershed Modeling Results 25
7.1 HEC-1 Results 25
7.1.1 Simulation A, No Upstream Control Structures 26
7.1.2 Branch Creek- Simulation 1 29
7.1.3 Duck Creek- Simulation 1 and 2 29
7.1.4 North Little Johns Creek- Simulations 3-6 31
7.2 Comparison to Previous Studies 34
7.3 Sensitivity Analyses of Watershed Parameters 35
7.3.1 Rainfall Distribution Curve 35
7.3.2 Manning's Roughness Coefficient, *n* 36
8 Summary and Discussion 37
9 Recommendations 38

List of Figures

Figure 1 - Annual rainfall data for three nearby rain gages.
Figure 2 - Historical water levels in the Farmington Reservoir.
Figure 3 - Water depth gage on Duck Creek at diversion structure (1993-2006).
Figure 4 - Water depth gage on Little Johns Creek above Little Johns diversion structure.
Figure 5 - NRCS Status of Soil Surveys, California.
Figure 6 - Salt Springs Valley Reservoir dam and spillway.
Figure 7 - Duck Creek Diversion structure. Water going through these two culverts remains in Duck Creek through the Mariposa Lakes project site.
Figure 8 - Weir at Duck Creek Diversion. Water flowing over weir is conveyed down the diversion channel into Little Johns Creek.
Figure 9 - Downstream side of Little Johns Creek Diversion structure.
Figure 10- Upstream side of Little Johns Creek Diversion Structure.
Figure 11 - South Little Johns Creek, looking downstream near diversion structure.
Figure 12 - North Little Johns Creek, looking upstream from Kaiser Road.
Figure 13 - Rainfall Intensity Curves and Rainfall Distributions used in HEC-1
Figure 14 - Discharge rating curves for Duck Creek diversion culverts (taken from Exhibit F of USACE, 1952).
Figure 15 - Discharge rating curve on South Little Johns Creek, assuming one 42" culvert is open at the diversion structure on North Little Johns Creek.
Figure 16 - Discharge rating curve of diversion structure on North Little Johns Creek.
Figure 17 - Inflow hydrograph at Farmington Reservoir, Node 90C
Figure 18 - Inflow hydrograph on Duck Creek at the Mariposa Lakes project boundary. This simulation assumes no upstream control structures.
Figure 19 - Inflow hydrograph on North Little Johns Creek at Mariposa Lakes project boundary. This simulation assumes no upstream control structures.
Figure 20 - Simulation 1. Inflow hydrograph on Branch Creek at the Mariposa Lakes project boundary.
Figure 21 - Simulation 1. Inflow Hydrograph on Duck Creek at Mariposa Lakes project boundary, assuming both the 60" and 72" culvert gates are open. This simulation represents the most realistic 100-year scenario.
Figure 22 - Simulation 2. Inflow hydrograph on Duck Creek at Mariposa Lakes project boundary. Simulation assumes the 72" culvert gate is closed, limiting the discharge in Duck Creek through the project
Figure 23 - Simulation 3. Inflow hydrograph on North Little Johns Creek at Mariposa Lakes project boundary, assuming all four culvert gates are closed at Little Johns Creek diversion structure, representing the "as-is" and most realistic 100-year flooding simulation.
Figure 24 - Simulation 4. Hydrograph on North Little Johns Creek at Mariposa Lakes project boundary, assuming one 42" culvert gate is open.
Figure 25 - Simulation 6. Hydrograph on North Little Johns Creek at Mariposa Lakes project boundary, assuming the 72" culvert gate is closed at Duck Creek diversion and all four culvert gates are open at North Little Johns Creek diversion. Considered the "worst-case" scenario for flooding on North Little Johns Creek.
Figure 26 - Duck Creek hydrographs at node 80C, the Duck Creek diversion, using different rainfall depth values.

List of Exhibits

Exhibit 1 - Regional Vicinity Map
Exhibit 2 - Drainage Network
Exhibit 3 - 1961-1990 Rainfall with San Joaquin County Isohyetal Rainfall
Exhibit 4 - Hydrologic Soil Groups
Exhibit 5 - Land Use and Land Cover
Exhibit 6 - Existing Channels and Reservoirs
Exhibit 7 - Diversion Structures
Exhibit 8 - Stream and Rain Gage Locations
Exhibit 9 - FEMA Flood Zones

List of Tables

Table 1 - Rain gages in the Duck Creek/Little Johns Creek area.
Table 2 - Table B-7 from the San Joaquin Hydrology Manual, 100-year Depth-Duration-Frequency for County of San Joaquin.
Table 3 - Rainfall Depth-Duration-Frequency data used in WMS model.
Table 4 - Summary of different modeling scenarios.
Table 5 - Modeling results for North Little Johns Creek
Table 6 - Modeling results for Branch Creek and Duck Creek

Appendices

Appendix A - Figure B-1 of the San Joaquin County Hydrology Manual. Isohyetal map of the Stockton area.
Appendix B - Rainfall tables and figures from the Hydrology Manual. Table B.7, Table B.1, Figure F-2.
Appendix C - Table of parameters used to calculate basin Curve Numbers.
Appendix D - Figure C-2 from the Hydrology Manual, list of land uses and their respective curve numbers.
Appendix E - Table of sub-basin parameters used to calculate Unit Hydrographs.
Appendix F - Figure E-3b and E-3d from the Hydrology Manual, S-graphs for the Valley and Foothill areas.
Appendix G - HEC-1 output data for Simulation 1.
Appendix H - HEC-1 output data for Simulation 3.

1 Introduction

1.1 General Watershed Description

The Mariposa Lakes land development project is located adjacent to the City of Stockton, just east of Highway 99 (see Exhibit 1). The project area is bound by US Route 4 to the north, Mariposa Road to the west and south, and Kaiser Road to the east. The two major streams that flow through the project site are Duck Creek and North Little Johns Creek, with the smaller Branch Creek also draining through the project site. The creeks flow from east to west, with their headwaters in the foothills of the Sierra Nevada Mountains between the Calaveras River watershed to the north and the Stanislaus River watershed to the south.

1.2 Study Objectives

This report summarizes the off-site hydrology in support of the EIR for the Mariposa Lakes development in East Stockton. This report has four major objectives, a.) to briefly summarize previous studies in and around the Duck Creek and Little Johns Creek watersheds, b.) to summarize current hydrometeorologic, topographic, geologic, and land use characteristics of the off-site watersheds, c.) to outline methodologies used to evaluate flood runoff potential, and d.) to develop and analyze comprehensive hydrologic modeling results. A future report will address the FEMA floodplain designations in the area.

1.3 Analysis Approach

The Hydraulic Engineering Center's HEC-1 program was utilized for hydrologic analysis. HEC-1 was designed to simulate the rainfall/runoff response mechanism within a river basin by subdividing the watershed into an interconnected network of hydrologic basins and hydraulic components. Runoff processes are simulated for each individual sub-basin, and hydraulic components such as channels, pipes, streets, and reservoirs store and convey water between sub-basins. HEC-1 is approved by San Joaquin County, and guidelines for a complex hydrologic model are documented in the San Joaquin County Department of Public Works Hydrology Manual. (SJCDPW, 1997).

2 Previous Studies

2.1 United States Army Corps of Engineers (USACE)

Three early USACE reports are referenced throughout this report regarding the operations and maintenance of the various in-channel structures that effect runoff. The first report is the Maintenance Manual for the Farmington Dam and Reservoir, dated July 1952. This manual not only specifies the details about how the reservoir and its structures are to be maintained, but it also provides a general background of the project, the need for flood control at Farmington, and some historical reference for building the Farmington Dam and Reservoir.

The second USACE document is the Operation and Maintenance Manual for Duck Creek Diversion, dated December 1952. Much like the previous document, this manual outlines the regular maintenance of the Duck Creek Diversion structures. Plans showing culvert geometry, levee embankment geometries, and diversion structure and channel plans are

included as Exhibit B, which is no longer attached to the copy of the report we received. Follow up calls to the County were fruitless and Exhibit B was never found.

The third USACE report is a Detailed Project Report on Duck Creek, dated May 1961. This report looks at Duck Creek flood control since the time the Farmington Dam and Reservoir and Duck Creek Diversion were built, and evaluates the feasibility of improvements to the project. This report provides detailed information about the hazard of damaging flood flows on Duck Creek and Little Johns Creek. Since little has been done to the Duck Creek and Little Johns Creek channels outside of regular channel maintenance and clearing, this 1961 report is still extremely timely.

2.2 Other Reports

A June 1958 report written by the Engineering Office of Clyde Kennedy titled Duck Creek Improvement Project outlines the flooding problems on Duck Creek downstream of the Duck Creek diversion structure. Similar to the 1961 USACE report, this document states that Duck Creek shall be subject to frequent flooding along extensive areas from the diversion structure to Mariposa Road. This report details the hand-calculations made to produce hydrographs and peak flow rates.

The most current hydrologic report is a drainage study prepared by Ensign & Buckley in May 1993. The report, titled North Little Johns Creek Drainage Study, was intended to determine the source of drainage problems and to recommend improvements in and around the North Little Johns Creek and Weber Slough. This report estimates existing channel capacities on North Little Johns Creek, as well as the 100-year flow event discharge. These numbers will be evaluated in regards to the new hydrology study later in this report. The report makes a number of recommendations for lessening the effects of damaging floods, but to date none of the recommendations have be advanced into improvement projects.

Other recent reports include The Mariposa Lakes Specific Plan. The Specific Plan presents parcel maps for the development area, Land Use plans for the development, and summarizes important land use statistics for the future development. Finally, Kleinfelder's Preliminary Geotechnical Report was referenced for information on soils and geology in the Mariposa Lakes development area (Kleinfelder, 2005).

3 Watershed Description and Characteristics

3.1 Physiography/Topology

The Duck Creek and North Little Johns Creek watersheds are adjacent watersheds that drain a total of 266 square miles above Highway 99. Both watersheds have headwaters in the Sierra Nevada Mountain foothills and drain west where they drain low-gradient areas typical of the Central Valley. Both creeks drain into Walker Slough, the San Joaquin River, and finally the San Joaquin Delta.

3.1.1 Duck Creek

The Duck Creek watershed drains a total of 47.32 square miles above of Highway 99 and 36.39 square miles above the Mariposa Lakes project boundary. Exhibit 1 is a vicinity map showing major watershed features. The peak elevation in the Duck Creek

watershed is 466 feet above sea level. Most of the watershed is Central Valley farmland, while the upper portions are mixed oak woodland.

3.1.2 North Little Johns Creek

The North Little Johns Creek watershed drains a total of 218.92 square miles above Highway 99, and 216.64 square miles above the Mariposa Lakes project boundary. The North Little Johns Creek watershed is much larger and has higher elevations than the Duck Creek watershed, with peak elevations about 2592 feet above sea level near the town of Copperopolis.

3.1.3 Branch Creek

The Branch Creek drainage area is approximately 4.05 square miles above the project site. The Branch Creek channel begins within the Mariposa Lakes development, and the small drainage area encompasses areas within Mariposa Lakes and a small areas adjacent to the project to the east.

3.2 Hydrometeorological Characteristics

3.2.1 Historical Rain Gage Data

Though design storms are utilized in hydrologic modeling, it is always valuable to collect historical rainfall data to use as a comparison and verification of design storm data. For this analysis, data from three separate rain gages were collected. All rain data comes from the California Data Exchange Center (CDEC). CDEC collects and houses USGS rainfall and stream gage data for the entire State of California.

Exhibit 8 shows the location of the three rainfall gages. The Farmington Dam gage (CDEC station FRM) is located on the north side of the reservoir spillway and has collected incremental data since August of 1988. The Sanguinetti Ranch rain gage (CDEC station SNR) is located on the valley floor just north of the Duck Creek watershed and has been active since February of 1989. Lastly, the Flower Mountain rain gage (CDEC station FLW) is located in the headwaters of the Little Johns Creek watershed at elevation 1480 ft and has been active since February of 1989. Table 1 lists important data associated with each gage.

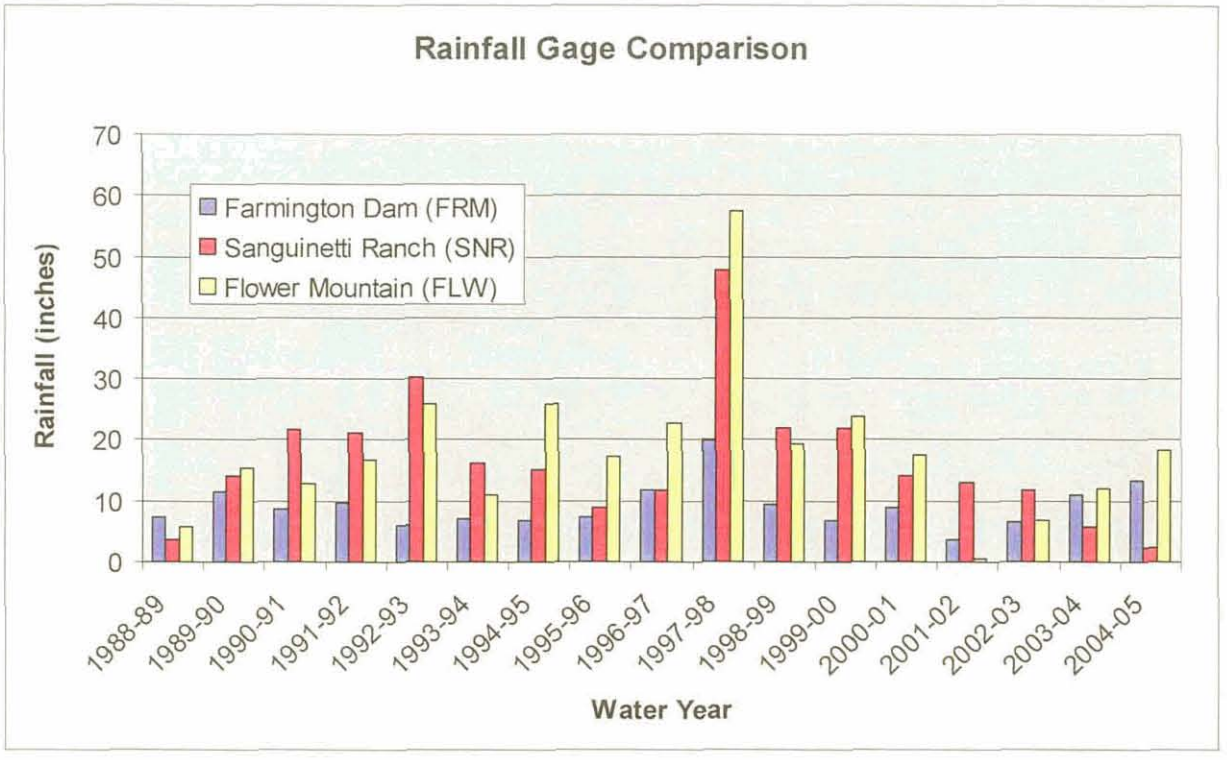
Table 1- Rain gages in the Duck Creek/Little John Creek area.

Station	Name	Lat.	Long	Elev. (ft.)	Yearly Average (in.)	Period of Coverage
FRM	Farmington Dam	37.915° N	120.935° W	180	9.25	8/7/88-present
SNR	Sanguinetti Ranch	37.993° N	120.981° W	238	17.39	1/31/89-present
FLW	Flower Mountain	37.920° N	120.677° W	1480	18.99	2/6/89-present

There are significant differences in the datasets from the three gages listed in Table 1. As seen in Figure 1, yearly totals vary considerably between the three gages. Note that the 1988-89 water year is incomplete for all three gages.

Figure 1 illustrates important issues regarding the variability of rain gage data. First of all, collecting rainfall data accurately and measuring rainfall volumes or intensities is extremely difficult. Most rain gages operate by using a tipping bucket. After a small amount of water, typically 0.06 inches of rainfall, collects in the tipping bucket, the bucket will spill its contents and return to vertical until another unit of rain is collected. Small variations in the actual amount collected can vary before the bucket actually tips. These small variations, multiplied out over the course of a rain event or an entire water year, can add up to significant amounts of water. Proper calibration of rainfall gages is both difficult yet extremely important.

Figure 1 - Annual rainfall data for three nearby rain gages.



Two other factors affecting the variability of rainfall totals are the type of storm systems (e.g., convective, cyclonic) and the elevation of the gage. Convective storm systems are typically very intense but localized in area. A convective storm can release a deluge of precipitation in one area while leaving nearby areas dry.

Cyclonic storm events tend to affect larger areas. As cyclonic Pacific storm systems move east against the mountains, they rise in elevation. As the rising air masses cool, they have less ability to hold water vapor. High elevation areas typically receive much more rainfall than low-elevation areas because of this orographic rainfall effect. Nowhere are these orographic rainfall patterns more pronounced than along the west slope of the Sierra Nevada Mountains.

The Flower Mountain gage has an average of 18.99 inches annually, the largest annual average. This is to be expected, considering the Flower Mountain's elevation. What is surprising is the discrepancy between the Farmington Dam gage and the Sanguinetti Ranch gage. Similar in elevation and in position on the floor of the San Joaquin Valley,

it would be expected that the gage results would be similar. However, nearly every year the Farmington Dam records significantly less rainfall than Sanguinetti Ranch. It is not understood what causes these discrepancies, either a hydrometeorologic occurrence or some type of gage error.

Some of the data in Figure 1 are questionable. For example, it is difficult to image that the Sanguinetti gage received only 2.4 inches of rainfall in the relatively wet winter of 2004-05. Also curious is the 0.5 inches of rain that fell in the winter of 2001-02 at the Flower Mountain gage. Again, it is not understood what caused these abnormally low yearly totals.

3.2.2 Historical Stage Gage Data

Three stage records were found in the Duck Creek and North Little Johns Creek watersheds. Water surface elevation gage records exist for the Farmington Reservoir, and depth gages exist on Duck Creek at the Duck Creek Diversion and on Little Johns Creek upstream of the Little Johns Creek Diversion.

Figure 2 shows a plot of water surface elevations at the Farmington Reservoir, including the spillway elevation. According to the CDEC gage data, only once has the water surface exceeded the spillway elevation at 156.5 ft. The gage reports water surface elevations to CDEC on a daily basis, so only one reading each day was recorded. Peak water surfaces on 2/7/98 and 2/8/98 reached 156.74 and 156.77 feet, respectively. These are the largest values recorded, and the only two values that were recorded above the reservoir spillway elevation. The winter of 1997-98 was an El Niño event that included especially high rainfall totals, as can be seen in the rainfall records in Figure 1. The largest annual rainfall totals for all three rain gages were recorded in 1997-98.

The two stage gages on Duck and Little Johns Creeks were both available from San Joaquin County's ALERT system. The ALERT system is county-wide flood warning system that collects data from a number of rainfall and stream gages. Data is collected telemetrically from remote gage sites and is reported to one master database. Individual rain and stream gage data can be accessed from the County's website (http://san-joaquin.diad.net/portal.php).

Figure 3 shows a stage record at the Duck Creek Diversion site. This gage site reports water depth above some unknown datum. Similarly, Figure 3 shows a depth record on Little Johns Creek, upstream from the diversion structure on Little Johns Creek. This gage also records water depth above an unknown datum and is not rated for discharge.

Both water depth records span from 1/1/93 to present, though there is a large gap in the data from 4/30/98 to 11/26/02, when no data exists for either gage site. The ALERT reporting network must not have been functioning properly.

Figure 2 – Historical water levels in the Farmington Reservoir.

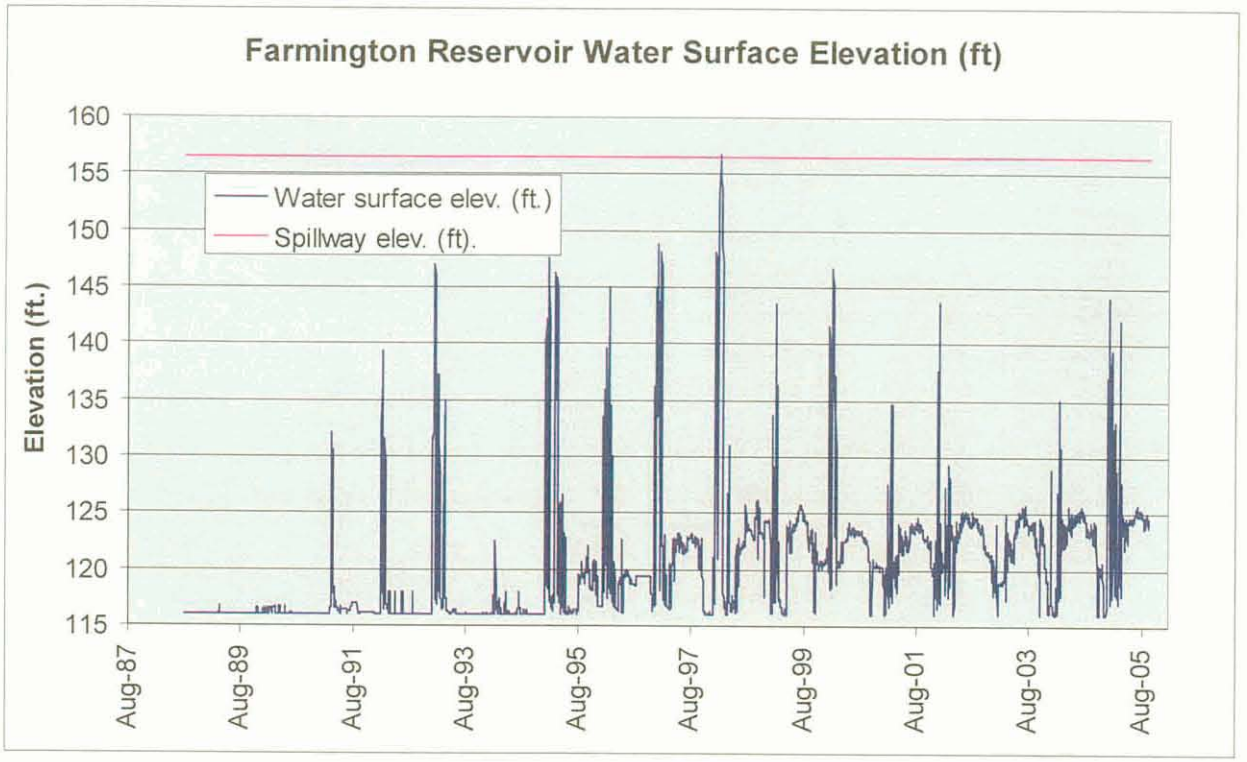


Figure 3 - Water depth gage on Duck Creek at diversion structure.

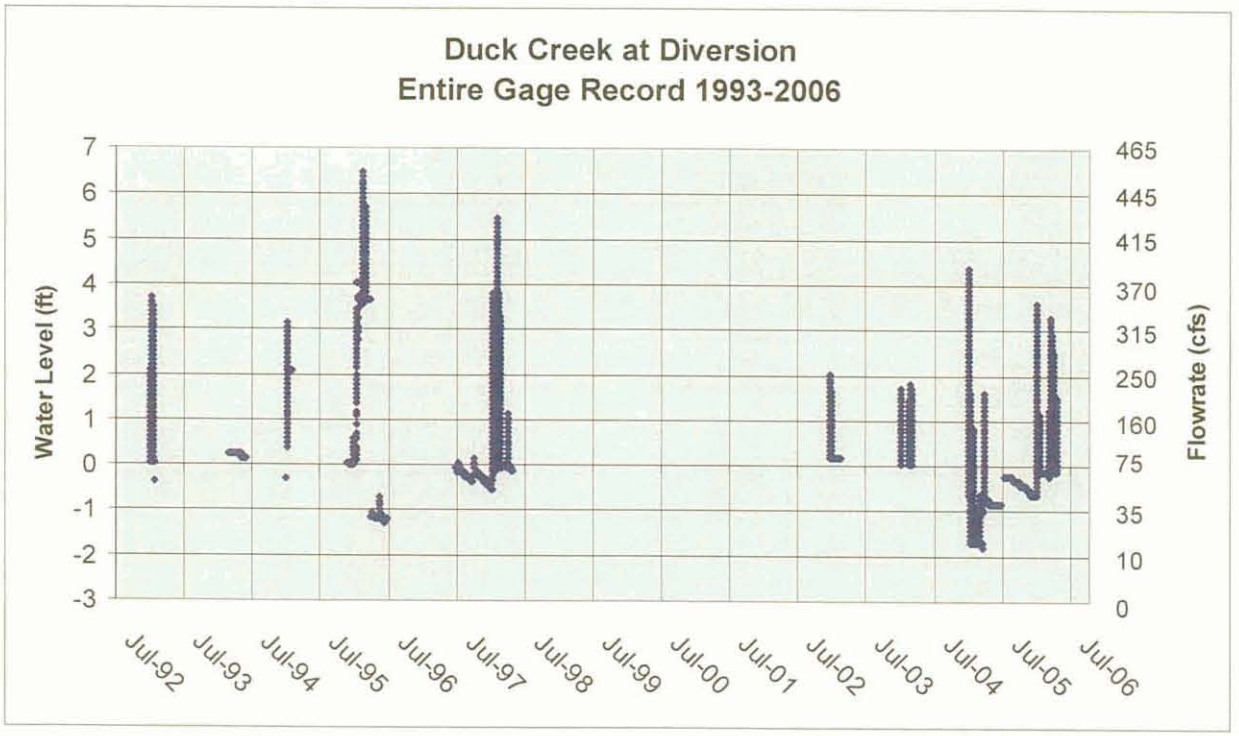
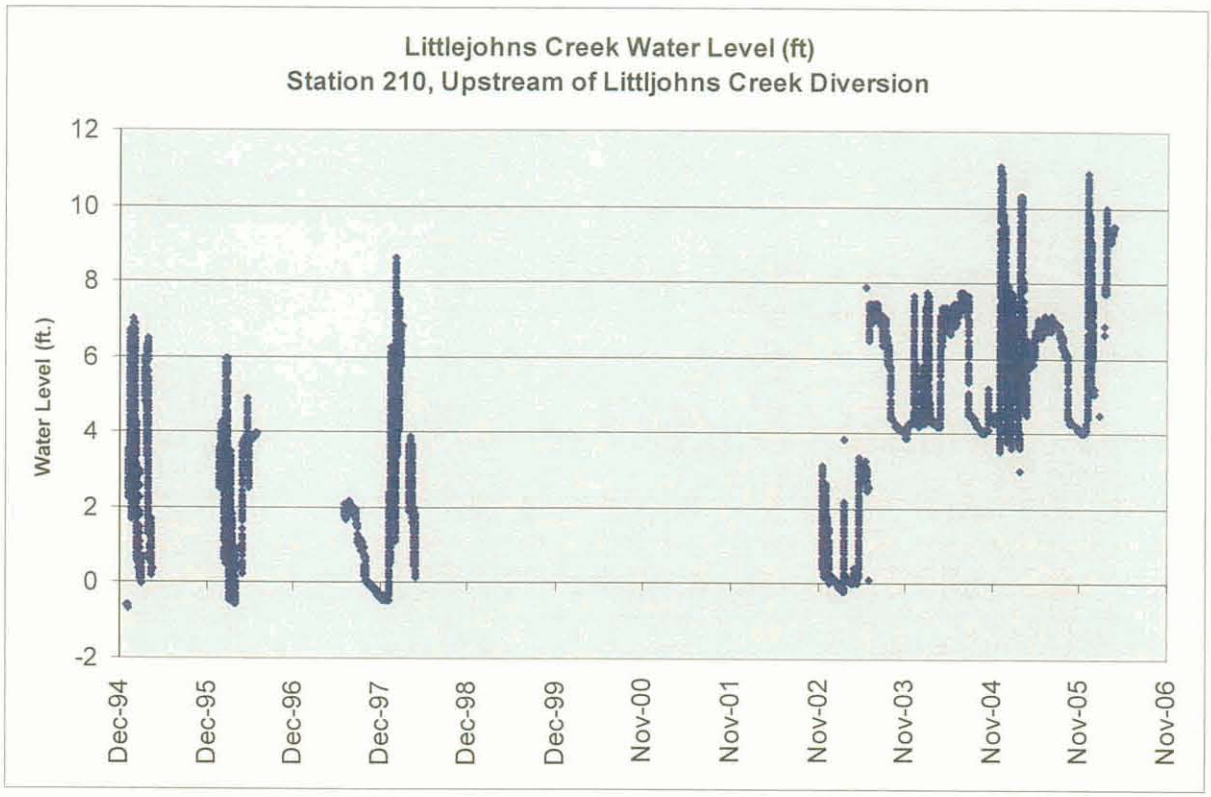


Figure 4 - Water depth gage on Little Johns Creek above Little Johns Diversion.



3.3 Geology/Soils

In January 2005, Kleinfelder, Inc., produced a preliminary geotechnical report in which they identified many of the predominant soil types in the lower portions of the watershed. Over 20 borings were drilled as part of this study in the Mariposa Lakes project site. The findings were consistent with previous investigations performed by Kleinfelder, Inc. in the Stockton area, summarized here:

> *"The subsurface soil encountered consisted predominately of moderately- to highly-plastic silty clay to depths ranging from about 2 to 9 ½ feet below site grade (bsg), followed by low-plastic sandy and clayey silt with highly interbedded and discontinuous strata of clay, silty sand, clayey sand, and 'clean' sand."* (Kleinfelder, 2005)

This study did not cover the area outside of the proposed Mariposa Lakes project. However, hydrologic soil type layers are available for parts of the surrounding watershed. These layers have been downloaded and included in the model for use in computing loss rates.

The Mariposa Lakes project lies within the Great Valley geomorphic province of California. The Great Valley is approximately 400 miles long and 50 miles wide, running north/south along the West slope of the Sierra Nevada mountain range. It is a synclinal trough formed by the tilting of the Sierran block, with the west side dropping to form the valley and the eastern side uplifting to form the Sierra Nevada Mountains. The low portions of the watershed have in-filled with a thick sequence of unconsolidated to semi-consolidated alluvial, basin, and delta plain sediments deposited by rivers of the Sierra Nevada

Mountains. The bedrock is comprised of metamorphosed marine sediments similar to those found in the Coast Ranges and the Western Sierra Nevada (Kleinfelder, 2005).

Understanding the geology and soils of the Duck Creek and North Little Johns Creek watersheds is important to evaluate the response these watersheds have to large rainfall events. The soil layers greatly affect rates of infiltration and percolation of water into the soils, thereby affecting the amount and timing of runoff from a particular drainage basin. There are various soil identification schemes used by various counties and governmental organizations. Frequently, as in the case of San Joaquin County, soils are organized by their hydrologic properties, their ability to transmit water to subsurface soil layers, their total storage capacity, and rates at which the soils transmit water. The following summarizes the four Hydrologic Soil Groups:

> **Group A**: Low runoff potential. Soils having high infiltration rates, even when thoroughly wetted, consisting of well-drained sands or gravels.
> **Group B**: Moderate infiltration rates. Soils consisting of moderately deep to deep, moderately well to well-drained sandy-loam soils with moderately fine to moderately course textures.
> **Group C**: Slow infiltration rates. Soils consisting primarily of silty-loam soils with a layer that impedes downward movement of water. Soils that have a moderately-fine to fine texture.
> **Group D**: High runoff potential. Soils having very slow infiltration rates consisting primarily of clay soils with high swelling potentials. Soils with a permanent high water table, soils with claypan or clay at or near the surface, and shallow soils over nearly impervious materials.

A predominant hydrologic soil group is determined for each sub-basin within the WMS model. Therefore, an area-weighting technique is required for each sub-basin.

The GIS hydrologic soil files used to import into the WMS watershed model are produced by the National Resource Conservation Service (NRCS). The NRCS conducted the original soil surveys and has been working to convert these paper maps to digital format. Currently, almost the entire State of California has been completed. Figure 5 is a California state map that shows the availability of NRCS soils maps for various areas. Note that Zone 630, Calaveras Area, which corresponds with the upstream area of the Duck Creek and North Little Johns watersheds, is classified "Non Project," meaning the data is not available.

Therefore, the areas of the watersheds that were not available digitally were given a hydrologic soil Group D. The process of measuring the area of each soil type in each sub-basin for the entire portions of the watershed in Calaveras and Stanislaus County and area-weighting each sub-basin, by hand, is a cost-restrictive task. Instead, the Group D soil type represents a conservative value and will produce the maximum potential runoff for a given storm event. The GIS soil layer used in WMS can be seen in Exhibit 4.

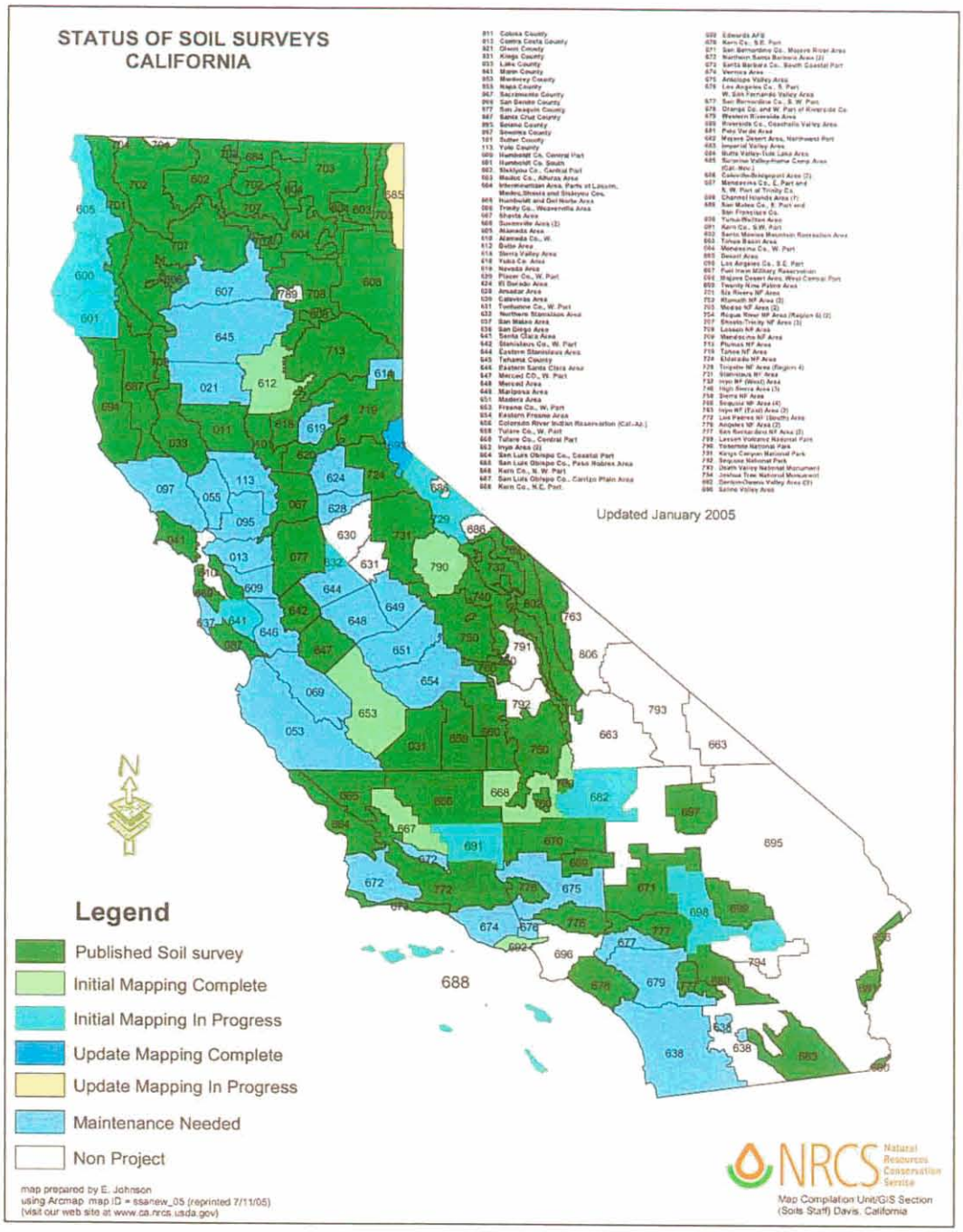
3.4 Land Use/Vegetation

Most of the downstream portions of the watersheds have been historically used for agricultural purposes, namely cropland, orchards, and pasture. The foothill areas in the mid-elevation portions of the watersheds are herbaceous rangelands, dominated by live

oak trees and native grasses. The high-elevation portions of North Little Johns Creek consist of mixed rangelands and evergreen forests.

Current Land Use and Land Cover (LULC) GIS layers were obtained from the USGS as part of its national mapping program. LULC layers are imported into the WMS hydrologic modeling model, where together with hydrologic soil files, can be used to create curve numbers to calculate runoff. The LULC layer for the Duck Creek and North Little Johns Creek watersheds can be seen in Exhibit 5.

Figure 5- NRCS Status of Soil Surveys, California. (Reproduced from www.ca.nrcs.usda.gov)



3.5 Structures Affecting Runoff

There are several structures that affect the timing, peak flows, and volume of runoff in the Duck Creek and North Little Johns Creek basins. Three primary structures, two diversion structures and one flood control dam, have been included in the model.

3.5.1 Farmington Flood Control Reservoir

The Maintenance Manual for the Farmington Dam and Reservoir (USACE, 1952) describes the location, function, and maintenance of the dam and reservoir, located approximately 20 miles east of Stockton. The dam impedes flow on both Rock Creek and Littlejohn Creek. The dam itself is about 7800 feet long with a crest width of 20 feet and a maximum height of 58 feet above the existing stream channel.

The Farmington Reservoir was designed to protect downstream areas from the largest flow on record from the time period of 1907-1950, know as the project design storm. The project design flood has a peak flow of 16,000 cfs and a volume of 40,000 acre-feet. However, USACE created the dam to have 52,000 acre-feet of storage at all times. The reservoir controls the floodwater runoff from a land area of approximately 202 square miles.

There are two low-flow outlets from the reservoir, both controlled by slide gates. The outlets are 6' x 9' twin-barreled reinforced concrete conduits located in the Rock Creek channel near the right abutment of the dam. Army Corps personnel manage the conduit gates to control flows downstream. The dam will be a focus of hydrologic simulations later in this report.

3.5.2 Salt Springs Valley Reservoir

The Salt Springs Valley Reservoir is a small reservoir used primarily for recreation. It blocks flow on Rock Creek, one of the major tributaries that confluences with Littlejohn Creek above the Farmington Reservoir. The location of Salt Springs Valley Reservoir can be seen in Exhibit 6. A small concrete dam structure creates the reservoir, as seen in Figure 3. Water simply spills over the spillway when the reservoir is full. In 2005, the reservoir was full from mid-December through mid-April (personal communication, local resident). When the reservoir is full, inflow roughly equals outflow, so the hydraulic effects of the reservoir and dam are negligible. Therefore, the Salt Spring Valley Reservoir was left out of the WMS model.

3.5.3 Duck Creek Diversion

The Duck Creek Diversion is a man-made diversion channel located approximately 1 mile east of the City of Farmington (see Exhibit 7). Water from Duck Creek is diverted into an excavated earthen channel for approximately 5000 feet until it joins Little Johns Creek. An earthen berm blocks water from continuing into Duck Creek. Two pipes form the culvert through the berm, a 72" diameter gated culvert and a 60" diameter ungated culvert allow the passage of flows down Duck Creek. The berm and culverts can be seen in Figure 3.

When water levels in Duck Creek reach an elevation of 106 feet, water spills over a 73-foot concrete weir into the diversion channel and is conveyed south to Little Johns

Creek. Figure 4 is an image of the weir where water spills into the Duck Creek diversion channel. Rating curves for the culverts and the diversion channel have been calculated and are included in the model.

Figure 6- Salt Springs Valley Reservoir dam and spillway, June 2005.

Figure 7- Duck Creek Diversion structure. Water going through these two culverts remains in Duck Creek through the Mariposa Lakes project site. 60" ungated culvert on left, 72 gated culvert on right.

3.5.4 Little Johns Creek Diversion

Little Johns Creek is the primary drainage that creates the Farmington Reservoir. From Farmington Reservoir, water is released back into Little Johns Creek. About a mile upstream of the town of Farmington, the Duck Creek Diversion channel joins Little Johns Creek. Downstream, near Stanley Road, Little Johns Creek bifurcates into two channels, North Little Johns Creek and South Little Johns Creek. Near this junction is the Little Johns Creek Diversion structure that meters flows down North and South Little Johns Creeks.

North Little Johns Creek is the channel that flows through the Mariposa Lakes project area downstream near Stockton. The Little Johns Diversion structure is located on the North Branch of Little Johns Creek, where an earthen berm blocks flows down North Little Johns Creek. Four 42" gated pipes convey water through the berm into North Little Johns Creek, while the majority of water flows freely down South Little Johns Creek. Figure 9 and Figure 10 are images of the diversion structure on North Little Johns Creek, while Figure 11 shows South Little Johns Creek. As can be seen, South Little Johns Creek has a much larger capacity for conveying flood flows than North Little Johns Creek.

North Little Johns Creek, both upstream and downstream of the Mariposa Lakes project area, is an impaired channel choked with vegetation and debris. Because it is not regularly maintained, its capacity to convey floodwaters is limited. Figure 12 shows how choked with debris the channel is at Kaiser Road, and how a lack of shade along the creek has contributed to extensive vegetation growth in the channel.

Figure 8 - Weir at Duck Creek Diversion. Water flowing over weir is conveyed down the diversion channel into Little Johns Creek.

Figure 9 - Downstream side of Little Johns Creek Diversion structure.

Figure 10 - Upstream side of Little Johns Creek Diversion Structure

Figure 11 - South Little Johns Creek, looking downstream near diversion structure.

Figure 12 - North Little Johns Creek, looking upstream from Kaiser Road.

4 Hydrologic Analysis Tools

4.1 WMS

Watershed Modeling System (WMS) is a computer program that has a number of hydrologic models imbedded to choose from. Housed within the WMS framework are applications that run a number of different hydrologic programs, including the rational method, HEC-1, HEC-HMS, TR-20, TR-50, or NFF. The benefit of using WMS over the previously mentioned individual software packages is that the user can organize and display data layers such as precipitation, soils, and land use as GIS shapefiles. These GIS layers can be queried to automatically compute important variables such as area-weighted values of precipitation, losses or curve numbers, which otherwise would be a time-intensive activity. The user loads GIS layers into WMS, organizes the watershed into a network of sub-basins and outlet points, and chooses a hydrology model to compute runoff produced from either historical storm events or hypothetical design storms.

WMS also has the ability to route hydrographs downstream through the drainage network while taking into account the timing issues associated with reservoirs, detention basins, and diversions. Three structures, the Farmington Dam and Reservoir, the Duck Creek Diversion, and the Little Johns Creek Diversion, were all included in the model.

4.2 HEC-1

The Hydraulic Engineering Center's HEC-1 computer application is a widely-used lumped parameter model that simulates the precipitation-runoff process through a network of interconnected sub-basins, streams, reservoirs, and diversions. Each sub-basin is described by a number of physical parameters such as area, rainfall depth, soil type, and land use. After the sub-basins are described in the model, basic routing parameters are described to convey stormwater from one basin to the next. Reservoirs and diversions can easily be added to the drainage network. Model results are produced as both a HEC-1 output file (*.out file) and as a series of storm hydrographs at sub-basin outlet points.

One of the basic assumptions inherent in HEC-1 is that a watershed can be subdivided into a number of sub-basins, each represented by a set of parameters that can be averaged for the entire basin. If average parameters do not represent entire sub-basin, sub-basins need to be further subdivided so that averaged parameters do apply.

A second limitation is that simulations are limited to single storm events due to the fact that the model does not consider soil moisture recovery during dry periods. The results produced by HEC-1 are in the form of peak discharges, runoff volumes, and storm hydrographs. Discharge in cubic feet per second (cfs) is used in result reporting rather than stage. In the future floodplain mapping report, channel cross-sections will be used in HEC-RAS to model fluctuating stages and to map 100-year return interval floodplain boundaries.

4.3 GIS Data

There are numerous advantages to using a GIS-based hydrology program. The most obvious advantage is that basin and reach parameters such as stream length, stream slope, basin slope, basin centroids and areas are often time-consuming to measure and

calculate are calculated automatically using GIS stream layers, basin polygons, and a DEM. GIS also has the ability to take two or three different data layers and use area-weighting techniques to quickly produce basin parameters. For example, a soil layer, a land-use layer, and a drainage layer showing sub-basin boundaries and the stream network, all in the same coordinate system, can be queried to compute runoff coefficients or curve numbers. All geometric properties such as basin area, basin slope, stream slope, stream length, and stream length to centroid, were all calculated using the GIS capabilities of WMS.

5 Hydrologic Modeling Parameters

5.1 Rainfall and Precipitation

Figure B-1 of the San Joaquin County Hydrology Manual is an Isohyetal Rainfall Map of average annual precipitation for San Joaquin County (SJCDPW, 1997). It has been reproduced and included as Appendix A. This isohydetal map only covers San Joaquin County. The Duck Creek and North Little Johns Creek watersheds cover areas in San Joaquin County as well as Stanislaus County and Calaveras County. Therefore, a larger dataset was required for hydrologic analysis.

Two separate USGS rainfall isohyetal maps were located for the entire State of California from the State of California's GIS website (http://gis.ca.gov/index.epl). The following passage was taken from the rainfall data layer metadata:

> *"The 'PRECIPITATION' layer represents lines of equal rainfall (isohyets) based on long-term mean annual precipitation data compiled from USGS, California Department of Water Resources, and California Division of Mines map and information sources. Source maps are based primarily on U.S. Weather Service data for approximately 800 precipitation stations. In the Los Angeles and San Francisco Bay areas the USWS data has been supplemented by county and local agency precipitation data. The data was collected over a sixty year period (1900-1960 and 1961-1990). Minimum mapping unit is 1000+ acres. The isohyetal contour intervals are variable due to the degree of variation of annual precipitation with horizontal distance"* (http://gis.ca.gov/index.epl).

The first map shows mean annual precipitation values using rain gage data from 1900-1960. The second map used data from 1961-1990. Rainfall isohyetal values varied between the two datasets, with higher values on the 1961-1990 map. Because many large storm events and heavy rainfall years happened between 1961-1990, this map was chosen and used in our hydrologic analyses. Exhibit 3 shows the 1961-1990 mean annual rainfall isohyetals with the San Joaquin County isohyetal values superimposed.

There is a considerable difference between mean annual rainfall amounts in the low-elevation portions of the watershed compared the higher elevation values. A clear orographic pattern exists, with higher elevations receiving more than twice as much rainfall annually. Annual average rainfall values vary from 12.5 inches per year near Stockton to 32.5 inches per year in the headwaters.

Converting mean annual precipitation data from Exhibit 3 to 48-hour, 100-year rainfall depths and rainfall distributions was accomplished by using various figures and tables from the Hydrology Manual. The first task was to compute rainfall depths for different durations for each Mean Annual Precipitation (MAP) zone on the 1961-1990 map, 12.5, 17.5, 22.5, 27.5 and 32.5 inches. The Hydrology Manual does not list rainfall depths for MAP zones above 19.

Table B.7 of the Hydrology Manual, titled "100-Year Depth-Duration-Frequency Curve," lists rainfall depths for different duration storm events for each MAP zone (see Table 2). Plotting MAP zones against any duration (5-min, 1-hour, 24-hour, etc.) showed a linear relationship. The linear relationship was extended to compute rainfall depths the larger MAP zones (22.5, 27.5, etc.), values not included in Table B.7. The rainfall depths for different MAP zones used in this study are shown in Table 3.

Table 2- Table B-7 from the San Joaquin Hydrology Manual

MAP	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
9	0.28	0.36	0.43	0.56	0.75	0.98	1.16	1.53	2.02	2.66
10	0.29	0.38	0.45	0.59	0.78	1.04	1.22	1.61	2.12	2.80
11	0.30	0.40	0.47	0.62	0.82	1.09	1.28	1.69	2.23	2.94
12	0.32	0.42	0.50	0.65	0.86	1.14	1.34	1.77	2.34	3.08
13	0.33	0.44	0.52	0.68	0.90	1.19	1.40	1.85	2.44	3.22
14	0.35	0.46	0.54	0.71	0.94	1.24	1.46	1.93	2.55	3.36
15	0.36	0.48	0.56	0.74	0.98	1.30	1.52	2.01	2.66	3.51
16	0.38	0.50	0.59	0.77	1.02	1.35	1.59	2.09	2.76	3.65
17	0.39	0.52	0.61	0.80	1.06	1.40	1.65	2.17	2.87	3.79
18	0.41	0.54	0.63	0.83	1.10	1.45	1.71	2.25	2.98	3.93
19	0.42	0.56	0.65	0.86	1.14	1.50	1.77	2.33	3.08	4.07

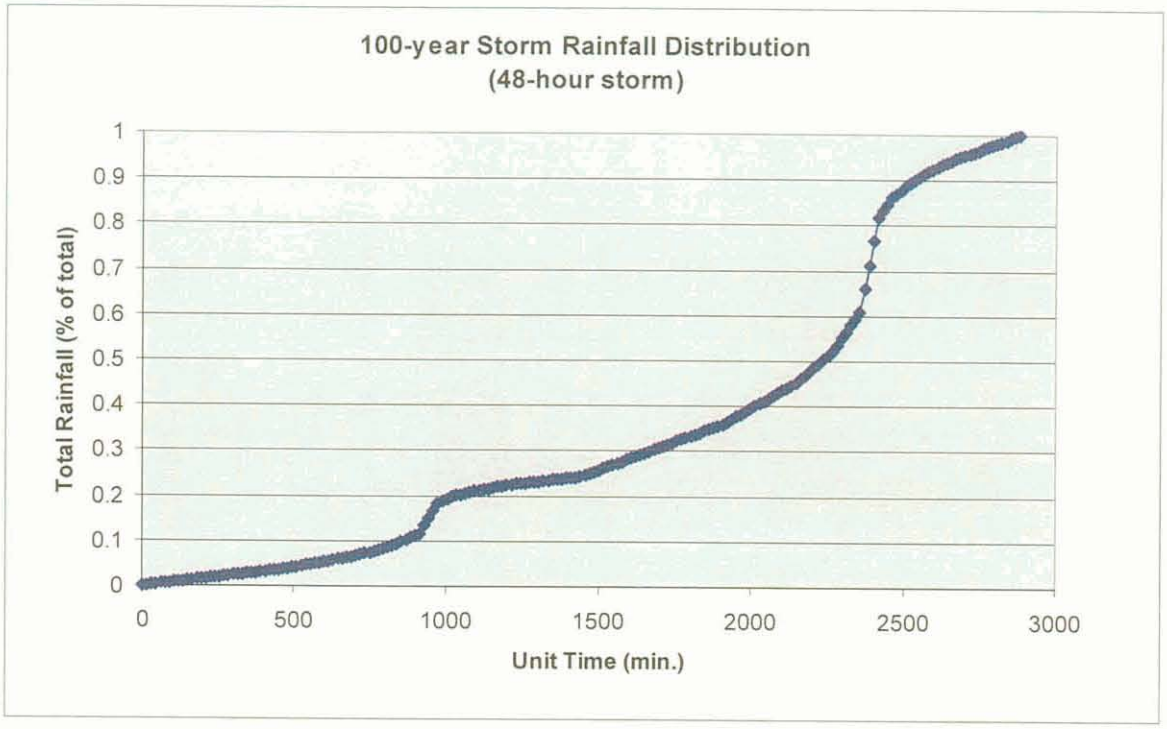
Table 3- Rainfall depths for various MAP zones used in this study

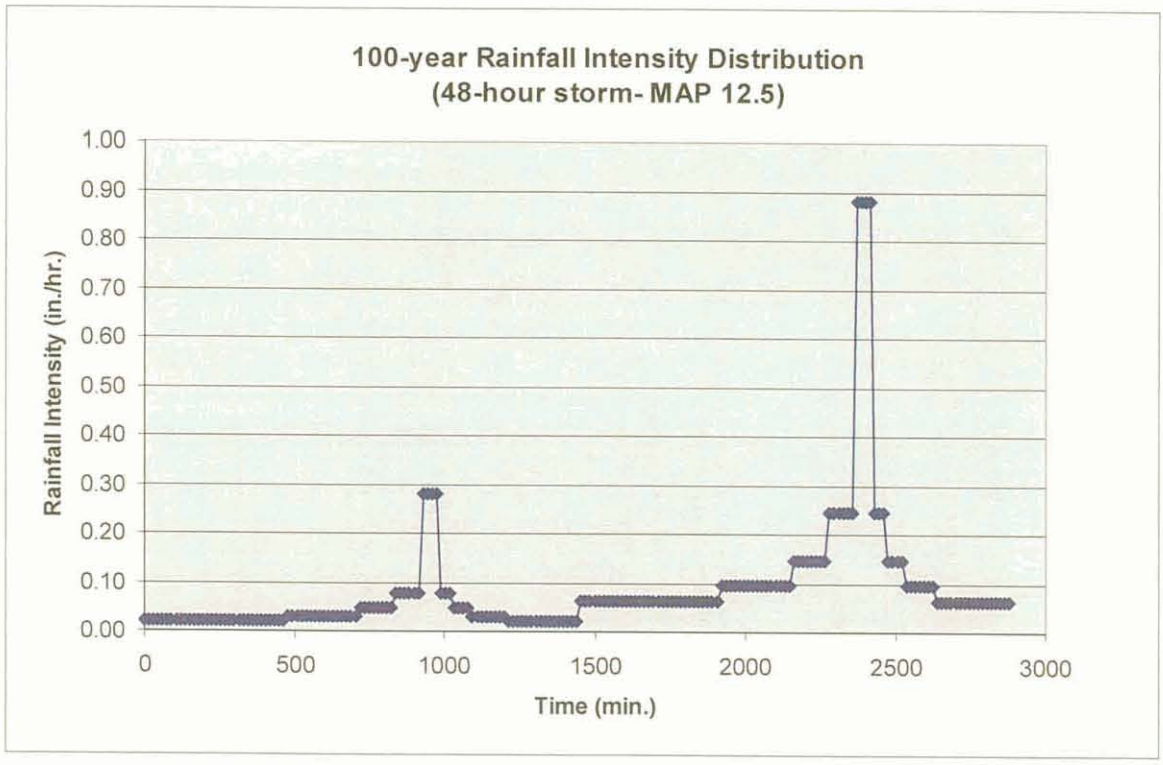
MAP	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
12.5	0.33	0.43	0.51	0.67	0.88	1.17	1.37	1.81	2.39	3.15
17.5	0.40	0.53	0.62	0.82	1.08	1.42	1.68	2.21	2.92	3.86
22.5	0.47	0.63	0.73	0.97	1.28	1.68	1.99	2.61	3.45	4.57
27.5	0.54	0.73	0.84	1.12	1.47	1.94	2.29	3.01	3.99	5.27
32.5	0.62	0.83	0.96	1.27	1.67	2.20	2.60	3.41	4.52	5.98

Figure F-2 of the Hydrology Manual specifies the methods used to create a 48-hour rainfall distribution. A 48-hour distribution is two back-to-back 24-hour events, but the values used for Day 1 are multiplied by a ratio of 0.32. This ratio of 0.32 is listed in Table B-1 of the Hydrology Manual, titled "Multiday Rainfall Mass Ratios for County of San Joaquin." The second day of the storm uses the same rainfall intensities for a 24-hour storm event

specified in Table 3. Table B.7, Table B.1, and Figure F-2 can all be found in Appendix B of this report. Figure 13 is the rainfall intensity curves and rainfall distributions used in HEC-1 for this study.

Figure 13- Rainfall Intensity Curves and Rainfall Distributions used in HEC-1





5.2 Losses

HEC-1 offers various methods to calculate basin losses. Losses include infiltration, evaporation, transpiration, and interception, and they go to describe the portion of rainfall that is converted to surface runoff. The most common loss method is to compute an SCS curve number, CN. The CN is a number between 1 and 100 that describes the percentage of rainfall that is converted to runoff.

WMS generates complete HEC-1 input and output files. The input file uses an LS card to describe sub-basin losses. The LS card uses three separate parameters to describe total basin losses, initial abstraction, curve number, and percent impervious. Initial abstraction was computed using the SCS equations, as follows:

$$Ia = 0.2S \qquad (1)$$

Where S is a measure of the soil capacity, given by:

$$S = (1000/CN) - 10 \qquad (2)$$

Where CN is the basin curve number. A table showing basin values of S and Ia can be found in Appendix C. Typical initial abstraction values ranged from 0.09 to 0.51 inches.

Composite SCS curve numbers can be calculated automatically in WMS. Two GIS layers, hydrologic soils and land use, are required to use WMS's automated process of generating curve numbers. Four curve numbers are associated with each land use type, one for each of the four hydrologic soil types. The NRCS defines and publishes these curve numbers, but a condensed list exists in the Hydrology Manual as Figure C-2 (see Appendix D). The true benefit to using WMS is that it is GIS-based and can automatically calculate areas. For each sub-basin, WMS calculates the area of each land use type within each soil type. WMS then calculates a composite CN for each sub-basin using area-weighting techniques.

The final loss parameter is percent impervious. Because this off-site regional hydrologic investigation is an existing condition model and most of the upstream watershed area is natural or agricultural, all imperviousness values were assigned 0.0 %.

5.3 Unit Hydrographs

Unit hydrographs are used in WMS to transform effective rainfall into runoff. By definition, a unit hydrograph is the hydrograph that results from one inch of excess rainfall falling uniformly over the basin at a uniform rate during a specific period of time.

The first step in developing a unit hydrograph is developing sub-basin lag times. Lag time is defined as the elapsed time, in hours, from the beginning of the unit effective rainfall to the instant that the summation hydrograph for the point of concentration reaches 50 percent of the ultimate discharge (SJCDPW, 1997).

Lag is given by the equation:

$$\text{Lag (hours)} = 24n((L \times Lca)/ S^{0.5})\text{^}m \qquad (3)$$

Where *n* is the visually-estimated basin roughness coefficient

L is watershed length (mi.)
Lca is length to centroid (mi.)
M is a power coeffieicnt 0.380
S is maximum flow path slope (ft./mi.)

A sub-basins were divided into two basin types based on elevation, the Valley Basins and the Foothill Basins. Valley basins are all sub-basins located below the 500-foot elevation contour, and Foothill Basins are those located above the 500-foot contour. Digital elevation models show that there is a significant change in basin slope from the flat valley channels and the steeper foothill channels at the 500-foot contour. Roughness coefficients chosen were 0.045 for Foothill Basins and 0.04 for Valley Basins. Streams in the Foothill Basins are characterized by sharply incised channel bottoms, while streams in the Valley Basins tend to be more urbanized, channelized, and straightened. A majority of the sub-basins were the valley type (below 500-feet). Appendix E shows basin the parameters used to calculate the Unit Hydrographs.

The UI Unit Hydrograph card was used in HEC-1 as input data for each sub-basin. Unit hydrographs were calculated using the Valley and Foothill S-graphs in the Hydrology Manual. Figure E-3b and E-4d from the Hydrology Manual are shown in Appendix F.

6 Hydraulics, Routing and Structures

6.1 Channels

Channel routing in WMS is described for each individual basin outlet point. Routing options are available at each basin outlet point to describe the channel geometry and channel roughness through the next basin downstream. The user is able to choose between various routing methodologies, including Muskingum, Muskingum-Cunge, Kinematic Wave, Straddler/Stagger, Convex and Storage Routing.

The Convex Routing method was chosen for use in this project. Convex Routing (RV card in HEC-1) allows the user to enter a channel geometry and roughness coefficients for the channel and its banks. A series of parameters describe the channel between outlet points, including stream length, stream slope,

Channel slope, calculated in WMS using the digital terrain model, was used to estimate the channel base width. Two base-widths were used, 40-feet and 80-feet. Channels with gradients below 0.2% were given a base width of 80-feet, while channels steeper than 0.2% were given a base width of 40-feet. Most of the steeper channels are located in the foothills portion of the watershed where channel widths are smaller.

Manning's roughness coefficients used were 0.040 and 0.045 for the valley and foothill channel types, respectively. These coefficients are thought to be rough approximations for the channels found in the field. All channel side slopes were set to 4:1.

6.2 Reservoirs

The Farmington Reservoir is a large flood-control reservoir that protects the Mariposa Lakes development area from extensive annual flooding. Much of the Little Johns Creek

watershed is located upstream of the reservoir, and the reservoir detains flood flows on a yearly basis.

The reservoir structure was included in the HEC-1 model at node 90C. The input includes two curves, an elevation-storage curve and an elevation-discharge curve. Preliminary modeling simulations assumed the low-flow outlets from the reservoir are left open. Since then, it was learned through personal communication with San Joaquin County Channel Maintenance personnel that the low-flow gates at the Farmington Reservoir are left closed. All flood flows entering the reservoir is detained for a time period sufficient for the flood wave to pass through the adjacent Duck Creek watershed. Because a majority of the Duck Creek discharge is diverted south into Little Johns Creek, the USACE waits until this wave is well downstream before releasing water from the reservoir. A 1961 USACE report on Duck Creek summarizes this well. "*Excess Duck Creek floodwaters now are diverted into Littlejohn Creek and Farmington Dam releases are coordinated with the diverted Duck Creek flows and local inflows on Littlejohn Creek*" (USACE, 1961). When water is finally released from the reservoir, the USACE releases a constant discharge of approximately 2000 cfs, well within the capacity of downstream channels and structures. Therefore, for modeling purposes, the low-flow gates remain closed throughout the simulation period.

Including the Farmington Reservoir in the model was still important to evaluate the storage capacity of the reservoir in respect to the 100-year runoff volume. Values from this curve were entered into WMS to define the storage capacity of the reservoir.

6.3 Diversions

6.3.1 Duck Creek Diversion

The Duck Creek Diversion is a man-made structure that diverts a majority of flood flow from Duck Creek into Little Johns Creek. An earthen berm blocks flows from Duck Creek, while two culverts (a 60" and a 72") allow the passage of water through the berm and into Duck Creek.

The 60" pipe at the Duck Creek diversion is always open, while the 72" pipe has a slide gate that can be opened or closed. San Joaquin County channel maintenance personnel operate the gate, but the gate on the 72" pipe is typically left open. It was closed once, in 1982, which was the only time it was closed in the last 25 years (personal communication, San Joaquin County Department of Public Works, September, 2005).

The 1961 USACE report summarizes the flood problems on both Duck Creek and Little Johns Creek, as follows

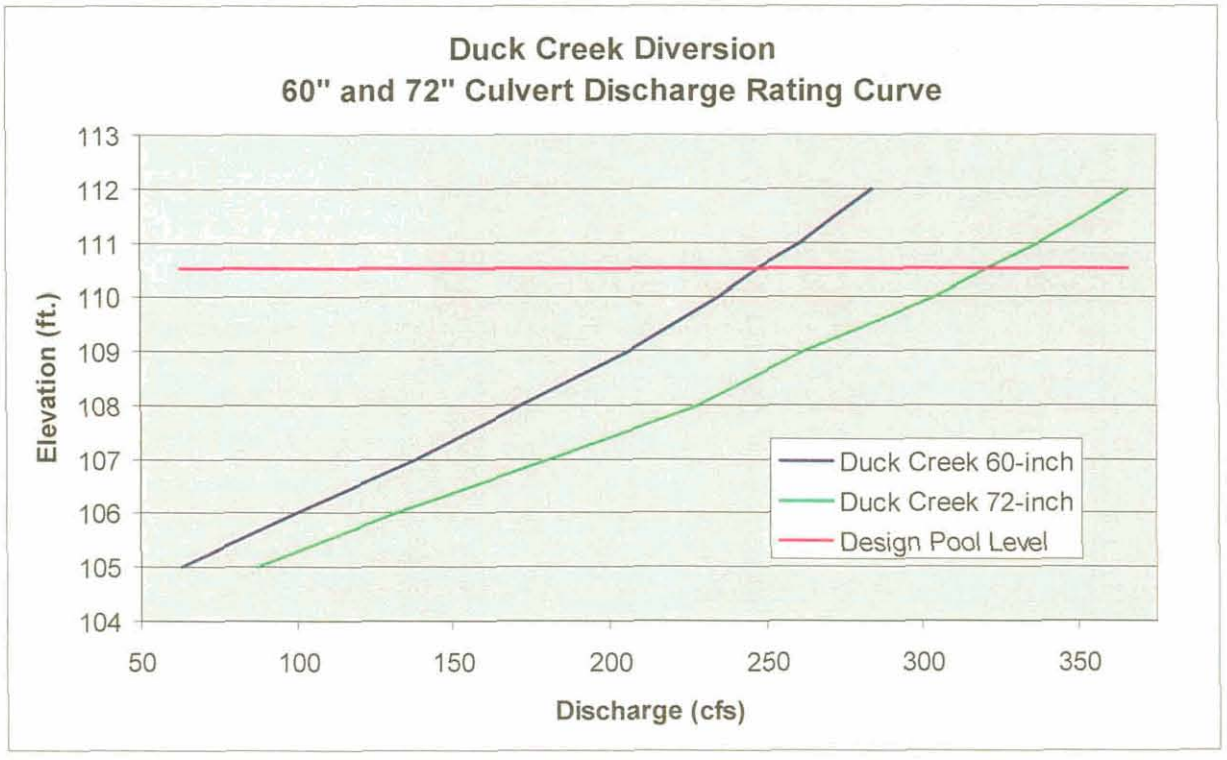
> *"The predominant flood problems in the Littlejohn and Duck Creek areas are caused by Duck Creek water. Farmington Reservoir is adequate for control of Littlejohn Creek water and provides a high degree of protection from floodwaters of the stream... The problem on Duck Creek is much more serious. The one principal channel of Duck Creek is too small to accommodate floods."* (USACE, 1961).

Little has been done since 1961 to alleviate the flood problem on Duck Creek. Downstream communities, farms, and orchards depend on the Duck Creek Diversion to drastically decrease flow rates in Duck Creek. The Army Corps of Engineers specifies the flow split at Duck Creek Diversion in Section 1-04 of the Operation and Maintenance Manual:

> *"The project works are designed to protect lands adjacent to Duck Creek downstream from the diversion works from flows in excess of 500 cubic feet per second. However, until such time as local interests desire to improve the channel of Duck Creek downstream from the diversion works, the flow will be restricted to the presently estimated non-damaging capacity of 250 cubic feet per second."* (USACE, 1952(b))

The same report states that the existing discharge capacity of Duck Creek downstream of the diversion is approximately 250 cfs (USACE, 1952(b)). This capacity corresponds with the 60" culvert being open, while the 72" gated culvert is kept closed. Figure 14 illustrates the Duck Creek diversion rating curve for both the 60" and 72" culverts. Initial modeling simulations assume the 72" culvert is open. For sensitivity analysis purposes, simulations were also run with the 72" pipe closed.

Figure 14 - Discharge rating curves for Duck Creek diversion culverts (taken from Exhibit F of USACE, 1952).



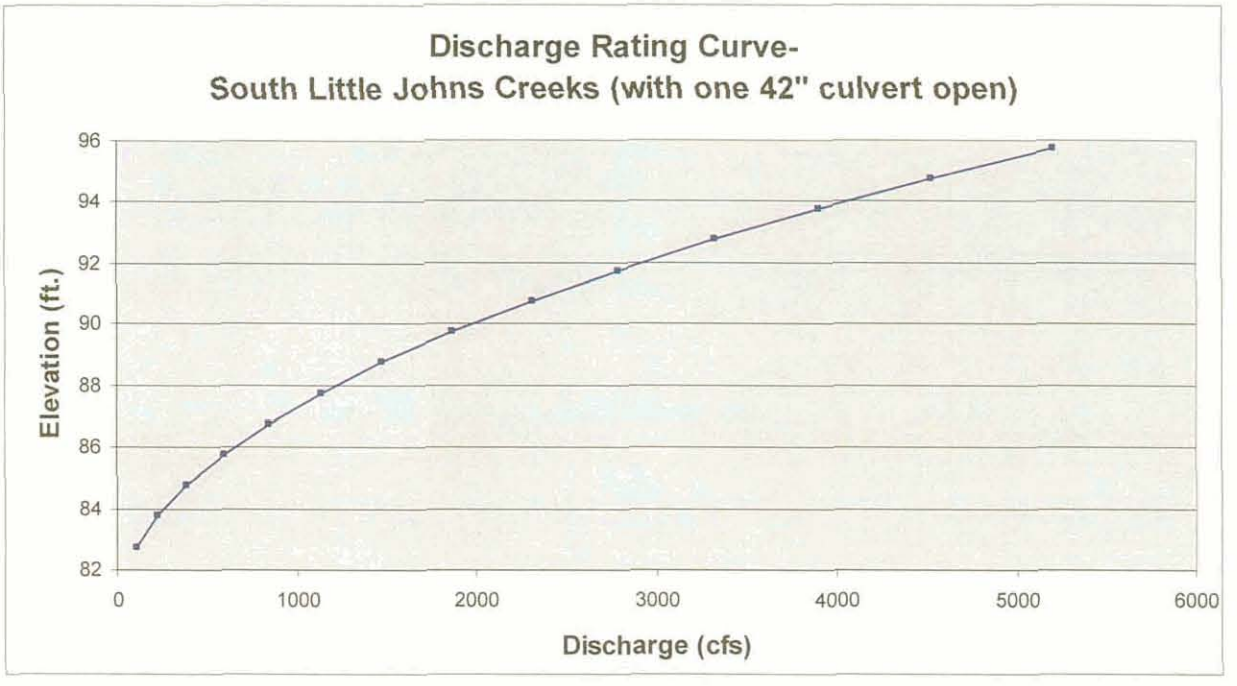
6.3.2 Little Johns Creek Diversion

The Little Johns Creek diversion structure is located near the junction where North Little Johns Creek bifurcates from South Little Johns Creek. An earthen berm blocks

North Little Johns Creek, and a culvert containing four 42" pipes allow the passage of water through the berm. South Little Johns Creek flows unrestricted from the junction. Figures 9 and 10 are images of this structure.

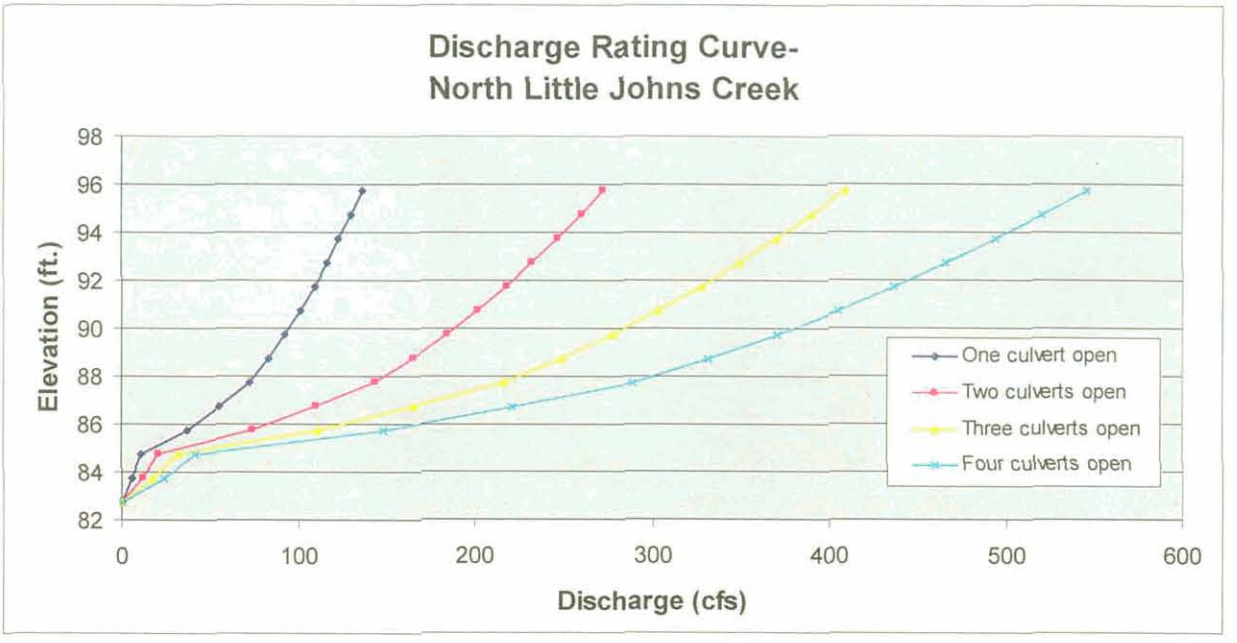
A detailed topographic GIS layer was purchased from Intermap for an entire area upstream of the Mariposa Lakes project encompassing North and South Little Johns Creeks and Duck Creek from Stockton to Farmington. This topographic dataset was flown using Intermap's Interferometric Synthetic Aperture Radar (STAR) technology. The horizontal resolution is 5 meters and the vertical resolution is 0.01 meters. From the Intermap data, channel cross-sections were cut on South Little Johns Creek near the Little Johns Creek diversion. Using this cross-section, Manning's equation was used to create a discharge rating curve, as seen in Figure 15. A discharge rating curve was also established for North Little Johns Creek at the diversion structure. A computer application called PIPE.com was used to calculate flow rates for the set of four pipes at the diversion structure, as seen in Figure 16.

Figure 15 - Discharge rating curve on South Little Johns Creek, assuming one 42" culvert is open at the diversion structure on North Little Johns Creek.



Primary modeling simulations assume that one gate is open at the Littlejohn's Creek diversion structure. All four gates are closed throughout most of the season, blocking all water from flowing down North Little Johns Creek except for the water that leaks through the diversion gates. In the history of the diversion structure, only one gate was opened once in the 1980's (personal communication, SJC Channel Maintenance). The Ensign and Buckley Report (1993) estimates the North Little Johns Creek existing channel capacity to be 50-100 cfs through the Mariposa Lakes project site, from Kaiser Road to the Burlington Northern Santa Fe Rail Road tracks near Mariposa Road. The low channel maintenance is clearly evident in the photograph of North Little Johns Creek in Figure 12.

Figure 16 - Discharge rating curve of diversion structure on North Little Johns Creek



Primary modeling scenarios will focus on the worst probable scenario. Therefore, one gate will be kept open for primary simulations. Sensitivity analyses will examine all gate circumstances, all four gates closed, one gate open, two gates open, and all four gates open, to examine downstream flooding potential.

7 Watershed Modeling Results

7.1 HEC-1 Results

The primary storm event evaluated in this analysis is the 48-hour, 100-year storm event. Rainfall values used in the hydrologic model reflect the 100-year storm, and all modeling scenarios assume the 100-year rainfall event affecting the entire watershed areas.

A set of seven primary scenarios were run in HEC-1, depending primarily on different culvert opening conditions at the various channel structures. Simulation A simulates pre-1950's channel conditions with no control structures whatsoever. Sim1 and Sim2 focus on the two different Duck Creek and Branch Creek conditions, while Sim3, Sim4, Sim5 and Sim6 focus on North Little Johns Creek. Table 4 summarizes these seven modeling scenarios.

Table 4- Summary of different modeling scenarios.

Simulation Name	Creek of study	Duck Diversion Scenario	Little Johns Diversion Scenario	Summary
SimA	Duck, Branch, Little Johns	No structures	No structures	Pre-1950's scenario, no upstream control structures
Sim1	Duck, Branch	72" open	N/A	As-is condition for Duck Creek
Sim2	Duck, Branch	72" closed	N/A	More water diverted to Little Johns Creek
Sim3	Littlejohn	72" open	All closed	Most realistic scenario for Little Johns Creek, as-is situation
Sim4	Littlejohn	72" open	One 42" open	1982 situation
Sim5	Littlejohn	72" closed	All closed	Maximum water diverted to South Little Johns
Sim6	Littlejohn	72" closed	Four 42" open	Worst case scenario for North Little Johns

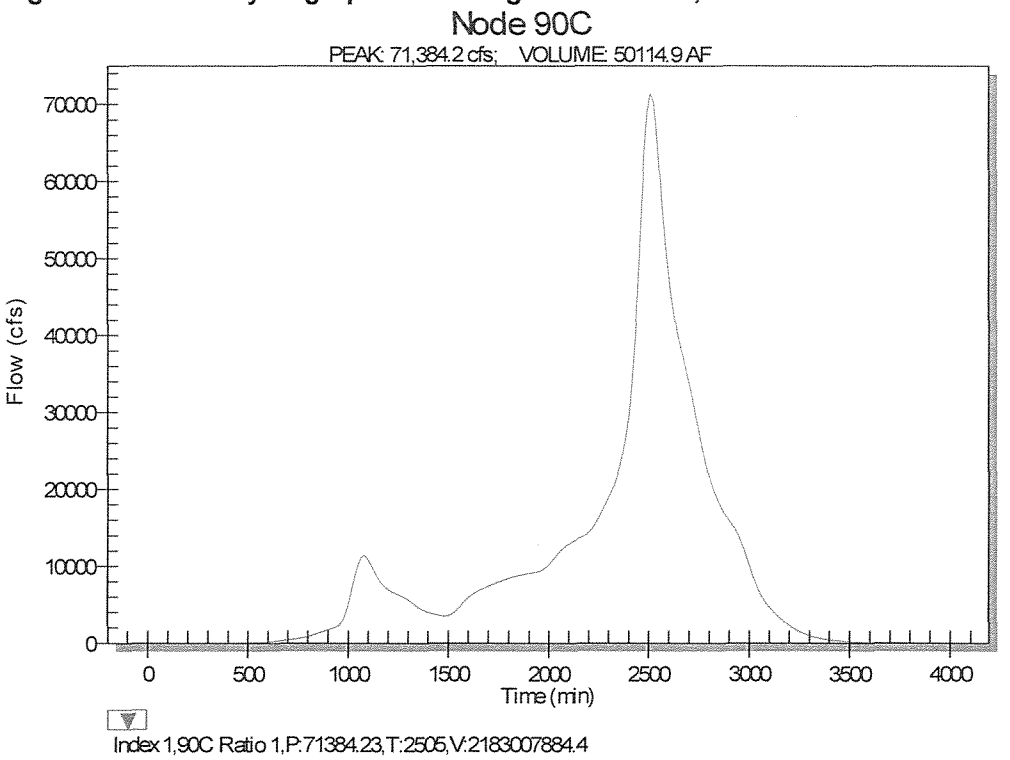
7.1.1 Simulation A, No Upstream Control Structures

Simulation A is a hypothetic simulation that assumes pre-1950 conditions. All man-made flood control structures, including the Farmington Dam and Reservoir, the Duck Creek Diversion structure, and the Little Johns Creek Diversion structure have been removed from the model. Therefore, all the water flowing down Duck Creek remains in Duck Creek. The same is true for Little Johns Creek. This simulation assumes that all the water in Little Johns Creek flows directly into North Little Johns Creek and no water is diverted to South Little Johns Creek. Again, this simulation is purely hypothetical just to evaluate the potential for flooding in a completely natural system devoid of man-made structures.

Figure 17 shows an inflow hydrograph at Farmington Reservoir. Recall that the Farmington Reservoir has a capacity of 52,000 AF of runoff storage. The 100-flood event produces 50,115 AF of runoff, which would be completely detained in the reservoir without spill. This is an important modeling result. The dam and reservoir were built to detain the largest flood event that occurred in the 1907-1950 time period. It appears that the 100-year recurrence interval is slightly smaller than the design storm used in the construction of the reservoir.

Modeling results suggest that the Farmington Dam and Reservoir has sufficient capacity to store the entire volume of the 100-year runoff hydrograph. The Maintenance Manual (USACE, 1952a) details how this water is retained in the reservoir until runoff drains through the Duck Creek watershed, through the Duck Creek Diversion structure, and into Little Johns Creek, before water is slowly released out of the reservoir. Therefore, water behind the dam was completely retained in additional modeling simulations. The primary flooding hazard, as documented in 1961, are flows from the Duck Creek watershed (USACE, 1961).

Figure 17 - Inflow hydrograph at Farmington Reservoir, Node 90C.



Figures 18 and 19 show pre-1950 flood hydrographs at the Mariposa Lakes project boundary on Duck Creek and North Little Johns Creek, respectively. Again, all upstream flood control structures have been removed from the model.

Again, these hydrographs are purely hypothetical and intend only to show the potential for flooding in the area without any control structures. In these hypothetical conditions, North Little Johns Creek watershed would produce a peak 100-year discharge of 80,324 cfs, while Duck Creek would have a peak discharge of 7892 cfs.

Figure 18 - Inflow hydrograph on Duck Creek at the Mariposa Lakes project boundary. This simulation assumes no upstream control structures.

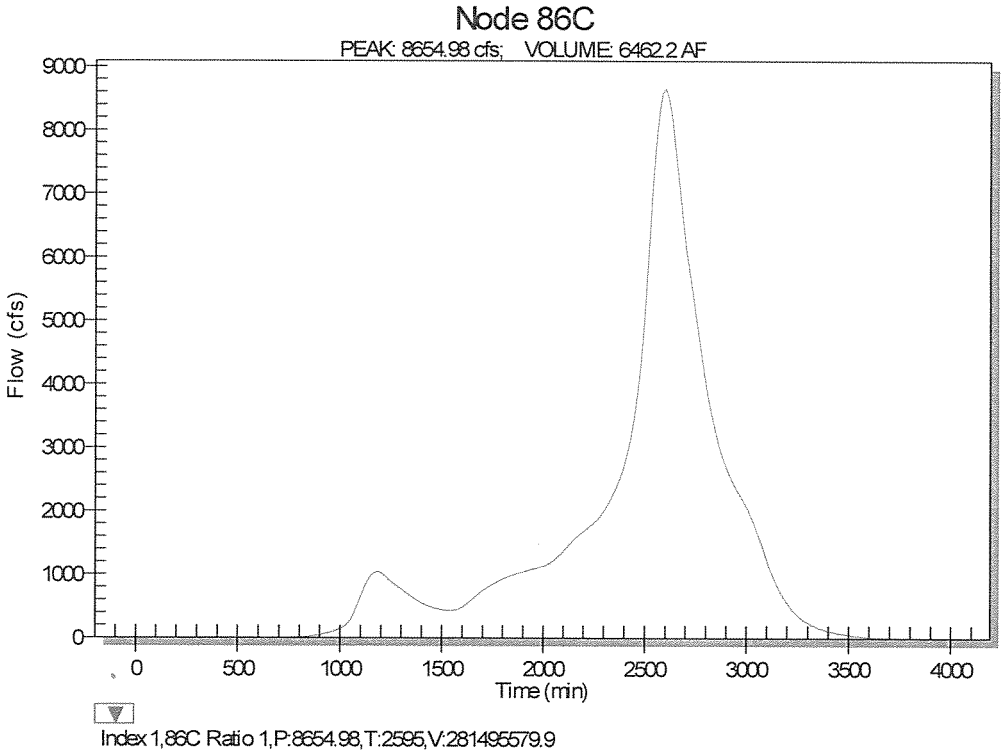
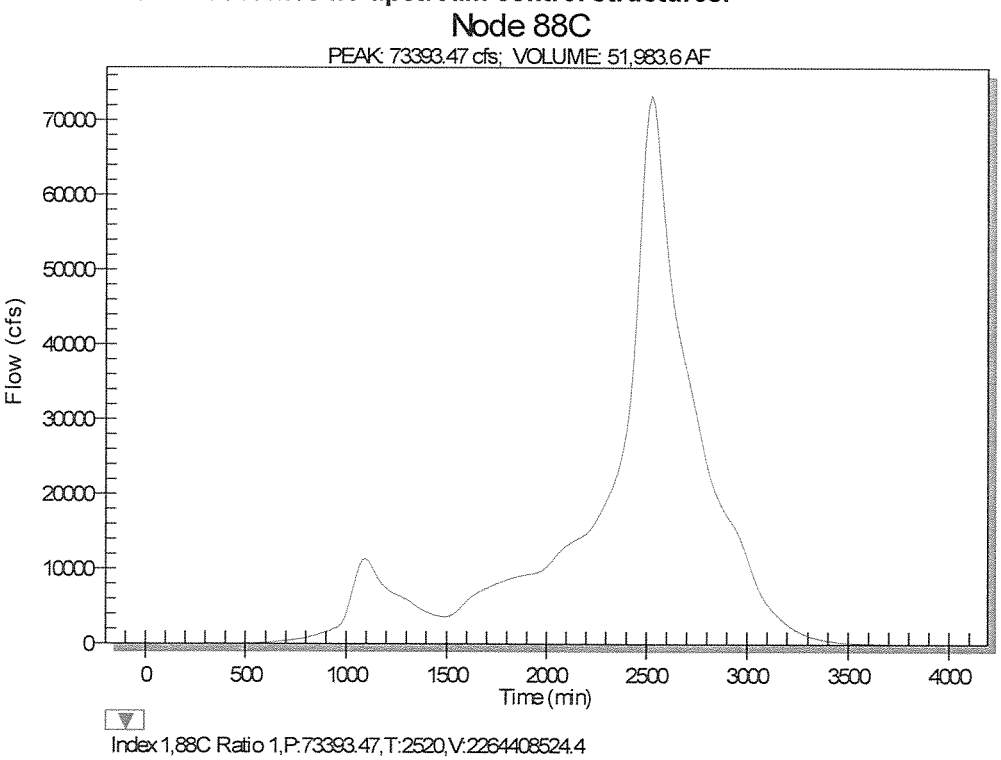


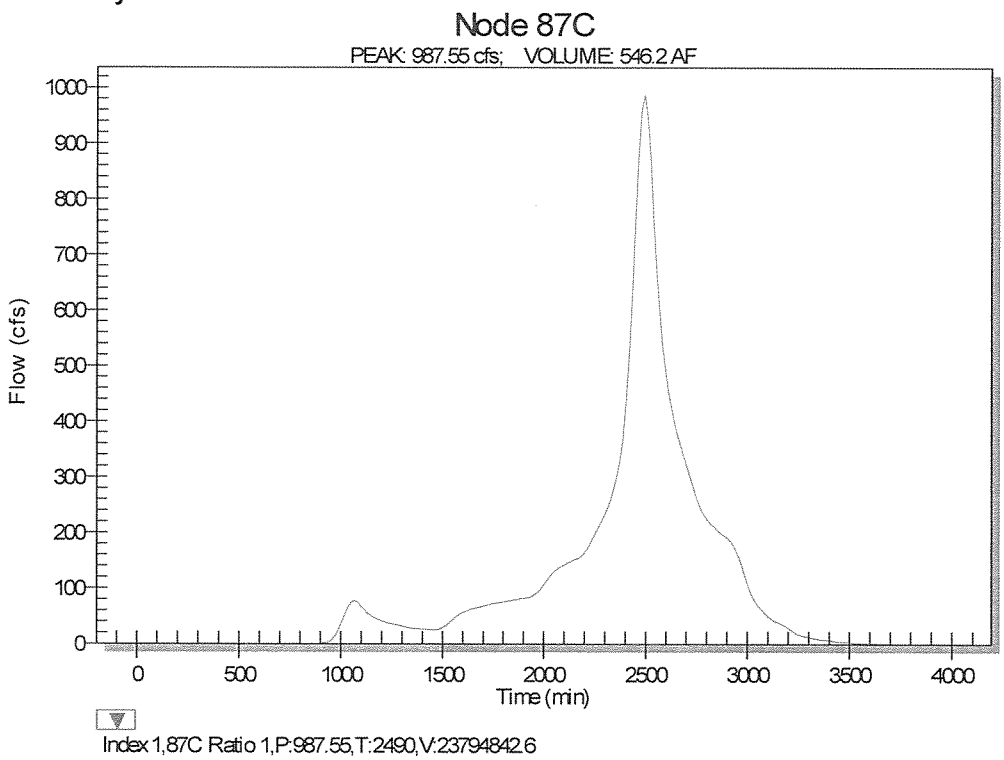
Figure 19 - Inflow hydrograph on North Little Johns Creek at Mariposa Lakes project boundary. This simulation assumes no upstream control structures.



7.1.2 Branch Creek- Simulation 1

Branch Creek drains the small watershed located between the Duck Creek and North Little Johns Creek watersheds just to the east of the Mariposa Lakes project boundary. Because the drainage area of Branch Creek is small, it presents little flooding hazard, even in the 100-year storm event. There are no diversion structures that affect Branch Creek, so there is only one basic modeling scenario. Figure 20 shows a hydrograph on Branch Creek at the Mariposa Lakes project boundary. The 100-year peak flow rate on Branch Creek is 997 cfs. HEC-1 output for Simulation 1 can be found in Appendix G.

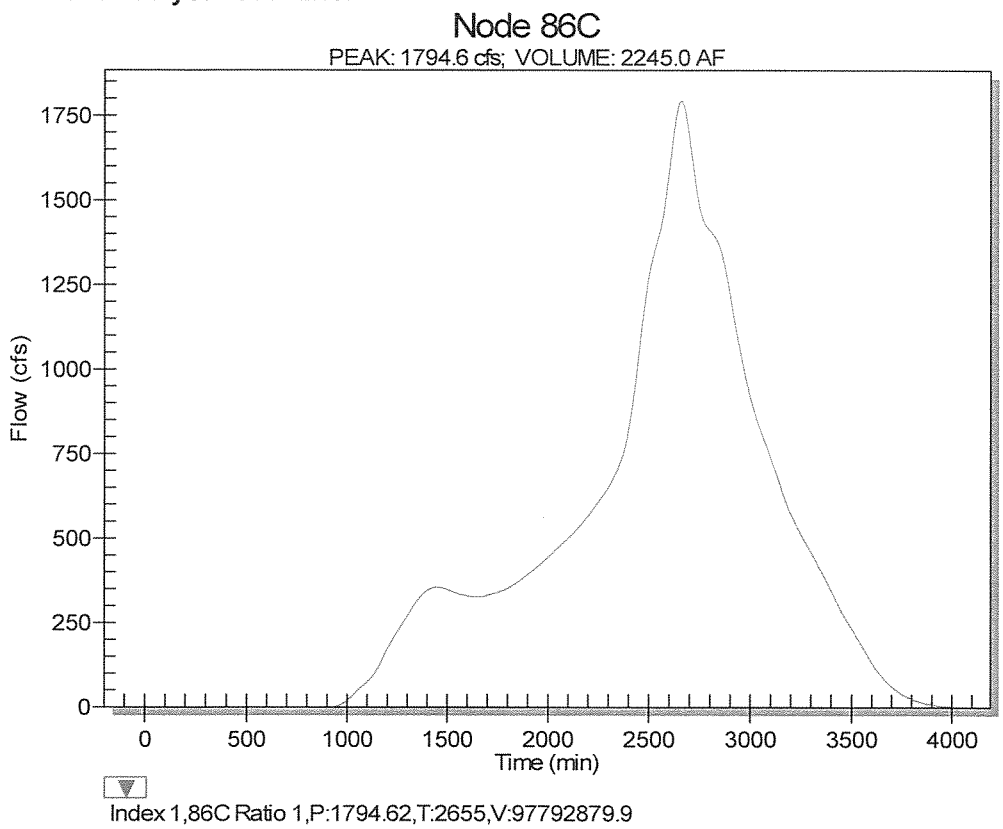
Figure 20 - Simulation 1. Inflow hydrograph on Branch Creek at the Mariposa Lakes project boundary.



7.1.3 Duck Creek- Simulation 1 and 2

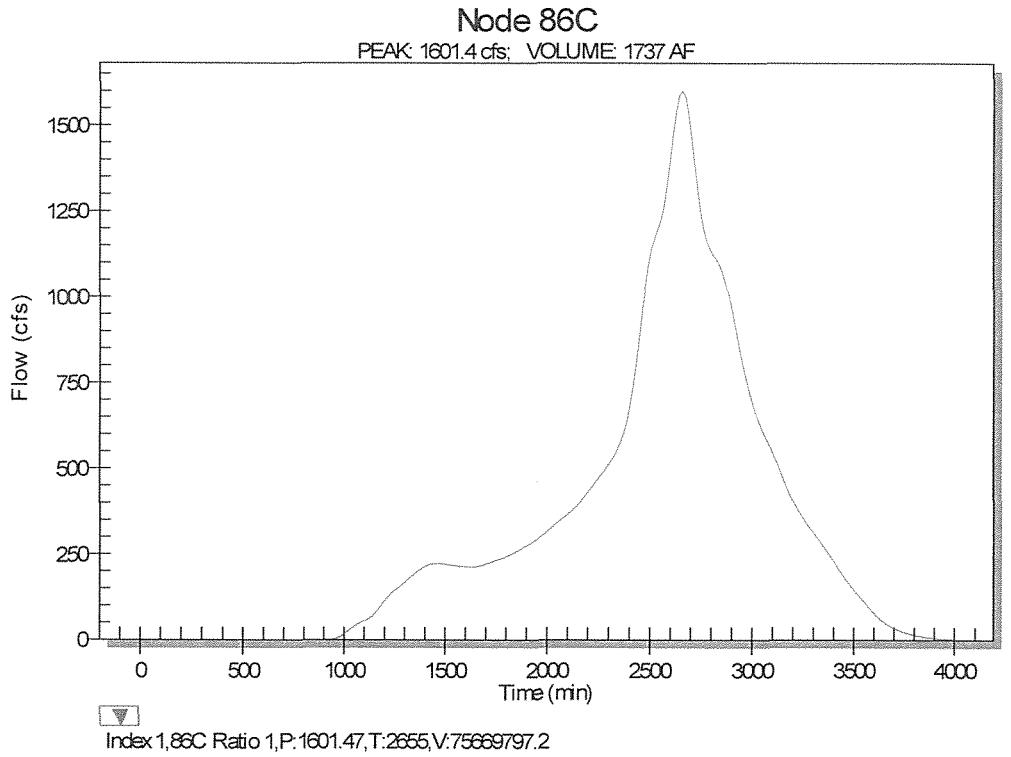
Simulation 1 and 2 focus on flooding from Duck Creek. These two simulations are relatively straight-forward, both include the Duck Creek diversion structure near Farmington. In simulation 1, both the 60" and the 72" culverts are open. This maximizes the discharge flowing down Duck Creek and minimizes flow leaving the Duck Creek system through the diversion channel. Because both pipes are typically open, Simulation 1 is the most accurate reflection of current conditions on Duck Creek. The 72" pipe has only been closed once, in 1982 (personal communication, SJC channel maintenance), in order to limit the downstream flooding on Duck Creek. Peak flow rates in this simulation reach 1795 cfs on Duck Creek at the project boundary. Figure 21 shows an inflow hydrograph on Duck Creek at the Mariposa Lakes project boundary with both pipe gates open.

Figure 21 - Simulation 1. Inflow Hydrograph on Duck Creek at Mariposa Lakes project boundary, assuming both the 60" and 72" culvert gates are open. This simulation represents the most realistic 100-year scenario.



Simulation 2 assumes that the gate on the 72" culvert is closed. Simulation 2 produces peak flow rates of 1601 cfs at the project boundary. Figure 22 shows an inflow hydrograph on Duck Creek at the Mariposa Lakes project boundary site assuming the 72" culvert gate is closed.

Figure 22 - Simulation 2. Inflow hydrograph on Duck Creek at Mariposa Lakes project boundary. Simulation assumes the 72" culvert gate is closed, limiting the discharge in Duck Creek through the project

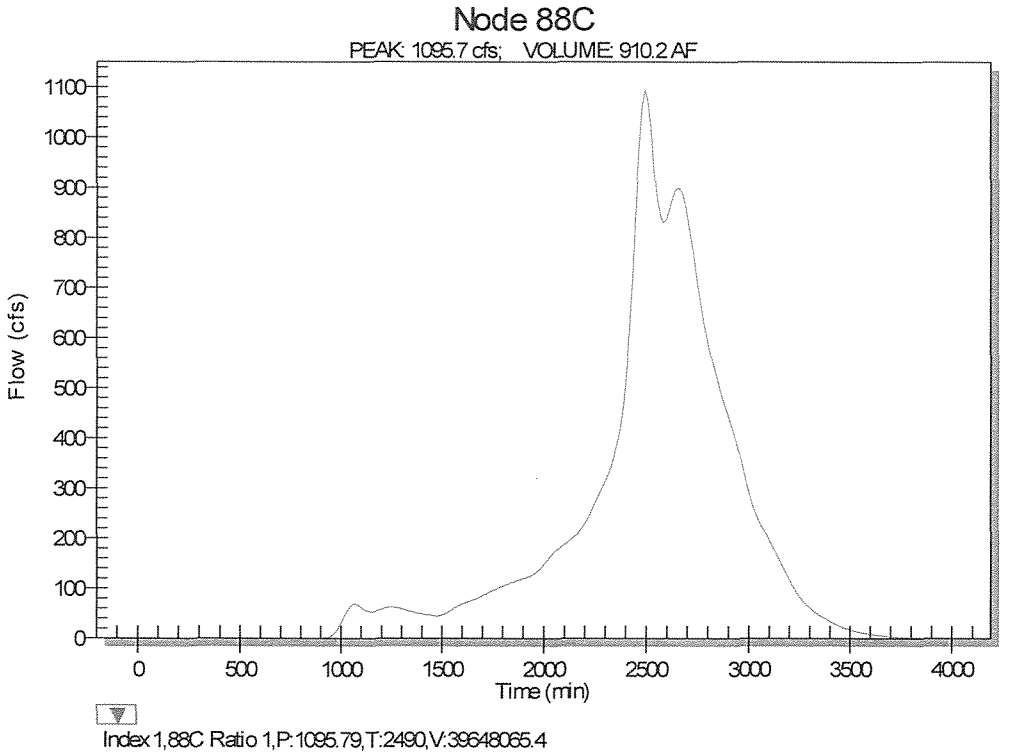


7.1.4 North Little Johns Creek- Simulations 3-6

Simulations on North Little Johns Creek are a bit more complex than those on Duck Creek. First of all, the culvert at the diversion structure on Little Johns Creek has four pipes rather than two, and what arrives at the diversion structure depends on the upstream Duck Creek diversion. Therefore, there are various permutations of potential simulations. Again, Table 2 summarizes the various simulations.

Simulation 3 is the most realistic simulation on North Little Johns Creek. In simulates the two diversion structures as they are today. On Duck Creek, both the 60" and 72" are open, and on North Little Johns Creek all four culvert gates are closed. Only once has one of the four culvert gates been opened, for a brief time in 1986 (personal communication, SJC Channel Maintenance personnel). San Joaquin County Public Works Department is well aware of the channel capacity problems on North Little Johns Creek near the Mariposa Lakes project site, and until these problems are addressed it is highly unlikely that any of the four culvert gates will be opened. Simulation 3 is the "as-is" condition and the most realistic simulation on North Little Johns Creek. Figure 23 is the Simulation 3 inflow hydrograph on North Little Johns Creek at the Mariposa Lakes project boundary. The HEC-1 output files for this simulation can be found in Appendix H.

Figure 23 - Simulation 3. Inflow hydrograph on North Little Johns Creek at Mariposa Lakes project boundary, assuming all four culvert gates are closed at Little Johns Creek diversion structure, representing the "as-is" and most realistic 100-year flooding simulation.



Simulation 4 is the same as Simulation 3 except that one of the four 42" pipe gates is open, allowing a slight increase of discharge to flow down North Little Johns Creek. This was the situation in 1986 when one of the four gates was opened. Figure 24 is a hydrograph on North Little Johns Creek from Simulation 4.

Simulation 5 assumes a different scenario at the upstream Duck Creek diversion. This simulation assumes the 72" culvert gate at the Duck Creek diversion is closed and all four culvert gates are closed at the North Little Johns Creek diversion. This simulation forces more water down South Little Johns Creek, and limits the discharge down both Duck Creek and North Little Johns Creek. This simulation is the best-case scenario for the Mariposa Lakes project area, and represents minimum 100-year discharge values for both creeks flowing through the project site. Hydrographs from Simulation 5 mimic hydrographs from Simulation 2 and Simulation 3 on Duck and Little Johns Creeks, respectively, so they were not reproduced here.

Finally, Simulation 6 models the worst-case scenario on North Little Johns Creek. The 72" culvert gate is closed at the Duck Creek diversion structure, and all four 42" culvert gates are open at the Little Johns Creek diversion structure. Again, this is a highly unlikely situation, considering the 72" culvert gate has only been closed once in its history, and never have all four 42" culvert gates been opened at the same time. Figure 25 shows a hydrograph from Simulation 6.

Figure 24 - Simulation 4. Hydrograph on North Little Johns Creek at Mariposa Lakes project boundary, assuming one 42" culvert gate is open.

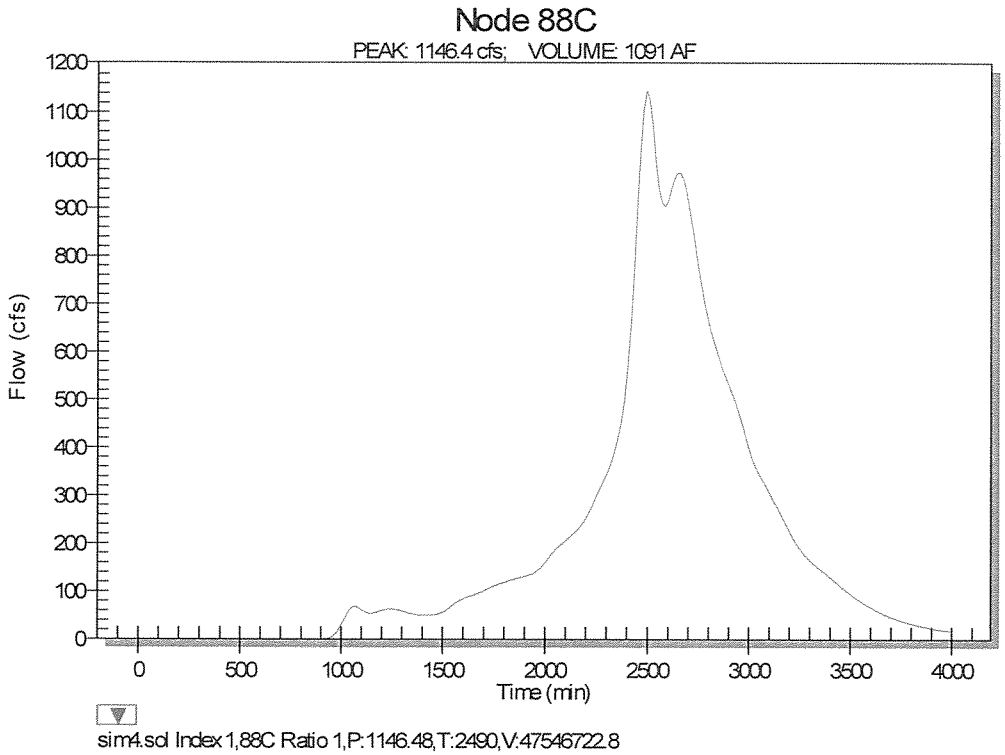
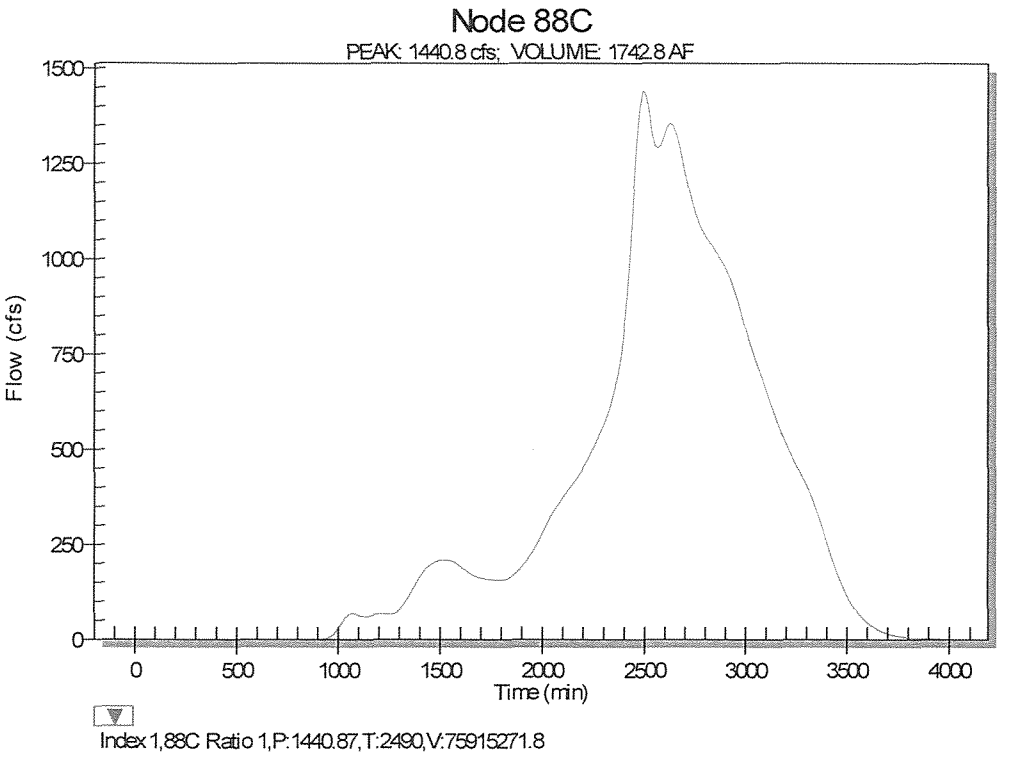


Figure 25 - Simulation 6. Hydrograph on North Little Johns Creek at Mariposa Lakes project boundary, assuming the 72" culvert gate is closed at Duck Creek diversion and all four culvert gates are open at North Little Johns Creek diversion. Considered the "worst-case" scenario for flooding on North Little Johns Creek.



7.2 Comparison to Previous Studies

The study that best addresses the flooding problems is the Ensign & Buckley (1993) report. The study area of the Ensign & Buckley report is North Little Johns Creek and Weber Slough. Duck Creek is not covered in this report. The report states that the 100-year discharge on North Little Johns Creek would be 540 cfs at Kaiser Road, assuming the upstream diversion structure on Little Johns Creek does not fail in the 100-year flood. Simulation 3, the most likely scenario on North Little Johns Creek, produced results of 1095 cfs in North Little Johns Creek. These results assume all four culvert gates are closed on North Little Johns Creek. The Ensign & Buckley report does not state whether or not the culvert gates are open in the simulation that produced 540 cfs.

The report also states that the 100-year flow on Little Johns Creek before the bifurcation is 4,300 cfs. This value was taken from the USACE's 1975 report. However, there is no bibliography as part of the Ensign & Buckley report, and the 1975 USACE report has not been obtained. We do not know all the parameters used to produce these results. However, Simulation 3 results produce peak discharge values of 8121 cfs at the same junction. PACE results in both comparisons is 90-100% more than the Ensign & Buckley and USACE reports. It would be helpful to compare runoff values as a separate comparison, but they are not available.

The Ensign and Buckley report also states that the estimated channel capacity of North Little Johns Creek between Kaiser Road and the railroad tracks is between 50-100 cfs.

Without field measurements of channel geometries, it is difficult to pinpoint the exact channel capacity today, but the 50-100 cfs estimate is reasonable based on field visits. North Little Johns Creek will need significant channel clearing and restoring to convey flood flows in the future.

7.3 Sensitivity Analyses of Watershed Parameters

It is important to evaluate the sensitivity of the various watershed parameters used in a hydrologic model. Changing one parameter by a small value may have large repercussions to the modeling results, or it may not change runoff values at all. Parameter values that are sensitive to minor changes should be evaluated so that modeling results envelope the range of potential results.

One of the advantages of starting with a DEM is that many of the watershed parameters are measured rather than estimated. Basin area, channel length, and channel slope were all measured by WMS from the DEM. Rainfall depths came from the USGS precipitation data for the State of California. Soil layers came from the NRCS, except for the areas that are not available. Those areas were given a hydrologic soil type D, which maximizes the runoff from those areas. So there is no need to run sensitivity analyses for soil types. Changing the soil type to C would only decrease the volume of runoff and the flood peaks. Therefore, three simple sensitivity analyses were performed.

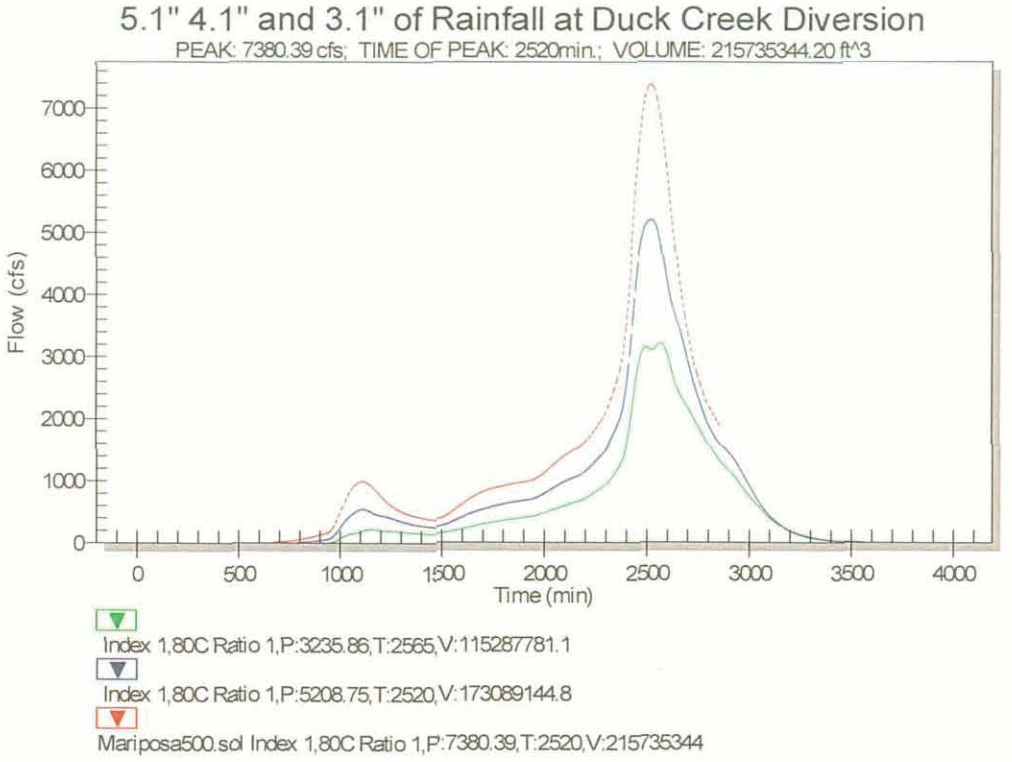
7.3.1 Rainfall Distribution Curve

The first submittal of this report included simulations of the 24-hour, 100-year storm event. This report focuses on the 48-hour, 100-year storm event. This longer storm event includes higher total rainfall depths. The 1961-1990 USGS rainfall map has significantly higher rainfall values than does the 1900-1960 dataset used in previous analyses.

Because of the drastic increase in peak discharges, a simple analysis was done in an effort to better understand the influence of rainfall depth on modeling results. For this, three separate simulations were run in which all the sub-basins in the Duck Creek watershed upstream of the diversion structure were given a different rainfall value. First, the current simulation using a storm rainfall depth of 5.099 inches. The second simulation used a rainfall depth of 4.099 and the third simulation used a rainfall depth of 3.099 inches. The results are illustrated on Figure 26.

The 5.09" rainfall event produced a peak discharge of 7380 cfs, the 4.09 storm produced a peak discharge of 5209 cfs, and the 3.09" storm produced a peak discharge of 3236 cfs. The Duck Creek watershed upstream of the diversion structure appears to be sensitive to rainfall depth.

Figure 26 - Duck Creek hydrographs at node 80C, the Duck Creek diversion, using different rainfall depth values.



7.3.2 Manning's Roughness Coefficient, *n*

In the use of hydraulic models such as HEC-2 or HEC-RAS, users frequently evaluate different Manning's *n* roughness values. Channel and floodplain roughness values have the ability to greatly alter water surface profiles. Because roughness coefficients cannot be directly determined by an instrument or field measurements, it is helpful to run simulations with both high and low roughness values. Low roughness will produce higher channel velocities while high roughness will produce higher water surface elevations.

Changing the roughness value of the routing parameter between sub-basins has a similar effect. The roughness values used in the primary simulations were 0.04 and 0.045 for different channel types. These values are our best estimate of actual roughness based on limited field visits. In all likelihood, actual roughness values are either close to the chosen values or slightly higher. A quick sensitivity analysis was performed using roughness values of 0.035 and 0.055, two values that bracket the potential roughness values found in the foothill and valley channels found in the area. The difference between the two simulations produced results that differed approximately 6% at the Duck Creek Diversion. The model does not appear to be overly sensitive to minor variations in roughness coefficient.

8 Summary and Discussion

Three unique watersheds drain through the Mariposa Lakes project boundary. Branch Creek has a small drainage area and channel without structures. Duck Creek has a diversion structure that diverts a majority of flood runoff into Little Johns Creek. Little Johns Creek has a large flood control dam and reservoir. Downstream from the reservoir, Little Johns Creek accepts diverted water from Duck Creek before bifurcating into two separate channels, South Little Johns Creek and North Little Johns Creek. Here there is another diversion structure that limits the discharge down North Little Johns Creek and forces the rest of the runoff down South Little Johns Creek and away from the Mariposa Lakes project area.

This study summarizes the watershed features that determine runoff, the channel structures that effect the runoff, and the hydrometeorologic events that future developments will need to protect against. The hydrologic simulations presented in this report involve various management decisions regarding the two diversion structures. Modeling results suggest that the Farmington Dam and Reservoir is large enough to successfully detain the 100-year recurrence interval flood event. The Dam is operated to slowly release water after the Duck Creek flood wave exits the Duck Creek/Little Johns Creek system. Modeling results support the 1961 USACE report that states the primary flooding problem comes from Duck Creek runoff, not Little Johns Creek runoff.

The Duck Creek runoff was in the range of 3500-3800 cfs, which overshadows typical USACE releases of approximately 2000 cfs from the reservoir. Therefore, after modeling results suggested that the dam sufficiently detains the entire Little Johns Creek flood volume, simulations focused on Duck Creek water and the routing of the Duck Creek flood wave through the various diversion structures and channels.

Table 5 summarizes modeling results for Branch Creek and Duck Creek, while Table 6 summarizes modeling results for North Little Johns Creek.

Table 5- Modeling results for Branch Creek and Duck Creek

Simulation Name	Duck Diversion Scenario	Summary of Simulation	Branch Creek Peak Discharge at Project	Duck Creek Peak Discharge at Project
SimA	No structures	Pre-1950's scenario, no upstream control structures	988 cfs	8655 cfs
Sim1	72" open	Worst case scenario for Duck Creek	N/A	1795 cfs
Sim2	72" closed	More water diverted to Little Johns Creek	N/A	1601 cfs

Table 6- Modeling results for North Little Johns Creek

Simulation Name	Duck Diversion Scenario	Little Johns Diversion Scenario	Summary of Simulation	North Little Johns Creek Peak Discharge at Project
SimA	No structures	No structures	Pre-1950's scenario, no upstream control structures	73,393 cfs
Sim3	72" open	All closed	Most realistic scenario for North Little Johns, "as-is" simulation	1095 cfs
Sim4	72" open	One 42" open	1982 scenario	1146 cfs
Sim5	72" closed	All closed	Maximum water diverted to South Little Johns	1096 cfs
Sim6	72" closed	All four 42" open	Worst case scenario for North Little Johns	1441 cfs

The modeling results presented in Table 5 and Table 6 summarize the various different diversion structure scenarios under the 100-year storm event. The most likely scenarios have a peak discharge of 1021 cfs on Duck Creek, 201 cfs on Branch Creek, and 393 cfs on North Little Johns Creek.

Hydrographs from these simulations will be used to route water through the lake systems and through the renovated Duck Creek channel as part of the on-site hydrology study that should be finalized by PACE in December. The on-site study will carefully examine on-site runoff as well as the conveyance of flood flows through the channels and lake systems. The on-site report will show that the lake systems will act to decrease peak flows leaving the Mariposa Lakes development, lessening the hazard of damaging floods to downstream areas.

9 Recommendations

This report does not include a detailed hydraulic analysis. A hydraulic modeling tool such as HEC-RAS, coupled with the hydrology data produced in this study, would provide a comprehensive understanding of the channels and structures of interest. It is recommended to use the hydrologic results from this report and create a hydraulic channel and floodplai model. FEMA floodplains in the Mariposa Lakes area (see Exhibit 9) will more than likely change with the channel restoration plans for the three creeks. At this time a Conditional Letter of Map Revision (CLOMR) will be completed. Finally, during construction, a Letter of Map Revision (LOMR) will be completed.

Water-surface elevations on North Little Johns Creek depend largely on how much flow can be conveyed in South Little Johns Creek. The channel elevation/discharge rating curves used in this analysis were measured from a detailed DEM, not from actual field measurements. Detailed field measurements of channel cross-sections near the South/North Little Johns Creek junction are recommended for future studies.

Channel geometries would also bolster any type of floodplain modeling results planned for the future. Floodplain modeling will be required for CLOMR applications since the building of the lakes will change the natural floodplain. If possible, it is recommended that field measurements take place before the rainy season.

References

Boyle Engineering Corporation 1997 *County of San Joaquin Hydrology Manual*, Prepared for San Joaquin Department of Public Works, Sacramento, California.

Engineering Office of Clyde C. Kennedy 1958a. *Duck Creek Improvement Project*. Prepared for San Joaquin County Flood Control & Water Conservation District. San Francisco, California.

Engineering Office of Clyde C. Kennedy 1958b. *Appendix to Report on Duck Creek Improvement Project*. Prepared for San Joaquin County Flood Control & Water Conservation District. San Francisco, California.

Ensign & Buckley Consulting Engineers 1993. *North Little Johns Creek Drainage Study*. Prepared for County of San Joaquin Flood Control & Water Conservation District.

Kleinfelder, Inc. 2005 *Preliminary Geotechnical Report, Mariposa Lakes Development, Stockton, California*. Prepared for Gerry N. Kamilos, LLC. Stockton, California.

Natural Resources Conservation Service 1986. Urban *Hydrology for Small Watersheds, TR-55*. Technical Release 55.

Randall Planning and Design, Inc. 2005. Draft Mariposa Lakes Development Specific Plan. Draft #100505, Walnut Creek, California.

San Joaquin County website (http://san-joaquin.diad.net/portal.php).

State of California GIS website (http://gis.ca.gov/index.epl).

United States Army Corps of Engineers 1952a. *Maintenance Manual- Farmington Dam and Reservoir*. Littlejohn Creek and Calaveras River Stream Group. Sacramento District, California.

United States Army Corps of Engineers 1952b. *Operation and Maintenance Manual for Duck Creek Diversion- A Unit of Farmington Reservoir Project*. Littlejohn Creek and Calaveras River Stream Group. Sacramento District, California.

United States Army Corps of Engineers 1961. *Detailed Project Report on Duck Creek, San Joaquin County, California*. Sacramento District, California.

United States Army Corps of Engineers 1990. *Flood Hydrograph Package, User's Manual, HEC-1*. Davis, CA.

TITLE
REGIONAL VICINITY MAP

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SAN JOAQUIN COUNTY CA

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CHECKED
DATE 10/26/05
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PACE
PACIFIC ADVANCED CIVIL ENGINEERING
17820 NEWHOPE STREET, SUITE 100
FOUNTAIN VALLEY, CA 92708
PH (714) 481-7300 FAX (714) 481-7399

EXHIBIT
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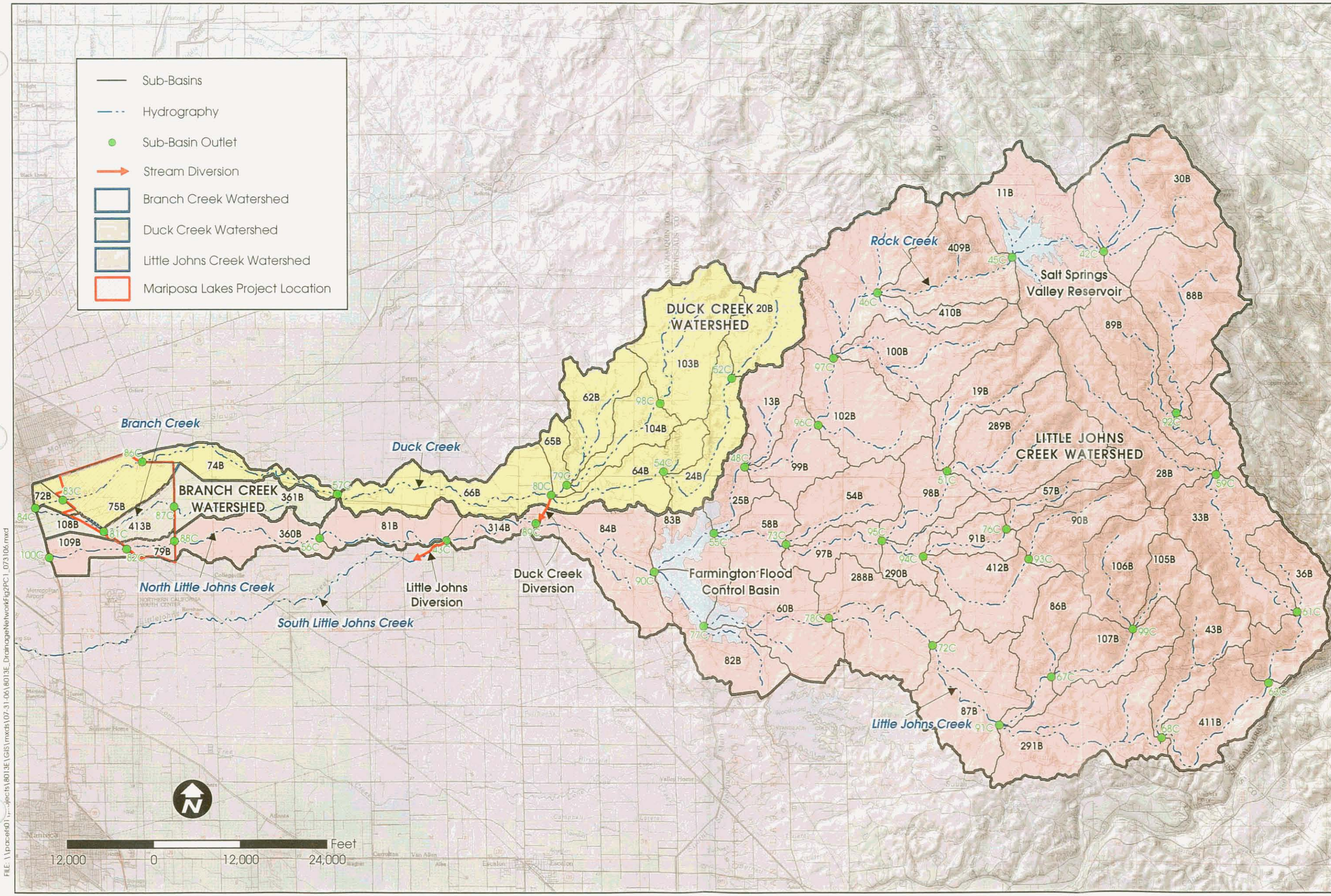

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CA
SAN JOAQUIN COUNTY

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PACE
PACIFIC ADVANCED CIVIL ENGINEERING
17520 NEWHOPE STREET, SUITE 200
FOUNTAIN VALLEY, CA 92708
PH (714) 481-7300 FAX (714) 481-7399

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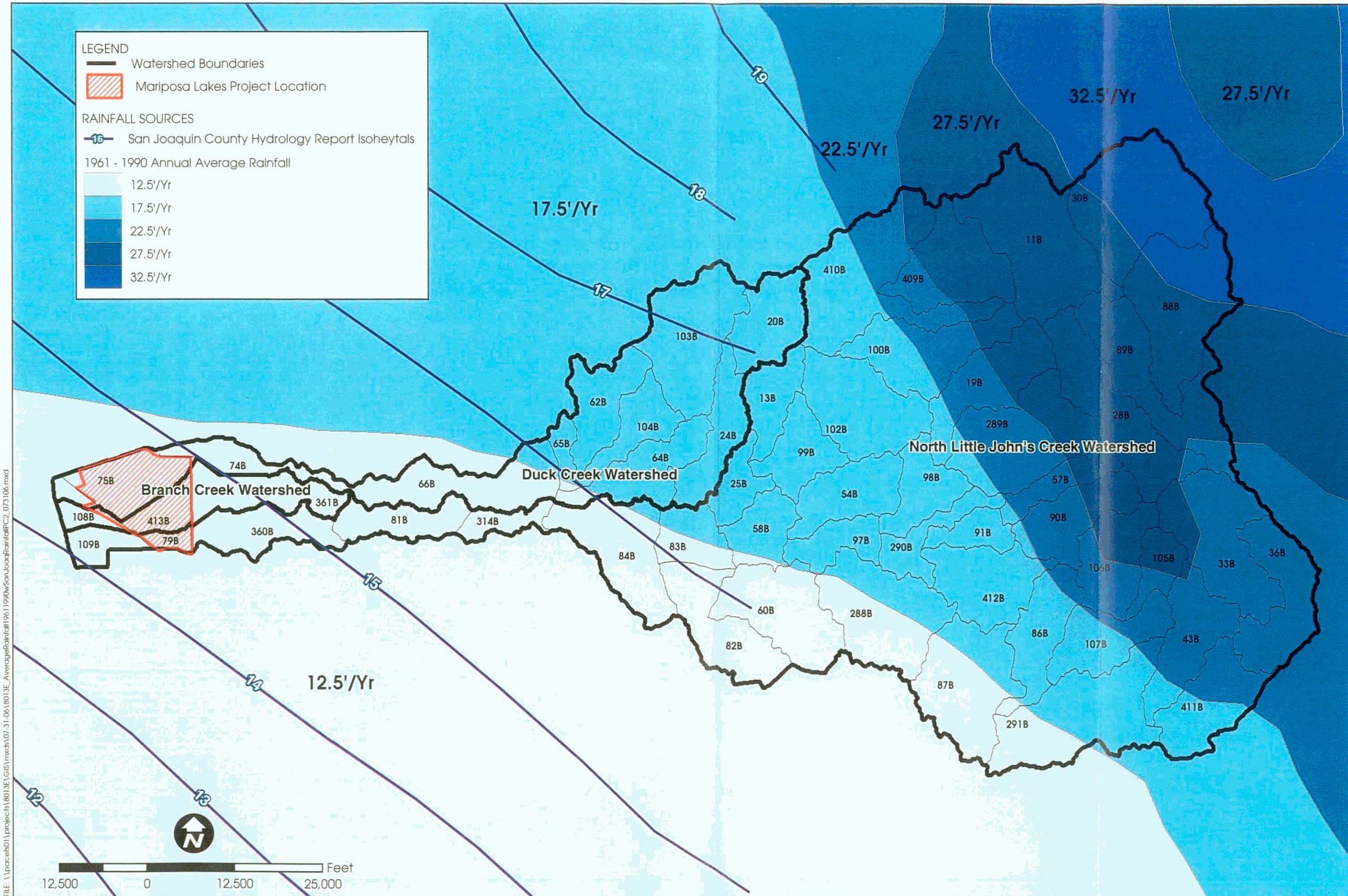

TITLE
1961 - 1990 Rainfall
with San Joaquin County
Isohyetal Rainfall

MARIPOSA LAKES
SAN JOAQUIN COUNTY CA

JOB

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DATE	7/31/06
JOB NO.	8013-E

PACE
PACIFIC ADVANCED CIVIL ENGINEERING
17550 NEWHOPE STREET, SUITE 200
FOUNTAIN VALLEY, CA 92708
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EXHIBIT
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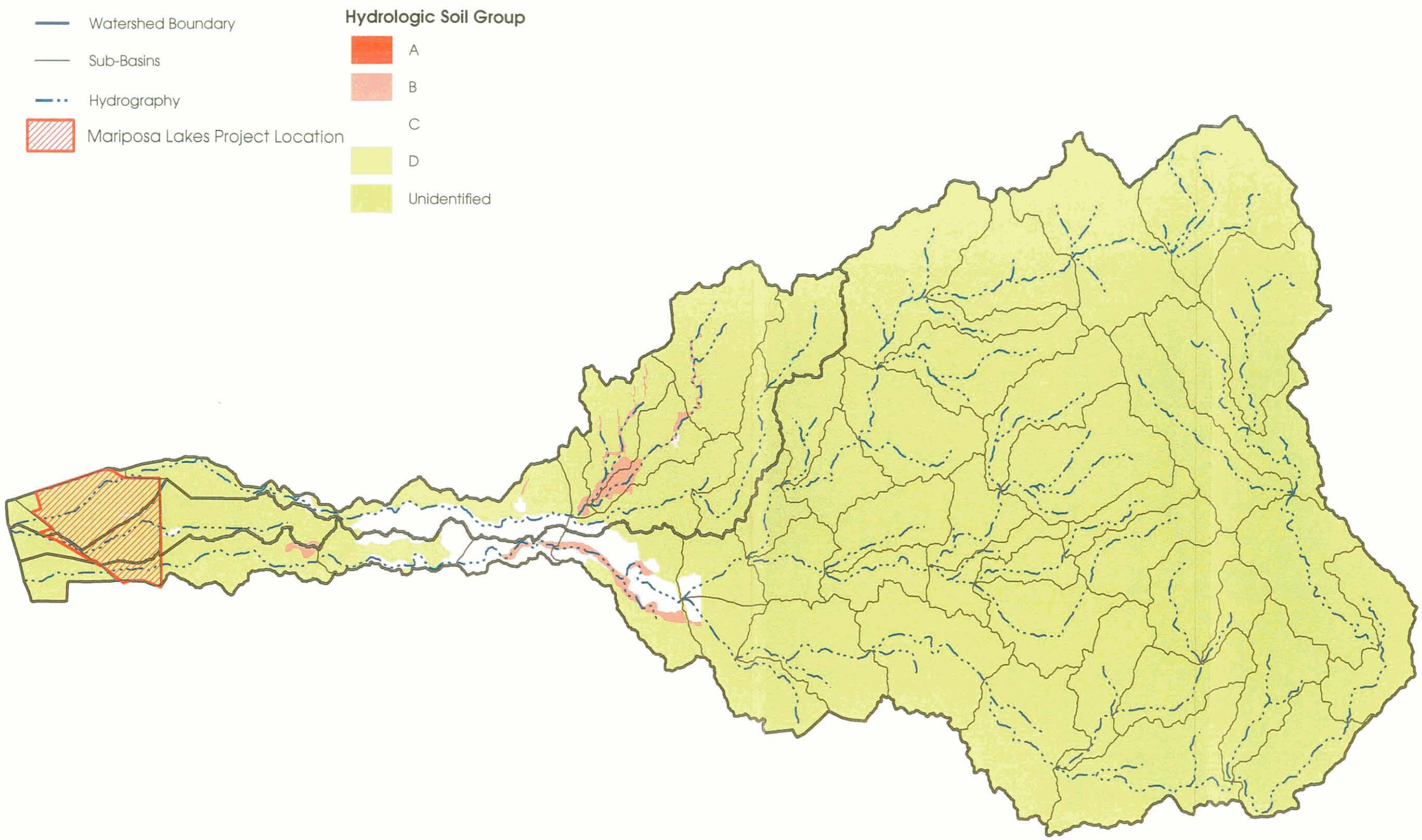

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Feet

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TITLE

HYDROLOGIC SOIL GROUPS

JOB

MARIPOSA LAKES

SAN JOAQUIN COUNTY CA

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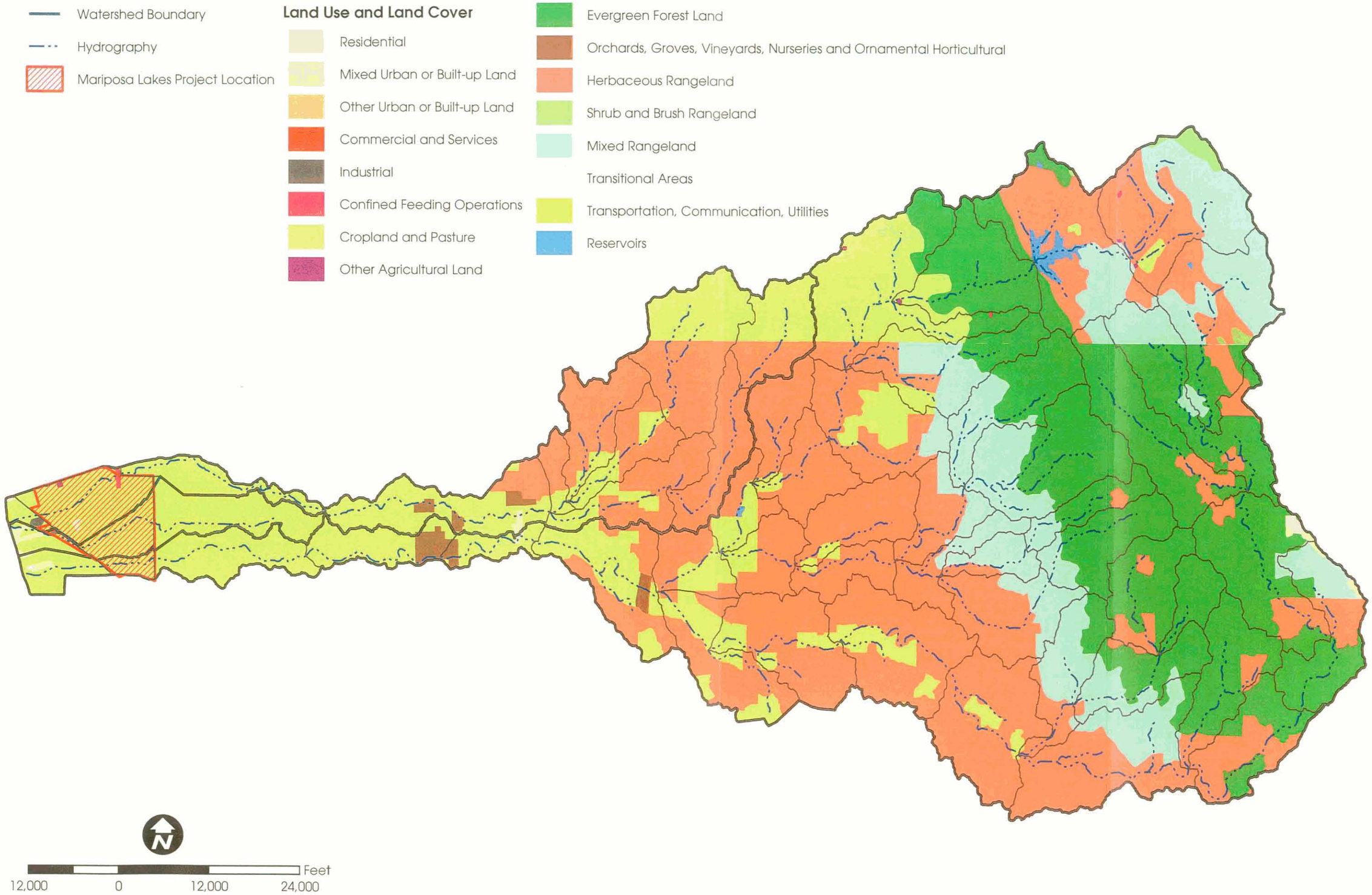
CHECKED	
DATE	10/26/05
JOB NO	8013-E

PACE
PACIFIC ADVANCED CIVIL ENGINEERING
17580 NEWHOPE STREET, SUITE 100
FOUNTAIN VALLEY, CA 92708
PH (714) 481-7300 FAX (714) 481-7299

EXHIBIT

4

FILE: \\pace\...jects\8013E\GIS\mxds\07-31-06\8013_SoilsFig4PC1_073106.mxd



TITLE

LAND USE AND LAND COVER

JOB

MARIPOSA LAKES

SAN JOAQUIN COUNTY CA

SCALE	1" = 12,000'
DESIGNED	JC
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DATE	10/26/05
JOB NO.	8013-E

PACE
PACIFIC ADVANCED CIVIL ENGINEERING
17520 NEWHOPE STREET, SUITE 200
FOUNTAIN VALLEY, CA 92708
PH (714) 481-7300 FAX (714) 481-7299

EXHIBIT

5

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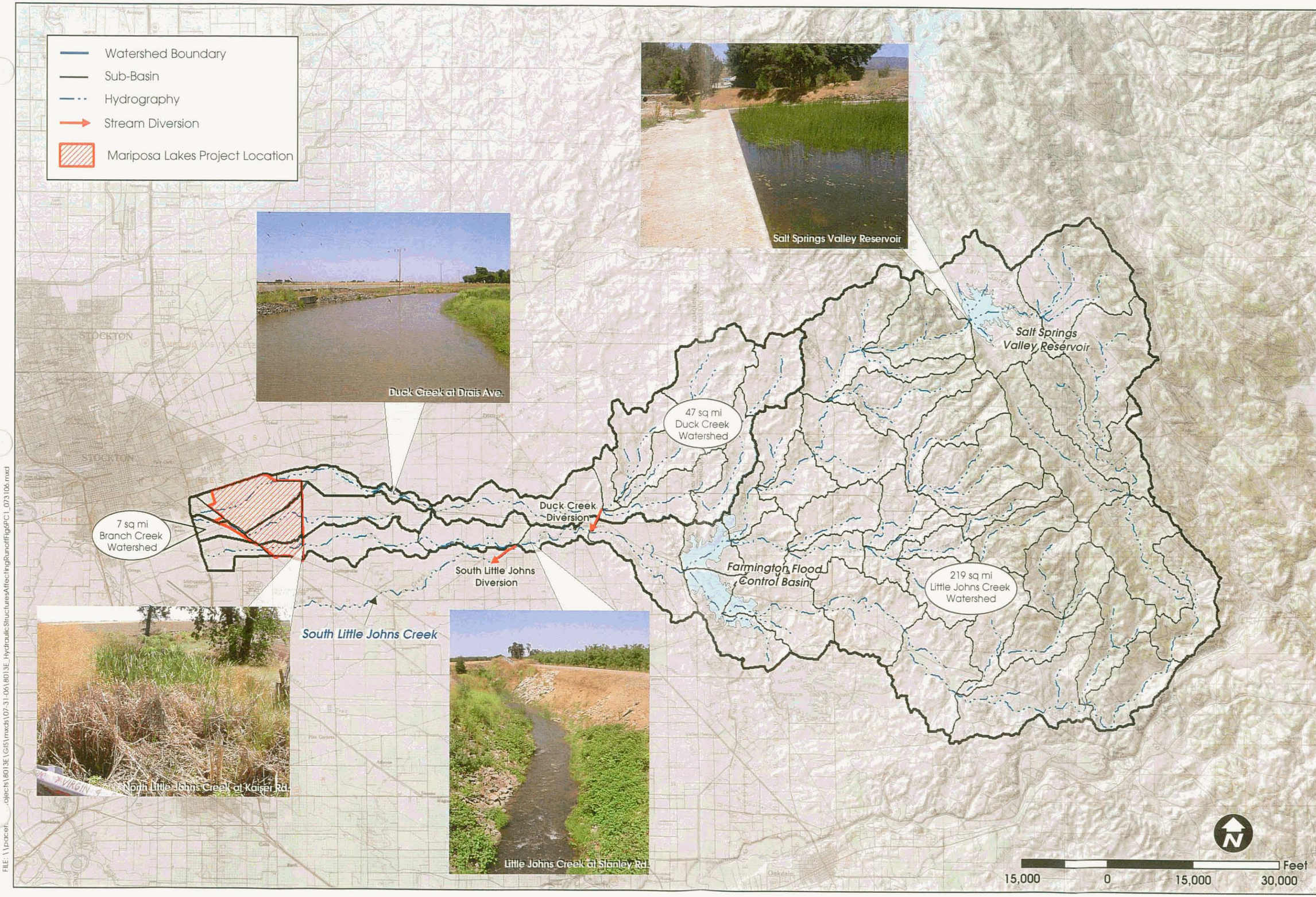

TITLE
EXISTING CHANNELS AND RESERVOIRS

JOB
MARIPOSA LAKES
SAN JOAQUIN COUNTY CA

SCALE	1" = 15,000'
DESIGNED	JC
DRAWING	
CHECKED	
DATE	10/26/05
JOB NO	8013-E

PACE
PACIFIC ADVANCED CIVIL ENGINEERING
17520 NEWHOPE STREET, SUITE 200
FOUNTAIN VALLEY, CA 92708
PH (714) 481-7300 FAX (714) 481-7299

EXHIBIT
6

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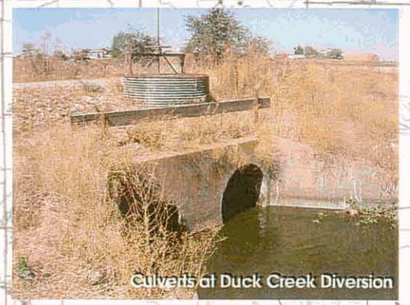
Sub-Basin
Hydrography
Stream Diversion
Mariposa Lakes Project Location
Branch Creek Watershed
Duck Creek Watershed
Little Johns Creek Watershed

Feet
7,000 0 7,000 14,000

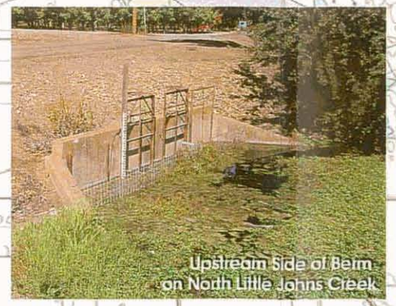
Weir into Duck Creek Diversion


Culverts at Duck Creek Diversion

Branch Creek
Duck Creek
BRANCH CREEK WATERSHED
DUCK CREEK WATERSHED
LITTLE JOHNS CREEK WATERSHED
Duck Creek Diversion
Little Johns Creek Diversion
North Little Johns Creek
South Little Johns Creek
Farmington Flood Control Basin

South Little Johns Creek

Downstream Side of Berm on North Little Johns Creek


Upstream Side of Berm on North Little Johns Creek

DIVERSION STRUCTURES

TITLE

MARIPOSA LAKES

CA

SAN JOAQUIN COUNTY

JOB

SCALE 1" = 7,000'
DESIGNED JC
DRAWING 8013E Diversion Vicinities 092905.mxd
CHECKED
DATE 10/26/05
JOB NO. 8013-E

PACE
PACIFIC ADVANCED CIVIL ENGINEERING
17520 NEWHOPE STREET, SUITE 200
FOUNTAIN VALLEY, CA 92708
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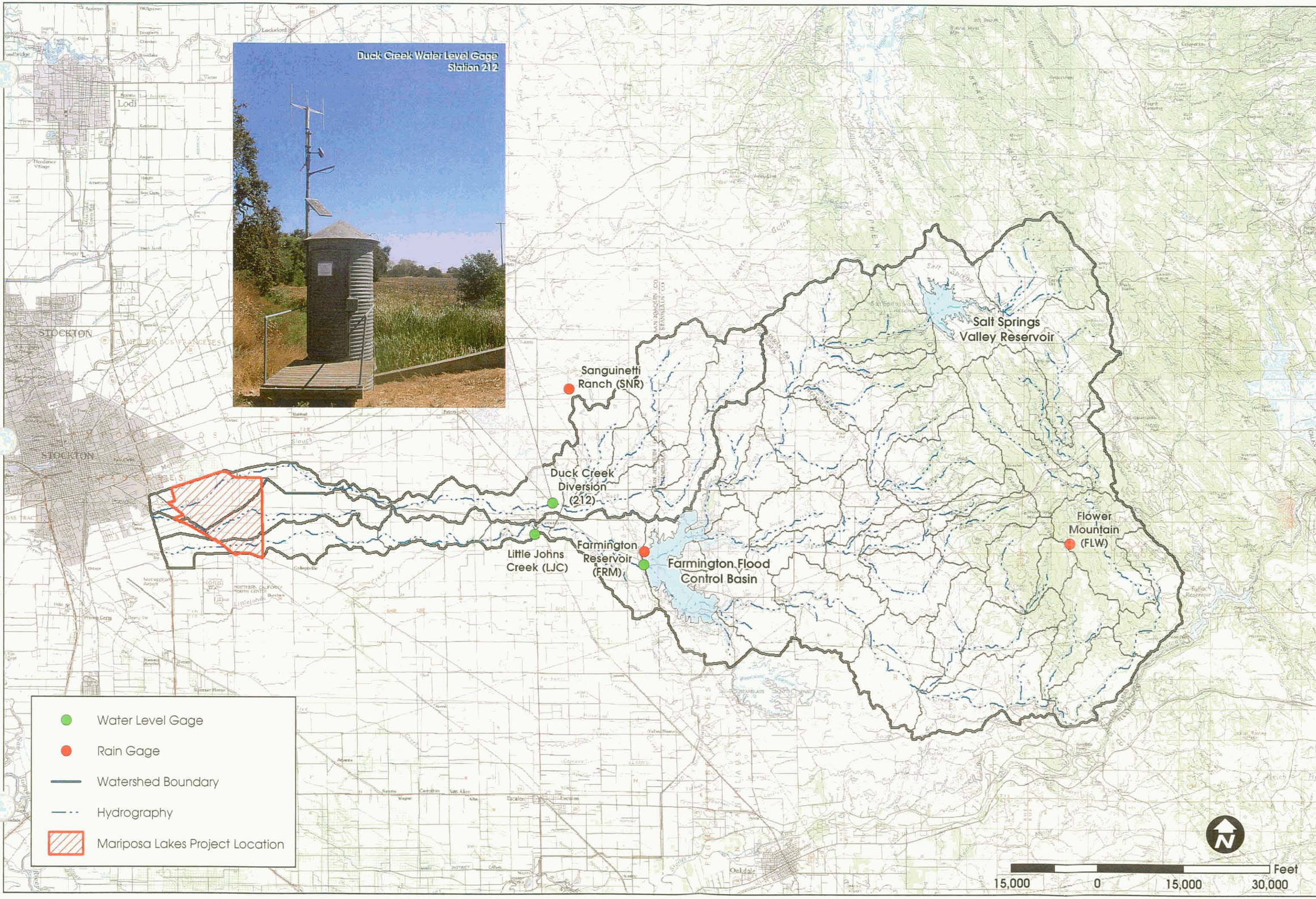

TITLE
STREAM AND RAIN
GAGE LOCATIONS

JOB
MARIPOSA LAKES
SAN JOAQUIN COUNTY
CA

SCALE	1"= 15,000'
DESIGNED	JC
DRAWING	BY:JE Rain&StreamGages_101405.mxd
CHECKED	
DATE	10/26/05
JOB NO.	8013.E

PACE
PACIFIC ADVANCED
CIVIL ENGINEERING
17520 NEWHOPE STREET, SUITE 200
FOUNTAIN VALLEY, CA 92708
PH (714) 481-7300 FAX (714) 481-7299

EXHIBIT
8

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TITLE
FEMA FLOOD ZONES

JOB
MARIPOSA LAKES
SAN JOAQUIN CNTY CA

SCALE	1"= 1500'
DESIGNED	BJ
DRAWING	RS
CHECKED	BJ
DATE	7/31/06
JOB NO.	8013-E

PACE
PACIFIC ADVANCED CIVIL ENGINEERING
17520 NEWHOPE STREET, SUITE 200
FOUNTAIN VALLEY, CA 92708
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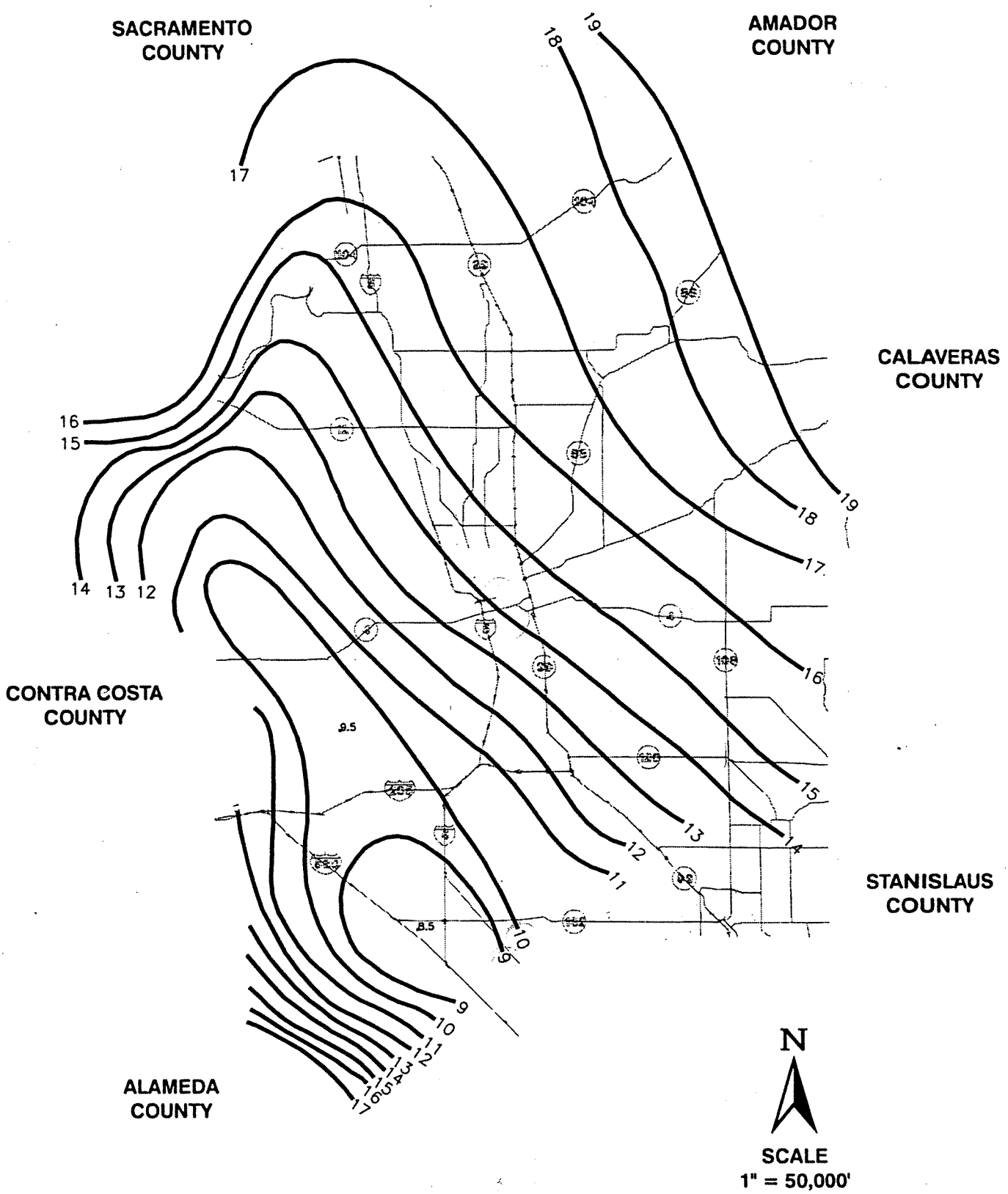
EXHIBIT
10



SAN JOAQUIN COUNTY
HYDROLOGY MANUAL

ISOHYETAL RAINFALL MAP

FIGURE B-1

TABLE B.7

100-YEAR DEPTH-DURATION-FREQUENCY FOR COUNTY OF SAN JOAQUIN

100-year DEPTH-DURATION-FREQUENCY

K = 3.087

Skew = 1.1

Cv = 0.354

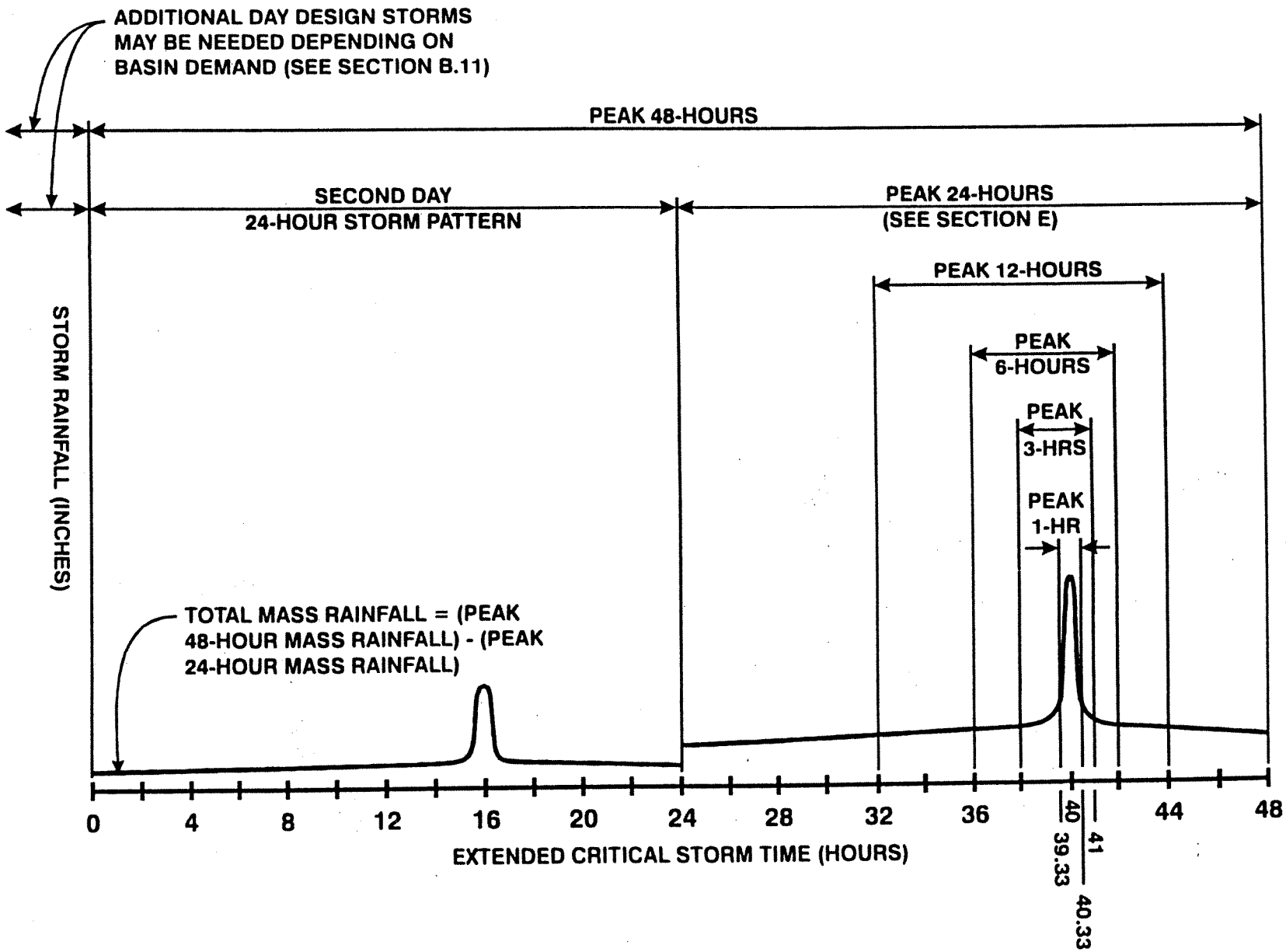
MAP	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
9	0.28	0.36	0.43	0.56	0.75	0.98	1.16	1.53	2.02	2.66
10	0.29	0.38	0.45	0.59	0.78	1.04	1.22	1.61	2.12	2.80
11	0.30	0.40	0.47	0.62	0.82	1.09	1.28	1.69	2.23	2.94
12	0.32	0.42	0.50	0.65	0.86	1.14	1.34	1.77	2.34	3.08
13	0.33	0.44	0.52	0.68	0.90	1.19	1.40	1.85	2.44	3.22
14	0.35	0.46	0.54	0.71	0.94	1.24	1.46	1.93	2.55	3.36
15	0.36	0.48	0.56	0.74	0.98	1.30	1.52	2.01	2.66	3.51
16	0.38	0.50	0.59	0.77	1.02	1.35	1.59	2.09	2.76	3.65
17	0.39	0.52	0.61	0.80	1.06	1.40	1.65	2.17	2.87	3.79
18	0.41	0.54	0.63	0.83	1.10	1.45	1.71	2.25	2.98	3.93
19	0.42	0.56	0.65	0.86	1.14	1.50	1.77	2.33	3.08	4.07

B.11. LONGER DURATION RAINFALL DATA

The County's design storm criteria extends to a multiday design storm when needed to evaluate detention basin characteristics (Sections F and G). The following tabulation provides a ratio of daily rainfalls to the peak 24-hour mass rainfall. (Table B.1 is a weighted average relationship developed from the twenty-eight rainfall stations in and adjacent to San Joaquin County.)

TABLE B.1
MULTIDAY RAINFALL MASS RATIOS
FOR
COUNTY OF SAN JOAQUIN

Rainfall Duration	Ratio to Peak 24-hours
Peak 24-hours	1
(Peak 48-hours)–(Peak 24-hours)	0.32
(Peak 72-hours)–(Peak 48-hours)	0.23
(Peak 96-hours)–(Peak 72-hours)	0.19
(Peak 120-hours)–(Peak 96-hours)	0.16



EXTENDED DESIGN STORM:
FLOW-THROUGH BASIN

FIGURE F-2

Appendix C- Parameter used to calculate initial abstraction (Ia)

Basin	CN	S	Ia
30B	91.5	0.93	0.19
11B	88.7	1.27	0.25
409B	79.8	2.53	0.51
410B	83.4	1.99	0.40
100B	88.8	1.26	0.25
102B	88.4	1.31	0.26
99B	88.7	1.27	0.25
13B	88.9	1.25	0.25
25B	86.2	1.60	0.32
19B	86.5	1.56	0.31
289B	86.1	1.61	0.32
57B	84.6	1.82	0.36
90B	82.4	2.14	0.43
98B	91.4	0.94	0.19
91B	95.9	0.43	0.09
412B	91.6	0.92	0.18
290B	92.6	0.80	0.16
97B	88.7	1.27	0.25
54B	88.8	1.26	0.25
58B	88	1.36	0.27
83B	86.2	1.60	0.32
88B	91.4	0.94	0.19
89B	84.6	1.82	0.36
28B	80.9	2.36	0.47
33B	81.5	2.27	0.45
36B	86	1.63	0.33
411B	84.3	1.86	0.37
43B	80.6	2.41	0.48
291B	91.5	0.93	0.19
105B	79	2.66	0.53
106B	80.8	2.38	0.48
107B	86.3	1.59	0.32
86B	92.4	0.82	0.16
87B	88.6	1.29	0.26
288B	88	1.36	0.27
60B	88.2	1.34	0.27
82B	86.7	1.53	0.31
84B	81.9	2.21	0.44
314B	77.6	2.89	0.58
81B	81.5	2.27	0.45
360B	83.2	2.02	0.40
79B	84	1.90	0.38
109B	84.2	1.88	0.38
361B	83.7	1.95	0.39
413B	84	1.90	0.38
108B	84.8	1.79	0.36
20B	86.1	1.61	0.32
24B	89	1.24	0.25
64B	87.3	1.45	0.29

103B	86.1	1.61	0.32
104B	83.6	1.96	0.39
62B	85.8	1.66	0.33
65B	86.5	1.56	0.31
66B	82.2	2.17	0.43
74B	83.6	1.96	0.39
75B	84.3	1.86	0.37
72B	86.7	1.53	0.31

Curve [1] Numbers of Hydrologic Soil-Cover Complexes for Pervious Areas-AMC II

Cover Type (3)	Quality of Cover (2)	Soil Group A	B	C	D
NATURAL COVERS -					
Barren (Ref. No. 21) (Rockland, eroded and graded land)		78	86	91	93
Chaparral, Broadleaf (Ref. No. 21) (Manzonita, ceanothus and scrub oak)	Poor	53	70	80	85
	Fair	40	63	75	81
	Good	31	57	71	78
Chaparral, Narrowleaf (Ref. No. 21) (Chamise and Redskank)	Poor	71	82	88	91
	Fair	55	72	81	86
Grass, Annual or Perennial	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadows or Seasonal Wetlands (Ref. No. 21) (Areas with seasonally high water table, principal vegetation is sod forming grass)	Poor	63	77	85	88
	Fair	51	70	80	84
	Good	30	58	72	78
Open Brush (Ref. No. 21) (Soft wood shrubs-buckwheat, sage, etc.)	Poor	62	76	84	88
	Fair	46	66	77	83
	Good	41	63	75	81
Woodland (4) (Coniferous or broadleaf trees predominate. Canopy density is at least 50 percent)	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Woodland, Grass (Coniferous or broadleaf trees with canopy density from 20 to 50 percent)	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
URBAN COVERS -					
Residential or Commercial Landscaping (Lawns, shrubs, etc.)	Good	39	61	74	80
Turf (Irrigated and mowed grass)	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80

REFERENCE NO. 26 UNLESS NOTED

SAN JOAQUIN COUNTY
HYDROLOGY MANUAL

CURVE NUMBERS FOR PERVIOUS AREAS

Curve [1] Numbers of Hydrologic Soil-Cover Complexes for Pervious Areas-AMC II

Cover Type (3)	Quality of Cover (2)	Soil Group A	B	C	D
AGRICULTURAL COVERS -					
Fallow (Bare Soil)		77	86	91	94
Close Seeded (alfalfa, sweetclover, timothy, etc.)	Poor	66	77	85	89
	Good	58	72	81	85
Contoured	Poor	64	75	83	85
	Good	55	69	78	83
Countoured and Terraced	Poor	63	73	80	83
	Good	51	67	76	80
Orchards, Evergreen (Ref. No. 2) (Citrus, avacodos, etc.)	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Pasture (Grassland or range, continuous forage for grazing)	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Contoured	Poor	47	67	81	88
	Fair	25	59	75	83
	Good	6	35	70	79
Row Crops (Straight row, non-contoured)	Poor	72	81	88	91
	Good	67	78	85	89
Contoured	Poor	70	79	84	88
	Good	65	75	82	86
Contoured and Terraced	Poor	66	74	80	82
	Good	62	71	78	81
Small Grain (Straight row, non-contoured))	Poor	65	76	84	88
	Good	63	75	83	87
Contoured	Poor	63	74	82	85
	Good	61	73	81	84
Contoured and Terraced	Poor	61	72	79	82
Grapes, New Orchards (4), and Decidious Orchards (Ref. No. 27)	Poor	62	76	84	88
	Fair	46	67	78	83
	Good	37	60	73	79

REFERENCE NO. 3 UNLESS NOTED

SAN JOAQUIN COUNTY
HYDROLOGY MANUAL

CURVE NUMBERS FOR PERVIOUS AREAS

FIGURE C-2 (2 of 3)

Notes:

1. Average runoff condition, Ia = 0.2(S)

2. Poor: Heavily grazed, regularly burned areas, or areas of high burn potential. Less than 50 percent of the ground surface is protected by plant cover or brush and tree canopy.

   Fair: Moderate cover with 50 percent to 75 percent of the ground surface protected. In wood areas the woods are grazed but not burned, and some forest litter covers the soil.

   Good: Heavy or dense cover with more than 75 percent of the ground surface protected. In wooded areas the woods are protected from grazing, litter and brush adequately cover soil.

3. See Figure C-1 for definition of cover types.

4. Based on 25% by vines or trees.

REFERENCE NO. 3

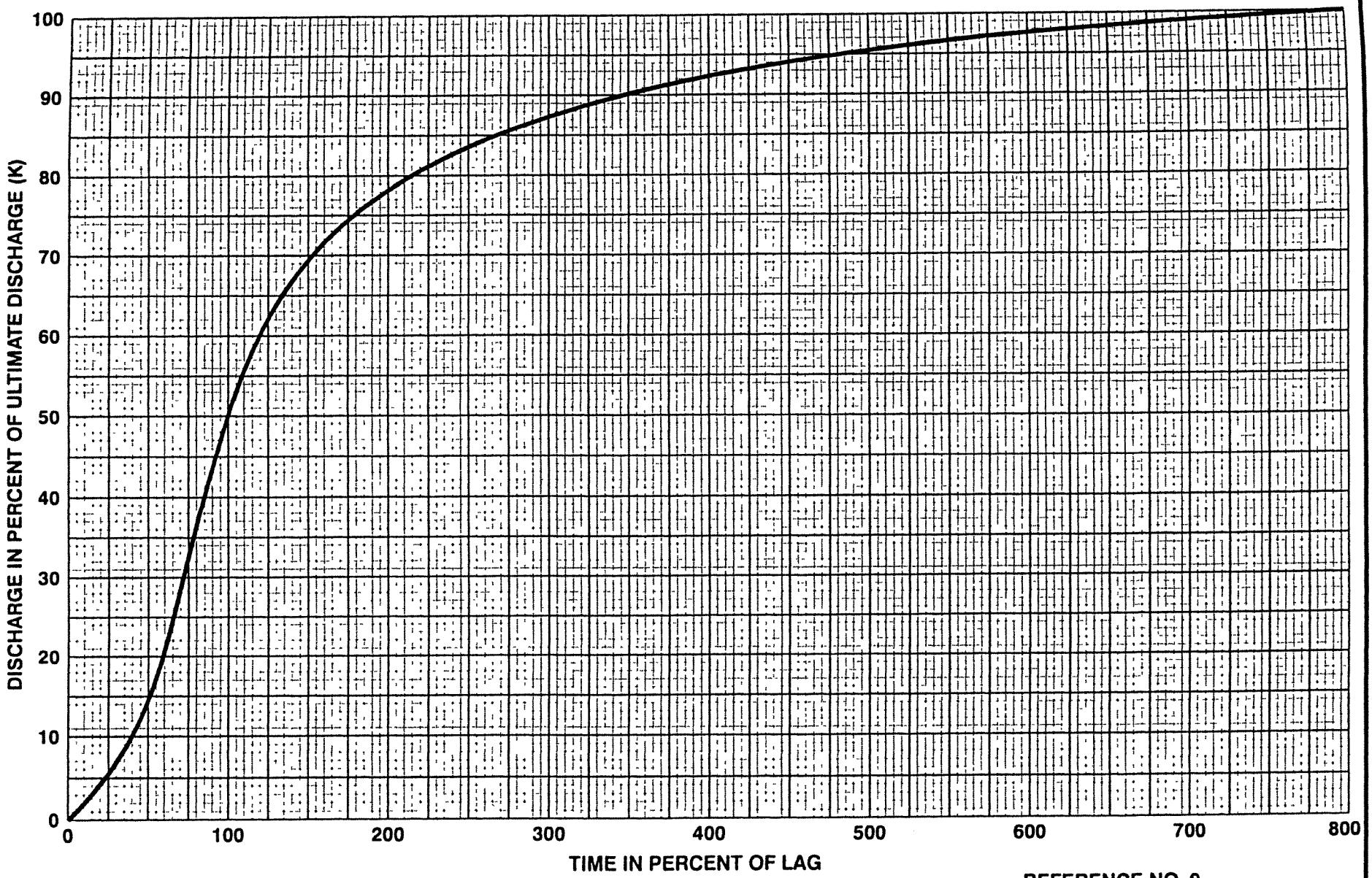
SAN JOAQUIN COUNTY
HYDROLOGY MANUAL

CURVE NUMBERS
FOR
PERVIOUS AREAS

Appendix E - Table of Subbasin Perameter used to Calculate Unit Hydrographs

Basin	Basin Type	n	Lag (hr.)
30B	Foothill	0.045	0.83
11B	Foothill	0.045	0.82
409B	Valley	0.040	0.90
410B	Valley	0.040	1.08
100B	Valley	0.040	1.09
102B	Valley	0.040	0.74
99B	Valley	0.040	0.90
13B	Valley	0.040	1.05
25B	Valley	0.040	0.85
19B	Valley	0.040	1.09
289B	Valley	0.040	1.04
57B	Valley	0.040	0.83
90B	Valley	0.040	0.86
98B	Valley	0.040	0.99
91B	Valley	0.040	0.69
412B	Valley	0.040	1.07
290B	Valley	0.040	0.83
97B	Valley	0.040	0.95
54B	Valley	0.040	1.26
58B	Valley	0.040	0.80
83B	Valley	0.040	0.78
88B	Foothill	0.045	1.39
89B	Foothill	0.045	1.94
28B	Foothill	0.045	1.65
33B	Foothill	0.045	1.44
36B	Foothill	0.045	1.31
411B	Valley	0.040	1.14
43B	Valley	0.040	0.95
291B	Valley	0.040	1.20
105B	Valley	0.040	0.57
106B	Valley	0.040	0.78
107B	Valley	0.040	0.88
86B	Valley	0.040	1.18
87B	Valley	0.040	1.23
288B	Valley	0.040	1.36
60B	Valley	0.040	1.37
82B	Valley	0.040	1.70
84B	Valley	0.040	1.59
314B	Valley	0.040	1.28
81B	Valley	0.040	1.78
360B	Valley	0.040	1.69
79B	Valley	0.040	0.73
109B	Valley	0.040	0.97
361B	Valley	0.040	1.68
413B	Valley	0.040	1.09
108B	Valley	0.040	0.85
20B	Valley	0.040	0.95
24B	Valley	0.040	1.39
64B	Valley	0.040	1.41

103B	Valley	0.040	1.17
104B	Valley	0.040	1.25
62B	Valley	0.040	1.26
65B	Valley	0.040	0.51
66B	Valley	0.040	2.17
74B	Valley	0.040	2.05
75B	Valley	0.040	1.32
72B	Valley	0.040	0.43

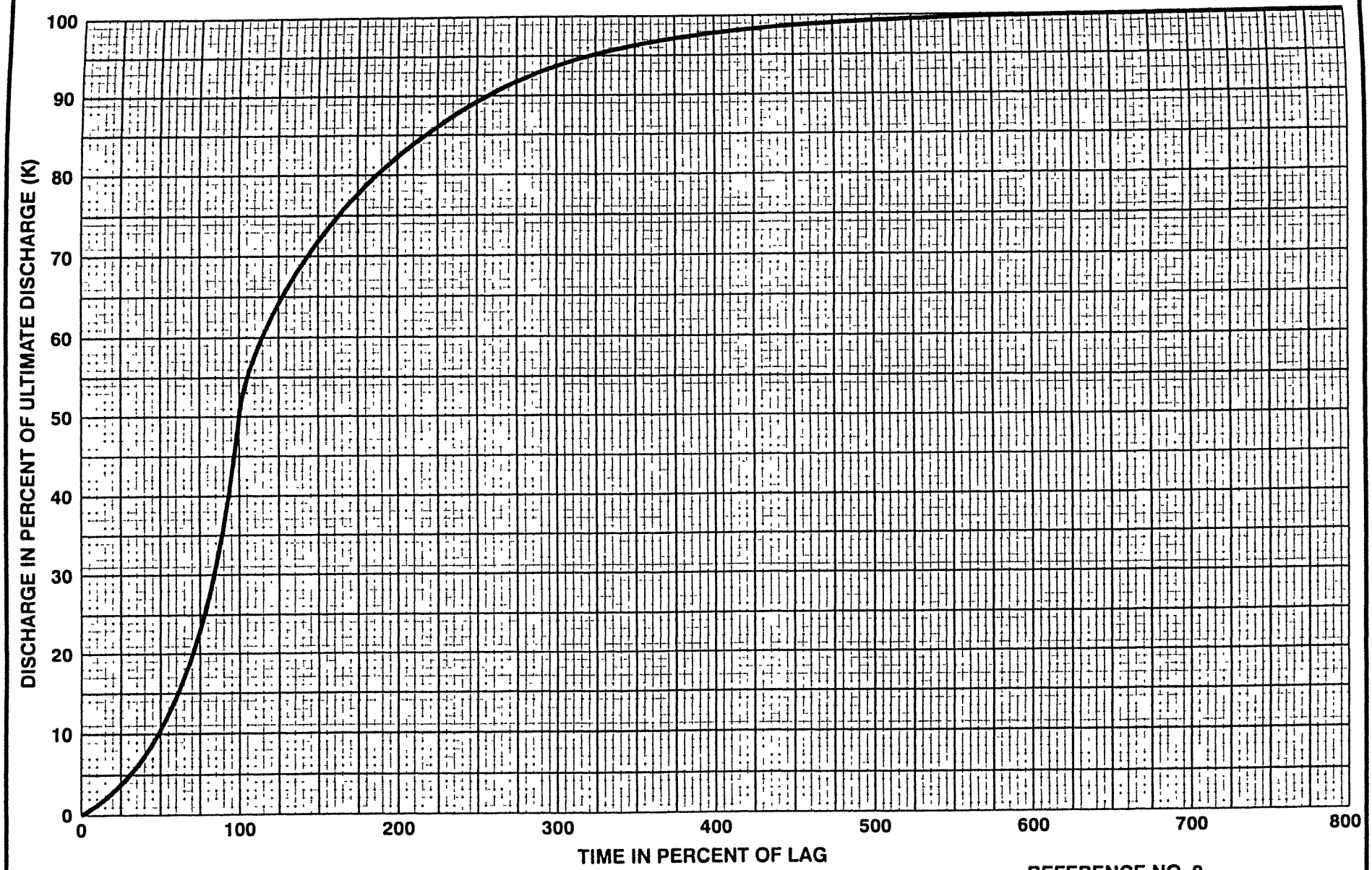


REFERENCE NO. 9

SAN JOAQUIN COUNTY
HYDROLOGY MANUAL

S-GRAPH FOR VALLEY: UNDEVELOPED

FIGURE E-3d



REFERENCE NO. 9

SAN JOAQUIN COUNTY
HYDROLOGY MANUAL

S-GRAPH FOR FOOTHILL AREAS

FIGURE E-3b

Appendix G- RUNOFF SUMMARY, SImulation 1
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT	20B	1668.	41.00	796.	348.	141.	4.07		
ROUTED TO	52R	1495.	42.25	793.	348.	141.	4.07		
HYDROGRAPH AT	24B	1398.	41.25	752.	343.	144.	3.83		
2 COMBINED AT	54C	2427.	42.00	1535.	690.	285.	7.90		
ROUTED TO	54R	2340.	43.00	1530.	689.	285.	7.90		
HYDROGRAPH AT	103B	2847.	41.00	1447.	643.	262.	7.55		
ROUTED TO	98R	2605.	42.25	1441.	642.	262.	7.55		
HYDROGRAPH AT	104B	1022.	41.25	534.	236.	94.	2.93		
HYDROGRAPH AT	62B	1463.	41.25	767.	342.	139.	4.05		
3 COMBINED AT	79C	4252.	41.75	2725.	1218.	495.	14.53		
ROUTED TO	79R	4222.	42.00	2723.	1218.	495.	14.53		
HYDROGRAPH AT	64B	1533.	41.25	829.	376.	155.	4.34		
HYDROGRAPH AT	65B	539.	40.75	221.	94.	38.	1.09		
4 COMBINED AT	80C	7308.	42.00	5242.	2371.	973.	27.85		
DIVERSION TO	0D	6500.	42.00	4666.	1965.	767.	27.85		
HYDROGRAPH AT	DO2	808.	42.00	576.	406.	206.	27.85		
ROUTED TO	80R	741.	45.00	573.	405.	206.	27.85		
HYDROGRAPH AT	66B	1238.	41.75	789.	352.	141.	6.04		
2 COMBINED AT	57C	1647.	42.00	1311.	756.	347.	33.89		
ROUTED TO	57R	1550.	44.25	1295.	755.	347.	33.89		
HYDROGRAPH AT	74B	548.	41.75	340.	152.	61.	2.49		
2 COMBINED AT	86C	1795.	44.25	1522.	903.	408.	36.39		
ROUTED TO	86R	1745.	45.25	1515.	903.	408.	36.39		
HYDROGRAPH AT	75B	1054.	41.25	560.	241.	95.	3.79		
2 COMBINED AT	83C	2002.	45.25	1853.	1129.	504.	40.18		
ROUTED TO	83R	1995.	45.50	1850.	1129.	504.	40.18		
HYDROGRAPH AT	361B	988.	41.50	570.	250.	99.	4.05		

```
+ ROUTED TO
                87R      844.  43.00      562.      249.      99.     4.05
+ HYDROGRAPH AT
               413B      504.  41.00      251.      106.      42.     1.68
+ 2 COMBINED AT
                81C     1047.  42.75      790.      354.     141.     5.72
+ ROUTED TO
                81R      987.  44.00      776.      353.     141.     5.72
+ HYDROGRAPH AT
               108B     1389.  40.75      647.      270.     106.     0.92
+ HYDROGRAPH AT
                72B      204.  40.50       83.       34.      13.     0.49
+ 4 COMBINED AT
                84C     3623.  41.00     3181.     1763.     764.    47.32
+ ROUTED TO
                84R     3623.  41.00     3181.     1763.     764.    47.32
+ HYDROGRAPH AT
               105B     1237.  40.75      514.      217.      86.     1.95
+ HYDROGRAPH AT
               106B     2701.  40.75     1209.      520.     209.     4.53
+ 2 COMBINED AT
                99C     3938.  40.75     1723.      737.     295.     6.48
+ ROUTED TO
                99R     3630.  41.50     1721.      737.     295.     6.48
+ HYDROGRAPH AT
               107B     1819.  40.75      854.      372.     151.     4.33
+ 2 COMBINED AT
                67C     5024.  41.25     2571.     1108.     446.    10.81
+ ROUTED TO
                67R     4866.  42.00     2568.     1107.     446.    10.81
+ HYDROGRAPH AT
                88B     4628.  41.25     2490.     1156.     498.     8.62
+ ROUTED TO
                92R     4383.  42.50     2485.     1155.     498.     8.62
+ HYDROGRAPH AT
                89B     3206.  41.75     1948.      906.     378.     7.52
+ HYDROGRAPH AT
                28B     3227.  41.50     1842.      837.     342.     7.25
+ 3 COMBINED AT
                59C     9748.  42.00     6256.     2898.    1218.    23.38
+ ROUTED TO
                59R     9719.  42.25     6255.     2897.    1218.    23.38
+ HYDROGRAPH AT
                33B     3571.  41.25     1945.      877.     359.     7.65
+ 2 COMBINED AT
                61C    12312.  42.00     8176.     3772.    1576.    31.03
+ ROUTED TO
                61R    12302.  42.00     8173.     3771.    1576.    31.03
+ HYDROGRAPH AT
                36B     3081.  41.25     1632.      742.     311.     5.61
+ 2 COMBINED AT
                63C    14505.  41.75     9773.     4508.    1887.    36.64
+ ROUTED TO
                63R    14436.  42.25     9767.     4507.    1887.    36.64
+ HYDROGRAPH AT
               411B     2704.  41.00     1364.      611.     252.     5.05
+ HYDROGRAPH AT
                43B     2741.  41.00     1309.      570.     229.     4.99
  3 COMBINED AT
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+	68C	17579.	41.75	12347.	5673.	2369.	46.68
+ ROUTED TO	68R	17550.	42.00	12344.	5673.	2369.	46.68
+ HYDROGRAPH AT	86B	1762.	41.00	901.	413.	178.	4.34
+ HYDROGRAPH AT	291B	3552.	41.00	1827.	834.	356.	8.89
+ 4 COMBINED AT	91C	26002.	41.75	17553.	8008.	3348.	70.71
+ ROUTED TO	91R	25864.	42.00	17543.	8007.	3348.	70.71
+ HYDROGRAPH AT	87B	2296.	41.00	1206.	528.	215.	7.55
+ 2 COMBINED AT	72C	27567.	41.75	18722.	8533.	3563.	78.26
+ ROUTED TO	72R	27478.	42.00	18717.	8532.	3563.	78.26
+ HYDROGRAPH AT	288B	2304.	41.25	1238.	545.	222.	7.80
+ 2 COMBINED AT	78C	29146.	41.75	19927.	9075.	3785.	86.06
+ ROUTED TO	78R	29139.	42.00	19924.	9075.	3785.	86.06
+ HYDROGRAPH AT	60B	1889.	41.25	1017.	449.	183.	6.40
+ 2 COMBINED AT	77C	30508.	42.00	20919.	9522.	3967.	92.46
+ ROUTED TO	77R	30348.	42.00	20902.	9521.	3967.	92.46
+ HYDROGRAPH AT	90B	2636.	40.75	1222.	532.	216.	4.52
+ ROUTED TO	93R	2373.	42.00	1218.	531.	216.	4.52
+ HYDROGRAPH AT	57B	1422.	40.75	653.	286.	118.	2.35
+ ROUTED TO	76R	1289.	41.75	651.	286.	118.	2.35
+ HYDROGRAPH AT	91B	968.	40.75	422.	189.	85.	1.89
+ HYDROGRAPH AT	412B	2234.	41.00	1102.	499.	213.	5.29
+ 4 COMBINED AT	94C	5432.	41.75	3365.	1500.	631.	14.04
+ ROUTED TO	94R	5394.	42.00	3363.	1500.	631.	14.04
+ HYDROGRAPH AT	289B	4740.	41.00	2316.	1036.	432.	8.33
+ HYDROGRAPH AT	19B	3026.	41.00	1503.	676.	283.	5.41
+ 2 COMBINED AT	51C	7767.	41.00	3819.	1712.	716.	13.75
+ ROUTED TO	51R	7487.	41.50	3816.	1712.	716.	13.75
+ HYDROGRAPH AT	290B	1192.	40.75	548.	245.	105.	2.55
+ HYDROGRAPH AT	98B	1456.	41.00	704.	317.	134.	3.37
+ 4 COMBINED AT	95C	14523.	41.25	8412.	3769.	1586.	33.71

+	ROUTED TO	95R	14472.	41.50	8407.	3769.	1586.	33.71
+	HYDROGRAPH AT	54B	1603.	41.25	842.	381.	159.	4.26
+	HYDROGRAPH AT	97B	1063.	41.00	508.	225.	93.	2.51
+	3 COMBINED AT	73C	16745.	41.50	9751.	4374.	1839.	40.48
+	ROUTED TO	73R	16493.	41.50	9746.	4374.	1839.	40.48
+	HYDROGRAPH AT	30B	7324.	40.75	3344.	1491.	648.	9.71
+	ROUTED TO	42R	7248.	41.00	3343.	1491.	648.	9.71
+	HYDROGRAPH AT	11B	6565.	40.75	2993.	1326.	552.	10.08
+	2 COMBINED AT	45C	13615.	41.00	6335.	2817.	1200.	19.80
+	ROUTED TO	45R	13519.	41.25	6334.	2816.	1200.	19.80
+	HYDROGRAPH AT	409B	3422.	41.00	1611.	692.	272.	6.06
+	2 COMBINED AT	46C	16561.	41.25	7945.	3508.	1473.	25.85
+	ROUTED TO	46R	16517.	41.50	7944.	3508.	1473.	25.85
+	HYDROGRAPH AT	100B	3489.	41.00	1732.	785.	335.	6.10
+	HYDROGRAPH AT	410B	5637.	41.00	2780.	1235.	506.	10.35
+	3 COMBINED AT	97C	24789.	41.25	12452.	5526.	2313.	42.31
+	ROUTED TO	97R	24537.	41.50	12446.	5525.	2313.	42.31
+	HYDROGRAPH AT	102B	3143.	40.75	1389.	605.	249.	6.75
+	2 COMBINED AT	96C	26435.	41.50	13823.	6127.	2562.	49.05
+	ROUTED TO	96R	26091.	41.50	13817.	6127.	2562.	49.05
+	HYDROGRAPH AT	99B	1493.	40.75	705.	311.	129.	3.46
+	HYDROGRAPH AT	13B	1260.	41.00	617.	276.	114.	3.06
+	3 COMBINED AT	48C	28173.	41.50	15130.	6713.	2806.	55.57
+	ROUTED TO	48R	27920.	41.75	15128.	6711.	2806.	55.57
+	HYDROGRAPH AT	58B	2288.	40.75	1036.	453.	186.	2.90
+	HYDROGRAPH AT	25B	939.	40.75	435.	189.	77.	2.20
+	4 COMBINED AT	55C	46153.	41.75	26319.	11723.	4907.	101.15
+	ROUTED TO	55R	46118.	41.75	26313.	11722.	4907.	101.15
+	HYDROGRAPH AT	82B	1389.	41.50	806.	359.	146.	5.37
+	HYDROGRAPH AT	83B	1262.	40.75	565.	244.	99.	2.84

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                4 COMBINED AT
+                         0C    77535.  41.75    48372.    21804.    9119.    201.82
                ROUTED TO
+                        90R        0.   0.25        0.        0.       0.    201.82
+                                                                                          156.16      65.00
                HYDROGRAPH AT
+                        84B     1497.  41.50       851.      368.     144.      6.25
                HYDROGRAPH AT
+                        DI2     6500.  42.00      4666.     1965.     767.      0.00
                3 COMBINED AT
+                        89C     7887.  41.75      5515.     2333.     912.    208.07
                ROUTED TO
+                        89R     7868.  42.00      5513.     2333.     912.    208.07
                HYDROGRAPH AT
+                       314B      365.  41.25       192.       79.      30.      1.54
                2 COMBINED AT
+                        43C     8121.  42.00      5702.     2412.     942.    209.61
                ROUTED TO
+                        43R     8066.  42.50      5696.     2412.     942.    209.61
                HYDROGRAPH AT
+                        81B      716.  41.50       422.      184.      72.      3.18
                2 COMBINED AT
+                        56C     8586.  42.25      6107.     2596.    1014.    212.79
                ROUTED TO
+                        56R     8533.  42.75      6099.     2595.    1014.    212.79
                HYDROGRAPH AT
+                       360B      927.  41.50       537.      235.      93.      3.85
                2 COMBINED AT
+                        88C     9098.  42.75      6602.     2830.    1107.    216.64
                ROUTED TO
+                        88R     9065.  43.00      6595.     2829.    1107.    216.64
                HYDROGRAPH AT
+                        79B      227.  40.75       100.       41.      16.      0.65
                2 COMBINED AT
+                        82C     9131.  43.00      6675.     2870.    1123.    217.29
                ROUTED TO
+                        82R     9100.  43.25      6672.     2870.    1123.    217.29
                HYDROGRAPH AT
+                       109B      512.  41.00       247.      104.      41.      1.62
                2 COMBINED AT
+                       100C     9272.  43.00      6867.     2971.    1164.    218.92
                ROUTED TO
+                       100R     9272.  43.00      6867.     2971.    1164.    218.92

*** NORMAL END OF HEC-1 ***
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Appendix H- RUNOFF SUMMARY, Simulation 3
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

	OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
+	HYDROGRAPH AT	20B	1668.	41.00	796.	348.	141.	4.07		
+	ROUTED TO	52R	1495.	42.25	793.	348.	141.	4.07		
+	HYDROGRAPH AT	24B	1398.	41.25	752.	343.	144.	3.83		
+	2 COMBINED AT	54C	2427.	42.00	1535.	690.	285.	7.90		
+	ROUTED TO	54R	2340.	43.00	1530.	689.	285.	7.90		
+	HYDROGRAPH AT	103B	2847.	41.00	1447.	643.	262.	7.55		
+	ROUTED TO	98R	2605.	42.25	1441.	642.	262.	7.55		
+	HYDROGRAPH AT	104B	1022.	41.25	534.	236.	94.	2.93		
+	HYDROGRAPH AT	62B	1463.	41.25	767.	342.	139.	4.05		
+	3 COMBINED AT	79C	4252.	41.75	2725.	1218.	495.	14.53		
+	ROUTED TO	79R	4222.	42.00	2723.	1218.	495.	14.53		
+	HYDROGRAPH AT	64B	1533.	41.25	829.	376.	155.	4.34		
+	HYDROGRAPH AT	65B	539.	40.75	221.	94.	38.	1.09		
+	4 COMBINED AT	80C	7308.	42.00	5242.	2371.	973.	27.85		
+	DIVERSION TO	0D	6500.	42.00	4666.	1965.	767.	27.85		
+	HYDROGRAPH AT	DO2	808.	42.00	576.	406.	206.	27.85		
+	ROUTED TO	80R	741.	45.00	573.	405.	206.	27.85		
+	HYDROGRAPH AT	66B	1238.	41.75	789.	352.	141.	6.04		
+	2 COMBINED AT	57C	1647.	42.00	1311.	756.	347.	33.89		
+	ROUTED TO	57R	1550.	44.25	1295.	755.	347.	33.89		
+	HYDROGRAPH AT	74B	548.	41.75	340.	152.	61.	2.49		
+	2 COMBINED AT	86C	1795.	44.25	1522.	903.	408.	36.39		
+	ROUTED TO	86R	1745.	45.25	1515.	903.	408.	36.39		
+	HYDROGRAPH AT	75B	1054.	41.25	560.	241.	95.	3.79		
+	2 COMBINED AT	83C	2002.	45.25	1853.	1129.	504.	40.18		
+	ROUTED TO	83R	1995.	45.50	1850.	1129.	504.	40.18		
+	HYDROGRAPH AT	361B	988.	41.50	570.	250.	99.	4.05		

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                    ROUTED TO
+                   87R      844.   43.00      562.      249.      99.      4.05
                    HYDROGRAPH AT
+                   413B     504.   41.00      251.      106.      42.      1.68
                    2 COMBINED AT
+                   81C     1047.   42.75      790.      354.     141.      5.72
                    ROUTED TO
+                   81R      987.   44.00      776.      353.     141.      5.72
                    HYDROGRAPH AT
+                   108B    1389.   40.75      647.      270.     106.      0.92
                    HYDROGRAPH AT
+                   72B      204.   40.50       83.       34.      13.      0.49
                    4 COMBINED AT
+                   84C     3623.   41.00     3181.     1763.     764.     47.32
                    ROUTED TO
+                   84R     3623.   41.00     3181.     1763.     764.     47.32
                    HYDROGRAPH AT
+                   105B    1237.   40.75      514.      217.      86.      1.95
                    HYDROGRAPH AT
+                   106B    2701.   40.75     1209.      520.     209.      4.53
                    2 COMBINED AT
+                   99C     3938.   40.75     1723.      737.     295.      6.48
                    ROUTED TO
+                   99R     3630.   41.50     1721.      737.     295.      6.48
                    HYDROGRAPH AT
+                   107B    1819.   40.75      854.      372.     151.      4.33
                    2 COMBINED AT
+                   67C     5024.   41.25     2571.     1108.     446.     10.81
                    ROUTED TO
+                   67R     4866.   42.00     2568.     1107.     446.     10.81
                    HYDROGRAPH AT
+                   88B     4628.   41.25     2490.     1156.     498.      8.62
                    ROUTED TO
+                   92R     4383.   42.50     2485.     1155.     498.      8.62
                    HYDROGRAPH AT
+                   89B     3206.   41.75     1948.      906.     378.      7.52
                    HYDROGRAPH AT
+                   28B     3227.   41.50     1842.      837.     342.      7.25
                    3 COMBINED AT
+                   59C     9748.   42.00     6256.     2898.    1218.     23.38
                    ROUTED TO
+                   59R     9719.   42.25     6255.     2897.    1218.     23.38
                    HYDROGRAPH AT
+                   33B     3571.   41.25     1945.      877.     359.      7.65
                    2 COMBINED AT
+                   61C    12312.   42.00     8176.     3772.    1576.     31.03
                    ROUTED TO
+                   61R    12302.   42.00     8173.     3771.    1576.     31.03
                    HYDROGRAPH AT
+                   36B     3081.   41.25     1632.      742.     311.      5.61
                    2 COMBINED AT
+                   63C    14505.   41.75     9773.     4508.    1887.     36.64
                    ROUTED TO
+                   63R    14436.   42.25     9767.     4507.    1887.     36.64
                    HYDROGRAPH AT
+                   411B    2704.   41.00     1364.      611.     252.      5.05
                    HYDROGRAPH AT
+                   43B     2741.   41.00     1309.      570.     229.      4.99
                    3 COMBINED AT
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+		68C	17579.	41.75	12347.	5673.	2369.	46.68
	ROUTED TO							
+		68R	17550.	42.00	12344.	5673.	2369.	46.68
	HYDROGRAPH AT							
+		86B	1762.	41.00	901.	413.	178.	4.34
	HYDROGRAPH AT							
+		291B	3552.	41.00	1827.	834.	356.	8.89
	4 COMBINED AT							
+		91C	26002.	41.75	17553.	8008.	3348.	70.71
	ROUTED TO							
+		91R	25864.	42.00	17543.	8007.	3348.	70.71
	HYDROGRAPH AT							
+		87B	2296.	41.00	1206.	528.	215.	7.55
	2 COMBINED AT							
+		72C	27567.	41.75	18722.	8533.	3563.	78.26
	ROUTED TO							
+		72R	27478.	42.00	18717.	8532.	3563.	78.26
	HYDROGRAPH AT							
+		288B	2304.	41.25	1238.	545.	222.	7.80
	2 COMBINED AT							
+		78C	29146.	41.75	19927.	9075.	3785.	86.06
	ROUTED TO							
+		78R	29139.	42.00	19924.	9075.	3785.	86.06
	HYDROGRAPH AT							
+		60B	1889.	41.25	1017.	449.	183.	6.40
	2 COMBINED AT							
+		77C	30508.	42.00	20919.	9522.	3967.	92.46
	ROUTED TO							
+		77R	30348.	42.00	20902.	9521.	3967.	92.46
	HYDROGRAPH AT							
+		90B	2636.	40.75	1222.	532.	216.	4.52
	ROUTED TO							
+		93R	2373.	42.00	1218.	531.	216.	4.52
	HYDROGRAPH AT							
+		57B	1422.	40.75	653.	286.	118.	2.35
	ROUTED TO							
+		76R	1289.	41.75	651.	286.	118.	2.35
	HYDROGRAPH AT							
+		91B	968.	40.75	422.	189.	85.	1.89
	HYDROGRAPH AT							
+		412B	2234.	41.00	1102.	499.	213.	5.29
	4 COMBINED AT							
+		94C	5432.	41.75	3365.	1500.	631.	14.04
	ROUTED TO							
+		94R	5394.	42.00	3363.	1500.	631.	14.04
	HYDROGRAPH AT							
+		289B	4740.	41.00	2316.	1036.	432.	8.33
	HYDROGRAPH AT							
+		19B	3026.	41.00	1503.	676.	283.	5.41
	2 COMBINED AT							
+		51C	7767.	41.00	3819.	1712.	716.	13.75
	ROUTED TO							
+		51R	7487.	41.50	3816.	1712.	716.	13.75
	HYDROGRAPH AT							
+		290B	1192.	40.75	548.	245.	105.	2.55
	HYDROGRAPH AT							
+		98B	1456.	41.00	704.	317.	134.	3.37
	4 COMBINED AT							
+		95C	14523.	41.25	8412.	3769.	1586.	33.71

+	ROUTED TO	95R	14472.	41.50	8407.	3769.	1586.	33.71
+	HYDROGRAPH AT	54B	1603.	41.25	842.	381.	159.	4.26
+	HYDROGRAPH AT	97B	1063.	41.00	508.	225.	93.	2.51
+	3 COMBINED AT	73C	16745.	41.50	9751.	4374.	1839.	40.48
+	ROUTED TO	73R	16493.	41.50	9746.	4374.	1839.	40.48
+	HYDROGRAPH AT	30B	7324.	40.75	3344.	1491.	648.	9.71
+	ROUTED TO	42R	7248.	41.00	3343.	1491.	648.	9.71
+	HYDROGRAPH AT	11B	6565.	40.75	2993.	1326.	552.	10.08
+	2 COMBINED AT	45C	13615.	41.00	6335.	2817.	1200.	19.80
+	ROUTED TO	45R	13519.	41.25	6334.	2816.	1200.	19.80
+	HYDROGRAPH AT	409B	3422.	41.00	1611.	692.	272.	6.06
+	2 COMBINED AT	46C	16561.	41.25	7945.	3508.	1473.	25.85
+	ROUTED TO	46R	16517.	41.50	7944.	3508.	1473.	25.85
+	HYDROGRAPH AT	100B	3489.	41.00	1732.	785.	335.	6.10
+	HYDROGRAPH AT	410B	5637.	41.00	2780.	1235.	506.	10.35
+	3 COMBINED AT	97C	24789.	41.25	12452.	5526.	2313.	42.31
+	ROUTED TO	97R	24537.	41.50	12446.	5525.	2313.	42.31
+	HYDROGRAPH AT	102B	3143.	40.75	1389.	605.	249.	6.75
+	2 COMBINED AT	96C	26435.	41.50	13823.	6127.	2562.	49.05
+	ROUTED TO	96R	26091.	41.50	13817.	6127.	2562.	49.05
+	HYDROGRAPH AT	99B	1493.	40.75	705.	311.	129.	3.46
+	HYDROGRAPH AT	13B	1260.	41.00	617.	276.	114.	3.06
+	3 COMBINED AT	48C	28173.	41.50	15130.	6713.	2806.	55.57
+	ROUTED TO	48R	27920.	41.75	15128.	6711.	2806.	55.57
+	HYDROGRAPH AT	58B	2288.	40.75	1036.	453.	186.	2.90
+	HYDROGRAPH AT	25B	939.	40.75	435.	189.	77.	2.20
+	4 COMBINED AT	55C	46153.	41.75	26319.	11723.	4907.	101.15
+	ROUTED TO	55R	46118.	41.75	26313.	11722.	4907.	101.15
+	HYDROGRAPH AT	82B	1389.	41.50	806.	359.	146.	5.37
+	HYDROGRAPH AT	83B	1262.	40.75	565.	244.	99.	2.84

+	4 COMBINED AT	0C	77535.	41.75	48372.	21804.	9119.	201.82	
+	ROUTED TO	90R	0.	0.25	0.	0.	0.	201.82	
+									156.16 65.00
+	HYDROGRAPH AT	84B	1497.	41.50	851.	368.	144.	6.25	
+	HYDROGRAPH AT	DI2	6500.	42.00	4666.	1965.	767.	0.00	
+	3 COMBINED AT	89C	7887.	41.75	5515.	2333.	912.	208.07	
+	ROUTED TO	89R	7868.	42.00	5513.	2333.	912.	208.07	
+	HYDROGRAPH AT	314B	365.	41.25	192.	79.	30.	1.54	
+	2 COMBINED AT	43C	8121.	42.00	5702.	2412.	942.	209.61	
+	DIVERSION TO	D3	8118.	41.50	5700.	2412.	942.	209.61	
+	HYDROGRAPH AT	DO3	3.	41.50	2.	0.	0.	209.61	
+	ROUTED TO	43R	0.	48.50	0.	0.	0.	209.61	
+	HYDROGRAPH AT	81B	716.	41.50	422.	184.	72.	3.18	
+	2 COMBINED AT	56C	716.	41.50	422.	184.	72.	212.79	
+	ROUTED TO	56R	555.	44.50	406.	183.	72.	212.79	
+	HYDROGRAPH AT	360B	927.	41.50	537.	235.	93.	3.85	
+	2 COMBINED AT	88C	1096.	41.50	867.	414.	166.	216.64	
+	ROUTED TO	88R	996.	42.50	854.	413.	166.	216.64	
+	HYDROGRAPH AT	79B	227.	40.75	100.	41.	16.	0.65	
+	2 COMBINED AT	82C	1077.	42.50	916.	453.	182.	217.29	
+	ROUTED TO	82R	1002.	44.00	900.	452.	182.	217.29	
+	HYDROGRAPH AT	109B	512.	41.00	247.	104.	41.	1.62	
+	2 COMBINED AT	100C	1142.	43.75	1023.	549.	222.	218.92	
+	ROUTED TO	100R	1142.	43.75	1023.	549.	222.	218.92	

*** NORMAL END OF HEC-1 ***