FINAL VERSION

Baseline Geomorphic and Hydrologic Conditions

Rancho Mission Viejo: Portions of the San Juan and Western San Mateo Watersheds

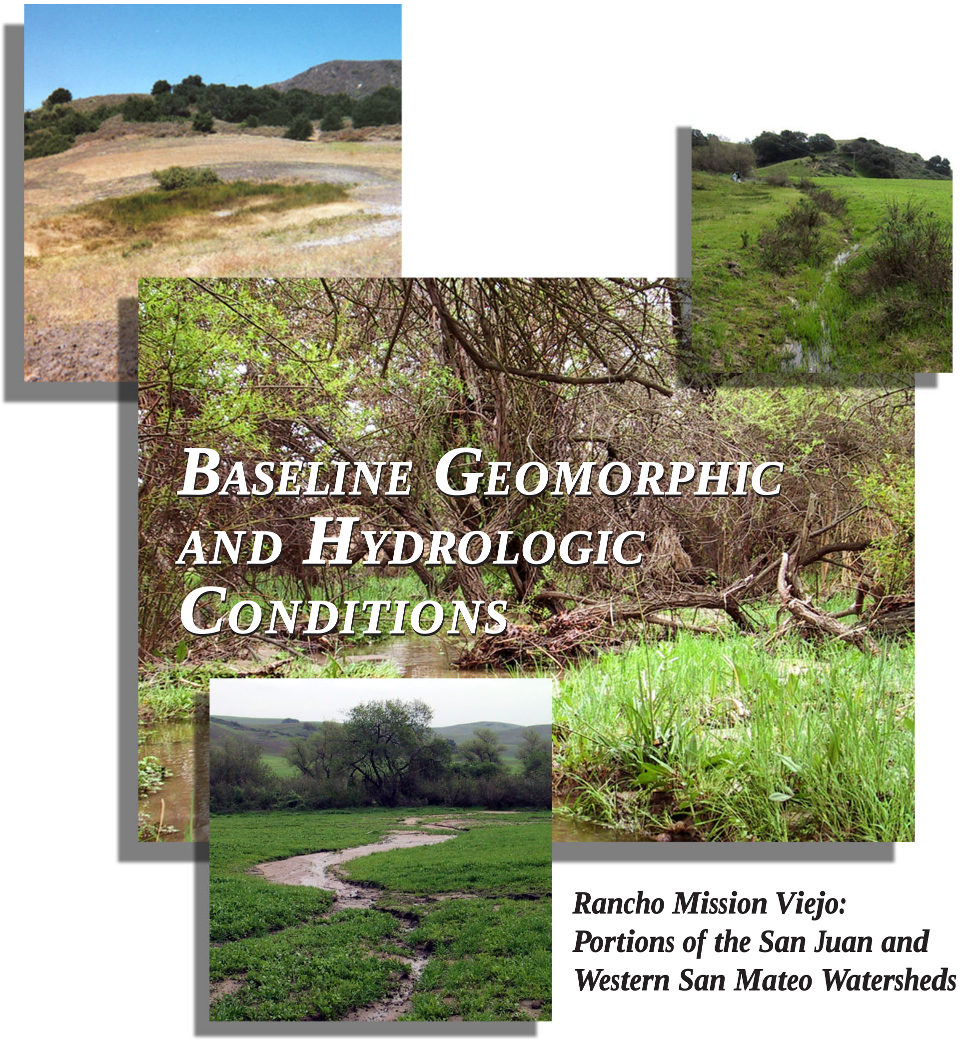
February 2002

PCR

PWA

Balance Hydrologics, Inc.

FINAL VERSION



Baseline Geomorphic and Hydrologic Conditions

Rancho Mission Viejo: Portions of the San Juan and Western San Mateo Watersheds

Prepared For:

Rancho Mission Viejo
28811 Ortega Highway
P.O. Box 9
San Juan Capastrano, California 92693
Tel: 714.240.3363
Contact: Laura Coley Eisenberg
Richard M. Broming

Prepared By:

PCR Services Corporation
One Venture, Suite 150
Irvine, California 92618
Tel: 949.753.7001
Contact: Eric Stein, Dr.Env., Principal Ecologist

PWA, Ltd.
770 Tamalpais Drive, Suite 401
Corte Madera, California 94925

Balance Hydrologics, Inc.
900 Modoc Street
Berkeley, California 94707-2208

February 2002

TABLE OF CONTENTS

Page

EXECUTIVE SUMMARY **ES-1**

1.0 INTRODUCTION **1**
- 1.1 GOALS, OBJECTIVES, AND ORGANIZATION OF REPORT 1
- 1.2 LANDSCAPE PERSPECTIVE IN ASSESSMENT AND PLANNING 4
- 1.3 RELATIONSHIP OF WORK PLAN STUDIES TO WES and CRRL REPORT 5
- 1.4 EXPECTED USE IN SAMP/MSAA, NCCP/HCP, WATER QUALITY, AND LOCAL ENTITLEMENT PROCESSES 6
  - 1.4.1 Clean Water Act Section 404/SAMP and Section 1600/MSAA 6
  - 1.4.2 State and Federal Endangered Species Acts (NCCP and HCP) 7
  - 1.4.3 Clean Water Act/NPDES Program/Porter Cologne/NPS Control 9
  - 1.4.4 Local Entitlement 10

2.0 ASSESSMENT APPROACH AND KEY ASSUMPTIONS **13**
- 2.1 GEOMORPHOLOGY AND TERRAINS 15
- 2.2 HYDROLOGY 15
  - 2.2.1 Stream Network Analysis 17
  - 2.2.2 Rainfall-Runoff Analysis 18
  - 2.2.3 Dry Season Flow Analysis 19
- 2.3 SEDIMENT YIELD AND TRANSPORT 20
- 2.4 WATER QUALITY 21
- 2.5 GROUNDWATER 22
- 2.6 RIPARIAN AND WETLAND HABITATS 23

3.0 OVERVIEW OF SAN JUAN AND SAN MATEO CREEK WATERSHEDS **25**
- 3.1 PHYSICAL SETTING 25
  - 3.1.1 San Juan Creek Watershed 25
  - 3.1.2 San Mateo Creek Watershed 25
- 3.2 GEOMORPHIC SETTING 26
  - 3.2.1 Regional Geology 26
  - 3.2.2 Terrains 28
    - 3.2.2.1 Runoff Patterns of Specific Terrains 28
    - 3.2.2.2 Channel Characteristics of Specific Terrains 30
- 3.3 HISTORIC CONTEXT 31
  - 3.3.1 Natural Processes 32
    - 3.3.1.1 Wet and Dry Cycles 32

TABLE OF CONTENTS (Continued)

Page

3.3.2 Floods 33
3.3.3 Watershed Scale Fires 33
3.3.4 Grazing 35
3.4 HYDROLOGY 36
3.4.1 San Juan Creek Watershed 36
3.4.1.1 Drainage Network 36
3.4.1.2 Infiltration.. 36
3.4.1.3 Storm Event Runoff.. 39
3.4.1.4 Comparisons with Previous Hydrologic Studies 46
3.4.2 San Mateo Creek Watershed 49
3.4.2.1 Drainage Network 49
3.4.2.2 Infiltration.. 50
3.4.2.3 Storm Event Runoff.. 54
3.4.3 Low Flow Conditions 58
3.5 SEDIMENT PROCESSES 59
3.5.1 Sediment Yield 59
3.5.2 Episodicity...69
3.5.3 In-Channel Sediment Transport 70
3.5.3.1 San Juan Watershed.. 71
3.5.3.2 San Mateo Watershed.. 76
3.6 WATER QUALITY..78
3.6.1 Analysis of Existing Water Quality Data for the San Juan Watershed 79
3.6.1.1 Nitrates and Phosphates... 80
3.6.1.2 Zinc 85
3.6.1.3 Total Dissolved Solids... 87
3.6.1.4 Bacteria 89
3.6.2 Analysis of Existing Water Quality Data for the San Mateo Watershed 89
3.7 GROUNDWATER..90
3.8 BIOLOGICAL RESOURCES 94
3.8.1 San Juan Creek Watershed 95
3.8.2 San Mateo Creek Watershed 97

4.0 SUMMARY OF WATERSHED ATTRIBUTES/REGIONAL CONTEXT 99
4.1 GEOMORPHOLOGY AND TERRAINS 99
4.2 SURFACE HYDROLOGY...102
4.3 GROUNDWATER..104
4.4 SEDIMENT PROCESSES 105

TABLE OF CONTENTS (Continued)

Page

4.5 WATER QUALITY 106
4.6 BIOLOGICAL RESOURCES 108

5.0 LAND USES 110
5.1 HISTORIC LAND USE PRACTICES 110
5.2 EXISTING LAND USES....................111
5.3 AREAS AVAILABLE FOR FUTURE LAND USE CHANGES 113

6.0 SUB-BASIN SUMMARY AND CONSIDERATIONS FOR FUTURE LAND USE....115
6.1 SAN JUAN CREEK WATERSHED....................115
6.1.1 Cañada Chiquita 115
6.1.1.1 Overview of Sub-basin Characteristics.................... 115
6.1.1.2 Summary of Sub-Basin Opportunities and Constraints.................... 120
6.1.2 Cañada Gobernadora....................120
6.1.2.1 Overview of Sub-Basin Characteristics.................... 120
6.1.2.2 Summary of Sub-Basin Opportunities and Constraints.................... 124
6.1.3 Verdugo 125
6.1.3.1 Overview of Sub-basin Characteristics.................... 125
6.1.3.2 Summary of Sub-Basin Opportunities and Constraints.................... 128
6.1.4 Central San Juan (including Trampas)....................128
6.1.4.1 Overview of Sub-Basin Characteristics.................... 128
6.1.4.2 Summary of Sub-Basin Opportunities and Constraints.................... 133
6.2 SAN MATEO CREEK WATERSHED....................134
6.2.1 Gabino 134
6.2.1.1 Overview of Sub-basin Characteristics.................... 134
6.2.1.2 Summary of Sub-Basin Opportunities and Constraints.................... 138
6.2.2 La Paz....................139
6.2.2.1 Overview of Sub-Basin Characteristics.................... 139
6.2.2.2 Summary of Sub-Basin Opportunities and Constraints.................... 140
6.2.3 Cristianitos....................141
6.2.3.1 Overview of Sub-basin Characteristics.................... 141
6.2.3.2 Summary of Sub-Basin Opportunities and Constraints.................... 144
6.2.4 Talega 145
6.2.4.1 Overview of Sub-Basin Characteristics.................... 145
6.2.4.2 Summary of Sub-Basin Opportunities and Constraints.................... 147

TABLE OF CONTENTS (Continued)

Page

7.0 MAKING USE OF THE BASELINE CONDITIONS ANALYSIS 148
- 7.1 APPLICATION OF THE TERRAINS ANALYSIS 148
- 7.2 APPLICATION OF THE HYDROLOGIC ANALYSIS 149
- 7.3 APPLICATION OF THE SEDIMENT ANALYSIS..150
- 7.4 APPLICATION OF WATER QUALITY STUDIES 151
- 7.5 APPLICATION OF THE GROUNDWATER ANALYSIS.......................................151
- 7.6 APPLICATION OF THE BIOLOGICAL RESOURCES ANALYSIS 152

8.0 REFERENCES...153

APPENDIX A: BASELINE HYDROLOGIC CONDITIONS

APPENDIX B: BASELINE WATER QUALITY CONDITIONS AND POLLUTANT TRANSPORT MECHANISMS

APPENDIX C: GROUNDWATER SUSTANING LANDSCAPE-SCALE WETLAND FUNCTIONS

Note: All technical appendices are included as separately bounded documents.

LIST OF FIGURES

Page

Figure 1 Study Area Boundary..2
Figure 2 Application of Technical Studies to Various Scales of Analysis 12
Figure 3 Relationship Between Technical Studies..14
Figure 4 Surficial Geology of Study Areas 27
Figure 5 Landscape Scale Terrains and Shallow Substrate Erodibility....................................29
Figure 6 Recent Fire History for Orange County...34
Figure 7 Distribution of Hydrologic Soil Groups for San Juan Watershed 38
Figure 8 Distribution of SCS Curve Numbers for San Juan Watershed 40
Figure 9 2-Year Event Hydrographs for San Juan Watershed 42
Figure 10 10-Year Event Hydrographs for San Juan Watershed 43
Figure 11 100-Year Event Hydrographs for San Juan Watershed 44
Figure 12 Peak Discharge and Event Runoff Volume for Selected Sub-Basins, Parts A and B .47
Figure 13 Peak Discharge per Unit Area and Event Runoff Volume per Unit Area for Selected Sub-Basins, Parts A and B...48
Figure 14 Distribution of Hydrologic Soil Groups for San Mateo Watershed 51
Figure 15 Distribution of SCS Curve Numbers for San Mateo Watershed 52
Figure 16 2-Year Event Hydrographs for San Mateo Watershed 55
Figure 17 10-Year Event Hydrographs for San Mateo Watershed 56
Figure 18 100-Year Event Hydrographs for San Mateo Watershed 57
Figure 19 Annual Minimum Streamflows vs. Time for Oso Creek..60
Figure 20 Mean Daily Stream Flows for the Month of July vs. Time for Oso Creek.................61
Figure 21 Developed Area vs. Increase in Average Daily Streamflow for Oso Creek................62
Figure 22 Peak 100-Year Sediment Transport Rates for San Juan and San Mateo Watersheds .72
Figure 23 Peak 100-Year Sediment Transport Rate per Unit Area for San Juan and San Mateo Creek Watersheds 73
Figure 24 Sediment Yield for 2-Year, 10-Year, and 100-Year Discharges 74
Figure 25 Sediment Yield per Unit Area for 2-Year, 10-Year, and 100-Year Discharges 75
Figure 26 Suspended Sediment Rating Curve for Streams of the San Juan and San Mateo Watersheds...77
Figure 27 Nitrate Concentrations for San Juan Creek at La Novia, Parts A and B.....................83
Figure 28 Phosphate Concentrations for San Juan Creek at La Novia, Parts A and B................84
Figure 29 Nitrogen/Phosphorus Ratios vs. Discharge for San Juan Creek at La Novia 86
Figure 30 Zinc Concentration for San Juan Creek at La Novia, Parts A and B...........................88
Figure 31 Generalized Effects of Major Terrains on Peak Flow...100
Figure 32 Sub-basin Peak Flow Timing Relative to the Main Stem of San Juan Creek............103
Figure 33 Generalized Land Use and Vegetation for San Juan and San Mateo Watersheds.....112
Figure 34 Riparian Vegetation in Existing Protected Open Space 114
Figure 35 Sub-Basin Watersheds for San Juan and San Mateo 116

LIST OF FIGURES (Continued)

Page

Figure 36 2-Year, 10-Year, and 100-Year Event Hydrographs for Cañada Chiquita 118
Figure 37 2-Year, 10-Year, and 100-Year Event Hydrographs for Cañada Gobernadora.........123
Figure 38 2-Year, 10-Year, and 100-Year Event Hydrographs for Verdugo Canyon...............127
Figure 39 2-Year, 10-Year, and 100-Year Event Hydrographs for Central San Juan Catchments...130
Figure 40 2-Year, 10-Year, and 100-Year Event Hydrographs for Gabino Canyon 136
Figure 41 2-Year, 10-Year, and 100-Year Event Hydrographs for Cristianitos Canyon...........143
Figure 42 2-Year, 10-Year, and 100-Year Event Hydrographs for Talega Canyon 146

LIST OF TABLES

Page

Table 1 Role of Each Technical Project in Completion of Alternatives Analysis 8
Table 2 Orange County Hydrologic Soil Type Descriptions 37
Table 3 San Juan Watershed Physical Characteristics 41
Table 4 Summary of Peak Flows (CFS), San Juan Watershed 45
Table 5 Storm Event Runoff Volumes, San Juan Watershed at the Pacific Ocean...................46
Table 6 Comparison of Estimated 100-Year Discharges (CFS), San Juan Creek Watershed....50
Table 7 San Mateo Watershed Physical Characteristics 53
Table 8 Summary of Peak Flows (CFS), San Mateo Watershed...58
Table 9 Storm Event Runoff Volumes, San Mateo Watershed at the Pacific Ocean.................58
Table 10 Base Sediment Yields And Particle Size Distributions, San Juan Creek Watershed....65
Table 11 Base Sediment Yields and Particle Size Distributions, San Mateo Creek Watershed ..67
Table 12 Comparison of Sediment Yield Estimates..68
Table 13 Summary Of Water Quality Data Measured by the Orange County Public Facilities and Resources Department as Function of Antecedent Rainfall, WY 1991 To WY 1999 81
Table 14 Designated Beneficial Uses for San Juan and San Mateo Creek Watersheds per San Diego Basin Plan Watershed..91
Table 15 California RWQCB Region 9 and CTR Standards and Objectives Applicable to the Quality of Water in the SAMP Study Area..92
Table 16 Sensitive Species in the San Juan Creek Watershed 96
Table 17 Sensitive Species in the Upper San Mateo Creek Watershed 98

EXECUTIVE SUMMARY

Federal, State, and local agencies, in cooperation with local landowners are currently engaged in a comprehensive land use and natural resource planning process for the San Juan Creek and western San Mateo Creek watersheds and other adjacent areas located within southern Orange County. This comprehensive planning process includes preparation of a Special Area Management Plan/Master Streambed Alteration Agreement (SAMP/MSAA), a Natural Communities Conservation Plan/Habitat Conservation Plan (NCCP/HCP), a Comprehensive Point and Non-point Source (NPS) Pollution Control Program, and a local entitlement process involving amendments to the County of Orange General Plan and Zoning Ordinance. This comprehensive planning process is intended to coordinate protection of riparian systems and upland habitats, and enable them to be managed over the long-term as part of a single integrated implementation program.

Numerous technical studies and surveys have been conducted during the past several years to support this comprehensive planning effort. Significant data has been gathered by the Corps of Engineers, Department of Fish and Game and the U.S. Fish and Wildlife Service in support of the SAMP/MSAA and NCCP/HCP processes, respectively. The Corps of Engineers has conducted a landscape scale delineation and functional assessment of the streams and riparian zones within the study area. The Corps studies have identified and mapped the extent of potential Corps (and Department of Fish and Game) jurisdiction and ranked the streams in terms of their overall hydrologic, biologic, and biogeochemical integrity. The Corps assessed integrity by dividing the riparian ecosystems into assessment units or "riparian reaches" and assessing each riparian reach using a suite of indicators of ecosystem integrity. Studies conducted for the NCCP/HCP program have mapped the general vegetation communities in the study area and identified areas occupied by sensitive species.

This report summarizes the results of a series of technical baseline studies conducted by Philip Williams and Associates (PWA), Balance Hydrologics (BH), and PCR Services Corporation (PCR) over the past two years. The studies summarized in this report analyze the physical processes and the underlying geomorphology that contribute to the ecologic conditions of the riparian resources in the study area. This report provides insight into the dynamics of the riparian ecosystems and is intended to supplement and complement the information gathered by the landscape scale delineation and functional assessments completed by the Corps of Engineers for the SAMP/MSAA. The report will also supplement the sensitive species and habitats surveys conducted by Dudek & Associates for the NCCP/HCP by providing an understanding of distinctive characteristics and stream systems at a sub-watershed, as well as watershed level. The relationships between hydrologic and geomorphic processes and habitat/lifecycle requirements of sensitive species are considered, but not explicitly addressed in the report, and these relationships will be addressed in detail in a subsequent document focusing on listed aquatic species both within the study area and immediately downstream of the study area.

As indicated above, the focus on this report is on understanding the manner in which the terrains found in the study area affect fundamental processes that alter and shape the study area creek systems and how these terrains respond to different storm events. In order to understand how proposed future changes in land use may result in potential changes in hydrology, it is essential to understand how the relative influence of terrains, soil hydrogroups and land use type on infiltration conditions and runoff can vary depending upon storm event magnitude and also to understand how sub-watersheds, and portions of sub-watersheds, may respond differently to the same storm event. In this way, the Baseline Report analytical approaches are intended to complement the WES studies, so that, taken together, the WES analyses and the methodologies presented in the baseline Report provide a multi-dimensional basis for assessing existing hydrologic and geomorphic conditions throughout the study area, differences in the way different terrains respond to the same hydrologic events, and the effects of proposed changes in land use on hydrologic functions and values at a variety of geographic scales.

The analyses summarized in this report address physical processes and conditions at the watershed and sub-basin scales because this scale of analysis encompasses natural hydrologic, terrains and vegetation features that shape the specific creeks in the study area. The use of the watershed and sub-basin helps create an analytic framework within natural processes can be better understood. Data in this report include direct measurements of processes such as stream network and runoff analyses that can be used to complement the indirect reach indicators selected by WES as part of their functional assessment. It should be understood by the reader that the use of sub-basin as a geographic unit of analysis does not result in the averaging of characteristics across distinctly different portions of a sub-basin. Instead, the use of the sub-basin as the geographic unit of analysis helps provide a scale of assessment that encompasses the distinctive natural hydrologic, terrains and vegetation features within a particular sub-basin that often result in quite different responses to storm events under existing conditions and different responses o future proposed changes in land use.

Thus, the purposes of this report are to: (1) characterize the baseline hydrologic and geomorphic conditions and processes within the study area; (2) identify development and resource management opportunities and constraints associated with hydrologic and geomorphic processes and ecologic conditions at the watershed/landscape scale; and (3) identify key considerations for assessing the potential impacts (including secondary and cumulative impacts) of various development alternatives on hydrologic and geomorphic processes and ecologic conditions. The emphasis throughout this report is to identify and evaluate opportunities at this broader scale which are usually not effectively addressed when planning occurs only at the individual project scale. To achieve these broader purposes, the following analyses were conducted:

Geomorphology and Terrains: The existing and historic land use/land cover, geology, and soils were investigated, mapped, and categorized. This information was used to develop recharge, runoff, and sediment generation characteristics for each sub-basin.

Hydrology: The existing 2-year, 10-year, and 100-year discharges were modeled for each sub-basin and for the overall watersheds. This information was used to identify key considerations relative to the timing and magnitude of flow for each sub-basin.

Sediment Yield and Transport: Expected sediment yields were estimated based on the results of the geomorphology and terrains analysis and a variety of past studies of Southern California watersheds. Sediment transport rates were modeled on a reach-basis and were integrated at the sub-basin and watershed scales. This information was used to identify key sediment production areas, as well as areas of deposition, scour, and key transport reaches. The effect of episodic events on stream stability was also analyzed.

Water Quality: Five existing water quality data sets were analyzed to assess the potential roles that various geomorphic or biologic features of the landscape may be playing in the control and mobilization of key water quality constituents. In addition, an ongoing water quality monitoring program has been initiated to supplement the existing data and provide more detailed baseline information for the San Juan and western San Mateo watersheds.

Shallow Groundwater: Areas where shallow sub-surface water may be important to the integrity of existing aquatic resources. The results of the geomorphology and terrains and the hydrology analyses were used to infer general groundwater flow directions and key recharge areas. This study did not include detailed modeling of groundwater movement or analysis of groundwater quality.

The physical processes analyzed are those that strongly influence the conditions of the riparian ecosystems. As such, the information produced by these studies will help provide an understanding of the long-term dynamic cycles that should be considered during the analysis of future land use alternatives.

The report is organized into seven sections:

<ins>Section 1</ins> introduces the purposes of the report and provides a framework for the landscape-scale perspective taken in the technical studies. Differences between landscape and site-specific scales of analysis are highlighted and the expected uses of the technical studies are discussed.

<ins>Section 2</ins> provides information on the general approach and assumptions used for each technical study. Each technical study used a combination of existing data and new

modeling/analysis to provide information on existing conditions in the study area. The approach used for each study was adjusted to accommodate the various scales of analysis (i.e., site specific, sub-basin, and overall watershed), but always included landscape-scale analysis.

Section 3 contains the results of the watershed-scale analyses and provides a discussion of the overall physical, chemical, and biological processes for the study area. The results are organized by watershed (i.e., San Juan and San Mateo) and by topic (i.e., hydrology, geomorphology, sediment transport, water quality, groundwater).

Section 4 summarizes the attributes of the watersheds that are most important from a land use planning perspective. The intent of this Section is to focus the results presented in Section 3 on those issues that are most critical for consideration during the alternatives analysis.

Section 5 contains a discussion of the effect of historic and present land uses on the watersheds. This section emphasizes analysis of areas remaining that are not already developed, entitled, or dedicated as open space. These remaining undeveloped and uncommitted areas are owned primarily by Rancho Mission Viejo (RMV) and are being considered for future land use changes as part of the County's General Plan and Zoning amendment process for the RMV property that is proceeding concurrent with the SAMP/MSAA and NCCP/HCP.

Section 6 provides summaries of the processes occurring in each major sub-basin in the study area and discusses how those processes relate to overall watershed condition. This section also identifies major opportunities and constraints for each sub-basin that should be considered during the alternatives analysis.

Section 7 preliminarily discusses how the analyses contained in this baseline report may be used for subsequent phases of the SAMP/MSAA, NCCP/HCP, water quality management planning, and local entitlement processes. Examples of how each technical study can be applied to each planning/entitlement process are also discussed.

This report is intended to provide a cohesive summary of the various baseline technical studies. The technical studies that are summarized in the report are attached to this report as stand-alone technical appendices.

The models and information summarized in this document will be used to help formulate and analyze alternatives, mitigation measures, and management recommendations. During the next phases of the coordinated planning process, the results of these technical studies will be used to: (1) analyze the effect of alternative land use scenarios on the physical and biological processes of the study area; (2) develop specific approaches, guidelines, and criteria for project design elements and BMPs that would contribute to minimizing the effects of land use changes by maintaining the existing hydrologic, water-quality, and hydrogeologic functions of the watersheds; (3) identify, where practicable, measures necessary to minimize or mitigate the effects of existing uses within the watersheds; and (4) develop specific elements of the aquatic and upland enhancement, restoration and management programs. In addition, during future phases of the coordinated planning process, the results of the landscape-scale analysis will be translated to an area-specific scale to analyze impacts and formulate specific development resource management recommendations.

1.0 INTRODUCTION

1.1 GOALS, OBJECTIVES, AND ORGANIZATION OF REPORT

This report summarizes the results of a series of technical baseline studies on the existing and historic physical processes and conditions in the San Juan Creek watershed and western 18 $mi.^2$ of the San Mateo Creek watershed (upstream and northwest of Camp Pendleton). The technical studies summarized in this baseline conditions report were conducted by Philip Williams and Associates (PWA), Balance Hydrologics (BH), and PCR Services Corporation (PCR), and are intended to complement studies prepared by the U.S. Army Corps of Engineers on the riparian systems in the same study area. Information from studies conducted by Dudek & Associates (Dudek) has also been used to identify preliminary biological considerations.

The studies summarized in this report were conducted in support of the San Juan/San Mateo Special Area Management Plan/Master Streambed Alteration Agreement (SAMP/MSAA), Southern Subregion Natural Communities Conservation Plan/Habitat Conservation Plan (NCCP/HCP), and Comprehensive Point and Non-point Source (NPS) Pollution Control Program. The boundaries of the study area generally coincide with those of the San Juan/San Mateo SAMP/MSAA and southern subregion NCCP/HCP as shown in Figure 1 on page 2. However, as discussed in Sections 5 and 6, the discussion of opportunities and constraints associated with potential changes in future land use focuses on the 25,000 acres owned by Rancho Mission Viejo that are being considered for future land use changes.

The approach, methodology, and inter-relationships between the studies, have been described in detail in the *Work Plan for Hydrology and Geomorphology Studies* (PCR, 2000b) (Work Plan). The specific goals of this Baseline Conditions report are:

1. Characterize the baseline hydrologic and geomorphic conditions and processes of the watersheds.

2. Identify development and resource management opportunities and constraints associated with hydrologic and geomorphic processes and ecologic conditions. The goal is to provide information that may be used in the analysis of the compatibility of various land use scenarios with physical processes and to ensure that proposed development alternatives provide for protection of major wetlands and riparian areas, maintain aquatic resource functions, and address sensitive species needs in terms of hydrology, geomorphology, and water quality.

Figure 1 Study Area Boundary

3. Identify key factors and considerations for assessing and mitigating the potential impacts (including secondary and cumulative impacts) of various development alternatives on hydrologic and geomorphic processes at the watershed and sub-watershed scales.

Recommendations resulting from the technical studies may include alternative locations or configurations of proposed future land uses or design features to help protect the integrity of aquatic resources.

As noted previously, this report is intended to complement studies previously completed by the U.S. Army Corps of Engineers for the SAMP (see Section 1.3) and by Dudek & Associates for the NCCP. This report does not assess biological baseline conditions, but does consider known biological constraints and opportunities. Similarly, the relationship between hydrologic and geomorphic processes and habitat and/or lifecycle requirements for aquatic species is not addressed in this report, but will be the focus of a subsequent effort.

Analysis and planning for an approximately 25,000-acre area with a variety of terrains and processes needs to address the particular habitat and hydrological/geomorphic characteristics of sub-watersheds within the larger planning region. Accordingly, this report provides information at both the watershed and sub-basin scales. The general approach and assumptions used for each analysis are described in Section 2. A discussion of the overall physical, and chemical processes and biologic conditions for the San Juan and San Mateo watersheds in Section 3. Section 4 summarizes the attributes of the watersheds that are most important from a land use planning perspective. Section 5 contains a discussion of the effect of historic and present land uses on the watersheds and highlights areas that will be analyzed for potential future land use changes. Section 6 provides summaries of the hydrologic and geomorphic processes occurring in each major sub-basin in the study area, describes how those processes relate to overall watershed condition, and identifies major opportunities and constraints for each sub-basin. Finally, Section 7 introduces how the analysis contained in this baseline report may be used for subsequent phases of the SAMP/MSAA, NCCP/HCP, water quality, and local entitlement processes. This report is intended to provide a cohesive summary of the various technical studies. The complete versions of each technical study are provided as technical appendices to this report.

This report supports the first phase of the coordinated SAMP/MSAA, NCCP/HCP, Water Quality, and local entitlement processes by summarizing the analysis of baseline conditions. The second phase of the coordinated planning process will analyze the effect of several alternative land use scenarios on the physical and biological processes of the watershed[1]. The second phase will also involve development of specific approaches, guidelines, and criteria for project design elements and

[1] *The effect of potential land use changes on hydrologic and geomorphic processes will be assessed in the next phase of the coordinated planning process. This report is not intended to address potential impacts or changes in physical processes, only to summarize baseline conditions.*

Best Management Practices (BMPs) that minimize the effects of land use changes by maintaining the hydrologic, water-quality, and hydrogeologic functions of the watersheds. Specific elements of the aquatic and upland restoration and management programs will also be developed during subsequent phases of this process.

1.2 LANDSCAPE PERSPECTIVE IN ASSESSMENT AND PLANNING

The SAMP/MSAA and NCCP/HCP programs are proactive planning efforts intended to achieve a balance between resource protection and economic development. The stated purpose of the SAMP/MSAA is:

> "to develop and implement a watershed-wide aquatic resource management plan and implementation program, which will include preservation, enhancement, and restoration of aquatic resources, while allowing reasonable and responsible economic activities and development within the watershed-wide study area."

The primary objective of the NCCP/HCP program is:

> "to conserve natural communities and accommodate compatible land use. The program seeks to anticipate and prevent the controversies and gridlock caused by species' listings by focusing on the long-term stability of wildlife and plant communities and including key interests in the process."

The overall goal of the State Non-point Source Program is:

> "to manage NPS pollution, where feasible, at the watershed level, including pristine areas and watersheds that contain water bodies on the CWA [Clean Water Act] section 303(d) list and where local stewardship and site-specific management practices can be implemented through comprehensive watershed protection or restoration plans."

A common theme with all three of these programs is planning and management at the landscape or watershed scale. Watershed scale protection, enhancement, and management of natural resources requires an understanding of the landscape-scale processes that govern the integrity and long-term viability of aquatic and other natural resources.

By taking a landscape perspective in assessment and planning, cumulative impacts and appropriate mitigation measures can be better addressed. Furthermore, the constraints associated with natural resources and processes can be integrated early in the development process. In addition to minimizing impacts, this large-scale perspective facilitates development of a comprehensive preservation, enhancement, and restoration plan that addresses long-term management of natural communities, enhancement of water quality, and flood hazard reduction. This planning process is intended to coordinate protection of riparian wetland systems and upland habitats and enable them to be managed over the long-term as part of a single, integrated implementation program.

A clear distinction must be maintained between the landscape perspective employed in this report and the site-specific perspective typically used in regulatory analyses. This report does not provide detailed information on specific locations; rather, it focuses on overall watershed and sub-watershed processes by evaluating potential cumulative effects and working toward site-specific considerations in the context of the overall watershed processes. This contrasts with the traditional approach of focusing on site-specific effects and attempting to integrate actions at multiple sites to assess cumulative impacts. The approach used in this report (and in subsequent phases of the coordinated planning process) allows a more thorough consideration of potential cumulative impacts and more effectively ensures that overall physical processes in the watersheds are not degraded as a result of the cumulative effect of incremental actions.

This comprehensive planning effort is intended to support applications for state and federal regulatory permits and can be used to assist the federal, state, and local regulatory agencies with their decision-making and permitting authority to protect and enhance upland and aquatic resources and water quality. The overall intent is to develop programmatic approaches for compliance with requirements of the Federal Clean Water Act, State Porter Cologne Act, State Fish and Game Code, and Federal and State Endangered Species Acts, as well as support development of California Environmental Quality Act/National Environmental Policy Act (CEQA/NEPA) documents and the local entitlement process (see Section 1.4).

1.3 RELATIONSHIP OF WORK PLAN STUDIES TO WES AND CRRL REPORT

Accomplishment of this landscape-scale, resource-based planning and management program requires an understanding of the current condition of natural resources and the physical processes that govern their long-term viability. The U.S. Army Corps of Engineers (Corps) Cold Regions Research Laboratory (CRRL) and Waterways Experiment Station (WES) have conducted a landscape scale delineation of aquatic resources (Lichvar et al., 2000) and a landscape scale functional assessment study (Smith, 2000) to characterize and assess the riparian resources in the study area.

The studies summarized in this report do not replace any data produced by the WES and CRRL studies; rather, these studies provide supplemental information in topical areas that are not the focus of the WES and CRRL studies. Together, the two efforts, the WES/CRRL studies and the studies summarized in this report, provide a set of tools for characterizing the existing conditions in the study area and for supporting the identification and analysis of SAMP/MSAA alternatives.

In the context of the future SAMP/MSAA, NCCP/HCP, and GP/zoning alternatives analyses, the results summarized in this report will be used to: (1) help identify areas susceptible or resilient to development impacts; and (2) help develop and analyze land use configuration and design alternatives based on the landscape-scale hydrologic/geomorphological constraints and opportunities. In turn, it is expected that the WES/CRRL study will be used to evaluate the differential effect of the alternatives on riparian integrity, as stated in the third task of their study:

> "The third task is to determine which of several proposed development alternatives will result in the least impact to the overall integrity of riparian ecosystems in the watersheds. This will be accomplished by comparing the baseline ecosystem integrity scores to scores following a 'simulation' of each development scenario. The 'simulations' will be based on the changes that can be expected to occur as a result of each proposed development scenario."

1.4 EXPECTED USE IN SAMP/MSAA, NCCP/HCP, WATER QUALITY, AND LOCAL ENTITLEMENT PROCESSES

A goal of this report is to provide critical information in a landscape-context to support regional and programmatic decisions and authorizations, specifically permits under Sections 401 and 404 of the Federal Clean Water Act, Section 10(a) of the Federal Endangered Species Act, 1600 et seq. streambed alteration agreements pursuant to the California Fish and Game Code Section, and NCCP/HCP plans pursuant to 2800 et seq. of the California Fish and Game Code. The roles of the technical studies (and the associated products) in state and federal permitting and the local entitlement process are explored in the following sections.

1.4.1 Clean Water Act Section 404/SAMP and Section 1600/MSAA

Under the SAMP/MSAA planning process, the WES/CRRL reports and the technical studies summarized in this report will be employed in the Corps 404 "*off-site alternatives analysis*" at a watershed level to provide the analytical framework for identifying land use, reserve design, and management/enhancement alternatives and measures that will reasonably assure the long-term integrity of the significant aquatic resources within the watershed and of watershed and subwatershed functions and processes. Design recommendations resulting from the studies summarized in this report will be used during the "*on-site alternatives analysis*" to ensure that impacts to aquatic resources are avoided, minimized, and mitigated to the maximum extent practicable. The geomorphic terrains analysis will be used to assess potential impacts on hydrologic integrity and drainage density and function and to avoid undesirable changes in recharge, shallow groundwater quality, erosion, and the presence of wetlands. Finally, the output from these studies will be used in conjunction with the WES/CRRL studies and other information concerning habitat and species to establish a regional protection, restoration, and management plan for aquatic resources in the study area, including development of a comprehensive aquatic resource reserve program. The role of each technical study in the on- and off-site alternatives analysis is summarized in Table 1 on page 8.

1.4.2 State and Federal Endangered Species Acts (NCCP and HCP)

The goal of the Southern Subregion NCCP/HCP program is to develop a subregional conservation strategy and management program that would provide for the long-term protection and management of upland and aquatic natural communities and species as part of a single, integrated implementation program. Protection and management of natural communities, and the associated sensitive species, requires consideration of the underlying physical processes that support the targeted natural communities. A primary goal of the technical studies is to understand the physical processes of the watersheds and then use that understanding to develop proposed land use and species/habitat management scenarios that accommodate sensitive species needs over the long term. In particular, the technical studies completed as part of the baseline report will provide information concerning the physical hydrologic processes that will support the following NCCP/HCP objectives:

1. Formulating an effective habitat reserve design that is capable of protecting significant upland and aquatic natural communities and their associated species. This includes providing an understanding of the significance of physical and hydrologic processes, providing opportunities for biological connectivity between source populations of species and with other subregions, and facilitating the evaluation of alternative locations for new development;

2. Identifying upland and aquatic species for regulatory coverage under the State and Federal Endangered Species Acts (ESAs) and NCCP/HCP;

3. Identifying and, if necessary, reconciling competing upland and aquatic resource restoration and adaptive management priorities;

4. Evaluating proposed adaptive management measures within the upland and aquatic natural communities for potential coordination and integration needs/issues; and

5. Identifying and evaluating funding needs and implementation measures that will be needed to support the long-term management of the overall habitat reserve system.

Species listed at the state or federal levels that are present or potentially present in the study area and are dependent upon aquatic resources within the NCCP/HCP subregion include the arroyo toad, least Bell's vireo, southwestern willow flycatcher, and San Diego fairy shrimp. Other aquatic species will be evaluated for designation as "identified" species that would receive regulatory coverage based, in part, on the information generated by this report.

Table 1

Role of Each Technical Project in Completion of Alternatives Analysis

Technical Study	Off-site Alternatives Analysis	On-site Alternatives Analysis
Geomorphic Terrain Analysis	**General constraints and opportunities associated with specific geologic features and soils.**	Runoff characteristics and typical constituents associated with runoff from different soil types.
Stream and Watershed Characterization	**Basic data for other technical studies/provide an overall view of the drainage patterns in the study area.**	Input to the sediment yield and transport analysis/design of stormwater management facilities.
Surface Water Hydrology	Landscape-scale hydrology and flow characteristics of major streams and potential changes in hydrology associated with off-site alternatives.	**Detailed modeling of runoff from proposed projects to design impact minimization and mitigation measures.**
Shallow Groundwater Analysis	**Interactions between hydrodynamics and chemistry of groundwater and surface flow/ dynamics of groundwater dependent wetlands.**	Infiltration rates and design features to mitigate the influence of changes in on-site recharge on water quantity or quality/estimates of groundwater storage and detention.
Surface and Groundwater Quality	Potential pollutant loadings to receiving waters associated with biogenic and anthropogenic sources/intra- and inter-annual variations in loadings.	**Management Measures (under the NPS program) and BMPs that will ensure that water quality standards are met and sensitive species needs are addressed.**
Sediment Analysis	**Major source, sinks, and transport patterns of sediment and effect of alternatives on sediment yield and long-term channel stability.**	Loadings from specific land uses and BMP design features to offset potential effects of development on channel stability.
First Order Stream Function	**Cumulative effect of development alternatives on headwater stream function/strategies to compensate for lost headwater functions.**	Development of project-specific mitigation strategies that address the site-specific contribution of first order streams to overall basin function.

Shaded Boxes	= output of study primarily used for this portion of the analysis (i.e., off-site or on-site alternatives analysis)

Source: PCR Services Corporation, 2000

Although the NCCP/HCP will not directly address ESA issues for lands outside the Southern Subregion boundaries, this report will enable agencies and interested parties to have a better understanding of the relationship between natural communities protection and management within the subregion and downstream areas. Downstream of the NCCP/HCP subregion boundary, in the lower portions of the San Mateo Creek watershed, aquatic resources support the tidewater goby, least Bell's vireo, southwestern willow flycatcher, and potentially the steelhead. The geomorphic terrains analysis will be used to help guide development strategies to avoid and mitigate indirect impacts to sensitive riparian habitat, such as downcutting, bank erosion, and changes in channel forming flows. The sediment yields and transport analysis will be used to evaluate the potential for development-related impacts on sensitive species, such as arroyo toad and least Bell's vireo, as well as potential impacts on lagoon sedimentation (which would be an issue of particular concern with respect to tidewater goby habitat). Analysis of the potential effects of alternative land use scenarios on landscape-scale channel form and process will help ensure that habitat integrity of sensitive species is maintained. Specific impact minimization and mitigation measures will be developed to ensure that proposed development does not directly or indirectly adversely affect the ability of streams to support sensitive species.

1.4.3 Clean Water Act/NPDES Program/Porter Cologne/NPS Control

The federally approved State water quality and NPS programs express a preference for watershed-scale approaches to control point and NPS pollution. The NPS-control Plan achieves this goal by dealing with NPS pollution via 61 Management Measures (MMs). Management measures serve as general guidelines for the control and prevention of polluted runoff and the attainment of water quality goals. Site-specific management practices are then used to achieve the goals of each management measure. Specifically, the Plan:

1. Adopts 61 MMs as goals for six NPS categories (agriculture, forestry, urban areas, marinas and recreational boating, hydromodification, and wetlands/riparian areas/ vegetated treatment systems);

2. Uses a "Three-Tiered Approach" for addressing NPS pollution problems (Tier 1: Self-Determined Implementation of Management Practices [formerly referred to as "voluntary implementation”]; Tier 2: Regulatory Based Encouragement of Management Practices; and Tier 3: Effluent Limitations and Enforcement Actions).

3. Expresses a preference for managing NPS pollution on a watershed scale where local stewardship and site-specific management practices can be implemented through comprehensive watershed protection or restoration plans.

The San Diego Regional Water Quality control board has proposed issuance of a new NPDES permit for discharges of urban runoff in the watersheds of south Orange County (Tentative Order No. 2001-193). The proposed NPDES permit requires preparation of a Watershed Urban Runoff Management Plan (W-URMP) that would require all co-permittees to work cooperatively to assess water quality throughout the watershed and institute land-use planning programs to reduce pollutant runoff to the maximum extent possible. The W-URMP is required , at a minimum to contain the following: mapping of the watershed, an assessment of the water quality of all receiving waters in the watershed, an identification and prioritization of major water quality problems in the watershed, an implementation time schedule of short and long-term recommended activities needed to address the highest priority water quality problem, a mechanism to facilitate collaborative "watershed-based" (i.e., natural resource-based) land use planning, and a short and long-term monitoring and adaptive management program.

The focus of the technical studies summarized in this report on watershed hydrologic/geomorphic processes is consistent with the watershed emphasis of the NPS and NPDES programs in that the output from the studies will be used to help locate and design proposed developments in a manner that minimizes impacts on the beneficial uses of receiving waters. To the extent feasible, the locations, extent, and configuration of development and open space/habitat reserve areas designated by the SAMP/MSAA and NCCP/HCP will be designed and managed to protect major streams from the effects of new development. Within development areas, design features, buffer requirements, and BMPs will be developed to address both point (i.e., National Pollution Discharge Elimination System) and NPS pollution control issues. The landscape-scale strategies will be consistent with the Watershed URMP requirements of the NPDES permit, while the on-site measures will be consistent with recommended Management Measures in the State NPS Pollution Control Program. The output from the technical studies will be used to help provide the basis for programmatic water quality certification pursuant to the State NPS and San Diego RWQCB programs.

1.4.4 Local Entitlement

Data generated by the technical studies will be used in the design of each new development area to comply with Orange County design requirements for flood hazard assessment. In particular, the work products developed through the surface water hydrology analysis, HEC-1 modeling, will be used to analyze the effect of proposed development on large flood events, particularly the 100-year event. Recommendations for design features and mitigation measures to offset potential hydrologic and sediment impacts of proposed land use changes will be developed. This information may also be used to supplement the existing data produced as part of the Corps of Engineers San Juan Creek watershed study. The Corps watershed study is evaluating potential environmental restoration and flood control projects in the watershed that may be implemented in partnership with the County of Orange.[2]

The contribution of the work plan products to the development of general and specific plans is summarized in Figure 2 on page 12.

[2] *The San Juan Creek watershed study is being administered by the Corps Planning Division. Although it covers some of the same areas as the SAMP/MSAA, it is focused on identifying specific flood control or restoration projects. Unlike the SAMP/MSAA, it is not intended to analyze overall watershed processes and provide management recommendations to maintain the integrity of those processes.*

Figure 2 Application of Technical Studies to Various Scales of Analysis

2.0 ASSESSMENT APPROACH AND KEY ASSUMPTIONS

The technical studies summarized in this report, evaluated information at three spatial scales. The landscape scale encompasses the entire watersheds from the headwaters to the coast. The intermediate scale includes areas within the boundary of RMV; the finest scale addresses the proposed development or reserve areas (Figure 3 on page 14). The analyses discussed in this report have been undertaken at the first two spatial scales and provide the basis for future analysis at the development or reserve area scale. As such, this report contains large-scale coarse resolution information with further refinement at the sub-watershed level.

The landscape-scale analyses contained in this report provide information about the constraints and opportunities associated with proposed future land use changes in order to support decision-making at the sub-watershed and programmatic levels. This report will support the off-site alternatives analysis by helping to evaluate the general location, extent, and configuration of alternative development and reserve areas (i.e., tier one of the alternatives analysis process). As the analysis and permitting needs progress to the on-site level, the technical information produced will be refined and applied with higher levels of resolution by analyzing potential changes in physical processes based on specific land use designs.

The methodology used for each of the analyses was specific to the needs of that technical discipline. In all cases, existing data was reviewed and utilized as appropriate and to the maximum extent possible. Because the analyses are intended to provide a landscape scale perspective, methods were geared to optimize this scale of analysis. In several instances, the scale of analysis favored qualitative analysis of processes and patterns over site-specific quantitative evaluations. In some instances, order of magnitude estimates were considered sufficient. In all cases, limitations of the data are disclosed along with the results. The following assumptions were used in all analyses:

1. Approximately 85 percent of the San Mateo creek watershed is outside the study area; therefore, assumptions have been made about land uses outside the study area (primarily on Camp Pendleton) and their influence on overall watershed integrity.[3] In contrast, the majority of the San Juan watershed (downstream of the boundary of the Cleveland National Forest) was directly analyzed by the studies summarized in this report.

2. Although this report focuses on resources subject to the jurisdiction of either the Corps of Engineers or the Department of Fish and Game, non-jurisdictional riparian areas, and

[3] *WES previously evaluated the functional integrity of aquatic resources on Camp Pendleton. This information can be used during the analysis of the cumulative impacts.*

Figure 3 Relationship Between Technical Studies

"channel-less" valleys (swales) have also been included in the analyses to the extent that they contribute to the biological, hydrologic, or geomorphologic function of the main stream systems. The fundamental unit of analysis for this report is the riparian corridor (as opposed to jurisdictional wetlands), with the focus being on the interaction between upland areas, floodplains, and streams.

The sections below summarize the methods used for investigation of specific disciplines. More detailed information on methodologies can be found in the technical appendices.

2.1 GEOMORPHOLOGY AND TERRAINS

The conditions of aquatic and riparian resources are influenced by land use practices in the contributing watershed. Upland land uses have the potential to affect surface and subsurface flow to wetlands, sediment input to streams and wetlands, and pollutant loading to streams. Increases or decreases in overland flow and sediment generation can alter the physical, chemical, and biological condition of streams. Changes in chemical input to streams can affect the ability to meet overall water quality standards. Sensitivity of wetland and riparian resources to changes in upland land use is determined largely by the geology, soils, and topography found in the contributing watersheds. These three factors can collectively be termed "the terrain" of the watershed.

The analysis of geomorphology and terrains in this report involved primarily a descriptive analysis of the watersheds using existing data on geology, soils, and past and present land uses. In addition, historic data and aerial photos were reviewed to investigate the effect of both natural and anthropogenic land use changes over time. The results of these investigations were used to produce GIS maps showing the constraints and opportunities inherent to each terrain type, such as potential changes in runoff and recharge associated with development in various substrate types. Much of the information on the hydrologic and geomorphic responses of sandy soils to urbanization was based on research conducted in the Pajaro basin in Santa Cruz County by Hecht and Woyshner (1984) and on Karen Prestegaard's 1978 investigations on the effects of urbanization on the coastal regions of northern San Diego County.

2.2 HYDROLOGY

The magnitudes, frequencies, and patterns of surface flow through uplands and within stream channels are the most deterministic factor of the integrity and distribution of wetlands and riparian habitat. Changes in the magnitude or frequency of peak flows for moderate events (i.e., 2-year), channel-forming events (i.e., 5-year or 10-year return interval), or extreme events (i.e., 25-year, 50-year, or 100-year return interval) can affect the long-term viability of riparian habitat and influence the type of community that persists. Increased frequency of high flows (resulting from increased runoff) can destabilize channels and encourage invasion by aggressive non-native plant species. Changes in baseflow can change the physical and biological structure of the stream. Habitat for sensitive species may also be affected by changes in the physical, chemical, or biological condition of the stream that results from alteration of surface water hydrology.

Hydrologic impacts associated with urbanization have been observed and described by several authors. Findings from past research provide a useful context to interpret current hydrologic conditions in the San Juan and San Mateo watersheds, as well as foresee potential impacts due to urbanization. Synthesizing the earlier work of others, Leopold (1968) summarized how increased impervious surfaces in a watershed results in increased stormflow volume, increased stormflow peak discharge, and a reduction in lag time between precipitation and runoff. Estimating the hydrologic impact on a 1 $mi.^2$ watershed, Leopold (1968) estimated that discharge for a given precipitation event would increase roughly 2.5 times if 50 percent of the watershed was urbanized and drained by a storm sewer system. James (1965), Anderson (1970), and Rantz (1971) described how the hydrologic impacts of urbanization are proportionally greater for more frequent interval storm events than larger events where soils saturated beyond their infiltration capacity behave similarly to impervious surfaces (Graf, 1988). More recently, Wong and Chen (1993), used computational models to suggest that increases in flood peaks caused by urbanization are due to increases in impervious areas more than increases in storm sewer networks for basins with variable slopes. Ferguson (1994) focused on stormwater infiltration as the key to solving urban runoff problems.

Researchers have also documented how such changes in hydrologic regime translate to geomorphic changes in stream channel form by altering processes and patterns of sediment erosion, transport, and deposition. Wolman (1967) suggested a cycle whereby urbanizing watersheds have extremely high sediment yields during the construction phase when barren slopes are disturbed and void of vegetation. Following the build-out phase, sediment yields drop to levels below existing conditions as sediment source areas are capped and replaced by urban landscapes. Hammer (1973) concluded that urbanization and its changes in streamflow regimen generally result in enlarged stream channels, with proportionally greater channel enlargement in steeper watersheds. More specific to the Orange County setting of the current report, Trimble (1997) reported how sediment yields in the San Diego Creek watershed increased during a period of urbanization. Trimble (1997) suggested that about two-thirds of this sediment yield was generated from in-channel sediment erosion, with about one-third supplied by upland hillslope sources. Recently, Doyle et al. (2000) used geomorphic assessment techniques (including quantitative measures of shear stress, stream power, and the recurrence interval of bed-mobilizing discharges) to predict channel stability or instability in urbanizing watersheds. A recent compendium of articles published by the Center for Watershed Protection (Schueler and Holland, 2000) offers a comprehensive review of watershed impacts of urbanization and techniques to mitigate such impacts. Although watershed science is a relatively new and emerging discipline, the current baseline report and future planning process for the San Juan and San Mateo creek watersheds benefit from these past studies which provide a framework to understand hydrologic and geomorphic impacts.

2.2.1 Stream Network Analysis

An early step in any watershed analysis is to assess the basic physical and hydrologic characteristics of the drainage basins, also referred to as a stream network analysis. Understanding the composition and spatial arrangement of channels in the watershed is key to understanding streamflow and ecologic conditions. This information also provides input into the subsequent hydrologic and geomorphic analyses.

The stream network for the watersheds was delineated using a multiple-threshold method based upon a digital elevation model (DEM). The created stream network model was validated against field data collected by the WES/CRRL team. The multiple-threshold method is based on the "erosion-threshold" theory (Montgomery and Foufoula-Georgiou, 1994) and predicts the location where channels begin by combining contributing flow areas and slopes of hillsides into a single channel-predicting parameter. The direction of flow is calculated from the DEM using the D8 method, which uses the eight neighboring cells to predict the water flow direction. A single flow direction is specified for every point in the watershed. This technique was applied to the study area at both 30-meter and 10-meter resolutions. In some areas, this method was insufficient to map the channels, and a modified approach was used. In steep areas, where the erosional threshold theory does not apply, a straight tributary source area was used to predict channel locations. For areas of low relief, such as floodplain valleys, mapped channel locations contained in the National Hydrography Dataset were input to the DEM data. These additional steps enabled channel delineations to match observed channels in areas where the DEM alone was not sufficient to predict channels. Finally, the WES/CRRL field-mapped channels were included as channel heads, and their flow paths were traced through the DEM using a calculated flow direction to create complete channels. In this way, all of the WES mapped channels are represented in the resulting stream delineation (see Appendix A).

Descriptive statistics were calculated for the resulting stream network. The number, length, and stream order of channels were calculated for each sub-basin. Drainage density was calculated for each basin by dividing total stream length by the total area of the basin. Additionally, the bifurcation ratio was calculated for each stream order by taking the number of channels for a particular order and dividing by the number of channels of the next highest order. This provides an outline of the stream network's natural structure. Using this information, confluence points where stream orders increase were mapped to highlight important locations in the stream network.

2.2.2 Rainfall-Runoff Analysis

Hydrologic characteristics of the watersheds and sub-basins were analyzed using the Corps' HEC-1 flood hydrograph model, as specified by the Orange County Hydrology Manual (OCHM, 1986). To facilitate the use of OCHM methodology, LAPRE-1 was used in combination with Visual HEC-1. LAPRE-1 is a Los Angeles District Corps pre-processor for HEC-1, customized for hydrologic analysis of Southern California watersheds. The 24-hour balanced design storm specified in the OCHM was used as precipitation input. A watershed GIS database was created to generate and evaluate various input parameters to LAPRE-1 and Visual HEC-1, including sub-basin area, basin roughness, channel lengths, areal rainfall distributions, and SCS runoff curve numbers. Input parameters accounted for existing land use and configuration of the drainage network. Infiltration losses were computed, based on the Natural Resource Conservation Service (NRCS) runoff curve (RI) method. This method incorporates soil characteristics, land use, vegetation, impervious cover, and antecedent moisture conditions to estimate loss rates[4]. The RI scale has a range from 0 to 100, where higher numbers indicate lower infiltration rates. Low loss fractions and maximum loss rates were incorporated into an S-graph unit hydrograph analysis, as specified to Orange County conditions. The model parameters were then used to generate the 2-year, 10-year, and 100-year design storms. Channel routing accounted for all existing hydraulic structures, and followed the Muskingum and Muskingum-Cunge methods. These routing techniques were evaluated and compared to the Convex routing method and considered consistent with the Orange County recommended method.

It should be noted that while HEC-1 is useful for analyzing rainfall-runoff processes in watersheds, the program has several limitations. HEC-1 was designed to model singular storm runoff events, such as the 24-hour Orange County design storm. It is not possible to accurately model two or more consecutive storm events with HEC-1 since the program does not account for dynamic soil moisture and infiltration processes. Even modeling a single storm with two large and distinct rainfall peaks (a "bimodal" storm) is not advisable with HEC-1.[5] The HEC-1 model also tends to over-estimate flows from smaller events, such as the 2-year storm especially in undeveloped catchments. This occurs because HEC-1 uses a relatively simple approach to analyze rainfall, infiltration, and runoff, which does not reflect the true complexities of these processes and SCS

---

[4] *The land-use, hydrologic soil group, and vegetation mapping used contained classification differences along the county boundaries. These classification differences affected only a small portion of the study area along the western Riverside county boundary. The boundary effects do not significantly impact the hydrologic modeling analysis or its results for two reasons: (a) the classification distinctions across the boundaries are not severe (e.g. difference of one soil hydrogroup or vegetation mapping as Chaparral vs. Narrow Leaf Chaparral) and (b) the hydrologic soil group, land-use, and vegetation data are integrated to develop Runoff Curve Numbers for the individual grid cells of the GIS database, which are then averaged according to hydrologic sub-basins used for the modeling (see Technical Appendix A for a more detailed discussion.)*

[5] *Although HEC-1 does not account for a bimodal storm, it is capable of accurately modeling bimodal runoff patterns that result from basin configuration, drainage network structure, and routing.*

curve numbers tend to be conservative in their estimation on runoff. To address this limitation of HEC-1 for the 2-year event discharges, the OCHM Addendum #1 (1995) was used. In this addendum, input parameters for soil loss and precipitation conditions are calibrated to regionally observed discharge conditions (expected value) taken from seven southern California watersheds under various flow conditions. For the 2-year flows, these guidelines assume higher infiltration than the more conservative "high confidence" approach used for the design of flood control facilities, thereby providing a more realistic discharge baseline that can more accurately depict impacts due to urbanization. In this way, the current hydrology approach is a hybrid which offers county-accepted "high confidence" results for the larger 10-year and 100-year events and 2-year "expected value" results, which are more sensitive to environmental concerns associated with urban-induced hydrogeomorphic changes within the watersheds.

2.2.3 Dry Season Flow Analysis

The quantity and timing of dry season flows can affect riparian resources. Changes in dry season flow can alter the plant community composition of a stream, alter bed-load sediment transport, and result in increased pollutant mobilization. To rigorously evaluate low-flow conditions in a stream, an extended historic record of daily flow conditions is required. To determine whether such records are available, four stream gauges in the study area were investigated,[6] and none contained reliable low-flow records of sufficient duration for a statistically valid analysis.

The historical role of development in increasing dry season flows is well documented (Hammer, 1973; Graf, 1975; Hamilton, 1992; Wong, 1993; Trimble, 1997). A trend analysis was conducted on low-flow data from the urbanized Oso Creek (Crown Valley gauge) basin using the Indicators of Hydrologic Alteration (IHA) program (Richter et al., 1996). The IHA program calculates summary statistics to characterize changes in flow regime resulting from changes in watershed conditions. The analysis of changes in dry-season flows over time for Oso Creek provides useful insight into the potential effects of future land use changes on dry-season flow in the central San Juan and western San Mateo watersheds. Potential effects of proposed development on dry-season flow and design features to minimize these effects will be analyzed during the on-site alternatives analysis.

[6] *Stream gauges investigated were San Juan Creek at La Novia (USGS #11046530), Trabuco Creek at Camino Capistrano (Orange County #5), Trabuco Creek at Del Obispo (USGS #11047300), and Oso Creek at Crown Valley Parkway (Orange County #218).*

2.3 SEDIMENT YIELD AND TRANSPORT

The entrainment, transport, and deposition of sediment in watersheds of coastal southern California occurs according to a cascading system involving upland hillslopes, alluvial stream channels, estuaries, and the coast. These different geomorphic zones within the cascading system variably shed, move, or store sediment. As the principal conduit of sediment transport, the stream channel system dynamically responds to changes in hydrologic conditions across the watershed. Increases or decreases in runoff and sediment delivery to specific reaches can result in shifts in erosional and depositional patterns throughout the drainage network. Additionally, changes in sediment storage functions within the channel create feedbacks which further alter stream geometry and slope and could further destabilize stream behavior.

Sediment yields were estimated, based on a review of a variety of data sources from southern California coastal watersheds. The lines of evidence used included more than 12 previous studies of sediment discharge and locally derived sediment rating curves; observed rates of accumulation in debris basins, reservoirs, and gravel pits; calculated yields based on the Los Angeles District method (LAD) and the Modified Universal Soil Loss Equation (MUSLE); and comparisons with adjoining watersheds having similar sediment-generating influences such as slope, geology, and soils. These sources generated estimated sediment yields that varied by more than 25-fold, so recommendations were made as to the most reliable estimates based on review of the study designs and assumptions used in each study. It should be noted that sediment transport measurements are often inherently inexact, particularly those measurements made during storms or floods. In most cases, it is either not feasible or not worthwhile to obtain additional accuracy. The data may, however, be validated to a level suited to use by applying multiple estimation techniques as was done in this study. Implied precision in sediment data exceeding two or three significant figures is not valid. We have tried to round computations and present values that are not deceptively precise. Discrepancies of up to 5 or 10 percent may arise from this practice and should not be a source of concern.

Storm event-based sediment transport rates and yields were estimated on a reach basis for the studied sub-basins using SAM, a Corps channel design package[7]. Required input to SAM includes average (or effective) hydraulic parameters (discharge rate, flow width, flow depth, energy grade slope, and velocity) and representative sediment parameters (bed-material particle gradation, sediment transport function). Average hydraulic parameters were estimated using an existing HEC-2 model generated by Simons, Li & Associates (SLA, 2000), 10 meter DEM data for the watershed U.S. Geological Survey (USGS), and field data collected by the Waterways Experimentation Station team (Smith, 2000) and Balance Hydrologics. Results from PWA's HEC-1 runoff analysis for the

[7] *Bedload transport accounts for a small fraction of the overall sediment movement in the watershed, and is a minor factor in shaping stream geomorphology.*

2-year, 10-year, and 100-year discharge events, were used as flow input to SAM. Sediment data from SLA's and WES's fieldwork were utilized, along with estimates of sediment delivery made to the channels by Balance Hydrologics. A representative channel cross-section was developed for selected stream reaches by synthesizing USGS 10-meter digital elevation data with WES channel observations and HEC-2 cross sections from SLA (1999).

SAM has over 19 sediment transport functions available for calculating transport rates. Selecting the appropriate sediment transport function is a crucial decision of the modeling process. For this study, two sediment transport functions were selected, based upon guidelines in the SAM reference manual and comparisons to previous results by SLA (1999) and Vanoni et al. (1980). The Laursen-Madden (LM) function was chosen for its suitability for sand and gravel bed streams, and the Engelund-Hansen (EH) function was initially utilized since it compared well with previous results. The Laursen-Copeland (LC) function was also initially selected because it better represented larger gravel sizes. This was considered more appropriate for places like Bell Canyon. In general, the Laursen-Madden function provides the best estimation of sediment transport for the broadest range of substrate types and topographies. Therefore, for the Baseline Conditions report, PWA emphasized results from the Laursen-Madden sediment transport function. A more detailed explanation of the methodology used in the sediment transport analysis is given in Appendix A.

Since the majority of sediment in this region is generated and transported during infrequent storm events, the effect of episodic events on overall channel stability, long-term sediment yields, erosional processes, and sediment storage in the watershed was evaluated. This analysis was based largely on the results of the terrains analysis and aerial photo interpretation. Ranges of coefficients were generated from the literature that can be applied to the sediment yield and transport results to estimate watershed responses to changes in the frequency or magnitude of episodic events.

2.4 WATER QUALITY

An understanding of the role played by watershed processes in the generation, transport, and assimilation of nutrients and pollutants is critical to informed decision-making that recognizes the combination of characteristics specific to these watersheds. This is especially true, given the diversity of geology, terrains, and land cover within the study area.

The baseline water quality analysis consisted of review, summary, and analysis of five substantial water quality data sets that have been collected within the study area, including data collected by the Orange County Public Facilities and Resources Department (Orange County PFRD). The water quality data collected by others was augmented by a series of field surveys within the study area sub-basins in order to assess the potential roles that various geomorphic and biological features may be playing in controlling the mobilization and cycling of key nutrients and constituents of concern such as nitrogen, phosphorus metals, and sediment. Historical aerial photography was used to put this present-day view of the sub-basins in a context more appropriate to the temporal scale that operates in these highly episodic watersheds. Comparison of the sub-basin characteristics will be used during the alternative analysis to identify the opportunities and constraints that will most directly influence land use planning, permitting processes, and the selection and design of features intended to maintain or enhance water quality.

The information summarized in this baseline conditions report will be augmented by ongoing monitoring of surface water quality. Eleven monitoring stations have been set up for collection of organic and inorganic water quality constituents. Grab samples will be taken during storm events at the beginning of the wet season (ideally during the "first flush" event), in the middle of the wet season, at the end of the season, and twice during the dry season. In addition, continuous analysis (via dataloggers) will occur at four stations. This information will be used to monitor inter- and intra-annual trends and to help detect changes in basic water chemistry such as temperature, pH, and EC (i.e., specific conductance) associated with natural and anthropogenic changes in the watershed. Sediment samples will be analyzed at target locations to determine the contribution of sediment to surface water quality. The results of the ongoing water quality monitoring will be the subject of a future separate report.

2.5 GROUNDWATER

The distribution and condition of aquatic resources is affected by the depth, hydrodynamics, and chemistry of the shallow groundwater (i.e., groundwater that is within the root zone at least seasonally or in the case of mature vegetation, semi-annually). Riparian species, such as willows and cottonwoods, are generally restricted to alluvial soils with shallow groundwater. On coarse substrates in dry regions, early establishment and growth to *Populus* spp. (i.e., cottonwoods) may require water tables within 3 to 6 feet (1 to 2 m) of the surface (Scott et al., 1999). However, *Populus* species have been observed to become established up to 8.5 feet (2.6 m) above the annual low water level (Shafroth et al., 1998; Busch and Smith, 1995). Mature riparian tree species are typically found in settings where the depth to the water table is less than 11.5 feet (3.5 m), but *Populus* spp. have been observed at sites where depth to the water table is 23 to 30 feet (7 to 9 m) (Scott et al., 1999). Changes in either overall depth or duration with which groundwater persists at a certain depth can result in desiccation, narrowing of the riparian zone, or changes in wetland and riparian plant communities. Mount (1995) reported that lowering of groundwater beyond 12 feet (3.7 m) associated with a mining-induced channel incision along Cache Creek in Northern California resulted in pervasive mortality of streamside riparian habitat. Similarly, Smith et al. (1998) reported that cover of phreatophytic shrubs along the Colorado River decreased significantly when groundwater levels drop below 16.4 feet (5 m). Changes in the salinity or pH of shallow groundwater may also adversely affect wetlands or may result in transitions to different community types (e.g., transition from alkali marsh to freshwater marsh or visa versa). For example, Smith et al. (1998) reported that increases in soil electroconductivity along the Colorado River resulted in mortality of willow and cottonwood species and colonization by more salt tolerant species, such as *Tamarix* and *Tessaria*. Slope and seep wetlands and riverine alkali marshes are particularly dependent on perennial or near-perennial sources of shallow groundwater which are strongly affected by the nature of subsurface geology. Finally base flows are affected by subsurface water depth in the contributing watershed.

Information on subsurface hydrodynamics in the San Juan and San Mateo watersheds is sparse, and extensive modeling of groundwater movement is a long, complex, and costly endeavor and therefore is beyond the scope of this study. Consequently, groundwater flow directions and the locations of key recharge areas were inferred from: (a) the results of the terrains analysis, the hydrogeologic conditions, the surface hydrology modeling, and the water quality analysis; and (b) existing well data and bore logs, earlier technical reports on groundwater conditions in the watershed, detailed investigations from the 1960s by the California Department of Water Resources and local water districts, and portions of the San Diego RWQCB Basin Plan. Functional relationships between groundwater and aquatic habitats in the study area were analyzed in light of the inferred relationships. In this report, the discussion of groundwater recharge, movement, and discharge has been integrated with discussions of terrains and surface hydrology, except in instances where groundwater is a significant component of the overall hydrology in a sub-basin (e.g., Cañada Chiquita).

The information summarized in this baseline conditions report will be augmented by ongoing monitoring of groundwater quality. Groundwater sampling will consist of two grab samples from each of four monitoring wells. One sample will be taken during the wet season, the other during the dry season. Samples will be tested for: salinity and major ions, dissolved metals, organics, organophosphates, and carbomate pesticides. In addition, as groundwater data from the TCA and Camp Pendleton become available our understanding of groundwater hydrodynamics in the study area will increase. The results of the ongoing groundwater quality monitoring will be the subject of separate future report.

2.6 RIPARIAN AND WETLAND HABITATS

Numerous biological studies with varying focuses have been conducted in the study area. Work completed for the NCCP/HCP process has mapped habitats and sensitive species locations. The WES/CRRL investigations resulted in mapping of riparian habitats and analysis of the functional integrity of those habitats. Studies conducted by PCR mapped and analyzed the condition of slope wetlands and vernal pool wetlands. The hydrologic and geomorphic processes necessary to support key sensitive species will be addressed in a subsequent report.

This report does not attempt to summarize all the results of the numerous biological investigations that have been conducted in the study area. Instead, the major biological attributes of the watersheds and the sub-basins are summarized and key considerations are provided for analysis of alternative land use scenarios. More detailed information can be found in the WES/CRRL reports, slope wetland and vernal pool reports (PCR) and the NCCP database (Dudek & Associates).

3.0 OVERVIEW OF SAN JUAN AND SAN MATEO CREEK WATERSHEDS

3.1 PHYSICAL SETTING

3.1.1 San Juan Creek Watershed

The San Juan Creek watershed is located in southern Orange County, California. The watershed encompasses a drainage area of approximately 176 $mi.^2$ and extends from the Cleveland National Forest in the Santa Ana Mountains to the Pacific Ocean at Doheny State Beach near Dana Point Harbor. The upstream tributaries of the watershed flow out of steep canyons and widen into several alluvial floodplains. The major streams in the watershed include San Juan Creek, Bell Canyon Creek, Cañada Chiquita, Cañada Gobernadora, Verdugo Canyon Creek, Oso Creek, Trabuco Creek, and Lucas Canyon Creek. Elevations range from over 5,800 feet above sea level at Santiago Peak to sea level at the mouth of San Juan Creek (Corps, 1999).

The San Juan Creek watershed is bounded on the north by the San Diego, Aliso Creek, and Salt Creek watersheds, and on the south by the San Mateo Creek watershed. The Lake Elsinore watershed, which is a tributary of the Santa Ana River watershed, is adjacent to the eastern edge of the San Juan Creek watershed.

3.1.2 San Mateo Creek Watershed

The San Mateo Creek watershed is located in the southern portion of Orange County, the northern portion of San Diego County, and the western portion of Riverside County. The watershed is bounded on the north and west by the San Juan Creek watershed, to the south by the San Onofre Creek watershed, and to the northeast by the Lake Elsinore watershed. San Mateo Creek flows 22 miles from its headwaters in the Cleveland National Forest to the ocean just south of the City of San Clemente. The total watershed is approximately 139 $mi.^2$ and lies mostly in currently undeveloped areas of the Cleveland National Forest, the northern portion of Marine Corps Base Camp Pendleton (MCBCP), and ranch lands in southern Orange County (Lang et al., 1998). Major (named) streams in the watershed include Cristianitos Creek, Gabino Creek, La Paz Creek, Talega Creek, Cold Spring Creek, and Devil Canyon Creek. The study area includes only the portion of the San Mateo Creek drainage within Orange County (approximately 17 percent of the watershed). Elevations range from approximately 3,340 feet above sea level in the mountains of the Cleveland National Forest to sea level at the mouth of San Mateo Creek.

3.2 GEOMORPHIC SETTING

3.2.1 Regional Geology

The San Juan and San Mateo Creek watersheds are located on the western slopes of the Santa Ana Mountains, which are part of the Peninsular Ranges that extend from the tip of Baja California northward to the Palos Verdes peninsula and Santa Catalina Island. The geology of the region is complex and has been dominated by alternating periods of depression and uplift, mass wasting, and sediment deposition (Figure 4 on page 27). Within the watersheds, the Santa Ana Mountains are composed of igneous, metavolcanic, and metasedimentary rocks of Jurassic age and younger. The exposed rocks in the mountainous areas are slightly metamorphosed volcanics, which have been intruded by granitic rocks of Cretaceous age, principally granites, gabbros, and tonalites. Overlying these rocks are several thousand stratigraphic feet of younger sandstones, siltstones, and conglomerates of upper Cretaceous age, composed largely of material eroded from the older igneous and metavolcanic rocks now underlying the Santa Ana Mountains.

Younger sedimentary rocks comprise the bedrock between the Santa Ana Mountains, their foothills, and the Pacific Ocean. Most of the SAMP/MSAA area is underlain by these marine and non-marine sandstones, limestones, siltstones, mudstones, shales, and conglomerates, many of which weather, erode, and/or hold groundwater in characteristic ways. Overlying them are Quaternary stream terrace deposits and Holocene stream channel deposits.

During the past two million years or longer, at least three processes that fundamentally affect structure and process along the major stream channels have affected the two watersheds:

1. Continuing uplift, typically 400 feet or more, which has left at least four major stream terrace levels along the major streams.

2. Downcutting of the main canyons to sea levels, which have fluctuated widely during the global glaciations.[8] The flat valley floors were deposited as sea level rose, leaving often-sharp slope breaks at the base of the existing hillsides and tributary valleys. These materials are geologically young, soft, and prone to incision under certain conditions.

3. Soils formed under climates both warmer/colder and drier/wetter than at present, which led to development of hardpans that have been eroded to form mesas. These hardpan mesas have minimal infiltration and presently channel flows into headwater streams.

[8] *As recently as 18,000 years ago, sea level was about 380 feet lower, and the shoreline was several miles further west than at present. San Juan, Chiquita, Gobernadora, San Mateo, and Cristianitos Creeks (among others) flowed in valleys 60 to 120 feet lower than at present.*

Figure 4 Surficial Geology of Study Areas

3.2.2 Terrains

Terrain designations are largely based on soils, geology and topography, as these provide many of the fundamental factors that influence the hydrology and geomorphology characteristic of each terrain. Bedrock is the raw material from which soils are weathered, and, as such, it determines the size and types of particles that will comprise the soil. The resistance of different kinds of bedrock to weathering and erosion also controls the topography of the landscape within a given terrain and, therefore, influences the hydrology of the watersheds and morphology of the drainage networks. Watershed hydrology is also strongly influenced by the climatic patterns typical of Southern California. Climatic factors are discussed in more detail in Section 3.3.1.

There are three major geomorphic terrains found within the San Juan Creek and San Mateo Creek watersheds: (a) sandy and silty-sandy; (b) clayey; and (c) crystalline. These terrains are manifested primarily as roughly north-south oriented bands of different soil types[9] (see Figure 5 on page 29). The soils and bedrock that comprise the western portions of the San Juan Creek watershed (i.e., Oso Creek, Arroyo Trabuco, and the lower third of San Juan Creek) contain a high percentage of clays in the soils. The soils typical of the clayey terrain include the Alo and Bosanko clays on upland slopes and the Sorrento and Mocho loams in floodplain areas. In contrast, the middle portion of the San Juan basin, (i.e., Cañada Chiquita, Bell Canyon, and the middle reaches of San Juan Creek) is a region characterized by silty-sandy substrate that features the Cieneba, Anaheim, and Soper loams on the hillslopes and the Metz and San Emigdio loams on the floodplains. The upstream portions the San Juan Creek watershed, which comprise the headwaters of San Juan Creek, Lucas Canyon Creek, Bell Creek, and Trabuco Creek, may be characterized as a "crystalline" terrain because the bedrock underlying this mountainous region is composed of igneous and metamorphic rocks. Here, slopes are covered by the Friant, Exchequer, and Cieneba soils, while stream valleys contain deposits of rock and cobbley sand. The upland slopes east of both Chiquita and Gobernadora Canyons are unique in that they contain somewhat of a hybrid terrain. Although underlain by deep sandy substrates, these areas are locally overlain by between 2 and 6 feet of exhumed hardpan.

3.2.2.1 Runoff Patterns of Specific Terrains

Runoff patterns typical of each terrain are affected by basin slope, configuration of the drainage network, land use/vegetation, and, perhaps, most importantly the underlying terrain type. Although all three terrains exhibit fairly rapid runoff, undisturbed sandy slopes contribute less runoff than clayey ones because it is easier for water to infiltrate into the coarser substrate. Runoff in

[9] *The different bands of terrain types should be considered as general trends; not every stream is comprised of a single terrain, and inclusions of other soil types occur within each terrain.*

Figure 5 Landscape Scale Terrains and Shallow Substrate Erodibility

crystalline terrains tends to be rapid and is highly influenced by the presence and density of coverage of impervious areas of rock outcrop that typify the terrain. As a result, the volume of runoff generated by the same amount and intensity of rainfall in a sandy watershed is generally lower than that generated in a clayey or crystalline watershed. When comparing clayey and crystalline terrains, the former seals and becomes impervious upon saturation, while the latter allows for some infiltration through shallow sands that overlay bedrock. Therefore, runoff in clayey terrains is generally more rapid than in crystalline terrains, not withstanding site-specific differences such as slope and land cover/vegetation.

Expected runoff patterns based on terrains should be distinguished from estimated runoff potential based on soil hydrogroups (see Section 3.4.1.2). Although both provide valid, and typically congruent information, the effect of terrains predominates at low to moderate return interval events (i.e., 2, 5, and 10 year events), while the effect of soil hydrogroups predominate at larger return-interval events (e.g., 25, 50, and 100 year events).

During low to moderate storm events terrains influence the likelihood and extent of channel migration, avulsion, or incision. However, during extreme storm events, the influence of terrains is minimal and runoff is more strongly influenced by soil hydrogroup. For example, a Type C soil in a sandy terrain would produce less runoff during a 5-year event than a Type C soil in a clayey terrain. However, during a larger storm event, runoff from both terrains would be comparable (assuming similar vegetation, slope, and land use).

3.2.2.2 Channel Characteristics of Specific Terrains

Sandy and silt-sandy terrains are generally able to infiltrate larger volumes of water than are clayey and crystalline terrains. As a result: (a) sandy terrains play a vital role in groundwater recharge; (b) undisturbed sandy terrains are typified by lower runoff rates than clayey or crystalline terrains; (c) stream valleys in undisturbed sandy terrains tend to have wide floodplains and are often channel-less; (d) flows tend to persist longer after storms or further into the summer within sandy watersheds; and (e) there is a greater contrast between runoff conditions in undeveloped and urbanized watersheds in sandy terrains than in clayey or crystalline terrains.

Crystalline terrains are typified by narrow, well-defined stream valleys nestled between steep mountainous slopes. Unlike sandy streams that are susceptible to incision, streams in crystalline areas often flow over bedrock and have stable grades. The topography, soils, and hydrography of the crystalline geomorphic terrain are all inherently controlled and influenced by the underlying bedrock.

In Southern California Clayey terrains are also typified by more gentle topography than sandy or crystalline areas. Ridges tend to be lower and broader because the underlying bedrock is often more easily eroded. Clayey terrains also feature streams with fairly well-defined channels that have evolved to handle the higher runoff rates associated with clayey slopes. Clayey terrains are generally less susceptible to many of the environmental problems that plague sandier soils (such as enhanced sediment loading, incision, and headcutting).

Of the three terrains present in the San Juan Creek watershed, streams in sandy terrains are the most vulnerable to channel incision or channel widening associated with land use changes. The two main risks associated with development within sandy terrains are dramatically increased peak discharge and channel incision accompanied by headward erosion. To a certain extent, the two are inherently linked, and both result from the unique erosion and runoff properties of sandy watersheds. Studies have shown that urbanization in sandy watersheds can result in a proportionately greater increase in storm peaks and associated alteration of downstream channel morphology than in more clayey watersheds[10] (Figure 5 on page 29). Sandy terrains are often typified (under undisturbed conditions) by the presence of poorly defined channels along grassy, vegetated valley floors. Increased flood peaks due to urbanization can not only cause channel incision along grassy swales, but channel incision itself further serves to increase flood peaks through enhanced conveyance. The result is an amplified cycle of erosion and downcutting that destroys floodplain interaction, increases sediment yields and the tendency for flooding downstream, and significantly alters habitat.

3.3 HISTORIC CONTEXT

Physical and biological conditions in the watersheds have been affected over time by both natural and anthropogenic forces. Early historical accounts of lower San Juan Creek suggest near-perennial flow, with a freshwater lagoon near the mouth and a "green valley full of willows, alders and live oak, and other trees not known to us" (c.f., Friar Crespi in 1769). Natural events that have helped shaped the current conditions in the watershed include wet and dry cycles, flooding and fires. Anthropogenic effects include changes in patterns of water use, urban development, mining, grazing, and agriculture. The spatial and temporal effect of key historical events is based on not only the scale of the event, but the timing relative to other events. Investigating these patterns can be valuable for understanding natural processes and for long-range planning of future land use changes.

[10] *Differences in the susceptibility of streams in the three terrains to increased runoff are most pronounced for moderate runoff events (e.g. 10 to 25 year events). During extreme runoff events, streams in all three terrains are susceptible to channel incision and headcutting.*

3.3.1 Natural Processes

The geology, topography, and climate of the coastal watersheds of Southern California make them unique among the watersheds in the United States. The Transverse and Peninsular Ranges are intensely sheared and steep due to ongoing uplift and tectonic activity. In addition, these ranges are located close to the coast, resulting in steeper, shorter watersheds than those found in most other portions of the country.

The Mediterranean climate in Southern California is characterized by brief, intense storms between November and March. It is not unusual for a majority of the annual precipitation to fall during a few storms in close proximity to each other. The higher elevation portions of the watershed (typically the headwater areas) typically receive significantly greater precipitation, due to orographic effects. In addition, rainfall patterns are subject to extreme variations from year to year and longer term wet and dry cycles. The combination of steep, short watersheds; brief intense storms; and extreme temporal variability in rainfall result in "flashy" systems where stream discharge can vary by several orders of magnitude over very short periods of time.

3.3.1.1 Wet and Dry Cycles

Wet and dry cycles, typically lasting up to 15 to 20 years, are characteristic of southern California. The region presently appears to be emerging from a wetter-than-normal cycle of years beginning in 1993. Previously, five consecutive years of sub-normal rainfall and runoff occurred in 1987 through 1991.

Prior droughts of recent note include the brief, "hard" droughts of 1976 to 1977 and 1946 to 1951. Previous notable wet periods of the recent past were observed in 1937 to 1944 and 1978 to 1983. An unusually protracted sequence of generally dry years began in 1945 and continued through 1977.[11] During this period, rainfall was approximately 25 percent below the average for the prior 70 years (Reichard, 1979; Lang et al., 1998). Both recharge and (especially) sediment transport were diminished to even greater degrees. Although wet years did occur during this period, dry conditions were sufficiently persistent to lower groundwater levels and contract the extent of riparian corridors. In many areas, landslide activity was much less than during strings of wet years. Throughout Chiquita and Gobernadora canyons, many of the channel segments that may have cut across debris aprons formed by the 1938 floods and subsequent wet years may have re-filled during this period. At a broader regional scale, the 33 years of below-average rainfall, recharge, and sediment entrainment coincided with the post-war period of especially intensive hydrologic data collection, resulting in underestimates of hydrologic activity. Most of the hydrologic design studies

[11] *Inman and Jenkins have classified the time period between 1948 and 1977 as a relatively dry cycle and the period of October 1977 to the present as a relatively wet cycle.*

performed in southern Orange County were based on data collected between the years of 1960 through 1985, when rainfall, recharge, and sediment yields were below longer-term norms. Therefore, they may not account for variations in flow and sediment associated with long-term climate trends.

3.3.2 Floods

Major floods are a necessary component of riparian ecosystems in that they serve to re-establish ("reset") the plant communities by scouring older vegetation, establishing new areas of bare substrate, and facilitating dispersal of disturbance-adapted riparian plant species. Furthermore, major floods alter the location, continuity, and supply of sediment and large organic matter to the channel networks.

Major, flood-related disturbance of the channel and riparian systems may be expected with mean recurrences of 10 to 20 years. Large floods occurred in coastal southern California in 1907, 1916, 1937, 1938, 1969, 1978, 1983, 1993, 1995, and 1998. Historical accounts of the 1916 flood indicate that San Juan Creek extended fully across the valley downstream from the mission and what is now Highway 5 (Corps, 1999). Peak runoff values were estimated to be in the range of 104 to 151 (cfs/mi.^{2}) for Aliso, Trabuco, San Juan, and San Onofre Creeks, and 234 cfs/mi.^{2} for Laguna Creek at Laguna Beach in a more clay-rich watershed.[12] No data are available for either flood from San Mateo Creek or its major tributaries. The February 1969 peak flows were long-duration events, which eventually generated peak flows of 22,400 cfs at the La Novia gauging station in San Juan Capistrano, the highest reported prior to general urbanization in the watershed. The January and March 1995 events led to peaks of 15,200 cfs and 25,600 cfs, respectively, the latter being the largest flow recorded on San Juan Creek. Five distinct major crests were observed in February 1998, with a peak flow of 17,000 cfs.

3.3.3 Watershed Scale Fires

Nearly all portions of the two watersheds have been subject to watershed-scale fires from one to three times (and in limited areas, four or five times) during the past century (Fife, 1979; Stephenson and Calcarone, 1999) (Figure 6 on page 34 shows the recent fire history for Orange County). The primary hydrologic effects of the fires are sharp increases in sediment yields and often aggradation in the channel downstream (see Section 3.4.2). It should be noted that not all areas falling within a mapped fire periphery have actually been burnt. Generally, north-facing slopes and riparian corridors are much less likely to burn, and other areas may be affected only by a

[12] *Substantially higher peaks were observed February 6, 1937, in the Aliso (230 cfs/mi.^{2}) and Trabuco (255 cfs/mi.^{2}) watershed during what is described as a minor regional storm; San Juan Creek conveyed 80 cfs/mi.^{2} during the 1937 storm.*

Figure 6 Recent Fire History for Orange County

rapidly moving (and less destructive) ground fire. Pockets of soil and vegetation which have survived for many decades (or perhaps centuries) without high-intensity burning occur throughout the two watersheds.

Fires can result in shifts or changes in the vegetation community. Coastal sage scrub is generally considered to be relatively resilient to disturbance. However, frequent or intense fires may result in temporary to long-term increases in grassland species. In extreme instances frequent or intense fires may result in a type-conversion from sage scrub to grassland. Such a conversion may decrease infiltration and increase runoff and erosion into streams that drain the burned sub-basins.

The combination of fire, followed by high rainfall runoff shortly thereafter, can be one of the most significant sequences of events that shape the riparian corridors. This series of events can result in mobilization of large sediment stores that significantly alter the geometry and elevation of downstream channels. Much of the eastern San Juan watershed was last burned in 1959. The combination of this fire and the subsequent 1969 floods (described above) may have resulted in considerable deposition within the channels and floodplains, which have subsequently incised for many years.

3.3.4 Grazing

Large portions of both watersheds have been grazed at varying intensities over the last two hundred years. The exact effects of grazing remain unclear. The season-long, -continuous grazing over many years associated with traditional grazing practices was likely responsible for conversion of much of the uplands in the watershed from native grasses and scrub to non-native annual grassland. However, Heady (1968, 1977) suggested that large native herbivores present prior to European colonization might have been an important factor in grassland formation and ecology. Edwards (19XX) also notes "-observation and experiment world-wide are increasingly showing that large grazing-browsing-trampling mammals and native grasslands are coevolved." Therefore, some level and intensity of seasonal grazing may be necessary and beneficial to maintaining native grasses. Edwards (19XX) postulates that livestock grazing can be ecologically beneficial, if specific strategies are devised on the basis of site-by-site needs. Because native plant communities are typically associated with higher infiltration than non-native grasses, grazing induced conversion of ground cover was likely accompanied by increased runoff and erosion. Lower infiltration rates in the surrounding watershed may have also resulted in a decrease in the depth of shallow subsurface water. Decreases in shallow subsurface water can affect baseflow and width of riparian zones.

Intensive grazing within riparian corridors has been associated with suppression of riparian habitat and trampling of stream banks. The lack of established woody vegetation combined with direct disturbance from cattle could destabilize streams and make them more susceptible to erosion and incision. Therefore, the current width, depth, and geometry of the creeks in the study area may have been influenced by the cumulative influence of long term grazing on the uplands and the stream corridors.

3.4 HYDROLOGY

3.4.1 San Juan Creek Watershed

3.4.1.1 Drainage Network

Hydrologically, the San Juan watershed can be organized into three regions: the western portion of the watershed with the highly developed Oso Creek sub-basin and the moderately developed Trabuco Creek sub-basin; the relatively undeveloped sub-basins of the central San Juan watershed (i.e., Cañada Chiquita, Cañada Gobernadora, Bell Canyon, Lucas Canyon, Trampas Canyon and Verdugo Canyon); and the steeper eastern headwater canyons. The drainage density of the entire watershed is 10 mi/mi.^{2}. This value is somewhat low compared to other published reports (Strahler, 1968; Schumm, 1956), which suggest average drainage densities for various geomorphic settings, including southern California, of between 20 to 30 mi/mi.^{2}. Geologic, soil, and basin configuration issues (as discussed above) may all contribute to this lower-than-expected drainage density value. In the San Juan Creek watershed, many tributary valleys are comprised of sandy terrains and, as such, include swales that do not have a clearly defined channel form (i.e., channel-less swales). Omitting these swales from the calculated surface drainage network also reduces the drainage density of San Juan Creek watershed. Stream network maps and a discussion of important stream network parameters for each of the sub-basins are presented in Technical Appendix A.

3.4.1.2 Infiltration

Infiltration was estimated using the USDA hydrologic soil group classification. This standard USDA classification is based upon estimated runoff potential based upon soil properties that influence runoff. Soils are classified into hydrologic soil groups A, B, C, or D, depending upon infiltration rates measured when the soils are thoroughly wet. A-type soils have the highest infiltration rates while D-type soils have the lowest infiltration potential. In general, Type A soils contain a higher proportion of coarser textures (sand and gravel) and/or have a deeper soil profile. These conditions result in good drainage with higher rates of water transmission into the subsurface. In contrast, Type D soils are likely to contain a less permeable restricting clay layer, or are shallow, and this results in slower rates of water transmission into the subsurface. Conditions for B and C type soils are intermediate to A and D type soils. Table 2 on page 37 defines each soil type

Table 2

Orange County Hydrologic Soil Type Descriptions

Type A	Low runoff potential. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands and gravels. These soils have a high rate of water transmission.
Type B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
Type C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. These soils have a slow rate of water transmission.
Type D	High runoff potential. Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

Source: USDA, September 1978

according to the OCHM. The distribution of hydrologic soil groups in the San Juan watershed is shown in (Figure 7 on page 38).[13]

It is important to note that permeability rates from the USDA-SCS Soil Survey hydrogroups are not the same thing as loss rates used in the HEC-1 runoff modeling process. Loss rates for the studied sub-basins are given in Tables 3-2 and 3-3 of Appendix A to the Baseline Conditions report. Loss rates represent the amount of precipitation that is "lost" to other processes and is not available to generate runoff. Loss rates include not only infiltration into the soil (represented by soil hydrogroup), but also vegetation cover, land-use classification, and percent impervious surface.

Overall, infiltration in the San Juan watershed is relatively low, due to the prominence of poorly infiltrating soils (e.g., 79.8 percent of the watershed in underlain by soil types C or D) and the significant proportion of development in the western watershed. However, there are significant pockets of the watershed, particularly in the central watershed, which do have more permeable soils and offer better potential infiltration. Following the methods described in the OCHM, SCS runoff curve numbers were assigned to synthesize the effect of soil type, land use, vegetation, and infiltration processes and provide an integrated overall "hydrologic loss" rate. Note, for the analysis

[13] *A discussion of the influence of terrains vs. soil hydrogroups on runoff patterns is provided in Section 3.2.2.1.*

Figure 7 Distribution of Hydrologic Soil Groups for San Juan Watershed

of 2-year events, loss rates were set at 0.6 in/hr, as indicated in the Addendum to the OCHM (1995). Figure 8 on page 40 and Table 3 on page 41 display the distribution of SCS runoff curve numbers for the San Juan watershed. Assigned runoff curve numbers range from 30 to 97, with an area-averaged curve number of 80.5 for the whole watershed. The majority of the watershed (91 percent) was characterized by higher curve numbers between 70 and 97. For modeling purposes, higher curve numbers result in a greater proportion of rainfall becoming surface runoff (i.e., less infiltration). The highly developed western watershed, as well as the northern portion of Cañada Gobernadora, have the highest runoff curve numbers. Lower curve numbers occur mostly along riparian corridors and alluvial valley floors. Arroyo Trabuco, Wagon Wheel Canyon, Cañada Gobernadora, Bell Canyon, Lucas Canyon, Verdugo Canyon, and the Central San Juan catchments all contain zones of lower curve numbers along their valley bottoms. Based on a spatial GIS analysis of these runoff curve numbers, loss rates were calculated and incorporated into the HEC-1 model.

3.4.1.3 Storm Event Runoff

The 2-year, 10-year, and 100-year storm events were analyzed using the HEC-1 model of the San Juan Creek watershed. Figure 9 through Figure 11 on pages 42 through 44, respectively, show hydrographs at four locations in the watershed for each event.[14] Peak flows for the four locations are summarized in Table 4 on page 45.

Certain notable trends are observable in the modeling results from Figure 9 through Figure 11 on pages 42 through 44, respectively. For the 2-year event, peak runoff from the western, more urbanized, Trabuco and Oso sub-watersheds occurs earlier than peak flows along the main San Juan Creek in the central watershed upstream of Horno Creek. The shape of the hydrographs from the more urbanized Oso and Trabuco sub-watersheds is steeper, or flashier, for both the rising and falling limbs of the 2-year hydrograph. As the magnitude of the modeled events increases for the 10-year and 100-year events, the earlier arrival and “flashiness” of peak runoff from the Oso and Trabuco sub-basins is less pronounced. The more rapid arrival of peak flows from the western watershed occurs for two reasons. Flow distances from the western tributaries are somewhat shorter to the lower San Juan watershed than from the areas to the east. Secondly, the western watershed is more urbanized than the eastern watershed. Impervious surfaces in these urban areas shed runoff much more quickly than more pervious areas to the east, and the hydrograph peak occurs earlier. Peaks from the different sub-regions of the watershed combine to produce a hydrograph with a

[14] *The four locations are as follows: San Juan Creek upstream of Horno Creek (approximately the location of the USGS streamflow gauge at La Novia Street); Oso Creek upstream of the Trabuco Canyon confluence; Trabuco Creek upstream of the Oso Creek Confluence; and San Juan Creek at the Pacific Ocean. Taken together, these locations provide a good representation of hydrologic events at the watershed scale.*

Figure 8 Distribution of SCS Curve Numbers for San Juan Watershed

Table 3

San Juan Watershed Physical Characteristics

Sub-Watershed Region	Area (mi.^{2})	Area as % of Upstream WS Area	Length (mi)	Elevation (ft)		Percentage Area with Hydrologic Soil Group				Area-Averaged Curve Number (AMC II)	Impervious Area (%) of Total Sub-Basin
				Max	Min	A	B	C	D		
Lucas Canyon	7.17	14.31%	7.99	3,022	430	3.62	0.17	48.57	47.64	78.60	0.20
Verdugo Canyon	4.80	6.21%	6.02	2,487	358	8.30	1.25	61.81	28.63	74.80	0.05
Bell Canyon	5.12		5.47	4,485	1,178	1.94	0.00	9.15	88.91	82.30	0.00
	9.10		6.86	3,061	584	3.41	2.95	43.29	50.34	78.80	7.44
	6.35		8.86	2,405	358	8.12	5.64	45.83	40.41	74.00	0.02
Area Averages	20.57	28.42%				4.50	3.05	35.58	56.87	78.20	3.30
Cañada Gobernadora	2.99		3.17	1,237	656	3.43	35.25	54.36	6.96	79.50	29.84
	2.93		4.31	1,050	390	7.37	27.82	60.71	4.11	76.50	12.05
Wagon Wheel Canyon	1.77		3.49	1,063	390	0.69	30.59	62.96	5.76	74.50	1.77
	3.40		4.01	797	230	4.40	19.89	38.90	36.81	79.40	0.26
Area Averages	11.08	11.58%				4.33	27.83	52.67	15.16	77.88	11.59
Cañada Chiquita	4.58		5.59	1,168	358	0.00	36.55	41.89	21.56	77.70	0.35
	4.66		3.82	656	154	3.27	14.95	31.65	50.13	79.20	1.72
Area Averages	9.24	8.80%				1.65	25.65	36.73	35.98	78.49	1.04
Central San Juan Catchments	7.42	8.77%	4.48	892	230	6.07	12.08	52.62	29.24	75.90	3.14
Entire Watershed	175.97	100.00 %				4.74	15.42	27.80	52.04	80.50	21.84

Source: PWA, 2000

Figure 9 2-Year Event Hydrographs for San Juan Watershed

Figure 10 10-Year Event Hydrographs for San Juan Watershed

Figure 11 100-Year Event Hydrographs for San Juan Watershed

Table 4

Summary of Peak Flows (CFS), San Juan Watershed

Watershed Location	2-Year Event		10-Year Event		100-Year Event	
	(cfs)	(cfs/mi.^{2})	(cfs)	(cfs/mi.^{2})	(cfs)	(cfs/mi.^{2})
Oso Creek, upstream of Trabuco Creek	1,490	92	4,650	286	6,180	380
Lower Trabuco Creek, upstream of San Juan	2,560	47	10,600	194	20,040	366
San Juan Creek, upstream of Horno Creek	2,940	27	18,280	167	44,120	403
San Juan Creek at Pacific Ocean	5,170	29	29,820	169	67,820	385

Source: PWA HEC-1 Analysis, 2000

sustained high peak flow of 67,820 cfs for the 100-year event. The shape of the hydrograph is indicative of the longer, more sustained hydrologic response time for all regions of the San Juan watershed during the 100-year event.

Total runoff volumes and runoff per unit area for San Juan Creek at the Pacific Ocean are shown in above for the three modeled events. Runoff volume per unit area is generally higher for the overall San Juan Creek watershed than it is for the individual sub-basins because the individual sub-basins of the central watershed are generally undeveloped. Increased runoff from the more developed western portions of the watershed increases the overall watershed-averaged runoff volumes. (See Table 5 on page 46).

In general, absolute peak flow rates and volumes are greatest from the largest sub-basins: Bell Canyon in the San Juan watershed and Gabino Canyon in the San Mateo watershed (see Figure 12 on page 47). Peak flows and runoff volumes per unit area are fairly similar for the sub-basins within each watershed (see Figure 13 on page 48). However, discharge per unit area is generally greater for the sub-basins of the San Mateo watershed than for the San Juan watershed. This pattern reflects the steeper slopes and crystalline terrains found in the San Mateo watershed, which are expected to produce larger peaks flows per unit area. Within the San Juan watershed runoff volumes per unit area are lowest for the Chiquita, Gobernadora, and central San Juan sub-basins, which have the sandiest terrains and the highest infiltration rates (i.e., highest relative proportion of Type A and Type B soils). Gobernadora has slightly higher peak flows per unit area than would be expected, given the inherent properties of the sub-basin; this likely results from (1) the upstream development, which acts to increase volume and decrease time of concentration; and (2) from the hardpan layer which covers much of the upslope areas in the sub-basin. Hydrologic and sediment transport conditions in these individual sub-basins are described in further detail in Section 6.

Table 5

Storm Event Runoff Volumes, San Juan Watershed at the Pacific Ocean

Event	Total Runoff Volume (acre-feet)	Runoff Volume per Unit Area (acre-feet/mile^2)
2- Year	6,410	36
10-Year	31,040	176
100-Year	70,800	402

Source: PWA HEC-1 Analysis, 2000

3.4.1.4 Comparisons with Previous Hydrologic Studies

Previous hydrologic studies of the San Juan watershed have been completed by Rivertech (1987), Simons, Li & Associates (SLA, 1999), and the USGS (1993). Rivertech (1987) calculated 100-year peak discharges in the San Juan Creek watershed for future development conditions. Rivertech estimated 100-year flows (high-confidence) for Trabuco Creek, Oso Creek, and the main stem of San Juan Creek upstream to Long Canyon, using AES software following the Orange County Hydrology Manual (OCHM, 1986). In general, the results of the 2000 PWA analysis of existing conditions compare closely with the 1987 Rivertech estimates of future conditions. This result is not unexpected, as many of the "future" land use conditions assumed by Rivertech in 1987 are, in fact, existing land use conditions in 2000.

SLA (1999) recently performed a flood frequency analysis, HEC-1 rainfall-runoff analysis, low flow analysis, sediment yield and transport analysis, and groundwater assessment in support of the San Juan Creek watershed management study being conducted by the Planning Division of the U.S. Army Corps of Engineers, Los Angeles District. The SLA project analyzed the entire San Juan Creek Watershed, including Oso and Trabuco Creeks, and calculated discharge-frequency relationships for two gauged locations: San Juan Creek at La Novia Street and Trabuco Creek at Camino Capistrano. Historical flow data from these two gauges and the HEC Flood Frequency Program were used to create discharge-frequency relationships.

In general, SLA followed the methods outlined in the OCHM to formulate its HEC-1 model. However, to refine its model it adjusted basin roughness parameters so the estimated peak flow rates from HEC-1 would match with calculated peak flows from the discharge-frequency analysis. As a result, peak-flow values from its HEC-1 analysis are identical to results from its discharge-frequency analysis. A more standard model calibration process involves comparing HEC-1 generated hydrographs from a known precipitation event to actual stream flow data from the same storm event. The SLA technique assumes that a design rainfall event of a given return frequency would produce a discharge event of equal return frequency, which may not always be a valid assumption.

Figure 12 Peak Discharge and Event Runoff Volume for Selected Sub-Basins, Parts A and B

Fig 11, Part 1 Peak Discharge for Selected Sub-basins

Fig 11, Part 2 Event Runoff Volume for Selected Sub-basins

Figure 13 Peak Discharge per Unit Area and Event Runoff Volume per Unit Area for Selected Sub-Basins, Parts A and B

Fig 12, Part 1 Peak Discharge per Unit Area for Selected Sub-basins

Fig 12, Part 2 Event Runoff Volume per Unit Area for Selected Sub-basins

Additionally, SLA reported peak flows as "expected values" and not the more standard "high confidence values." Expected value estimates typically assume lower antecedent moisture conditions and, therefore, produce lower predicted runoff and associated stream flow than the high confidence values. If SLA had used high confidence values, as required by the OCHM (and used by PWA), its predicted discharges would have been significantly higher. Consequently, SLA's peak flow numbers are not directly comparable to Orange County design values and are generally lower than Rivertech's "high confidence" values (see on page 50).

Results of the current PWA analysis were also compared to discharge values for the San Juan watershed based on USGS regional regression equations. Because most of the watershed is undeveloped, the USGS *rural* regression was used to calculate peak flows for the overall watershed. Discharge values based on the USGS regional regression method (rural) were the lowest of all approaches. This is not surprising, as these USGS regional rates do not reflect developed land conditions and are, therefore, not entirely appropriate for the semi-developed San Juan watershed. A comparison of the calculated 100-year discharge values from PWA (2001), Rivertech (1987), SLA (1999), and the USGS regional regression approach are shown in Table 6 on page 50.

In general, the results of the PWA analysis compare closely with Rivertech's estimates for the Oso Creek, Trabuco Creek, and San Juan Creek at La Novia locations. Despite this general agreement at upstream locations, at the Pacific Ocean river mouth, 100-year results by PWA are somewhat higher than Rivertech. When considered per unit area, PWA's estimated 100-year discharge for the entire San Juan Creek watershed (67,820 cfs) equates to roughly 385 cfs/mi.^{2} (see Table 4 on page 45). This value plots below enveloping curves for maximum recorded floods for Pacific slope basins and is similar to values recorded for the March 1938 flood events on the Santa Ana River and the Tujunga Creek tributary of the Los Angeles River (see Figure 2-Figure 14, Technical Appendix A). For the current PWA analysis, the coincidental timing of hydrographs, where flows from the Oso, Trabuco, and central San Juan sub-basins arrive to the lower San Juan Creek region at roughly the same time for the 100-year event may account for the higher PWA runoff numbers at the ocean (Figure 11 on page 44). Other potential sources for this discrepancy are found in the use of different sub-basin delineations, routing parameters, land use designations, and modeling software by the two studies. Nevertheless, within the bounds of error associated with hydrologic models, there is reasonably close agreement between peak flow estimates generated by Rivertech and PWA.

3.4.2 San Mateo Creek Watershed

3.4.2.1 Drainage Network

The 133.2 mi.^{2} San Mateo Creek watershed has two principal drainage systems that join in the lower stream valley, 2.7 miles upstream of the ocean. The focus area of the SAMP/MSAA

Table 6

Comparison of Estimated 100-Year Discharges (CFS), San Juan Creek Watershed

Location	Rivertech [a]	SLA [b]	USGS [c]	PWA [d]
Oso Creek at confluence with Trabuco Creek	6,700	5,400	4,580	6,180
Trabuco Creek at confluence with San Juan Creek	22,600	18,700	12,500	20,040
San Juan Creek at La Novia Street Bridge	40,600	36,100	22,300	44,120
San Juan Creek at the Pacific Ocean	59,500	53,300	33,000	67,820

[a] *Rivertech (1987), "high confidence" values based on ultimate development conditions.*
[b] *Simons, Li & Associates (1999), "expected values" based on frequency-magnitude relations.*
[c] *USGS (1993), regional regression approach based upon rural (undeveloped) conditions.*
[d] *PWA (2001), HEC-1 based on undeveloped conditions following OCHM, 1986.*

Source: PCR Services Corporation, 2001

analysis is the western watershed north of the main stem of San Mateo Creek. The sub-basins of interest include La Paz, Gabino, Cristianitos, Blind, and Talega Canyons upstream of the Cristianitos and San Mateo creek confluence. Approximately 17 percent of the total runoff in the San Mateo Creek basin emanates from these tributaries (Carlson, pers. comm., 2000).

The predicted drainage density for the San Mateo watershed is 8 mi/mi.^{2}. Since the WES/CRRL study only mapped the portion of the San Mateo watershed within the SAMP/MSAA study area, complete calibration of the basin channel mapping was not possible. However, the predicted channel networks and drainage densities for the northwestern portion of the watershed (within the area mapped by WES/CRRL) have comparable accuracy to those in the San Juan Creek watershed. These results are discussed in the sub-basin analysis found in Section VI of this report (beginning on page 99) and presented more fully in Technical Appendix A.

3.4.2.2 Infiltration

Infiltration was estimated using the USDA hydrologic soil group classification as described in Section 3.4.1.2 (see Figure 14 on page 51). Overall, infiltration in the San Mateo watershed is relatively low due to the prominence of poorly infiltrating soils (e.g., 89.8 percent of the watershed is underlain by soil types C or D). However, there are pockets of the watershed, particularly in the upper western watershed, which do have more permeable soils and offer higher infiltration. Using the OCHM methods, SCS runoff curve numbers were assigned to synthesize the effect of soil type, land use, vegetation, and infiltration processes and offer an integrated overall "hydrologic loss" rate. Note, for the analysis of 2-year events, loss rates were set at 0.6 in/hr, as indicated in the Addendum to the OCHM (1995). Figure 15 on page 52 and Table 7 on page 53 displays the distribution of SCS

Figure 14 Distribution of Hydrologic Soil Groups for San Mateo Watershed

Figure 15 Distribution of SCS Curve Numbers for San Mateo Watershed

Table 7

San Mateo Watershed Physical Characteristics

Sub-watershed Region	Area (mi.^{2})	Length (mi)	Elevation (ft) max	Elevation (ft) min	Percentage Area with Hydrologic Soil Group A	B	C	D	Area-averaged Curve Number (AMC II)	Impervious Area (%)
La Paz Canyon	7.25	6.8	2,497	436	6.70	1.72	43.77	47.81	77.0	0.03
Upper Gabino Canyon	5.03	5.82	1,923	436	5.59	7.68	55.72	31.02	74.9	0.00
Lower Gabino Canyon with Blind Canyon	3.28	4.02	1,050	282	3.46	2.54	33.99	60.00	78.4	1.67
Upper Cristianitos Canyon	3.67	3.69	1,007	282	0.63	12.86	43.86	42.66	77.2	< 1.00
Talega Canyon	8.38	10.08	2,438	177	2.91	2.63	18.83	75.63	79.2	0.55
Entire Watershed	133.28	28.81	3,412	0	1.92	8.29	49.31	40.48	78.7	3.917

Source: PWA HEC-1 Analysis, 2000

runoff curve numbers for the San Mateo watershed. Assigned runoff curve numbers range from 31 to 97, with an area-averaged curve number of 78.7 for the whole watershed. The majority of the watershed (93 percent) was characterized by higher curve numbers between 70 and 97. Higher curve numbers result in a greater proportion of rainfall becoming surface runoff. The lower valley zones and riparian corridors along Cristianitos, Gabino, La Paz, and Talega canyons, as well as some reaches along the main San Mateo Creek upstream, include several areas of lower curve numbers. Based on a spatial GIS analysis of these runoff curve numbers, loss rates were calculated and incorporated into the HEC 1 model.

3.4.2.3 Storm Event Runoff

The 2-year, 10-year, and 100-year storm events were analyzed using the HEC-1 model of the San Mateo Creek watershed. Figure 16 through Figure 18 on pages 55 through 57, respectively, show hydrographs at four locations in the watershed for each event.[15] Peak flows for the four locations are summarized in Table 8 on page 58.

Several things are notable about the predicted hydrographs. In general, the hydrographs show the characteristic pattern of a large watershed, increasing in peak discharge and time of peak as they move downstream through the watershed. Flows from Cristianitos Creek, the most significant western tributary to San Juan Creek, join the main San Mateo channel prior to the passing of peak flows in the main San Mateo channel for all three events. As a result, contributing flows from Cristianitos Creek help sustain flows for the overall San Mateo watershed at the Pacific Ocean, where peak flows have a relatively long duration. The long duration is also reflective of the relatively un-urbanized condition of most of the watershed. Runoff rates tend to increase and decline much less rapidly in natural watersheds than in urbanized watersheds. Unlike the San Juan watershed to the north that contains large urbanized areas with impervious surfaces, the event hydrographs for the undeveloped San Mateo Creek do not exhibit heightened or accelerated flows.

Total runoff volumes and runoff per unit area for San Mateo Creek at the Pacific Ocean are shown in Table 9 on page 58 for the three modeled events. The individual sub-basins of the western San Mateo watershed have generally higher infiltration conditions and less runoff per unit area than the overall San Mateo watershed rates. Interestingly, for the 10-year and 100-year events, runoff volume per unit area for the relatively undeveloped San Mateo watershed is comparable to the more developed San Juan watershed to the north. However, as discussed in Section 3.4.1.3, peak discharge per unit area for the San Mateo sub-basins is generally higher than for the San Juan sub-

[15] *The four locations are as follows: San Mateo Creek downstream of the Nickel Canyon and Tenaja canyons; San Mateo Creek downstream of Cristianitos Creek; Cristianitos Creek downstream of Talega Canyon; and San Mateo Creek at the Pacific Ocean. These locations provide a good representation of hydrologic events at the watershed scale.*

Figure 16 2-Year Event Hydrographs for San Mateo Watershed

Figure 17 10-Year Event Hydrographs for San Mateo Watershed

Figure 18 100-Year Event Hydrographs for San Mateo Watershed

Table 8

Summary of Peak Flows (CFS), San Mateo Watershed

Watershed Location	2-Year Event (cfs)	2-Year Event (cfs/mi.^{2})	10-Year Event (cfs)	10-Year Event (cfs/mi.^{2})	100-Year Event (cfs)	100-Year Event (cfs/mi.^{2})
Cristianitos Creek at Talega Canyon	740	27	5,220	189	11,800	427
San Mateo Creek at Nickel/Tenaja Canyons	2,980	37	16,990	211	39,440	489
San Mateo Creek downstream of Cristianitos Creek	3,200	25	19,100	148	47,070	366
San Mateo Creek at Pacific Ocean	3,200	24	19,160	144	47,530	357

Source: PWA HEC-1 Analysis, 2001

Table 9

Storm Event Runoff Volumes, San Mateo Watershed at the Pacific Ocean

Event	Total Runoff Volume (acre-feet)	Runoff Volume per Unit Area (acre-feet/mi.^{2})
2-Year	4,550	34
10-Year	24,970	187
100-Year	59,100	443

Source: PWA HEC-1 Analysis, 2000

basins due to differences in terrain and slope between the two watersheds (see Figure 13 on page 48). In comparing runoff and discharge between the San Mateo sub-basins, the absolute discharges are highest for the Gabino sub-basin due to its large area; however, discharge per unit area is slightly higher for Cristianitos and La Paz primarily due to their shape and predominance of poorly infiltrating soils (see Figure 12 and Figure 13 on page 47 and on page 48, respectively). Hydrologic and sediment transport conditions in these individual sub-basins are described in further detail below in Section 6.

Unlike the San Juan Creek watershed, we have been unable to locate any previous hydrologic modeling studies completed for the San Mateo Creek watershed. Therefore, no comparisons can be made at this time.

3.4.3 Low Flow Conditions

The potential effect of urbanization on low-flow conditions was investigated by analyzing the Oso Creek sub-basin as an example of what could potentially happen in other parts of the San

Juan or San Mateo Creek watersheds if similar land use transformations were to occur. The results of the trend analysis conducted for Oso Creek show that annual minimum stream flows and mean summer flows consistently increased over time as the basin progressively developed (see Figure 19 and Figure 20 on page 60 and on page 61, respectively). Annual minimum stream flows, average summer daily stream flows, and annual base-flows all increased during the 12-year period of increased urbanization. The correlation between percentage of watershed area developed and percentage increase in mean July flows is shown in Figure 21 on page 62. The relationship observed in the Oso Creek sub-basin is consistent with the findings of Hamilton (1992) that indicate that urbanization increases dry season low flow discharge in arid climates. The effect of upstream development on dry season flows is currently observable in the northern portion of the Cañada Gobernadora sub-basin, where the Coto de Caza development has increased the magnitude and persistence of low flows to the central Cañada Gobernadora watershed. The potential biotic impacts associated with these changes in low-flow conditions may include a shift in the plant species composition of the wetland and riparian areas in response to changes in extent and duration of saturation, as well as changes in water chemistry (e.g., salinity, alkalinity). In addition, faunal habitats may shift to support species more dependent on persistent moisture than intermittent flow conditions.

The effect of increased urbanization on low-flow conditions will vary, based on the underlying terrains. In general, the sandy terrains of the central San Juan watershed will be more susceptible to increased low flow associated with urbanization. In contrast, crystalline terrains found in the eastern San Juan and portions of the San Mateo watershed have intrinsically low infiltration rates. Therefore, the proportionate increase in low flow associated with urbanization in these areas may be less than in the sandy portions of the study area. Impacts to low-flow conditions will be used as a criterion to evaluate potential land use alternatives in a future phase of work, as well as during the on-site alternatives analysis. Analysis of potential changes in low flow will be more meaningful once future land use changes are better defined.

3.5 SEDIMENT PROCESSES

3.5.1 Sediment Yield

Sediment yield is the result of all of the erosive processes that take place in a watershed. Rates of erosion in coastal southern California are among the highest in the world, and in the semi-arid environment of Southern California, more sediment is typically shed from upland slopes than can be transported by stream networks (Mount, 1995). Floodplains and stream valleys, therefore, serve as areas of sediment deposition and temporary storage. Erosion rates tend to increase with both the seasonality of rainfall and the tendency toward relatively large, infrequent storms (c.f., Wells, 1981). Hillslopes are episodically subjected to fire and channels tend to periodically incise

Figure 19 Annual Minimum Streamflows vs. Time for Oso Creek

Figure 20 Mean Daily Stream Flows for the Month of July vs. Time for Oso Creek

Figure 21 Developed Area vs. Increase in Average Daily Streamflow for Oso Creek

into their valley floors, processes that may generate most of the sediment yielded by some watersheds.

Many factors affect sediment yield. Among the most significant are geology, topography, rainfall, vegetation, multi-year wet and dry climatic cycles, fires, floods, landslides, and land use. Of these factors, fires, floods, and landslides are all episodic events that interact with the geology, topography, vegetation, and land use to affect the volume and timing of sediment delivery in the study area.

Sediment yields for the San Juan and San Mateo watersheds were estimated from existing data on measured sediment discharge in San Juan Creek and other creeks in the region, estimates of upland sediment yield rates in southern California, and application of the Corps of Engineers LAD debris method and the MUSLE.

Using measurements of streamflow and suspended sediment discharge, as well as estimates of bedload sediment discharge based on the modified Einstein method, Kroll and Porterfield (1969) estimated that long-term total sediment discharge for the San Juan drainage basin between 1931 and 1968 was approximately 1,230 tons per $mi.^2$ per year. This value is believed to underestimate total sediment yield from the watershed because: (a) it is an estimate of the sediment that is actually transported by the streams rather than the total amount of sediment provided to them; and (b) the data from which long term sediment yields were extrapolated were collected during two years that did not experience significant floods. Because most sediment is moved during extreme events, such as relatively large floods, this last point is key.

Taylor (1981) developed a catchment sediment yield model based on data from 36 water conservation reservoirs, flood control reservoirs, and debris basins throughout Southern California. Taylor's model estimates sediment yield using the relationship:

$$DR = \alpha L^{\beta} A^{\gamma}$$

Where:

DR = denudation rate, equivalent to the volume of accumulated sediment divided by the total erosional area in the drainage and the number of years over which the accumulation took place.

L = a topographic variable that reflects the dominant land type, defined as mountains, hills, or plains. Mountainous drainages have the highest denudation rates. Hill areas have lower rates, and on plains, measured denudation rates are extremely small.

A = a factor that takes into account the size of the basin, as studies have shown that there is a decrease in denudation rate as basin size increases.

α, β, and γ = fitted coefficients computed for each of 24 hydrographic drainage units defined by the study.

Taylor's denudation rates, expressed as base sediment yield rates, for the sub-watersheds in the San Juan and San Mateo drainages are shown in Table 10 on page 65 and Table 11 on page 67, respectively. Computed denudation rates are highest in the mountainous crystalline areas, where projected sediment yields are almost 6,000 tons per mi.^{2} per year. Within the foothills, projected base sediment yield rates range from approximately 2,500 to 3,100 tons per mi.^{2} per year. The foothill denudation rates calculated by Taylor are approximately twice the average annual sediment load for San Juan Creek estimated by Kroll. This difference may be attributable to the fact that: (a) denudation rates represent the amount of material available to streams for transport rather than the amount that they are actually able to move on a regular basis; (b) as discussed previously, Kroll may underestimate sediment transport during large storms; and (c) sediment sampling and calculation of yearly sediment budgets by Kroll do not appear to include the bedload sediment being transported.[16]

The sediment yields estimated based on the LAD and MUSLE methods are expressed as cubic yards per mi.^{2} for specific design discharge events, including the 2-year, 25-year, 50-year, 100-year, 200-year, and 500-year floods, making direct comparison with historical measured or estimated sediment yields obtained from other sources difficult. Computed sediment yields based on the LAD method were 145 and 10,270 tons per mi.^{2} for the 2-year to 100-year floods in the San Juan watershed and 640 and 14,840 tons per mi.^{2} for the same design storms in the Arroyo Trabuco watershed. Sediment yield estimates obtained using the MUSLE method were 71 and 7,800 tons per mi.^{2} in the San Juan watershed for the 2-year and 100-year floods and 200 and 8,900 tons per mi.^{2} in the Arroyo Trabuco watershed for the same design storms. Yields calculated using the MUSLE and LAD methods for the 25-year and 50-year events are within a similar range of baseline sediment yields estimated by Taylor's denudation rate formula. Table 12 on page 68 provides a comparison of estimated sediment yields in the San Juan watershed using the techniques discussed above.

For all methods, calculated sediment yields that attempt to quantify the amount of material available for stream transport exceed estimates and measurements of transported sediment loads by more than a factor of 2. This may accurately reflect the condition of watersheds in an arid environment, where far more material is weathered and eroded than can typically be conveyed to and transported by local stream systems.

[16] *Sediment yield associated with episodic events is the most significant factor in the overall sediment budget for southern California coastal watersheds. Bedload transport accounts for a small fraction of the overall sediment movement in the watershed, and is a minor factor in shaping stream geomorphology.*

Table 10

Base Sediment Yields And Particle Size Distributions, San Juan Creek Watershed

Stream	Major Geologic (Unit(s))	Weathers to [a]	Streambed Characteristics	Transport Characteristics	Base Sediment Yield Rate [b] (mm/year)	Base Sediment Yield Rate (tons/sq mi/year)	Particle Size Distribution: Suspended Load: Clay/Silt	Particle Size Distribution: Suspended Load: Sand	Particle Size Distribution: Bedload: Sand	Particle Size Distribution: Bedload: Gravel	Particle Size Distribution: Bedload: Cobble	Percent Bedload
OSO			sand, silt, clay	supply limited	0.35	2,491	high	high	high	v. low	v. low	15 to 25
	Niguel Sandstone	clayey and sandy silt										
	Capistrano Siltstone	clayey silt, expansive clay, some sand										
TRABUCO			gravel, sand, silt, clay	transport limited	0.35	2,491	high	high	high	med	low	10 to 20
	Bedford Canyon Metamorphics	sand, silt, clay, pebbles										
	Santiago Peak Volcanics	angular pebbles and clay										
	Sespe and Vaqueros Sandstone and Conglomerate	clay, silt, sand, gravels										
	Old channel deposits	clay, silt, sand, gravels cobbles										
	Monterey Shale	silt and clay										
	San Onofre Breccia	silt, sand, gravels, cobbles										
	Niguel Sandstone	clayey and sandy silt										
	Capistrano Siltstone	clayey silt, expansive clay, some sand										
CHIQUITA			sand, some silt	supply limited	0.41-0.45	2,918 to 3,202	high	high	high	v. low	v. low	5
	Sespe Sandstone and Conglomerate	clay, sand, gravels										
	Santiago Sandstone, Siltstone, Claystone	clayey sand										
	San Onofre Breccia	silt, sand, gravels, cobbles										
GOBERNADORA			sand, silt, clay	supply limited	0.41	2,918	high	high	high	low	v. low	5 to 10
	Sespe Sandstone and Conglomerate	sand, silt, clay; minor gravels										
	Santiago Sandstone, Siltstone, Claystone	clayey sand										
BELL			cobbles, gravels, sand	transport limited	0.38	2,704	med	med	med	high	high	50 to 60
	Bedford Canyon Metamorphics	sand, silt, clay, pebbles										
	Starr Fanglomerate and Sandstone	silt with pebbles and cobbles										
	Santiago Sandstone, Siltstone, Claystone	clayey sand										
UPPER SAN JUAN			bedrock, gravels	supply limited	0.84	5,978	low	high	med	med	high	60 to 80
	granitic	sand or smaller w/ large boulders										
	meta-sedimentary	sand, silt, clay, pebbles										
	Santiago Peak Volcanic	angular pebbles and clay										
	Trabuco Conglomerate	sand, cobbles, boulders										
	Starr Fanglomerate and Sandstone	silt with pebbles and cobbles										
VERDUGO			cobbles, gravels, sand, silt	transport limited	0.44	3,131	med	high	high	med	high	50 to 60
	Trabuco Conglomerate	sand, cobbles, boulders										
	Starr Fanglomerate and Sandstone	silt with pebbles and cobbles										

Table 10 (Continued)

Base Sediment Yields And Particle Size Distributions, San Juan Creek Watershed

Stream	Major Geologic (Unit(s))	Weathers to [a]	Streambed Characteristics	Transport Characteristics	Base Sediment Yield Rate [b] (mm/year)	Base Sediment Yield Rate (tons/sq mi/year)	Particle Size Distribution: Suspended Load: Clay/Silt	Particle Size Distribution: Suspended Load: Sand	Particle Size Distribution: Bedload: Sand	Particle Size Distribution: Bedload: Gravel	Particle Size Distribution: Bedload: Cobble	Percent Bedload
TRAMPAS			sand, silt, clay (?)	supply limited			low	high	high	v. low	v. low	40 to 50
	Shultz Ranch Sandstone	sand and silt										
	Santiago Sandstone	sand and clay										
	Monterey Shale	silt and clay										
	San Onofre Breccia	silt, sand, gravels, cobbles										
LUCAS			cobbles, gravels, sand, silt	transport limited	0.44	3,131	low	med	low	high	high	50 to 60
	Trabuco Conglomerate	sand, cobbles, boulders										
	Starr Fanglomerate and Sandstone	silt with pebbles and cobbles										
	Shultz Ranch Sandstone	sand and silt										

[a] *Gravels are 2 to 64 mm. Pebbles are a subset of larger gravels (16 to 64 mm). Cobbles are 64 to 256 mm (2.5 to 10 inches). Boulders are larger.*

[b] *Sediment yield rates presented are based on Taylor (1981) and should be revised to reflect a more refined understanding of local conditions. Data are presented as calculated to allow replication; readers should be aware that these values should be read to no more than two significant figures.*

Source: Balance Hydrologics, 2000

Table 11

Base Sediment Yields and Particle Size Distributions, San Mateo Creek Watershed

	Stream	Major Geologic (Unit(s)) [a]	Weathers to	Streambed Characteristics	Base Sediment Yield Rate [b] (mm/year)	Base Sediment Yield Rate (tons/ $mi.^2$/year)	Particle Size Distribution: Suspended Load: Clay/Silt	Suspended Load: Sand	Bedload: Sand	Bedload: Gravel	Bedload: Cobble	Percent Bedload
Within Study Area	CRISTIANITOS	Santiago Sandstone, Siltstone, Claystone	clayey sand	sand, silt, clay,	0.48	3,416	high	high	high	low	low	40 to 50
Within Study Area	GABINO	Williams Sandstone, Conglomerate Shultz Ranch Sandstone Santiago Sandstone, Siltstone, Claystone	sand, silt, gravels sand and silt clayey sand	sand, silt, gravel, cobbles	0.42	2,989	med	med	med	med	med	50 to 60
Within Study Area	LA PAZ	Trabuco Conglomerate Williams Sandstone, Conglomerate Shultz Ranch Sandstone Santiago Sandstone, Siltstone, Claystone	gravels, cobbles, boulders, sand sand, silt, gravels sand and silt clayey sand	sand, silt, gravel, cobbles	0.42	2,989	med	med	med	med	low	50 to 70
Beyond Study Area	TALEGA	volcanics and meta-volcanics Williams Sandstone, Conglomerate Santiago Sandstone, Siltstone, Claystone Capistrano Siltstone, Sandstone	sand, silt, clay, gravels, cobbles sand, silt, gravels clayey sand clay, silt, sand		0.39	2,775	high	?	?	high	?	20 to 40
Beyond Study Area	DEVIL CANYON	granodiorite volcanics and meta-volcanics	sand or smaller with large boulders sand, silt, clay, gravels, cobbles	bedrock, gravel, sand	0.35	2,490	med	high	high	high	high	30 to 50
Beyond Study Area	LOWER SAN MATEO (south of confluence with Cristianitos)	mid-Miocene marine upper Miocene marine Pleistocene marine terrace	sand, silt, clay silt and clay sand, silt, clay; minor cobbles, gravels	sand, silt, cobble, gravel (sandiest near mouth)	0.35	2,490	high	high	low	low	v. low	20 to 40
Beyond Study Area	UPPER SAN MATEO	upper Cretaceous marine Santiago Sandstone, Siltstone, Claystone	sand, silt, clay clayey sand	bedrock, gravel, sand, silt	0.35	2,490	low	high	med	med	high	20 to 40

[a] *Taylor classified Devil Canyon and Upper San Mateo as "hills" rather than "mountains," which leads to an anomalously low base sediment yield. We have increased estimated denudation rates from 0.30 to 0.35 mm/yr.*

[b] *Sediment yield rates presented are based on Taylor (1981) and should be revised to reflect a more refined understanding of local conditions. Data are presented as calculated to allow replication; readers should be aware that these values should be read to no more than two significant figures.*

Source: Baseline Hydrologics, 2000

Table 12

Comparison of Sediment Yield Estimates

Watershed	County	Author	Dominant Substrate Type	Method	Time Period	Sediment Type (tons/ mi.^{2})	Comments
San Juan	Orange	Kroll & Porterfield	crystalline & sedimentary	rating curve applied to gauging record	1931-1968	1,230	based on measurements taken during 1967-1968
San Juan	Orange	Taylor	crystalline & sedimentary	calculated denudation rate	—	1,500 to 6,000	highest in mountainous areas, lower in foothills
San Juan	Orange	SLA	crystalline & sedimentary	LADB	—	4,350 to 6,850	indicated range is Q25 to Q50 with no burn
San Juan	Orange	SLA	crystalline & sedimentary	MUSLE	—	3,000 to 5,000	indicated range is Q25 to Q50
Arroyo Trabuco	Orange	SLA	crystalline & sedimentary	LADB	—	5,700 to 9,950	indicated range is Q25 to Q50 with no burn
Arroyo Trabuco	Orange	SLA	crystalline & sedimentary	MUSLE	—	3,000 to 5,500	indicated range is Q25 to Q50
San Diego	Orange	OCPFRD	crystalline & sedimentary	sampled sediment transport	1983-1998	1,800	suspended sediment only
San Diego	Orange	OCPFRD	crystalline & sedimentary	debris basin sediment removal	1983-1998	395	low trap efficiency

Source: Balance Hydrologics, 2000

3.5.2 Episodicity

In Central and Southern California, up to 98 percent of the amount of sediment moved in any single decade is often mobilized during one or two intense flow events (Knudsen et al., 1992), a conclusion that is supported by estimates of sediment discharge in Arroyo Trabuco and in San Juan Creek near San Juan Capistrano over a period extending from 1932 to 1968 (Kroll and Porterfield, 1969). The amount of sediment mobilized during an intense flow event is governed by available sources in the watershed, landform, and time since the last major fire.[17] Major sediment stores and expected fire frequencies are discussed below.

Rotational slumps, block glides, and soil slips have all been observed and mapped in different portions of the San Juan and San Mateo Creek watersheds. Residual bedrock landslide debris covers more than 3.7 mi.^{2} within the San Juan Creek watershed alone, and it has been estimated that more than one billion tons of landslide debris are ready for transit down this drainage area during a major flood event (Vanoni et al., 1980).

Landslides cover more than one-third of the Cristianitos fault zone area, and composite slides as great as 630 acres are present. Although impressive in aerial extent and important from a geotechnical perspective, these large bedrock slides are likely geologically-old relict features thought to contribute less sediment to streams than do shallow failures on much steeper slopes.

West of the fault zone, the landscape is comprised mostly of low hills that terminate at a broad, wave cut terrace formed by marine erosion at the coastline. This area is not marked by extensive landslides because capping deposits help to protect the underlying bedrock, and stream erosion is not significantly active near the coast. Landslides in the hills between the coastal terrace and the Cristianitos fault are prevalent and consist mainly of bedrock failures that generally occur along the slopes of streams as discrete units or as aprons of coalescing slides. Although earth movement is common in these areas, localized slides probably do not contribute significantly to episodic sediment yields, unless they impinge directly into the channel, but rather contribute to baseline sediment yields.

East of the fault zone, landslides cover less than 1 percent of the area. More importantly, from the perspective of sediment yield, the area east of the fault zone has a propensity for the occurrence of mud-debris flows, notably in the Trabuco and Williams Formations. During periods of extended rainfall, such as during the 1969 floods, mud-debris flows emanating from the heads of steep canyons were commonplace (Morton, 1974). Failures occurred mostly in accumulations of slopewash or colluvial debris that lay somewhat perched high and at the heads of narrow, steep drainage channels above alluvial valleys. When these materials became saturated, they were

[17] *An estimated 70 percent of all sediment production in California's chaparral is triggered by fire (Wells, 1981).*

mobilized en masse. The steeper and straighter the channel, the farther the material flowed, picking up additional rock debris, mud, and vegetation in the process (Morton, 1974).

Factors that account for the estimated effects of fire on sediment yield are based on several studies that describe changing sediment rating curves and yields following large fires (for example, DeBano, 1998; Roberts et al., 1984; Hecht et al., 1983; Hecht, 1981; Glysson, 1977; Brown and Jackson, 1973). After reviewing the available field evidence, we conclude that post-fire sediment yields from the subwatersheds of the SAMP/MSAA area may be best predicted from base rates of sediment transport by using multipliers of 10, 7, 4, 2, 1.5, and 1 for the first through sixth winter following the fire. For watersheds of 2 to 20 mi.^{2}, multipliers of 12, 7, 3, 1.5, and 1 times the base rate may be used to estimate sediment yields during the first five winters following the fire. These factors assume that the burn periphery covers 100 percent of the watershed, although (as is typical) large areas of unburned vegetation remain on north and east facing slopes or adjoining the riparian zones. For watersheds smaller than 2 mi.^{2}, a briefer and more extreme set of multipliers might be used, such as 15, 5, 1.5, and 1, with base rates of sediment yield resuming after 3 to 4 years; existing research, however, is probably not sufficient to support any particular set of multipliers.[18]

3.5.3 In-Channel Sediment Transport

Peak sediment transport rates were calculated using the SAM model[19] for each major sub-basin in the study area for the 2-year, 10-year, and 100-year discharge events. Peak transport rates per unit area were also calculated for each of the sub-basins. The Laursen-Madden transport function was used to generate sediment transport rates for general comparison purposes and for use in the alternatives analysis. This transport function has been shown to be a reliable estimate of sediment transport across basins of various substrate types. Technical Appendix A provides a discussion of the validity of using this transport function as well as a detailed comparison and sensitivity analysis of the various sediment transport functions. It should be noted that these rates represent the capacity for the system to transport sediment and may not describe actual sediment transport rates. Actual sediment transport is determined by both transport capacity and sediment supply (see terrains discussion above).

[18] *Watersheds smaller than 2 mi.^{2} (1,280 acres) may not have sufficient alluvial development to develop a consistent sediment rating curve. Hence, these factors should be used only for comparisons of alternatives and other planning applications, not for design. The approximation given in the text is most valid for the larger small watersheds and least valid for those smaller than a mi.^{2}.*

[19] *The Laursen-Madden (LM), Laursen-Copeland (LC), and Engelund-Hansen (EH) sediment transport functions were used within the SAM application. In general, the Laursen-Madden (LM) function is most suitable for sand and gravel bed streams and is a general all purpose function suitable for comparison across basins with various substrate types.*

3.5.3.1 San Juan Watershed

Absolute peak sediment transport capacities for each major sub-basin during the 100-year flow event are compared in Figure 22 on page 72. Transport rates are given at the most downstream end of each sub-basin. For the Laursen-Madden transport function, Cañada Gobernadora and Bell Canyon had the highest absolute sediment transport rates in the San Juan watershed. This result is likely explained by the relatively large size of these two canyons (11.08 mi.^{2} and 20.57 mi.^{2} respectively), although Cañada Gobernadora also has a relatively high transport capacity per unit area (see Figure 23 on page 73). After Bell Canyon and Cañada Gobernadora, the main stem of the Central San Juan Creek sub-basin had the next highest absolute sediment transport rate. Peak transport rates from Lucas Canyon were the lowest of the San Juan Creek watershed sub-basins.

Transport rates per unit area at the most downstream reach of each sub-basin for a 100-year flow event are shown in Figure 23 on page 73. Since these rates are independent of sub-basin size, they reflect sediment shedding properties, integrating factors of channel geometry, runoff rates, and geology. For the Laursen-Madden transport function, Trampas Canyon had the highest transport rates per unit area of any of the studied sub-basins entering San Juan Creek. Cañada Gobernadora, Verdugo Canyon, and Lucas Canyon had the next highest transport capacities per unit area. Transport rates per unit area are likely highest for Trampas Canyon, due to steep channel slopes at the basin mouth, transportable sediment sizes, and a small drainage area. In many ways, Trampas Canyon is different from the other studied sub-basins, which are larger canyon systems that occupy broader valleys. Trampas Canyon is more representative of the steeper headwater systems of the San Juan watershed where sediment yields are much higher. Conversely, sediment yields per unit area for the main San Juan channel are the lowest. More detailed sediment transport results for each sub-basin are presented in Section 6 and in Technical Appendix A.

Calculated sediment yields for the 2-year, 10-year, and 100-year storm events are shown in Figure 24 on page 74. These results essentially represent the potential volume of sediment delivered to the main stem of San Juan Creek from each of the tributary sub-basins during various magnitude storm events. In general, average annual measures of sediment yield estimated by Balance Hydrologics (see Table 12 on page 68) are consistent with the absolute transport rates for a 2-year storm event estimated by PWA. Bell Canyon exhibited the highest sediment yield to San Juan Creek. This is not surprising, since Bell is the largest of the sub-basins and produced relatively high transport rates. The main stem of the Central San Juan sub-basin, Gobernadora, Trampas, and Lucas Canyons also produced relatively high yields. Cañada Chiquita produced the lowest yields of the San Juan watershed sub-basins. Figure 25 on page 75 shows sediment yields per unit area. Trampas Canyon has the highest yields per area. This is consistent with the results for transport rates described above for this steep, small tributary catchment. Of the studied canyon sub-basins, Verdugo Canyon had the highest yield per unit area.

Figure 22 Peak 100-Year Sediment Transport Rates for San Juan and San Mateo Watersheds

Figure 23 Peak 100-Year Sediment Transport Rate per Unit Area for San Juan and San Mateo Creek Watersheds

Figure 24 Sediment Yield for 2-Year, 10-Year, and 100-Year Discharges

Figure 25 Sediment Yield per Unit Area for 2-Year, 10-Year, and 100-Year Discharges

Based on the in-channel yield results, sediment mass balances were calculated for the four modeled reaches of the main stem of San Juan Creek to assess if the reaches were erosional or depositional. Upstream sediment input to San Juan Creek, from the upper watershed above Lucas Canyon, was estimated using results from BH. Although the magnitude of results varies somewhat for the two sediment transport functions (i.e., Laursen-Madden and Laursen-Copeland), both functions indicate a general pattern of deposition in three of the four modeled reaches during large flood events. The most downstream reach was predicted to be slightly erosional during extreme flood events. The delivery of sediment from the canyon sub-basins to the main San Juan Creek channel likely plays a significant role in this depositional pattern observed in the three upstream reaches.

3.5.3.2 San Mateo Watershed

In the San Mateo Creek watershed, Gabino Canyon (upstream of the Cristianitos Creek confluence) was calculated to have the highest sediment transport capacity (see Figure 22 on page 72). This absolute rate is the highest of all modeled sub-basins in the San Juan and San Mateo watersheds and is similar in magnitude to rates calculated for Gobernadora and Bell Canyons in the San Juan watershed. Transport rates calculated for La Paz and Cristianitos Canyons are the lowest in of the modeled San Mateo sub-basins and are similar to values calculated for Lucas and Verdugo canyons. The Upper Cristianitos sub-basin (3.67 $mi.^2$) had the highest transport capacity per unit area of the three modeled San Mateo sub-basins (see Figure 23 on page 73). The basin's per unit area transport rate surpasses rates calculated for all other sub-basins except Trampas Canyon. This implies that the hydrology, geology, and geomorphology of Upper Cristianitos Creek are conducive to transporting sediment. The transport capacity per unit area of Gabino Canyon is intermediate between estimated rates for La Paz and Cristianitos Canyons. Of the modeled sub-basins in the San Mateo Creek watershed, La Paz Canyon had the lowest transport rates per unit, only slightly higher than those for Lucas Canyon.

Calculated sediment yields at the mouth of the sub-basins for the 2-year, 10-year, and 100-year storm events are shown in Figure 24 on page 74. This figure illustrates that the Gabino Canyon sub-basin exhibits the highest sediment yield of the three San Mateo sub-basins. This is most likely due to the somewhat larger size of Gabino Canyon, relative to the Upper Cristianitos and La Paz sub-basins. Although the Upper Cristianitos sub-basin is half the size of the La Paz sub-basin, its relatively high rate of sediment transport per unit area (see Figure 23 on page 73) resulted in total sediment yields that were slightly higher than those from the La Paz sub-basin for the 10-year and 100-year events.

Figure 26 on page 77 shows the sediment rating curves developed for several streams of the San Juan and San Mateo watersheds. In comparing yield figures or sediment rating curves for different basins, it is important to keep in mind differences between the basins in the primary factors

Figure 26 Suspended Sediment Rating Curve for Streams of the San Juan and San Mateo Watersheds

that affect sediment yields and transport, including precipitation regime, geology and soils, relief, bank and bed stability, drainage area, type of stream (i.e., alluvial or bedrock), tectonic setting, and fire and land use history of the basin. Of particular interest are subwatersheds underlain by Monterey shale, which have steeply sloping sediment rating curves. This diatomaceous, chalky rock weathers quickly and yields high quantities of sediments at all flows. Very little sand is produced from this geologic type. In contrast, the crystalline bedrock sediment yield is highly episodic. At most flows it will produce few sediments, however, at extremely high flows and/or after fires it yields high quantities of sediments. In general, suspended sediment discharge in San Mateo Creek is generally less than in San Juan Creek for all measured flows. One factor that may contribute to the lower suspended sediment discharge in San Mateo Creek is the absence of Monterey shale in the drainage geology. This diatomaceous rock that underlies 10 percent of the drainage area in San Juan Creek is known to yield high quantities of sediment as it weathers. Another factor contributing to the lower rate of suspended sediment transport in San Mateo is the smaller drainage area size.

3.6 WATER QUALITY

Pollutant pathways and cycles within settings as diverse as the San Juan and San Mateo Creek watersheds can be complex. Constituents of concern in these watersheds include temperature, turbidity, nutrients (primarily nitrogen and phosphorus), metals, and pesticides (primarily diazanon and chloropyrofos). Although the biogeochemical relationships that govern the fate of different constituents can be complicated, it is important to note that a number of generalizations are possible regarding the effect of the environmental setting and the terrains on water quality. These generalizations, if applied in the proper context, can provide a framework within which to understand monitoring data and to develop strategies for water quality management.

In general, pollutants are transported and sometimes transformed into other compounds with storm water runoff. They are either in dissolved form, particulate form, or are adsorbed to other particles in the water (clays, colloids, etc.). The availability of particulates and pH affect the distribution of pollutants between dissolved and bound forms. Therefore, land use characteristics that promote infiltration and slow the flow of water allowing sediments to settle or filter out are the main factors that control pollutant mobility.

Geology can also have a direct impact on specific water quality constituent concentrations. For example, the Monterey shale bedrock, which occurs in several of the San Juan Creek sub-basins, has been reported to be a source of high levels of phosphate (Dickert, 1966) and certain metals, such as cadmium (Majmundar, 1980).

Terrains can influence the mobilization, loading, and cycling of pollutants. Some general water quality characteristics of the major terrains in the study area are:

- **Sandy terrains**. Sandy terrains generally favor infiltration of rainfall and therefore have the potential to direct pollutants mobilized in low to moderate rainfall events into sub-surface pathways, with little or no actual biogeochemical cycling taking place in surface waters. Sequestered in sands, pollutants have the opportunity to degrade and attenuate via contact with soils and plants in the root/vadose zones before passage to groundwater or mobilization and transport to surface waters during larger storm events.

- **Silty terrains**. Silty terrains are characterized by higher runoff rates and tend to favor surface water pathways more than sandy terrains (but less than clayey terrains). Silty substrates can also be a significant source of turbidity (i.e., fine sediments). Conversely, the finer sediments derived from the silty substrates promote the transport of metals and certain pesticides in particulate form. This makes them less-readily available in first and second-order stream reaches, but potentially allows transport to higher order streams and subsequent deposition over long distances.

- **Clayey terrains**. Clayey terrains are characterized by very high rates of surface runoff during low and moderate storm events. Although clay soils are generally quite resistant to erosion, they can be very significant sources of turbidity during extreme rainfall events when erosion occurs and/or headcutting or incision within the streambed begins.

- **Crystalline terrains**. Crystalline terrains are common only in the uppermost reaches of the San Juan and San Mateo Creek systems where development and agricultural activities are absent. Similar to clayey terrains and in contrast to sandy terrains, during low to moderate rainfall events, primary pollutant pathways will be in surface water flow, leading to the potential for rapid mobilization and transport of constituents. Unlike clayey terrains, however, the crystalline substrates may be relatively poor in the finer particles that cause turbidity. Like all terrain types, extreme events will likely result in the mobilization and transport of all sizes of sediments from these areas.

3.6.1 Analysis of Existing Water Quality Data for the San Juan Watershed

Orange County has collected a significant amount of water quality data for San Juan Creek since the 1950s.[20] The bulk of recent water quality monitoring data in the San Juan Creek watershed was collected by the Orange County PFRD in the 1990's at three sampling points that allow for a generalized comparison among land use and terrain types. The sampling points are: (a) the main stem of San Juan Creek at La Novia bridge in San Juan Capistrano has a large drainage area that includes all terrain types and contains diverse land uses; (b) the main stem of San Juan Creek at Caspers Regional Park (approximately 10 miles upstream of San Juan Capitstrano) represents runoff

[20] *Concurrent discharge measurements were not taken at the time of sampling for much of the data, creating some limitations on its use.*

from primarily open space coastal scrub and chaparral on crystalline terrains; and (c) the Oso Creek sample location represents mostly urban land uses on clayey terrains.

The data for the key nutrients (nitrate, ammonia, and phosphate) monitored by Orange County is summarized in Table 13 on page 81. This table includes statistical summaries for the measured concentrations of these nutrients as a function of the 3-day antecedent rainfall measured at the Tustin rain gauge.[21] It is important to note that the measured nutrient concentrations, especially during dry periods, were at or below the detection limit for one of more of these constituents. In this case, the detection limit values were used in the statistical summaries. For this reason, any conclusions about absolute nutrient concentrations at low levels should be considered tentative. The disaggregation of the data was carried out in an effort to identify patterns of nutrient mobility as a function of rainfall, which is generally considered the primary mobilizing event within any low-elevation watershed that is not influenced by snow-melt runoff.

3.6.1.1 Nitrates and Phosphates

Several observations can be made on the basis of this data, as well as the historical data which is included in Appendix B:

- The data suggest that there are one or more significant sources of nitrogen loading between the Caspers and La Novia monitoring stations. It is not possible with the available data to ascertain the sources of the additional loading, but it may include factors such as the location of several nursery operations downstream of the Caspers site, development on San Juan tributaries (e.g., Coto de Caza on Cañada Gobernadora), and

[21] *Rainfall data from the Tustin gauge was chosen due to the completeness of the data and the relative proximity of the gauge to the watershed. The gauge is operated by the Orange County PFRD and is located northwest of the water quality stations on San Juan and Oso Creeks. Additionally, the gauge is located at an elevation (and, thus, mean annual rainfall) similar to the monitored watersheds. It is reasonable to assume that storm patterns and relative intensities observed at Tustin will be generally representative of conditions within the San Juan, Arroyo Trabuco, and Oso Creek sub-watersheds. Additional insight could be gained with precipitation data collected, and especially stream discharge data, collected within these basins.*

Table 13

Summary Of Water Quality Data Measured by the Orange County Public Facilities and Resources Department as Function of Antecedent Rainfall, WY 1991 To WY 1999

3-Day Rainfall [a]	Caspers Regional Park			La Novia			Oso Creek/Mission Viejo		
	# of Samples	Mean	Median	# of Samples	Mean	Median	# of Samples	Mean	Median
Nitrate Concentrations (mg/l NO_3 as N)									
0.00	32	0.1	0.1	43	0.3	0.2	10	0.9	1.0
0.01-0.50	10	0.2	0.1	21	0.5	0.5	23	1.2	1.3
0.51-1.00	6	0.9	0.1	15	1.2	1.2	15	1.2	1.2
1.00-1.50	1	0.7	0.7	7	1.5	1.7	15	1.4	1.3
>1.50	0	n.d.	n.d.	5	0.4	0.4	18	1.0	0.8
Ammonia Concentrations (mg/l NH_3 as N)									
0.00	31	0.1	0.1	42	0.1	0.1	10	0.9	1.0
0.01-0.50	9	0.4	0.1	20	0.1	0.1	23	1.2	1.3
0.51-1.00	5	2.5	0.5	14	0.1	0.1	15	1.2	1.2
1.00-1.50	1	0.5	0.5	7	0.3	0.6	15	1.4	1.3
>1.50	0	n.d.	n.d.	5	0.1	0.1	18	1.0	0.8
Phosphate Concentrations mg/l PO_4 as P)									
0.00	31	0.1	0.1	43	0.1	0.1	10	0.7	0.6
0.01-0.50	9	0.4	0.1	21	0.2	0.2	23	0.4	0.3
0.51-1.00	5	3.4	3.6	15	0.6	0.4	15	0.7	0.5
1.00-1.50	1	1.0	1.0	7	0.7	0.7	15	0.7	0.6
>1.50	0	n.d.	n.d.	5	0.5	0.5	18	1.0	0.5
Zinc Concentrations (Total Zn mg/l)									
0.00	11	23	22	12	28	16	10	68	63
0.01-0.50	9	77	23	17	52	20	23	61	49
0.51-1.00	7	87	100	18	48	32	15	87	92
1.00-1.50	1	38	38	7	51	43	14	135	58
>1.50	0	n.d.	n.d.	5	30	24	18	58	54

[a] *Sum of three-day rainfall in inches as measured at the Orange County PFRD gauge in Tustin.*

n.d. = *no data*

Source: Balance Hydrologics, 2000

the large amount of grassland in the sub-basins below Caspers.[22] There is insufficient reliable data to determine whether a similar situation exists with regard to phosphate loadings between the two sites.

Figure 27, Part A on page 83 illustrates the relationship between measured nitrate concentrations at La Novia and 3-day antecedent rainfall. There are strong indications that nitrate is introduced into the lower San Juan Creek system by a mechanism that generally increases proportionally with precipitation up to 1.50 inches of 3-day rainfall. Regression analysis of the relationship between nitrate concentrations and 3-day antecedent rainfall up to 1.50 inches yielded an r-squared value of 0.42. Given the natural variability in the data and the small sample size, this correlation is considered meaningful. This relationship can be further examined by plotting the sampled nitrate concentrations as a function of mean daily discharge as measured at the USGS gauge (see Figure 27, Part B on page 83). The latter figure gives a better indication of the relative saturation of the watershed at the time of sampling. The data are consistent with N mobilization either through direct transport by surface storm water runoff or by the displacement of nitrate-rich groundwater into the stream system. The cluster of points at higher discharge rates likely represents the baseline nitrate loading associated with rainfall, since most rainfall would be running off under these saturated watershed conditions and nitrate assimilation by the biota would be relatively insignificant.[23]

- The monitoring results for phosphate at La Novia indicate that there is a tendency to higher phosphate levels with increases in both 3-day antecedent rainfall and discharge. These relationships are presented graphically in Figure 28, Parts A and B on page 84. The r-squared value for the relationship between phosphate concentrations and 3-day antecedent rainfall is 0.28. This weak correlation likely results from differences in the point during the season in which samples were collected. Because phosphate is typically transported in the bound form with particulates, the amount of seasonal rainfall (and runoff) that occurred prior to the sampling affects phosphate concentration by affecting the amount of sediment mobilization. Nevertheless, the apparent relationship between phosphate and rainfall/discharge is consistent with erosion being the primary contributor of phosphorus loading. Unfortunately, not enough samples were collected at Caspers to ascertain whether this observation applies to the watershed as a whole or only to that portion below Bell Canyon.

---

[22] *Grasslands (both native and non-native) have been shown to contribute relatively high loadings of nitrogen in studies carried out in several locations. One obvious potential contributing factor is the fact that grasslands are ideal for livestock grazing with the associated potential for N mobilization from animal wastes. Additionally, grassland soils are typically roughly 4 to 5 percent nitrogen by weight, and this N is available to rainfall passing over or through these soils.*

[23] *A background nitrate concentration of 0.4 mg/L in rainfall would be consistent with studies in other locations in the nation. For example, Betson (1978) measured a nitrate plus nitrite concentration of 0.47 mg/L in rainfall at Knoxville, Tennessee.*

Figure 27 Nitrate Concentrations for San Juan Creek at La Novia, Parts A and B

Part A – Nitrate Concentration vs. Antecedent Rainfall

Part B – Nitrate Concentrations vs. Discharge

Figure 28 Phosphate Concentrations for San Juan Creek at La Novia, Parts A and B

Part A – Phosphate Concentration vs. Antecedent Rainfall

Part B – Phosphate Concentrations vs. Discharge

- It is possible that channel incision can be a contributing factor to both nitrogen and phosphorus loading in the San Juan system. The link between channel incision and phosphorus loading is relatively straightforward: Erosion of channel and floodplain terrace material can release significant quantities of stored phosphates. The link to nitrogen loading may be less readily apparent and centers around the potential for changes to groundwater inflows to stream reaches as the channel bed degrades. Deeper groundwater is often enriched in nitrate. As a stream incises, it dewaters adjacent aquifers from progressively greater depths thereby increasing the nitrogen loading in the surface waters under baseflow conditions,

The ratio of available nitrogen to available phosphorus within a water body often has an important regulating effect on the growth of aquatic plants and animals.[24] The monitoring data support the contention that these systems are generally nitrogen limited (i.e., N/P ratio < 10)[25]. One notable exception is found for San Juan Creek at La Novia.

Figure 29 on page 86 illustrates the N/P ratio at this monitoring location as a function of discharge. In this case, it appears that the San Juan system is nitrogen limited at both very low and very high flow rates. Intermediate flow rates correspond with the period when the nitrate concentrations have increased (with increasing rainfall as discussed above) but phosphate levels have yet to increase significantly. Once discharge increases, with the associated general tendency to increase phosphate levels, nitrogen once again becomes the limiting nutrient. Interestingly, even though the overall Nitrogen values in the more urbanized Oso Creek sub-watershed are higher, phosphate levels are still high enough to lead to nitrogen limitation.

3.6.1.2 Zinc

Monitoring carried out by the Orange County PFRD in the 1990s in San Juan Creek included analysis of several metals: cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), silver (Ag), and zinc (Zn). The results are reported in Appendix B.[26] In waters with typical pH levels of 7 to 8, as found in San Juan Creek, metals are most likely to be found in their particulate phase. Therefore, one can assume that the more bio-available dissolved fraction will have a much

---

[24] *Aquatic organisms, such as algae, require carbon, nitrogen, and phosphorus to fuel their basic metabolic processes. If one of these elements is present at low concentrations in the environment, it may become a limiting factor in their growth. The nitrogen/phosphorus ratio (N/P) is often used to indicate which element is limiting, with ratios below 10 indicating that nitrogen is limiting and ratios above 10 indicating that phosphorus is limiting.*

[25] *It should be noted that the threshold of N/P < 10 is generalized from a wide range of aquatic systems. The actual level in the SAMP watersheds may vary with location, time of year and particular species being considered.*

[26] *The analyses were primarily conducted on unfiltered samples, meaning that the reported values represent the total metal concentration that includes both the dissolved and particulate fractions.*

Figure 29 Nitrogen/Phosphorus Ratios vs. Discharge for San Juan Creek at La Novia

lower concentration. Because metals are typically found in their particulate form and are, therefore, transported in the same manner as sediments, it is unlikely that significant metal transport will occur during dry weather, as the majority of sediment transport occurs during storm events. An initial examination of the San Juan Creek monitoring data shows that, with the notable exception of zinc, most metals are found in concentrations below the detection limit. The zinc data are summarized in Table 13 on page 81 and Figure 30 on page 88. Several observations can be made on the basis of this data:

- The data do not indicate a significant difference in zinc concentrations between the Caspers and La Novia monitoring stations. This suggests that equivalent zinc sources are found both upstream and downstream of the Caspers site. Such sources likely include galvanized metal products (e.g., steel culverts), automobile tire wear, roof drainage, and natural mineral weathering.

- Zinc mobility with rainfall. The relationship between measured zinc concentrations and 3-day antecedent rainfall suggest that zinc concentrations increase with increasing rainfall until approximately 1 inch of 3-day cumulative antecedent rainfall is reached, at which point zinc concentrations begin to decrease (see Figure 30, Part A on page 88). This response is further illustrated the relationship between measured zinc concentrations and daily flow, which shows that the highest levels of zinc occur at flows between 10 and 100 cfs (see Figure 30, Part B on page 88). This pattern can be explained by a background loading of zinc, as seen at low flows. As discharge increases, sediments are mobilized and transported downstream with the associated particulate metals. At the highest flows, zinc concentrations decrease as a result of dilution from rainwater and removal of contaminated sediments from the system.

- Total zinc concentrations in water samples collected from San Juan Creek range from below the detection limit to 420 µg/L (measured at Caspers Regional Park on November 15, 1993). As a point of comparison, the monitoring results indicate that, on several occasions, zinc concentrations surpassed the 120 mg/L criteria (for both acute and chronic levels) that have been established for priority toxic pollutants under the California Toxics Rule. In general, we would expect the dissolved fraction of total zinc to have much lower concentrations than particle-bound fractions.

3.6.1.3 Total Dissolved Solids

During the 1960's, surface water samples were analyzed for total dissolved solids (TDS) as part of an effort to locate drinking water sources in the San Juan Creek watershed. The TDS sampling consisted of a bulk parameter that measured dissolved salts, in this case primarily sodium (Na^+), calcium (Ca^{++}), magnesium (Mg^{++}), potassium (K^+), chloride (Cl^-), sulfate (SO_4^-), bicarbonate (HCO_3^-), and silica (SiO_2) in water. Sources of these constituents include both natural weathering of

Figure 30 Zinc Concentration for San Juan Creek at La Novia, Parts A and B

Part A Zinc Concentrations vs. Antecedent Rainfall

Part B Zinc Concentrations vs. Discharge

bedrock and soils as well as anthropogenic sources from agriculture and urbanization. The data set suggests that TDS concentrations in San Juan Creek increase from 200 mg/L at its upper reaches to over 1,000 mg/L in the lower reach. Given the minimal urbanization of the watershed in the 1960's, this 500 percent increase in TDS is likely the result of: (a) inputs from sub-basins that drain highly erodible substrates such as Monterey Shale (e.g., Cañada Chiquita and Oso Creek); (b) irrigation return flows in Oso Creek, Cañada Chiquita and Cañada Gobernadora; and (c) evaporative processes that concentrate salts in the water column throughout the length of San Juan Creek. These data suggest that high TDS is indicative of a baseline condition for the lower San Juan watershed.

3.6.1.4 Bacteria

Frequent, but spatially limited bacteria monitoring data is available for the lower reaches of San Juan Creek under a program carried out by the South East Regional Reclamation Agency (SERRA). These data indicate persistently high counts of total and fecal coliform (FC), and enterococcus (EC), both at the mouth of San Juan Creek and upstream of the Latham Treatment Plant. The RWQCB water quality objective for contact recreation of 200/ml of total bacteria (log mean over 30-day period) is consistently exceeded. However, the water quality objective for non-contact recreation of 2000/ml of total bacteria is generally attained at the upstream monitoring site. For calendar year 2000 the log mean fecal coliform concentration at Del Obispo Park was roughly 300/ml. The U.S. EPA guidelines for enterococci that are cited in the Basin Plan (151/ml for infrequently used freshwater areas) was met on only roughly one-third of the samples taken over recent years at the upstream Del Obispo Park monitoring site. The log mean enterococci concentration for calendar year 2000 was approximately 540/ml.

It is important to note that both the SERRA monitoring sites are located at the most downstream reaches of San Juan Creek, within and below extensive urbanized areas. The sources of these bacterial contaminants cannot be ascertained with existing data.

3.6.2 Analysis of Existing Water Quality Data for the San Mateo Watershed

Unfortunately, there is limited available comparable baseline data for San Mateo Creek. Limited water quality data from various studies (Lang et al.1998) were compiled. However, these studies contained no samples that were analyzed for metals, and the five samples analyzed for nutrients were all collected on the same day (March 17, 1997) without corresponding discharge measurement (see Appendix B). The ability to analyze baseline water quality conditions for the San Mateo Watershed would be furthered if the monitoring data collected on the Marine Base Camp Pendleton were available for review.

Additional and ongoing water quality monitoring is currently being conducted by Rivertech Inc. for Rancho Mission Viejo. The sampling plan, begun in early 2001, calls for a comprehensive analysis of both storm event and dry weather samples collected from nine locations within the SAMP/MSAA study area, including two sites within the San Mateo Creek watershed (Cristianitos and Gabino Creeks). This data is supplemented by continuous monitoring of temperature, conductivity, dissolved oxygen, pH and flow at four stations (including Cristianitos Creek). Data already collected is not yet available for analysis. However, it will be an important resource for future updates to this report.

As part of the San Diego Basin Plan, Region IX of the Water Quality Control Board has designated beneficial uses (pursuant to Section 303 of the CWA) for San Juan and San Mateo Creek. These designated beneficial uses for these two watersheds are defined and listed in Table 14 on page 91. In addition, applicable water quality standards established by Region 9 of RWQCB and by the State Water Board under the California Toxics Rule are summarized in Table 15 on page 92.

3.7 GROUNDWATER

The vast majority of the San Juan and San Mateo watersheds is underlain by semi-consolidated sandstones and by alluvial and terrace sediments derived from the sandstones that have the capacity to store groundwater (Williams, 1969; Morton, 1970). Several of the bedrock geologic units in the central portion of the San Juan watershed are moderately sandy and largely uncemented, affording significant opportunities for infiltration and groundwater storage. In this portion of the watershed, the sandy deposits in the floodplain and stream valleys are permeable and therefore, can be a major source of groundwater recharge to both local and regional aquifers. Clay portions of the watershed and areas with geologic units composed of siltstones, shales, and mudstones, contain few beds of water-bearing sandy sediments. These areas also tend to have the highest groundwater salinity because negatively charged clay particles are often coated with ions that are released into the groundwater.

Weathered and fractured crystalline rocks yield moderate amounts of water sustaining springs and baseflows, commonly in the more mountainous upper portions of the two watersheds and their neighboring basins. These flows support some of the more significant and continuous bands of riparian vegetation. They are typically the least mineralized and highest quality of the groundwaters in both watersheds, and their contributions to baseflows are often significant in maintaining water quality in the alluvial aquifers downstream within levels suitable for aquatic habitat functions.

Table 14

Designated Beneficial Uses for San Juan and San Mateo Creek Watersheds per San Diego Basin Plan Watershed

Description of Use	San Juan Creek Watershed	San Mateo Creek Watershed
Agricultural Supply (AGR)—Includes uses of water for farming, horticulture, or ranching, including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing.	Yes	
Industrial Service Supply (IND)—Includes uses of water for industrial activities that do not depend primarily on water quality, including, but not limited to, mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, or oil well re-pressurization.	Yes	
Contact Water Recreation (REC-1)—Includes uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and SCUBA diving, surfing, white water activities, fishing, or use of natural hot springs.	Yes	
Non-Contact Water Recreation (REC-2)—Includes the uses of water for recreational activities involving proximity to water, but not normally involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tidepool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.	Yes	Yes
Warm Freshwater Habitat (WARM)—Includes uses of water that support warm water ecosystems, including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish or wildlife, including invertebrates.	Yes	Yes
Cold Freshwater Habitat (COLD)—Includes uses of water that support cold water ecosystems, including, but not limited to, preservation and enhancement of aquatic habitats, vegetation, fish or wildlife, including invertebrates.	Yes	
Wildlife Habitat (WILD)—Includes uses of water that support terrestrial ecosystems, including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.	Yes	Yes
Rare, Threatened, or Endangered Species (RARE)—Includes uses of water that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under state or federal law as rare, threatened, or endangered.	[a]	Yes (lower reaches only)

[a] *Although the San Juan Creek watershed supports endangered species, such as the arroyo toad, the San Diego Water Board has not designated RARE as a beneficial use for this watershed.*

Source: San Diego Water Quality Control Board

Table 15

California RWQCB Region 9 and CTR Standards and Objectives Applicable to the Quality of Water in the SAMP Study Area

Constituent	Units	California Drinking Water Standards [a]	Basin Plan Objectives [b]	California Toxics Rule [f] (CMC) [g]	California Toxics Rule [f] (CCC) [h]
Inorganic Chemicals					
Aluminum	mg/L	1	--	--	--
Antimony	mg/L	0.006	--	--	--
Arsenic	mg/L	0.05	--	0.34	0.15
Asbestos	MFL	7	--	--	--
Barium	mg/L	1	--	--	--
Beryllium	mg/L	0.004	--	--	--
Boron	mg/L	-- [c]	0.75	--	--
Cadmium	mg/L	0.005	--	0.0043	0.0022
Chromium	mg/L	0.05	--	0.016	0.011
Chloride	mg/L	none	250	--	--
Copper	mg/L	1.3	--	0.013	0.009
Cyanide	mg/L	0.2	--	--	--
Fluoride	mg/L	2	1	--	--
Iron	mg/L	0.3	0.3	--	--
Lead	mg/L	0.015	--	0.065	0.0025
Manganese	mg/L	0.05	0.05	--	--
Mercury	mg/L	0.002	--	--	--
Nickel	mg/L	0.1	--	0.47	0.52
Nitrate+Nitrite (as N)	mg/L	10	-- [e]	--	--
Nitrite (as N)	mg/L	1	--	--	--
Selenium	mg/L	0.01	--	--	0.005
Silver	mg/L	0.05	--	0.0034	--
Sodium	%	-- [c]	60	--	--
Sulfate	mg/L	250, 500	250	--	--
Thallium	mg/L	0.002	--	--	--
Zinc	mg/L	5	--	0.12	0.12

Table 15 (Continued)

California RWQCB Region 9 and CTR Standards and Objectives Applicable to the Quality of Water in the SAMP Study Area

Constituent	Units	California Drinking Water Standards [a]	Basin Plan Objectives [b]	California Toxics Rule [f] (CMC) [g]	California Toxics Rule [f] (CCC) [h]
Others					
pH	pH Units	6.5-8.5	6.5-8.5	--	--
Specific Conductance	(µs)	900, 1600	--	--	--
Total dissolved solids	mg/L	500	500	--	--
Ammonia (as N)	mg/L	30	-- [4]	--	--
Fecal coliform bacteria	MPN/100m	log mean <20	--	--	--

[a] *Maximum contaminant levels established by the DHS, from Title 22 of the California Code of Regulations, April 2000. Where two values are shown, they represent the "recommended" and "mandatory" values.*
[b] *Concentrations not to be exceeded more than 10 percent of the time during any one year period.*
[c] *No primary drinking water standards have been established for boron or sodium. At elevated concentrations, these constituents may constrain plant or crop growth.*
[d] *Un-ionized ammonia concentrations exceeding 0.0025 mg/L can be toxic.*
[e] *Biostimulating constituents.*
[f] *California Toxics Rule (CTR) freshwater aquatic life criteria.*
[g] *Criteria Maximum Concentration (CMC) equals the highest concentration to which aquatic life can be exposed for a short period of time.*
[h] *Criteria Continuous Concentration (CMC) equals the highest concentration to which aquatic life can be exposed for an extended (4-days) period of time.*

Source: Balance Hydrologics, Inc., 2001

There are three shallow alluvial basins that sustain perennial or near-perennial stream flow in the San Juan Creek Watershed. These basins are located in Chiquita Canyon above the “Narrows”, Chiquita Canyon below the “Narrows,” and Gobernadora Canyon. These alluvial basins are all recharged primarily by ground water emanating from the adjoining bedrock aquifers. The shallow alluvial aquifers of the Gobernadora and Chiquita valleys are partially isolated from the San Juan aquifer via a “damming effect” resulting from the presence of fine-grained lake-bed deposits which underlay their lower reaches.

At the landscape scale, most of the riparian and aquatic habitats have at least transient reliance on groundwater. The exception to this would be in Chiquita and Gobernadora Canyons, which contain some of the largest areas of sandy soils and the greatest volumes of aquifer storage. The low permeability lake-bed deposits in these canyons form sand wedges that help sustain shallow groundwater levels in the lower half mile of the Chiquita and Gobernadora Canyons. These shallow groundwater conditions are an important component of maintenance of riparian habitat in these areas.

Slope wetlands in the study area are also sustained by groundwater. Approximately half of the slope wetlands are sustained by water emanating directly from landslides, while others may be supported by groundwater stored in the Santiago formation that is upwelling along bedrock fractures and faults. Generally, both the yields and the quality of groundwater vary considerably over the course of a season. More detailed analysis of the slope wetlands is provided in the *Slope Wetland Functional Assessment* (PCR, 2000a); detailed analysis of groundwater in the study area is provided in Appendix C.

3.8 BIOLOGICAL RESOURCES

A total of 16 vegetation types have been mapped within the San Juan and San Mateo watersheds (Holland, 1986; OCHCS, 1992). A diversity of vegetation typifies most of these two watersheds. Riparian woodlands and forests occur along most portions of the stream corridors. Some of the major stands of riparian vegetation can be found in the following areas: San Juan and Trabuco to the confluence with Oso Creek; Cañada Gobernadora tributaries; Bell Canyon; and many of the tributaries to San Juan and San Mateo creeks. Dispersed sections of riparian vegetation occur along Oso, Horno, and Cañada Chiquita Creeks. The slopes along these corridors are dominated by coastal sage scrub or chaparral communities. With increasing elevation, chaparral communities replace coastal sage. Coastal sage scrub is restricted to xeric, south facing slopes. Oak woodlands and forest become common in the upper reaches of the watersheds on north-facing slopes and along drainages. In several parts of the watersheds, increased urbanization has eliminated the natural vegetation.

According to the WES/CRRL studies, the study area contains approximately 3,080 acres of aquatic and riparian resources, and 1,252 miles of intermittent and ephemeral drainages. Based on the Corps' planning level delineation, approximately 1,871 acres of aquatic and riparian resources would be considered subject to Corps jurisdiction under Section 404 of the Clean Water Act, within the bank full and active flood areas (i.e., CRRL Rating 1). Of these 1,871 acres, approximately 996 acres of riparian habitat would be considered Corps jurisdictional wetlands (Lichvar et al., 2000). The remaining 1,209 acres of aquatic and riparian resources may or may not be subject to Corps jurisdiction and would need to be delineated using a routine jurisdictional determination/wetland delineation procedure. The specific extent of CDFG jurisdiction will be determined at a later time using routine site-specific jurisdictional determination methods. However, the information contained in the CRRL landscape-scale delineation should provide a strong foundation for determining the extent of CDFG jurisdiction.

Dominant aquatic habitat types in the study area are southern willow scrub and mule fat scrub. Southern sycamore riparian woodland and southern coast live oak woodland are also common, especially in the San Mateo Creek watershed. There are also isolated instances of alkali marsh, slope wetlands, and vernal pools, primarily in the San Juan Creek watershed. The functional integrity of the riverine and non-riverine resources were evaluated by WES (Smith, 2000) and PCR (2000a), respectively, and are discussed in companion reports.

3.8.1 San Juan Creek Watershed

The San Juan Creek watershed within the study area supports a variety of habitats. The predominant habitats are coastal sage scrub (12,255 acres or 34 percent of the study area), chaparral (8,448 acres or 23 percent), grassland (4,193 acres or 11 percent), agriculture (3,572 acres or 10 percent) and riparian (2,703 acres or 7 percent, as mapped in the generalized NCCP/HCP vegetation database). Other natural habitats include oak woodland (844 acres), forest (449 acres), open water (176 acres), marsh (14 acres), cliff and rock (9 acres), streams (7 acres), and vernal pools (5 acres). Developed land comprises 2,789 acres (7 percent), and disturbed habitat comprises 756 acres (2 percent).

Riparian woodlands and forests occur along most of the stream courses in the study area. The type of riparian forest along the drainages of the San Juan watershed varies based on elevation, geology, and hydroregime. San Juan Creek itself is a broad riverine complex in certain reaches, has intermittent to near-perennial flow, and is dominated by willow-cottonwood riparian forests. Perennial streams such as Cañada Chiquita and Cañada Gobernadora contain communities typical of more hydric conditions and include sections that support alkaline marsh and meadow wetlands. The valley floors of Cañada Chiquita and Gobernadora have been subjected to extensive agriculture and grazing, and little native vegetation remains on the valley floor beyond that found within the riparian zone. Tributaries to the east and further up in the watershed, such as Verdugo and Bell Canyons, are drier, have coarser substrates, and typically support sycamore-cottonwood riparian forests.

The San Juan Creek watershed supports a large variety of sensitive species (see Table 16 on page 96). The resident gnatcatcher population is considered one of the core populations of the species in southern California. The least Bell's vireo occurs primarily in two locations in the watershed; approximately eight pairs occur in Canada Gobernadora within the Gobernadora Ecological Restoration Area (GERA) and a significant population has been documented to occur in Arroyo Trabuco. Populations of vireo in the watershed have generally been increasing over the last decade. The arroyo toad population is relatively small in the middle to lower portions of San Juan Creek, but larger populations occur in Bell Canyon and upper San Juan Creek.

Table 16

Sensitive Species in the San Juan Creek Watershed

Common Name	*Scientific Name*
State or Federally Listed Species	
California gnatcatcher	*Polioptila californica*
arroyo toad	*Bufo californicus*
least Bell's vireo	*Vireo bellii pusillus*
thread-leaved brodiaea	*Brodiaea filifolia*
Sensitive Fauna	
Cooper's hawk	*Accipiter cooperii*
white-tailed kite	*Elanus leucurus*
long-eared owl	*Asio otus*
rufous-crowned sparrow	*Aimophila ruficeps*
yellow warbler	*Dendroica petechia*
California horned lark	*Eremophila alpestris actia*
Mountain lion	*Puma concolor*
southwestern pond turtle	*Clemmys marmorata pallida*
San Diego horned lizard	*Phrynosoma coronatum blainvillei*
orange-throated whiptail	*Cnemidophorus hyperythrus beldingi*
coastal western whiptail	*Cnemidophorus tigris multiscutatus*
northern red-diamond rattlesnake	*Crotalus ruber ruber*
western patch-nosed snake	*Salvadora hexaplepis virgultea*
two-striped garter snake	*Thamnophis hammondii*
western spadefoot toad	*Scaphiopus hammondi*
red-shouldered hawk	*Buteo lineatus*
great horned owl	*Bubo virginianus*
cactus wren	*Campylorhynchus brunneicapillus*
grasshopper sparrow	*Ammodramus savannrum*
yellow-breasted chat	*Icteria virens*
SD desert woodrat	*Neotoma lepida intermedia*
mule deer	*Odocoileus hemionus*
Sensitive Plants	
salt spring checkerbloom	*Sidalcea neomexicana*
Catalina mariposa lily	*Calochortus catalinae*
Coulter's saltbush	*Atriplex coulteri*
beaked spikerush	*Eleocharis rostellata*
Coulter's matilija poppy	*Romneya coulteri*
southern tarplant	*Centromadia [Hemizonia] parryi* ssp. *australis*
intermediate mariposa lily	*Calochortus weedii* var. *intermedius*
many-stemmed dudleya	*Dudleya multicaulis*
Palmer's grapplinghook	*Harpagonella palmeri*
mud nama	*Nama stenocarpa*

Source: Dudek & Associates, 1999

3.8.2 San Mateo Creek Watershed

The portion of the San Mateo watershed within the study area supports a variety of natural habitats. The predominant habitats are coastal sage scrub (3,876 acres or 32 percent of the study area), grassland (3,166 acres or 26 percent), and chaparral (2,808 acres or 23 percent). Riparian habitat (as mapped in the generalized NCCP/HCP vegetation database) comprises 1,089 acres (9 percent). The remaining habitat/land cover is comprised of agriculture (3 acres), developed land (491 acres), disturbed habitat (233 acres), woodland (100 acres), forest (160 acres), open water (3 acres), streams (6 acres), marsh (0.6 acre), and cliff and rock (5 acres).

The San Mateo watershed is dominated by sycamore and oak woodland riparian forests. The canyons in the San Mateo watershed tend to be steeper and narrower than those in the San Juan watershed. Consequently, substrates are coarser, with many of the streams dominated by rock and cobbles. The upper portions of Gabino and La Paz watersheds have been subject to intensive grazing, and many of the riparian zones are somewhat denuded. Landslides have facilitated expression of groundwater in some sections of the watershed, promoting development of isolated patches of alkaline marsh plant communities. The lower portion of the watershed flows through MCBCP has been subjected to some agricultural, recreational, and military uses.

The upper San Mateo watershed supports a large variety of sensitive species (see Table 17 on page 98). With the exception of the arroyo toad, which is abundant in Talega Creek, none of these species occurs in great numbers within the study area. However, the least Bell's vireo occurs in large numbers downstream in San Mateo Creek. It also is notable that the southern steelhead and the federally listed endangered tidewater goby occur in the San Mateo Creek watershed; however, they occur outside the SAMP/MSAA study area.[27] Detailed discussion of the integrity of the riverine and non-riverine aquatic resources in the study area can be found in the WES study (Smith, 2000) and the PCR analysis (PCR, 2000a), respectively.

[27] *The National Marine Fisheries Service (NMFS) is currently reviewing the status of the southern steelhead in San Mateo Creek.*

Table 17

Sensitive Species in the Upper San Mateo Creek Watershed

Common Name	*Scientific Name*
State or Federally Listed Species	
California gnatcatcher	*Polioptila californica*
least Bell's vireo	*Vireo bellii pusillus*
arroyo toad	*Bufo californicus*
thread-leaved brodiaea	*Brodiaea filifolia*
Sensitive Fauna	
Cooper's hawk	*Accipiter cooperii*
rufous-crowned sparrow	*Aimophila ruficeps*
grasshopper sparrow	*Ammodramus savannrum*
long-eared owl	*Asio otus*
great horned owl	*Bubo virginianus*
red-shouldered hawk	*Buteo lineatus*
cactus wren	*Campylorhynchus brunneicapillus*
white-tailed kite	*Elanus leucurus*
California horned lark	*Eremophila alpestris actia*
yellow-breasted chat	*Icteria virens*
southwestern pond turtle	*Clemmys marmorata pallida*
western spadefoot toad	*Scaphiopus hammondi*
orange-throated whiptail	*Cnemidophorus hyperythrus beldingi*
coastal western whiptail	*Cnemidophorus tigris multiscutatus*
northern red-diamond rattlesnake	*Crotalus ruber ruber*
San Diego horned lizard	*Phrynosoma coronatum blainvillei*
western patch-nosed snake	*Salvadora hexaplepis virgultea*
two-striped garter snake	*Thamnophis hammondii*
San Diego desert woodrat	*Neotoma lepida intermedia*
mule deer	*Odocoileus hemionus*
mountain lion	*Puma concolor*
Sensitive Plants	
Catalina mariposa lily	*Calochortus catalinae*
prostrate spineflower	*Chorizanthe procumbens*
mesa brodiaea	*Brodiaea jolonensis*
upright burhead	*Echinodorus beteroi*
San Diego County viguiera	*Viguiera lanciniata*
vernal barley	*Hordeum intercedens*
chaparral beargrass	*Nolina cismontane*
western dichondra	*Dichondra occidentalis*
Fish's milkwort	*Polygala cornuta* var. *fishiae*
intermediate mariposa lily	*Calochortus weedii* var. *intermedius*
many-stemmed dudleya	*Dudleya multicaulis*
Palmer's grapplinghook	*Harpagonella palmeri*
mud nama	*Nama stenocarpa*

Source: Dudek & Associates, 1999

4.0 SUMMARY OF WATERSHED ATTRIBUTES/REGIONAL CONTEXT

The technical analyses summarized in this report provide an overview of the physical processes and biological conditions of the San Juan and upper San Mateo creek watersheds and provides information for land use planning at the watershed scale. The major attributes of the watershed that should be considered during land use planning include the underlying geology, patterns of runoff, interaction of groundwater with surface hydrology, sediment processes, historic land uses and existing water quality. Following is a summary of how these major attributes can be incorporated into decisions regarding future land use.

4.1 GEOMORPHOLOGY AND TERRAINS

The SAMP/MSAA study can be divided into three major geomorphic terrains which are manifested as north-south running zones through the watersheds: clayey, sandy, and, crystalline. The runoff patterns and susceptibility of the channels to incision are influenced by the soils and subsoils that are characteristic of each terrain. The western portions of the study area (i.e., Oso Creek, Arroyo Trabuco, and the lower third of San Juan Creek) are predominately clayey terrains. The central portion of the study area (i.e., Chiquita, Bell, and the middle reaches of San Juan Creek) is underlain by sandy or silty-sandy substrates. This is reflected by drainage densities that are lower than other coastal watersheds in southern California and by channel-less tributary valleys that are characterized by swales that are hydrologically connected to the main stem creek, but lack true bed and bank structure. The eastern portion of the study area (i.e., Lucas Canyon, Gabino, La Paz, Cristianitos, and Talega Creeks) is underlain by crystalline rocks (granitic or partly metamorphosed volcanic in origin) which have developed slopes and soils that are both shallow and sandy. The slopes east of both Chiquita and Gobernadora Canyons are unique in that they contain somewhat of a hybrid terrain. Although underlain by deep sandy substrates, they are locally overlain by between 2 and 6 feet of exhumed hardpan.

Although all three terrains exhibit fairly rapid runoff, undisturbed sandy slopes contribute less runoff than clayey ones because it is easier for water to infiltrate into the coarser substrate. Runoff in crystalline terrains tends to be rapid and is highly influenced by the presence and density of coverage of impervious areas of rock outcrop that typify the terrain. As a result, the volume of runoff generated by the same amount and intensity of rainfall in a sandy watershed is generally lower than that generated in a clayey or crystalline watershed. A schematic illustration of the effect of major terrains on peak flows is provided in Figure 31 on page 100.

Figure 31 Generalized Effects of Major Terrains on Peak Flow

The differences in runoff patterns between terrains provide opportunities for the land use planning process. In clayey and crystalline terrains, the difference in runoff response between an urbanized and a natural condition is much less pronounced than in sandy terrains (i.e., clayey watersheds generally do not experience as dramatic an increase in post-urbanization runoff as sandy watersheds). Consequently, channels in clayey and crystalline terrains are generally more resistant to erosion, incision, and headcutting than sandy ones, if appropriate runoff management measures are implemented.[28] Crystalline terrains are characterized by shallow bedrock with an overlying layer of sandy substrate; therefore, they typically allow for higher infiltration rates than clayey terrains, which seal and become impervious upon saturation. Therefore, in clayey terrains, it may be preferable to situate development on the ridge tops and maintain vegetated buffers adjacent to the stream corridors.

Unless stabilized by riparian vegetation, streams in sandy terrains are generally the least stable and, therefore, the most susceptible to channel incision or channel widening associated with changes in land use. Studies have shown that urbanization in sandy watersheds can result in a more marked proportionate increase in storm peaks and associated alteration of downstream channel morphology than in more clayey watersheds. Therefore, in sandy terrains, management of post-development runoff is critical. The least damaging development prescription would be to provide ample set backs from the streams in order to retain the infiltration capacity of the valley floor and cluster residential uses on the hillslopes or ridges while avoiding the main tributary swales. Because the effect of markedly increased flow in sandy watersheds following urbanization has been observed to be inversely proportional to the size of the watershed, placing development atop ridges in sandy terrains above small, vulnerable sub-watersheds soils must be accompanied by adequate detention/infiltration (which could occur in the adjacent swales). Such management will decrease the risk of erosion, incision, and downcutting of lower order drainages on the slopes below the development.

Although these generalized patterns can guide land use planning at a watershed scale, the specific characteristics of a given sub-basin should direct planning at the site-specific scale. For example, while the eastern slopes and ridges of Chiquita and Gobernadora are generally sandy, the ridges are locally capped by hard clay layers that geologists interpret to be ancient subsoils. These areas receive rainfall and generate extremely rapid runoff, especially during large storm events. Runoff from these hardpan caps is rapid even during moderate sized storms, presently forming numerous gullies at the heads of individual tributary valleys before it percolates into the sandy soils further downslope. In the context of the entire study area, the hydrologic effects of development can be minimized if sited, to the extent feasible, in areas that already yield low-infiltration and high runoff patterns. However, in all terrains, sensitive biological communities or habitats should be

[28] *Oso Creek is located in an area dominated by clayey terrain. However, the magnitude of urbanization, uncontrolled increases in runoff, and floodplain encroachment have exceeded the resilience of the channel and resulted in extreme channel incision.*

avoided to the maximum extent possible and runoff from developed area should be managed and floodplain integrity maintained in order to help maintain the geomorphic and biologic integrity of the streams.

The terrains reflect the properties of the underlying geologic formations, parent materials to the soils. While most of the rock units which form sandy terrains do occur elsewhere in Orange County, they outcrop to a much greater extent in the San Juan and San Mateo watersheds, where they are predominant landscape-shaping influences in some of the larger sub-basins. The SAMP/MSAA provides an opportunity to develop approaches and guidelines consistent with the properties of these distinct and unfamiliar substrates rather than using traditional criteria that are likely to prove ineffective or even harmful to habitat functions in these soils and watersheds.

4.2 SURFACE HYDROLOGY

Both the San Juan and San Mateo watersheds are generally characterized by slow infiltration rates relative to adjacent watersheds. For example, review of existing data for the Santa Margarita and San Luis Rey watersheds shows that these two watersheds have a higher percentage of Type B soils than the San Juan and San Mateo watersheds (Steinitz et al, 1996). Therefore the San Juan and San Mateo watersheds would be considered more slowly infiltrating areas than the Santa Margarita and San Luis Rey (in general). Compared with the San Mateo watershed, San Juan contains approximately 10 percent less coverage with poorly infiltrating soils (i.e., C and D soil hydrogroups). In contrast, the steep crystalline terrains of the San Mateo watershed exhibit rapid runoff and relatively lower infiltration capacity.

Significant differences can be found within the watersheds at the sub-basin scale. Within the San Juan watershed, Chiquita and Gobernadora Canyons possess broad valleys of relatively higher infiltrating sandy soils. However, as noted above, the slopes above portions of Gobernadora are characterized by B soils that are overlain by several feet of hardpan that, if undisturbed, cause this area to respond more like a C or D soil

The composite hydrograph for 2-year, 10-year, and 100-year flows in San Juan Creek at flows the ocean are 5,170 cfs, 29,280 cfs, and 67,280 cfs, respectively. For San Mateo watershed, the predicted 2-year, 10-year, and 100-year flows at the ocean are 3,200 cfs, 19,160 cfs, and 47,530 cfs, respectively. Predicted flows in the San Mateo watershed are between 21 percent and 24 percent lower than those in the San Juan watershed, which is consistent with the 24 percent size difference between the two watersheds (i.e., 133 mi.^{2} vs. 176 mi.^{2}). Several things are notable about the hydrologic modeling results. First, peak flows from the western portion of the watershed arrive in the lower San Juan watershed more rapidly than peak flows from the central and eastern portions of the watershed (see Figure 32 on page 103). Peak flows from Oso Creek and Trabuco Creek

Figure 32 Sub-basin Peak Flow Timing Relative to the Main Stem of San Juan Creek

arrive at the main stem of San Juan Creek approximately 2.8 hours before flows from the central and eastern portions of the watershed (as represented by the hydrograph for San Juan Creek upstream of Horno Creek). The more rapid arrival of peak flows from the western watershed occurs for three reasons: (a) Flow distances from the western tributaries are somewhat shorter to the lower San Juan watershed than from the areas to the east; (b) The western watershed is more urbanized than the eastern watershed. Impervious surfaces in these urban areas shed runoff much more quickly than more pervious areas to the east, and the hydrograph peak occurs earlier; (c) The central portion of the San Juan watershed contains higher infiltrating sandy areas that act to attenuate runoff to the main stem of San Juan Creek.

In a planning context, it is important to be aware of the relationship between the timing of peak flows along the main stem creek relative to those of the sub-basins. The goal should be to not alter the runoff interactions between the main stem and sub-basin creeks to a level that results in coincident flood peaks, thereby exacerbating the effects of urbanization on downstream hydrology. As a general rule, land planning should attempt to maintain the function of the existing channel network and minimize floodplain constriction in major tributary valleys.

The potential effect of urbanization on low-flow conditions was investigated by analyzing the Oso Creek sub-basin as an example of what could potentially happen in other parts of the San Juan or San Mateo Creek watersheds if similar land use transformations were to occur. The results of the trend analysis conducted for Oso Creek show that annual minimum stream flows and mean summer flows have consistently increased over time as the basin progressively developed. The effect of upstream development on dry season flows is currently observable in the northern portion of the Cañada Gobernadora sub-basin, where the Coto de Caza development has increased the magnitude and persistence of low flows to the central Cañada Gobernadora watershed.

Wet and dry cycles in southern California typically last for 15 to 20 years, with major floods that act to “reset” the riparian plant communities occurring every 10 to 20 years. The long-term implications of these wet and dry cycles on groundwater levels, width of riparian zones, and landslide activity (which increases sediment delivery to the streams) must be accounted for during future land use planning.

4.3 GROUNDWATER

The vast majority of the San Juan and San Mateo watersheds are underlain by alluvial and alluvial-terrace aquifers that have the capacity to store groundwater. Unlike many of the other portions of southern Orange County, the sandy portions of the central San Juan watershed are moderately permeable and provide significant groundwater recharge opportunities. These areas should be taken into account during the land planning process. Maximizing infiltration especially in sandy terrains could also have the effect of minimizing changes in surface runoff and water quality associated with increasing impervious surfaces. At the landscape scale, most of the riparian and aquatic habitats have at least transient reliance on groundwater. Of particular import are Chiquita and Gobernadora Canyons, which contain some of the greatest volumes of alluvial-aquifer storage and contain riparian zones that depend on contact with groundwater year-round. In these watersheds, maintenance of shallow groundwater with appropriate water chemistry is an important component of maintenance of riparian habits.

These areas also support most of the slope wetlands in the area of study, all of which are sustained by groundwater. Approximately half of the slope wetlands are sustained by water emanating directly from landslides, while the other half are sustained by deeper bedrock aquifers with the water being merely conveyed through landslides. Because landslides are more localized features than the bedrock aquifers, both the yields and the quality of groundwater vary considerably over the course of a season. In contrast, flows that are sustained by deeper bedrock aquifers tend to be more consistent in terms of both yield and quality. Groundwaters originating within the landslides and other slope deposits are locally significant because they sustain wetlands; however, they have little role in supporting the larger, continuous riparian and aquatic systems.

4.4 SEDIMENT PROCESSES

Like many arid systems, sediment yields in the San Juan and San Mateo watersheds generally exceed the transport capacity of the streams. Some of the less steep sub-basins are supply limited, but this is not the general trend for the watersheds. Consequently, San Juan and San Mateo creeks are generally depositional during large flow events. Approximately 80 percent of long-term sediment yields are produced during a few episodic events. Calculated potential average annual sediment yields for the San Juan watershed range from 1,500 to 6,000 tons/mi.^{2}. Using the LAD and MUSLE methods, predicted yields in San Juan Creek during a 100-year event range from 7,800 to 10,270 tons/mi.^{2}. Base sediment yields may increase by factors of approximately 10, 7, 4, and 2 in the first four years following a major fire. In all cases, calculated sediment yields exceed estimated transport capacities by more than a factor of two. Furthermore, the estimated sediment yields do not account for the estimated one billion tons of landslide debris that could be mobilized during a major flood-fire sequence.

Calculated peak sediment transport rates indicate that in the San Juan Creek watershed, Bell and Cañada Gobernadora Canyons represent the largest sediment contribution to San Juan Creek. Cañada Gobernadora has recently exhibited increased sediment transport; however, this is likely due to the construction of Coto de Caza, as opposed to a natural phenomenon. In-channel sediment generation resulting from incision in lower Cañada Gobernadora also contributes to high sediment yield from this sub-basin. Of the sub-basins within the study area of the San Mateo watershed, the Gabino sub-basins had the highest absolute transport capacity, while the Cristianitos sub-basin had the highest transport rate per unit area. Suspended sediment discharge in San Mateo Creek is generally less than in San Juan Creek for all measured flows. One factor that may contribute to the lower suspended sediment discharge in San Mateo Creek is the presence of less-erosive crystalline terrain in the basin geology. This diatomaceous rock that underlies 10 percent of the drainage area in San Juan Creek is known to yield high quantities of sediment as it weathers. Another factor contributing to low yields of suspended sediment in San Mateo is the smaller drainage basin size.

A key element of any effective sediment management plan will be avoiding the creation of major new sources (or sinks) of sediment. New sources can include either new locations or mobilizing sediment through accelerating processes that have been recently inactive in the landscape (e.g., landslides). The most common new source of sediment in a developing landscape is in-channel sediment generation associated with channel incision. Avoiding incision and channel widening are among the most promising approaches to managing sediment yields. Channel incision can increase sediment yields, often by 3 to 7 times, and can persist over a period of 2 to 3 decades. Non-incised, unchanneled reaches, such as portions of middle and upper Chiquita Canyon (as well as most of its tributaries), and middle Gobernadora are important opportunities to maintain existing channel configurations, principally through maintaining existing riparian woodlands plus keeping water tables up and changes in peak flows down, to the degree feasible.

Although avoiding inducing new sediment-generating locations or processes is the most promising approach to managing sediment yields, it should be coupled with land use planning that maintains sediment transport processes through designated channel reaches without interruption or in-stream modifications. This strategy not only will help ensure channel stability, but also will help sustain suitable habitat for sensitive species, such as the southwestern arroyo toad. As with management of hydrologic processes, it is important to remember that sediment yields can vary widely over time due to episodic events and long-term climatic cycles; land use designs must take these cycles into account.

4.5 WATER QUALITY

Water quality constituents of concern in the study watersheds include temperature, turbidity, nutrients (primarily nitrogen and phosphorus), metals, and pesticides (primarily diazinon and chloropyrifos). A significant amount of water quality data has been collected for San Juan Creek since the 1950s. However, most of this data was for nutrients and bacteria and was collected during high-flow events. Unfortunately, there is limited available comparable baseline data for San Mateo Creek. Four water quality monitoring locations have been initiated as part of the baseline data collection for the SAMP/MSAA and should provide useful information.

The data collected along San Juan Creek suggest that there are one or more significant sources of nitrogen loading between the Caspers and La Novia monitoring stations. It is impossible to ascertain the sources of the additional loading, but it may include factors such as the location of several nursery operations downstream of the Caspers site, development on San Juan tributaries (e.g., Coto de Caza on Cañada Gobernadora), and the large amount of grassland in the sub-basins below Caspers. Nitrate measurements at La Novia show a trend of increasing concentration with increased stream discharge, from 0 to approximately 100 cfs (where nitrate concentration = 2.5 to 3.0 mg/l). At higher discharges, nitrate concentration decreases until it drops to background levels at a discharge of approximately 1,000 cfs. These data are consistent with N mobilization either through direct transport by surface storm water runoff or by the displacement of nitrate rich groundwater into the stream system. Nitrogen levels at higher discharge rates reflect the effects of complete washout and subsequent dilution and watershed saturation. The monitoring data for phosphate at La Novia indicate that there is a tendency to higher phosphate levels with increasing stream discharge. This relationship is consistent with erosion being the primary contributor of phosphorus loading via phosphate adsorbed to particulates.

The streams in the San Juan Creek watershed appear to be generally nitrogen limited (i.e., N/P ratio < 10). However, for San Juan Creek at La Novia, the N/P ratio is a function of stream discharge. At both very low and very high flow rates, the San Juan system is nitrogen-limited. However, at intermediate flow rates, the nitrate concentrations have increased (with increasing discharge as discussed above) but phosphate levels have yet to increase significantly, resulting in a transient condition where phosphate is the limiting nutrient. The general pattern of nitrogen being the limiting nutrient implies that algal primary productivity within the San Juan Creek watershed could generally be reduced most effectively by reducing phosphorus loadings to the streams. Similarly, primary productivity would likely be impacted more by increases in nitrogen loadings than by increases in phosphorus.

Orange County PFRD has monitored several metals in San Juan Creek since the early 1990s. The Orange County data is a composite of both dissolved and particulate phases; however, in waters with typical pH levels of 7 to 8, as found in San Juan Creek, metals are most likely to be found in their particulate phase. Therefore, one can assume that the more bio-available dissolved fraction will have lower concentrations than the particulate phase. Because metals are typically found in their particulate form and are, therefore, transported in the same manner as sediments, it is unlikely that significant metal transport will occur during dry weather, as the majority of sediment transport occurs during storm events. An initial examination of the San Juan Creek monitoring data shows that, with the notable exception of zinc, most metals are found in concentrations below the detection limits.

Monitoring data for zinc at La Novia show that the highest levels of zinc occur at flows between 10 and 100 cfs. This pattern likely results from increased sediment mobilization with higher rainfall and stream discharge, increasing the concentration of particle-bound zinc in San Juan Creek. At the highest flows, zinc concentrations decrease as a result of dilution from rainwater and removal of contaminated sediments from the system. The monitoring results indicate that, on several occasions, zinc concentrations surpass both the acute and chronic toxicity objectives for fresh surface waters (21 μg/L and 23 μg/L) set by other Regional Water Quality Boards in California (RWQCB, 1995). It is not clear whether the zinc originates from anthropogenic origins, or if reflects higher naturally occurring concentrations of zinc in the Monterey Shale or other sediment-generating geologic units which outcrop just upstream of this station.

Bacterial monitoring at the mouth of San Juan Creek indicates persistently high counts of total and fecal coliform (FC), and enterococcus (EC). Total bacterial counts frequently exceed 200/ml, which is the RWQCB objective for contact recreation. For calendar year 2000 the log mean fecal coliform concentration at Del Obispo Park was roughly 300/ml. The log mean enterococci concentration for calendar year 2000 was approximately 540/ml. These monitoring stations are located at the most downstream reaches of San Juan Creek, within and below extensive urbanized areas. Although the sources of these bacterial contaminants cannot be ascertained with existing data, future land use changes in the upper watershed will need to protect against additional loadings that may exacerbate the existing bacterial contamination problems in the lower San Juan Creek watershed.

Pollutant pathways and cycles within the San Juan and San Mateo Creek watersheds can be generalized based upon critical characteristics of sub-basin terrain types. Sandy terrains typically favor infiltration, mobilizing pollutants in subterranean pathways with little or no biogeochemical cycling taking place in surface waters. Silty terrains have higher runoff rates and often contribute fine sediments (that have the ability to adsorb metals and pesticides) to downstream waterways. Clayey terrains are characterized by very high surface runoff rates and therefore play only a minor role in groundwater processes. Although typically resistant to erosion, clay soils can be a significant source of turbidity where incision occurs. Crystalline terrains have high runoff rates during larger storms and, in a natural state, produce much of the sediment and eroded soil that moves down the creeks.

Pollutants may travel with storm water or dry season runoff in either the dissolved or particulate phases. Therefore, a series of water quality management features (i.e., a “treatment train”) may be the most appropriate strategy to control all potential sources of water quality impairment. This “treatment train” should involve a combination of land use and management features, such as promotion of infiltration, retention facilities, series of water quality wetlands, and streamside buffers.

4.6 BIOLOGICAL RESOURCES

A total of 16 vegetation community types are mapped within the San Juan and San Mateo watersheds (Holland, 1986; OCHCS, 1992). The study area contains approximately 3,080 acres of aquatic and riparian resources. Riparian woodlands and forests occur along most portions of the stream corridors. Some of the major stands of riparian vegetation can be found in the following areas: San Juan to the confluence with Oso Creek, Cañada Gobernadora tributaries, Bell Canyon, and many of the tributaries to San Juan and San Mateo creeks. Dispersed sections of riparian vegetation occur along Oso, Horno, and Cañada Chiquita Creeks. The slopes along these corridors are dominated by coastal sage scrub or chaparral communities. With increasing elevation, chaparral communities replace coastal sage. Coastal sage scrub is restricted to xeric, south facing slopes. Oak woodlands and forest become common in the upper reaches of the watersheds on north-facing slopes and along drainages. The study area also contains slope wetlands, concentrated mainly along the toe of slopes in Chiquita Canyon and several vernal pool complexes in the middle portion of the San Juan Creek watershed.

Multiple sensitive species inhabit the San Juan and San Mateo watersheds. Of particular note are resident gnatcatcher populations in Chiquita Canyon that are considered one of the core populations in Southern California. Portions of San Mateo watershed and Bell Canyon support large numbers of southwestern arroyo toad. Least Bell's vireo are associated with a number of riparian systems in the study area and could increase as the species continues to recover. Consideration of watershed-scale physical processes, as discussed above, will be critical to ensuring the long-term integrity of the biological resources of the study watersheds. Protection and management of habitat for sensitive species, such as the arroyo toad and least Bell's vireo, will depend on maintenance of channel stability, adequate channel-floodplain interaction, appropriate buffers adjacent to riparian zones, key groundwater recharge areas, appropriate sediment transport patterns, and control of pollutant loading to major tributaries and the main stem creeks.

5.0 LAND USES

The extent of the study area available for future land use planning has been affected by both historic land use practices and existing commitments. The historical patterns of changing human activities in the San Juan and San Mateo basins have been described in prior reports (Corps, 1999a; KEA, 1998; Lang et al., 1998). The following sections are intended to highlight changes or activities of the past 60 years which continue to affect the channels or watersheds. Existing land use commitments are summarized to help focus subsequent analysis on areas available for future land use changes.

5.1 HISTORIC LAND USE PRACTICES

Several historic land use practices have affected both the linear and lateral extent of the riparian zones along the streams in the study area. These include grazing, agriculture, mining, groundwater use, and urbanization.

Cattle-grazing and cutting of the riparian woodlands for fuel and timber have reduced the extent of streamside vegetation. As has been the case in most of the western United States, grazing has resulted in trampling of streamside vegetation and shifted the distribution streamside vegetation to favor more non-native species. At the watershed-scale, consistent, intense and prolonged grazing facilitates a transition of upland vegetation from native grasses and scrub to non-native, annual grasses. The latter are associated with much lower infiltration and higher runoff than native plant communities. Increased runoff and erosion from grazed upland landscapes, in combination with grazing of streamside vegetation, have probably contributed to changes in the geometry and depth of the creeks in the study area and decreased the width of the riparian corridors. Intentional clearing for fields and pastures continued into the middle of the twentieth century, most notably in Cañada Chiquita and Gobernadora (Aguirre, pers. comm., 2000) and probably in Cristianitos and lower Gabino Canyons.

Mining has occurred in the watershed during the past 60 years, gradually declining in extent and scope. Commercial sand and gravel operations have been concentrated primarily along upper Arroyo Trabuco (Livingston & Graham) and in San Juan Creek near the Bell Canyon confluence (Conrock/Calmat). Both facilities have been inactive for at least the past five years, and neither is likely to be re-established. In-channel mining may have had a substantial role in narrowing the riparian woodland and inducing downcutting, notably in Oso, Trabuco, and San Juan Creek between Lucas and Chiquita Canyons. High-quality glass sand continues to be mined from the Los Trancos sub-basin and is expected to continue through 2014. The facility includes a large settling basin that acts to decrease peak flows from this sub-watershed. This retention associated with this basin may be retarding bank retreat along Trampas Canyon, which has been fully incised since the 1938 floods, if not earlier. Numerous day pits have been excavated in upland areas at various locations in the San Juan and San Mateo watersheds, with activity generally ceasing by 1950 or earlier. These pits may provide seasonal habitat for avifauna, but probably have little effect on hydrology or sediment processes in adjacent streams.

Groundwater pumping in the early part of the twentieth century (through the 1930s) led to seasonal or multi-year draw-down of groundwater levels, compounding the effects of the 1929 to 1935 dry period (Browning, 1934; KEA, 1998). However, by 1963, Orange County made the decision to base future land uses in the southern part of the county on purchases of imported water from the State Water Project and the Colorado River Aqueduct. This decision limited the long-term effect of alluvial groundwater withdrawals to approximately 3,000 to 3,500 acre feet per year pumped by RMV. The San Juan Basin Authority currently pumps groundwater from the aquifers of the lower San Juan Basin; however, high salinity constrains which portions of the aquifer can be used and limits withdrawals. The San Mateo alluvial aquifer has been operated primarily to meet irrigation needs for the past 60 years. Use of groundwater for water supply in adjoining units of Camp Pendleton has been increasing intermittently. Pumping from this aquifer is thought to be met in part from increased deep percolation of runoff in San Mateo Creek and its tributaries, decreasing the length of channel available to sustain riparian vegetation (Lang et al., 1998).

Commercial nurseries and agricultural operations have existed for at least 50 years and continue to exist in the San Juan Creek watershed. These operations contribute increased runoff to San Juan Creek that may contain nitrates, phosphates, and other pesticide-related compounds. In summary, the conditions of the riparian zones in the study area today are a result of both natural processes and cycles and over 60 years of land use practices.

5.2 EXISTING LAND USES

The study area includes both developed and undeveloped areas, with major urban development beginning in the early 1970s (see Figure 33 on page 112). In the San Juan Creek watershed, the Dove Canyon subdivision introduced medium-density residences into the middle Bell Canyon watershed during the early 1970s. The Coto de Caza project introduced full urban infrastructure into the middle one-third of the Cañada Gobernadora watershed during the early- to mid-1980s; the project has expanded and intensified during the late 1990s. Tesoro High School, presently (2000) under construction in the middle Chiquita watershed, serves both of these communities and nearby projects along the Oso Parkway corridor. Rancho Santa Margarita, Trabuco Canyon, Robinson Ranch, and the Ladera projects have resulted in urbanization of much of the Oso and Arroyo Trabuco sub-watershed. The lower San Juan Creek watershed is occupied by

Figure 33 Generalized Land Use and Vegetation for San Juan and San Mateo Watersheds

the cities of San Juan Capistrano and Mission Viejo. The majority of upper San Mateo Creek watershed remains undeveloped. However, portions of the upper watershed and most of the lower watershed are occupied by Camp Pendleton Marine Corps Base. Lands owned by the Marine Corps are subject to military, agricultural, and recreation activities.

Significant portions of the watersheds are protected as open space, including the Cleveland National Forest, which occupies the majority of the upper watersheds. The middle portion of Arroyo Trabuco is within O'Neill Regional Park. Caspers Wilderness Park covers portions of Bell Canyon and the middle reaches of San Juan Creek. Other protected areas in the San Juan Creek watershed include the Upper Chiquita Canyon Conservation Area, Chiquita Ridge Open Space, Tijeras Creek Open Space, Cañada Gobernadora Mitigation and Reserve area, Thomas Riley Park, Starr Ranch and the Ladera Ranch Open Space. The Rancho Mission Viejo Conservancy is adjacent to both the San Juan and San Mateo Creek watersheds. This area contributes to overall ecology of the region, but drains into the Segunda Deshecha watershed. Overall, approximately 40 percent of the watershed areas are currently protected as open space (see Figure 34 on page 114).

5.3 AREAS AVAILABLE FOR FUTURE LAND USE CHANGES

By the year 2025, Orange County will see increases in population, employment, and housing. According to Orange County Growth Projections 2000 (OCP, 2000), the official demographic data adopted by the County of Orange, Orange County's population will increase by 19 percent from 2,853,757 to 3,416,037. Employment is projected to increase by 36 percent or 30,000 jobs per year. Using SCAG's target 1.44-jobs/housing ratio for Orange County, 13,039 dwelling units per year (a total of 308,809 units) are needed to house this projected increase in employees. However, housing growth is expected to increase by only 14 percent or 5,513 dwelling units per year (137,819 total units). Therefore, a deficit of 7,526 housing units per year (170,990 total units) will result.

Rancho Mission Viejo is the largest private landholding in the study area. RMV owns the only significant areas that are not already developed entitled or dedicated as open space. To help address the projected housing shortage in Orange County, RMV is proceeding with a local entitlement process, concurrent with the SAMP/MSAA and NCCP/HCP, to gain development approvals for those portions of the ranch not set aside for open space purposes. Therefore, RMV lands are the focus of the SAMP/MSAA and NCCP/HCP planning process. The remainder of this baseline conditions report will focus on analysis of lands on RMV that are available for consideration for future development. The overall goal is to allow for sensible development in a manner that minimizes overall impacts and does not result in significant adverse impacts (incrementally or cumulatively) on the biological and physical condition and processes of the watersheds.

Figure 34 Riparian Vegetation in Existing Protected Open Space

6.0 SUB-BASIN SUMMARY AND CONSIDERATIONS FOR FUTURE LAND USE

Although the sub-basins in the San Juan and San Mateo Creek watersheds are hydrologically and biologically connected, each major sub-basin has somewhat unique or distinctive attributes. Understanding these attributes is essential in a planning context and can help identify key considerations during the alternative analysis process.

The review of existing land uses in Chapter 5 concluded that the only lands available for significant land use changes are on RMV. Other areas in the San Juan and San Mateo watersheds are not available for consideration for future land use changes because they are committed to open space preservation, developed, or currently under development. In the San Juan watershed, the areas that are available for consideration for future land use changes include portions of Chiquita, Gobernadora (including Wagon Wheel), Verdugo, and Central San Juan Creek (including Trampas Canyon). In the San Mateo watershed, available areas include portions of Gabino (including Blind Canyon), La Paz, Upper Cristianitos, and Talega (see Figure 35 on page 116). This chapter will summarize the major characteristics of these sub-basins and provide some major opportunities and constraints that should be considered during the evaluation of both off-site and on-site alternatives for the SAMP/MSAA, development of various reserve designs for the NCCP/HCP, and design of watershed-scale water quality features. The hydrologic and sediment transport characteristics of the major sub-basins are compared in Sections 3.4 and 3.5, respectively (see Figures 11, 12, 21-24, 31 and Tables 3, 7, 10, 11).

6.1 SAN JUAN CREEK WATERSHED

6.1.1 Cañada Chiquita

6.1.1.1 Overview of Sub-basin Characteristics

Cañada Chiquita is the northwestern-most full sub-basin in the SAMP/MSAA study area. With a catchment of 9.24 $mi.^2$ it is aligned north-to-south. Local relief (from ridgetop to channel) gradually increases southward in this watershed, reaching a maximum of about 500 feet. Cañada Chiquita is the downstream-most major tributary before the confluence of Trabuco Creek, near Mission San Juan Capistrano. Approximately 60 percent of the San Juan watershed lies upstream of the confluence with Cañada Chiquita.

Figure 35 Sub-Basin Watersheds for San Juan and San Mateo

The Cañada Chiquita drainage basin is underlain by bedrock of the Monterey, San Onofre, Topanga, Sespe, and Santiago formations. The lower portion of the sub-basin is underlain primarily by the Santiago formation. The Cristianitos fault zone runs through the vertical extension of Chiquita Canyon. Faulting associated with the major portion of the Cristianitos Fault Zone results in highly variable bedding within the bedrock along the southern half of the east side of the canyon. The surficial geologic units within the project boundaries consist of alluvium, colluvium, nonmarine terrace deposits, and landslide deposits. Several large bedrock landslide complexes occur along and adjacent to the Cristianitos fault system, especially west of the fault zone (Morton, 1974). These larger landslides are located within the southwestern one-third of the drainage basin and appear to have failed along weak, sheared bedrock associated with the Cristianitos fault system.[29] These large landslides are likely remnants of the glacial ages, when the dimate was wetter and Cañada Chiquita was 50 to 100 feet deeper than the present-day valley floor.

Cañada Chiquita is a fifth order stream at its confluence with San Juan. There are 470 first order drainages within this sub-basin that represent about 47 percent of the total stream length within the sub-basin. The drainage density of this watershed is lower than comparably sized sub-basins in the region, and many of the lateral valleys are channel-less swales. The terrains of Cañada Chiquita are considered to be primarily sandy, and as such the sub-basin generally has high infiltration capacity. This is especially true in the long channel-less swales, which contain deep sandy terrace deposits. This sub-watershed is primarily underlain by soils from three hydrologic groups: B (25.7 percent), C (36.7 percent), and D (36.0 percent). The dominant land use is agriculture (approximately 40 percent of the sub-basin), with developed lands accounting for less than 2 percent of the sub-basin.

The relatively high proportion of permeable soils and low percentage of developed area result in Cañada Chiquita presently having a moderate- to low-runoff response to precipitation events compared to the other sub-basins analyzed. The high infiltration rates also contribute to the perennial nature of Chiquita Creek. The hydrographs for the 2-year, 10-year, and 100-year events display a rapid singular peak between equally shaped rising limbs and falling limbs (see Figure 36 on page 118). Peak flows exiting Cañada Chiquita occur approximately 24 minutes before the San Juan Creek peak at its confluence with Cañada Chiquita for both the 10-year and 100-year events. Peak flows from Cañada Chiquita do not have a significant impact on the magnitude of peak flows in San Juan Creek at the confluence and downstream. Relative runoff volumes for Chiquita are also relatively low at present with the sub-basin contributing 4 percent and 6 percent of the runoff volume to San Juan Creek at their confluence, while occupying approximately 9 percent of the watershed area at that point. Peak flows from Cañada Chiquita are also approximately 4 percent to 6 percent of peak flows in San Juan Creek at the confluence. For the three events modeled, Cañada

[29] *Review of available geologic literature indicates this fault systems is not considered active, pursuant to the guidelines of the Alquist-Priolo Earthquake Fault Zone Map.*

Figure 36 2-Year, 10-Year, and 100-Year Event Hydrographs for Cañada Chiquita

Chiquita produced between 42 percent and 74 percent as much runoff on a per-acre basis as the average for the San Juan Creek watershed as a whole. However, during extreme flow events (i.e., 50-year or 100-year storms), the infiltration capacity of the soils may be exceeded (partially due to shallow groundwater), and during such major storm events, the soils may behave like poorly infiltrating Class C and D soils.

Below the "narrows" in middle Chiquita Canyon, soils are predominantly sands, silts, and clays. Above the narrows, the soils contain slightly more gravels and cobbles. The sandy substrates mean that the main creek is prone to incision under altered hydrologic regimes. Several active headcuts are present in Chiquita Creek, and the channel is presently incising in several locations. Continued channel incision will increase the sediment generation for the sub-basin by increasing in-channel sediment generation. The Chiquita sub-basin provides some of the lowest sediment yields and transport rates of the sub-basins analyzed in the San Juan watershed and produces substantially less sediment than the neighboring Gobernadora Canyon. However, during episodic events, sediment stored in the lateral channel-less swales may be mobilized and transported to the main portion of Chiquita Creek and further downstream.

The underlying Monterey shale bedrock, prevalence of grassland valleys, and the presence of a relatively high proportion of clay terrain in the valley floor means that nitrogen and phosphorus loadings from this sub-basin are likely quite high, with limited capacity for assimilation within the watershed itself. This may be especially true for phosphorus loadings given the presence of the Monterey formation and evidence of channel incision. Both metals and any pesticides would tend to move in particulate forms.

Chiquita Creek is one of the few naturally perennial streams in the watershed. Water likely flows from the ridge tops toward the valley bottom along subsurface impermeable layers and comes to the surfaces at changes in topography or where substrates of differing transmissivities intersect (i.e., where terrace deposits intersect floodplain alluvial deposits). The valley bottom is characterized by shallow sub-surface water for long portions of the year. This water daylights at the toe of the valley wall in several locations, supporting a series of slope wetlands.

The perennial nature and subsurface water movement in Chiquita Canyon support riparian habitats, freshwater and alkaline marsh, and slope wetlands. The majority of Chiquita Creek is southern willow riparian forest and willow scrub with pockets of alkaline marsh. The middle portions of Chiquita Creek (below Oso Parkway) support a mixture of southern willow scrub and coast live oak riparian woodland. The riparian canopy is mostly intact, but the soils and understory vegetation does exhibit some impacts from cattle-grazing. In areas where the creek has incised (up to 15 vertical feet), connection with the floodplain has been lost and overbank flow seldom occurs. Lateral canyons support primarily California live oak and scrub oak woodlands. The majority of the slope wetlands in the study area occur in the lower portion of Chiquita Canyon. These perennially moist wetlands occur in series along the toe of the slopes (primarily on the east side) and may provide refugia or act as stepping-stones for several taxa of animals. Chiquita Ridge contains several vernal pools including the largest pool in Orange County that supports the federally listed endangered Riversidean fairy shrimp and San Diego fairy shrimp. The slopes and ridges adjacent to the main creek are dominated by coastal sage scrub that supports one of the largest populations of California gnatcatcher in the study area.

6.1.1.2 Summary of Sub-Basin Opportunities and Constraints

Cañada Chiquita includes significant riparian habitat, slope wetlands, vernal pools, a gnatcatcher population, and sources of groundwater recharge. However, the main stem creek is incising in several locations. Specific opportunities and constraints are as follows:

- The sandy substrates have a high susceptibility to erosion and gully formation if runoff is increased to the channel network;
- Channel-less swales, primarily on the east side of the creek, are likely important infiltration areas, but are susceptible to erosion and incision;
- Runoff volumes per unit area are moderate to low (due to high infiltration), but peak flow is relatively high (due to the shape of the sub-basin) when compared to the other San Juan sub-basins;
- Groundwater recharge, especially through the tributary swales, is likely important to maintaining the hydrology of the slope wetlands along the margins of the valley;
- Existing channel incisions and headcuts represent risks of continued channel degradation if runoff is not managed appropriately.
- Existing channel incisions present restoration opportunities, including restoration of floodplain connections and overbank flows along Chiquita Creek; and
- The existing gnatcatcher population in this sub-basin is part of a larger "core population" of gnatcatchers present in the San Juan Creek watershed.

6.1.2 Cañada Gobernadora

6.1.2.1 Overview of Sub-Basin Characteristics

The 11.10 $mi.^2$ Cañada Gobernadora sub-basin is an elongated valley that is aligned north to south. At 9.7 miles, it is the longest watercourse in the San Juan Creek watershed and represents about 11.6 percent of the total watershed area upstream of the Cañada Gobernadora and San Juan Creek confluence.

The geology, soils, and resultant terrains in Cañada Gobernadora are extremely complex. The sub-basin has the lowest percentage of Class D (low infiltrating) soils of any of the sub-basins analyzed and is underlain by geologic formations associated with shallow aquifers. The upper portion of the sub-basin (mainly beyond the RMV boundary) is underlain by the Sespe Formation, while the lower portion of the sub-basin (within the RMV boundary) is underlain by the Santiago Formation. Surficial geologic units within the project boundaries consist of alluvium, colluvium, nonmarine terrace deposits, and a few landslides.[30] Consequently, Cañada Gobernadora contains some of the highest potential infiltration areas in the study area. This is especially true in the valley floor, which is characterized by deep alluvial deposits with interbedded clay lenses that support seasonally shallow groundwater. However, the sandy and silty substrates on many of the hill slopes and ridges in the sub-basin are overlain by several feet of exhumed hardpan or contain exposed rock outcrops. These areas presently exhibit rapid runoff comparable to Class D soils.

Runoff patterns in Cañada Gobernadora are influenced by the shape of the watershed, the underlying soils and geology, and upstream development in Coto de Caza. In the northern portion of the sub-basin, upstream of the Wagon Wheel confluence, the main valley is drained by a fifth order channel for most of its length. Downstream of the confluence with Wagon Wheel, Gobernadora becomes a sixth order system until it joins San Juan Creek further downstream. More than 30 third order channels, and six fourth order streamcourses converge on the main Cañada Gobernadora channel from the western and eastern side slopes. The overall drainage density is approximately 9 mi/mi.^{2} for the combined basins, which share 500 first order channels. First order drainages represent about 45 percent of the total stream length, whereas fifth and sixth order drainages comprise 8.6 percent of total channel length. Due to the elongated configuration of this basin, first order streams are proportionally less of the total stream length than in some of the other sub-basins like Verdugo, Lucas, or Bell Canyons. In addition, many of the tributaries are channel-less swales. These areas represent high infiltration zones that likely convey stream runoff to the main-stem of Cañada Gobernadora and only exhibit surface connection following extreme runoff events. These infiltration zones may also contribute to baseflow and the perennial nature of Cañada Gobernadora.

Runoff volumes and peak flows from Cañada Gobernadora are relatively high in comparison to the other San Juan sub-basins presented. Cañada Gobernadora contributes about 8 percent of the runoff volume to San Juan Creek at their confluence while it occupies approximately 11.6 percent of the watershed area at that point. For the three events modeled, Cañada Gobernadora produced

[30] *Review of aerial photographs and available geologic maps indicate that the landslides located within the project boundaries are shallow and of relatively limited aerial extent.*

approximately 62 to 75 percent as much runoff on a per-acre basis as the average for the San Juan Creek watershed as a whole. However, runoff response is rapid as indicated by 2-year, 10-year, and 100-year hydrographs that display rapid singular peaks with similarly shaped rising limbs and falling limbs (see Figure 37 on page 123). This pattern results from the long, thin shape of the sub-basin; the impervious hardpan and bedrock outcrops; and the relatively greater proportion of developed areas in this sub-basin (particularly in the northern basin). Peak flows from Cañada Gobernadora arrive at San Juan Creek approximately 4.4 hours, 2.4 hours, and 1.6 hours prior to the passing of peak flows along San Juan for the 2-year, 10-year, and 100-year events, respectively. Although this represents a substantial time separation, peak flows from Cañada Gobernadora do have a recognizable impact on peak flows in San Juan Creek at the confluence and downstream due to the relatively large size of the peak flow from the canyon.

Cañada Gobernadora is predominantly underlain by sands and silts and has the potential to generate relatively high amounts of sediment where the surface is disturbed and channelized. Currently, high sediment yields (mainly from the disturbed upper portion of the sub-basin outside the RMV boundary) result in a transport limited system with yields and transport rates (both absolute and per unit area) for Cañada Gobernadora that are the highest of any sand-dominated sub-basin. Sediment yield and transport rates are comparable to the Verdugo sub-basin, which is a steeper and coarser substrate basin, and absolute sediment transport is second only to the larger Bell Canyon sub-basin. In recent years, natural sediment sources have been augmented by sediment runoff from graded slopes in the developing areas of the upper sub-basin (outside the RMV boundary). Much of the sediment generated from the upstream development in Coto de Caza deposits in the lower portion of the canyon, typically within the riparian zone.

Pollutant transport within the Cañada Gobernadora sub-basin is quite complicated with different pathways dominating by location and even season. Much of the watershed lands in the middle and lower reaches are underlain by the permeable Santiago sandstone. Therefore, early in the winter it is reasonable to assume that most rainfall infiltrates, and that groundwater pollutant pathways are predominant. The presence of sandy apron deposits at the mouth of side canyons can locally encourage infiltration. Where the channel is aggrading, there is a greater connectivity with the floodplain and more possibilities for the riparian corridor to play a role in assimilating constituents of concern. However, surface water pathways likely predominate in the lower reaches due to incision that has led to a loss of channel-floodplain connectivity and the presence of heavy clays that bring groundwater to the surface. This sub-basin is likely a significant source of both nitrogen and phosphorus loadings, from grasslands/agriculture, urbanization in the upper reaches with minimal use of BMPs and the presence of large nursery operations. Conditions favor the transport of metals and pesticides in particulate form.

Figure 37 2-Year, 10-Year, and 100-Year Event Hydrographs for Cañada Gobernadora

Along with Chiquita, Cañada Gobernadora is the only portion of the study area where shallow subsurface water plays an important role in the ecology of the aquatic resources. The Santiago formation that predominates the lower portion of the sub-basin is associated with lateral groundwater flow along interfaces between thinly interbedded impermeable clay and permeable sand (Morton, 1974). This creates areas of shallow groundwater in the valley bottom and the lower portion of some of the lateral swales. The shallow groundwater (along with urban runoff from upstream development) contributes to the perennial nature of Cañada Gobernadora. In addition, several of the tributaries to Cañada Gobernadora, such as Wagon Wheel and Sulfur Canyons, support wetlands along faults or fracture zones that cut the sands of the Sespe formation, releasing water stored in the sandstone.

The broad floodplain valley bottom and shallow groundwater found in Cañada Gobernadora allow the creek to support relatively dense riparian habitat. The lowest portion of the main creek (upstream from the confluence with San Juan Creek) has been restored and enhanced as mitigation for authorized impacts to riparian habitats in other areas of Orange County. This portion of the creek supports dense thickets of willow scrub, open water, and emergent marsh. An area adjacent to the middle portion of the creek has recently been utilized to create emergent wetlands as mitigation for impacts in other locations. Over time, this area is expected to develop to a matrix of willow scrub, emergent marsh, and woodland communities that will increase the overall width of the riparian zone in this location. Upstream of the confluence with Wagon Wheel Canyon, the stream contains a mix of southern willow riparian and sycamore-willow woodland to the boundary with Coto de Caza. Several of the major tributaries to Cañada Gobernadora support mature oak woodland with coarser substrate streambeds.

6.1.2.2 Summary of Sub-Basin Opportunities and Constraints

Cañada Gobernadora includes significant riparian habitat and sources of groundwater recharge. Specific opportunities and constraints are as follows:

- Because much of the slopes and ridges are currently covered with a hardpan cap, they exhibit low infiltration rates and rapid runoff patterns.
- The swales and valley bottom are underlain by deep alluvial deposits that function as important infiltration/recharge areas. At the same time, infiltration capacity in the valley bottom and swales may be limited by high groundwater levels.
- Peak runoff per unit area is the among the highest of any sub-basin studied as a result of existing upstream development and the presence of hardpan caps on the slopes and ridges that increase overall basin runoff.

- The timing of the peak flows in Cañada Gobernadora and San Juan Creek at the confluence with San Juan Creek does not produce coincident peaks.

- The lower portion of Cañada Gobernadora receives excessive sediment input from the upstream development of Coto de Caza. Sediment generation will likely be replaced by increased clear-water flow as construction in Coto de Caza is completed. However, the clear water flow may exacerbate existing channel incision thereby increasing sediment delivery to downstream areas.

- The sub-basin contains high loadings of both nitrogen and phosphorus from agriculture nursery's and upstream development.

- The valley floor currently contains swales, ponds, wetlands, and buffers that help partially assimilate nutrient loadings from upstream areas before they reach Cañada Gobernadora or San Juan Creek thereby providing water quality benefits to these receiving waters. However, the role of the riparian zone in nutrient assimilation is reduced where channel incision has isolated the creek from the floodplain.

- The riparian habitat associated with Cañada Gobernadora and the major oak-woodland tributaries provide important aquatic buffers. The floodplain area adjacent to the main portion of the creek provides good opportunities for additional restoration/mitigation efforts.

- The lower portion of Cañada Gobernadora supports a population of least Bell's vireo.

6.1.3 Verdugo

6.1.3.1 Overview of Sub-basin Characteristics

The 4.80- $mi.^2$ Verdugo Canyon watershed has roughly an east-west orientation with several tributary channels entering the main valley stream from the north and south. The sub-basin is underlain by bedrock of the Williams, Ladd, and Trabuco formations and the Santiago Peak Volcanics. Approximately one-half to two-thirds of the Verdugo Canyon drainage basin lies within the project boundary. Within the boundaries of the project, the underlying bedrock consists of the Schulz Ranch and Starr members of the Williams formation, the Holz Shale and Baker Canyon members of the Ladd Formation, and the Trabuco formation. Surficial geologic units within the project boundaries consist of alluvium, colluvium, nonmarine terrace, deposits and a few landslides. The landslides located within the project boundaries are shallow and of relatively limited areal extent.

Drainage density for the sub-basin varies spatially, with an average density of 13 mi/mi.^{2}. The eastern headwaters of Verdugo Canyon have a lower drainage density, while the area north of Verdugo Creek in the central canyon area has a higher drainage density. This increased drainage density likely reflects the geologic substrate beneath the central Lucas and Verdugo basins. Overall, 562 first order drainages are delineated in the Verdugo Canyon sub-basin. Similar to Lucas Canyon, these first order reaches comprise about 51 percent of the total stream length in the basin. Verdugo Canyon is a fifth order stream system at its confluence with the main San Juan channel, immediately downstream of Bell Canyon.

Verdugo Canyon had one of the highest predicted infiltration rates of any of the sub-basins studies in the San Juan watershed. This results from the undeveloped condition of the sub-basin, the relatively high proportion of Type A (8.3 percent) soils (compared to other sub-basins), and relatively low proportion of Type D soils (28.6 percent) compared to other sub-basins in the watershed. The hydrographs for Verdugo Creek show two distinct, peaks with a smaller, yet distinct peak, occurring prior to the main peak of the hydrograph (see Figure 38 on page 127). This shape is characteristic of the hydrographs for Lucas Canyon, Verdugo Canyon, and the Central San Juan catchments, and likely results from the shape of the precipitation hyetograph modeled for this portion of the watershed. Peak flows from Verdugo Creek arrive at San Juan Creek approximately 2.4 hours, 2.8 hours, and 4.8 hours before the flow in San Juan Creek for the 2-year, 10-year, and 100-year event, respectively. Therefore, peak flows from Verdugo Canyon do not significantly increase peak flows in San Juan Creek at the confluence or downstream. Runoff volumes and peak flows from Verdugo Canyon are relatively small, as is expected given the high infiltration rates in the sub-basin. Verdugo Canyon contributes less than 4 percent of the runoff volume to San Juan Creek at its confluence with Verdugo Canyon, while it occupies approximately 6.2 percent of the watershed area at that point. Peak flows from Verdugo Canyon are also less than 4 percent of the total peak flows in San Juan Creek at the confluence. Verdugo Canyon produced less runoff on a per-acre basis than four out of the five other San Juan sub-basins analyzed. Only the central San Juan catchments had lower runoff per-area values.

Verdugo Canyon, along with Lucas and Bell Canyons, constitute the more silty portions of the San Juan Creek watershed, with upper portions of the sub-basins containing crystalline terrains. These areas are characterized by coarser substrates, shallower soils, and steeper slopes than Chiquita or Gobernadora. The combination of substrate type and slope results in Verdugo Canyon having the highest sediment transport rate per unit area of any of the sub-basins in San Juan Creek watershed. Sediment yield for Verdugo is second behind Bell Canyon. Like many of the steep silty and crystalline areas of the study area, much of the sediment in Verdugo is mobilized during episodic events and, when mobilized, has the potential to have substantial effect on sediment delivery and on the geomorphology of the downstream areas.

Figure 38 2-Year, 10-Year, and 100-Year Event Hydrographs for Verdugo Canyon

The large quantities of highly erodible soils in the Verdugo sub-basin can be expected to provide a source of phosphorus loading to San Juan Creek. Nitrogen loading from the sub-basin is expected to be low given that only six percent of the watershed is covered with grasslands, there are limited anthropogenic sources, and little channel incision. The terrains and steep slope of Verdugo Canyon likely results in direct nutrient and pollutant pathways to surface waters. The existence of an intact riparian corridor implies that there is potential for sequestration of constituents of concern within floodplain terraces, with increased amounts of organic carbon available to augment nitrogen cycling. Speciation is expected to favor the transport of metals and pesticides (were any to be present) in an adsorbed form.

The biological resources of Verdugo Canyon are also similar to those found in Bell or Lucas Canyon. The streams are predominantly coarse substrate with southern coast live oak riparian woodland, surrounded by sage scrub and chapparal. These areas are more similar to habitats found in the upper San Mateo watershed than to those found in Chiquita and Gobernadora. Because groundwater is less prevalent than in Chiquita or Gobernadora, the habitats are more mesic than the willow riparian habitats found in those sub-basins. The narrowness of the canyon results in high biological interaction between the habitats of the floodplain and the adjacent uplands.

6.1.3.2 Summary of Sub-Basin Opportunities and Constraints

Verdugo Canyon contains riparian habitat and possesses important sediment generation and transport processes. Specific opportunities and constraints are as follows:

- Verdugo Canyon contains significant riparian habitat and resources within a relatively narrow (i.e., geologically confined) floodplain.
- Verdugo Canyon is an important infiltration area within the watershed.
- Because Verdugo Canyon exhibits low relative discharge and low runoff volume and the peak flows lag behind those of San Juan Creek, it does not significantly contribute to runoff in the main stem of San Juan Creek.
- Verdugo Canyon provides an important source of sediments to downstream areas.

6.1.4 Central San Juan (including Trampas)

6.1.4.1 Overview of Sub-Basin Characteristics

In the central portion of the San Juan watershed, about 10 to 12 miles upstream from the coast, there is a 7.4- $mi.^2$ area (between the mouths of Cañada Gobernadora and Bell Canyon upstream) that contains several small tributary drainages which feed directly into the main stem of

San Juan Creek. The area surrounding the Color Spot Nursery drains directly southward into the main San Juan system and, as such, is not part of either the Gobernadora or Bell Canyon sub-basins. This triangular area is drained by two third order creeks and one fourth order stream. On the south side of San Juan Creek, Trampas Canyon and two unnamed fourth order streams drain steep terrain directly to San Juan Creek. The central portion of the main stem of San Juan Creek, downstream of Bell, Lucas, and Verdugo Canyons, consists of a meandering river with several floodplain terraces in a wide valley bottom.

The Central San Juan and Trampas Canyon drainage basin is underlain by bedrock of the Santiago, Silverado, and Williams formations. Bedding within the bedrock of the Santiago, Silverado, and Williams formations is near horizontal to gently dipping. Surficial geologic units within the project boundaries consist of alluvium, colluvium, nonmarine terrace deposits, and a few landslides. There are two large landslide complexes located south of San Juan Creek along the western boundary of the drainage basin. In addition, two Late Quaternary fault systems, the Cristianitos and the Mission Viejo faults, trend through this drainage basin. The Cristianitos fault trends approximately northwest–southeast along the western boundary of the drainage basin south of San Juan Creek. Two branches of the Mission Viejo fault trend approximately north-south through the eastern portion of the drainage basin. Review of available geologic literature indicates these fault systems are not considered active pursuant to the guidelines of the Alquist-Priolo Earthquake Fault Zone Map.

The majority of the central San Juan sub-basin area is underlain by soils of hydrologic groups C (52.6 percent) and D (29.2 percent). Of the six sub-basins studied in the watershed, the Central San Juan catchments had nearly the highest maximum loss rate, second only to Lucas Canyon. This is likely reflective of the shallow slope and broad floodplain valley that facilitates infiltration.

Multiple tributary inputs result in hydrographs for the Central San Juan catchments characterized by two distinct and one subtle peak (see Figure 39 on page 130). This sub-basin differs from the other studied sub-basins in that the other sub-basins typically consist of a single canyon whose discharge joins San Juan Creek at a single confluence. The effects of these discharges on San Juan Creek occur primarily at the confluence point. By contrast, within the Central San Juan catchments sub-basin, effects of the surface runoff will be distributed in numerous locations along the reach of the main San Juan Creek channel. Therefore, it is difficult to establish a direct relationship between land use patterns in specific catchments and the effect on runoff patterns in San Juan Creek. For this reason, the results that characterize the runoff from this sub-basin and the effect of this runoff upon the flows in San Juan Creek discussed below should be interpreted cautiously.

Figure 39 2-Year, 10-Year, and 100-Year Event Hydrographs for Central San Juan Catchments

In the Central San Juan catchments, peak flows from the tributaries occur approximately 4.4 hours, 2.4 hours, and 2.0 hours before the San Juan Creek peak flows through this area for the 2-year, 10-year, and 100-year events, respectively. Partially due to this difference in peak timing, and also due to the moderate rates and volumes or runoff from this sub-basin, peak flows from the Central San Juan catchments do not have a significant impact on peak flows in San Juan Creek at the confluence and downstream. In absolute terms, runoff volumes and peak flows from the Central San Juan catchments are among the lowest of the six San Juan sub-basins studied. For all three events, the Central San Juan catchments contribute between 2 percent and 5.5 percent of the runoff volume to San Juan Creek at their confluence, while they occupy approximately 8.8 percent of the watershed area at that point. Peak flows from the Central San Juan catchments are approximately between 3.5 percent and 5.5 percent of peak flows in San Juan Creek at the confluence. For the three events modeled, the Central San Juan catchments produced between 24 percent and 69 percent as much runoff on a per-acre basis as the average for the San Juan Creek watershed as a whole, and peak discharge per unit area was among the lowest of the San Juan sub-basins. These low runoff values are likely due to the large proportion of undeveloped areas in the sub-basin, particularly along the central San Juan Creek floodplain, and the small size of the sub-basin in comparison to the other reported sub-basins. Low sub-basin slopes and a broader sub-basin shape may also reduce runoff by increasing infiltration.

The central portion of San Juan Creek is most important as a sediment transport reach. All the catchments that drain into this portion of San Juan Creek together produce a comparable amount of sediment as the Chiquita Canyon sub-basin. In addition, due to its size, there is a substantial amount of bedload transport that occurs along the central portion of San Juan Creek. However, the yield per unit area for the central catchments is the lowest of any area studied in the San Juan watershed. Like Cristianitos Creek, the central portion of San Juan functions as a sediment conduit between the major sediment-producing sub-basins and downstream areas. The nature of the soils in the central San Juan tributaries favors the relatively rapid mobilization of constituents into surface water flows and ready transport of pollutants out of the central sub-basins (e.g., Trampas Canyon) and into the main stem of San Juan Creek. The combination of predominant grasslands, erodible soils, and anthropogenic sources means that the sub-basins can be expected to generate relatively large nitrogen and phosphorus loadings for their size and may be a contributor to the increases in nutrient concentrations between Caspers Regional Park and La Novia that is evident in the Orange County PFRD monitoring program. However, some of the constituents may be sequestered (at least seasonally) within the permeable alluvial aquifers of San Juan Creek. High loads of fine sediment and particulates should favor the adsorbed phases of heavy metals and pesticides.

The central portion of San Juan Creek has intermittent to near perennial flow that is supported by alluvial groundwater that is near the surface, at least seasonally. The riparian habitats and pool and ponds depend on sufficient duration of shallow groundwater. This groundwater is recharged from sub-basins higher in the watershed and is conveyed in the alluvium through the central portion of San Juan Creek.

Agricultural and developed lands cover approximately 12 percent of the land in this sub-basin, with the nurseries being a key component of the land use. On the north side of San Juan Creek, above the Color Spot nursery, there are two major tributaries of note. The first bisects the site beginning as a moderate- to high-gradient, scrub-oak – dominated riparian zone in a chaparral matrix. As the gradient decreases, the sinuosity increases, and the stream corridor supports mature oak woodland. The lowest portion of the stream transitions into a 3-foot-deep-by-5-foot-wide incised channel, characterized by mule fat scrub habitat. The substrate of the stream is dominated by rock and boulders indicating a high energy system where the stream condition is controlled by episodic high velocity flows that convey a lot of debris from the upper watershed. The second drainage feature on the north side of the creek flows out of a canyon to into a manmade impoundment. The upper portion of the stream consists of high gradient, scrub-oak dominated riparian habitat in a chaparral matrix, similar to the main canyon. As this stream flows toward the impoundment, the slope flattens and the vegetation community transitions into southern-willow riparian habitat, with an understory dominated by *Scirpus* spp. and *Baccharis salicifolia* (mule fat). Although not occupied at present, the structure and composition of the lower portion of the drainage appears to be suitable for occupation by least Bell's vireo or southwestern willow flycatcher. The pond at the terminus of this drainage is impounded by a road fill and lacks any substantive fringing wetland vegetation.

The area along Radio Tower Road, on the south side of San Juan Creek, contains representatives of all the major wetland types in the study area: riverine, alkali marsh, slope wetlands, vernal pool, and lacustrine fringe wetlands. The riverine areas on the site are generally high-gradient, low-order streams characterized as steep canyons dominated by sycamore or willow riparian forest. Portions of the drainages appear to have perennial flow, probably associated with groundwater discharge and areas of heavy soils (i.e., relatively high clay content).

Two portions of the site were found to contain slope wetlands associated with localized slumps that result in groundwater discharge. The first area has formed in a small slump adjacent to the main dirt road traversing the site, while the second area is above a corral and contains two slope wetlands. A natural spring has been altered to create a stock pond, and a 240-foot-long-by-45-foot-wide slope wetland has formed in, association with the spring and pond. A second slope wetland is located approximately 200 feet west of the spring, in association with a cut in the slope. Both slope wetlands are saturated at or near the surface for the majority of the year. The site contains three distinct areas that support vernal pools. All the pools have recently been documented to support both the San Diego and the Riversidean fairy shrimp. Several manmade stockponds in this areas support fringing lacustrine wetlands. These ponds provide year-round habitat for amphibians (including bullfrogs) and waterfowl. All upland areas have been heavily grazed and are dominated by non-native grasslands.

Sand, hard rock, and minerals have been mined from Trampas Canyon over the last 50 years. A lake in the abandoned quarry pit dominates this sub-basin. The lake is steep-sided, relatively deep, and does not appear to support any aquatic resources of note. The surrounding uplands are dominated by ruderal vegetation and contain minimal habitat value. Consequently, there are minimal resources of import associated with this drainage area.

The middle reach of the main stem of San Juan Creek is a broad, meandering stream with several floodplain terraces. The creek supports a mosaic of southern willow riparian woodland, mule fat scrub, open water, and sand bars. The adjacent terraces support coast live oak woodland and southern sycamore riparian woodland. The creek has relatively coarse substrate and high topographic complexity, with a variety of secondary channels, pits, ponds, and bars. An abandoned aggregate mining pit has been filling in over the last several years and supports an open water and emergent marsh community. The southwestern arroyo toad is known to occur in the middle reaches of San Juan Creek, but the bullfrog population associated with the old mining pit may affect the population size.

6.1.4.2 Summary of Sub-Basin Opportunities and Constraints

The Central San Juan catchments support a suite of aquatic resources and provide important sediment transport capacity, and arroyo toads have been observed using this area. Specific opportunities and constraints are as follows:

- The area along Radio Tower Road contains a diversity of wetland types in close proximity to each other, thereby increasing heterogeneity of the landscape from an aquatic resources perspective.

- The Trampas Canyon sub-basin is severely degraded and contains minimal aquatic resources of note.

- Most of the Central San Juan catchments are in sandy terrains that provide good infiltration capacity. However, these terrains are susceptible to adverse impacts associated with increased erosion and sediment production to San Juan Creek.

- The central portion of San Juan Creek provides important sediment transport capacity. If not properly addressed, increases in the velocity or volume of discharge could result in increased channel sediment generation and resultant channel incisions.

- High nitrogen and phosphorus loadings are expected from the tributary sub-basins of central San Juan Creek.

- Arroyo toad habitat is present that provides connectivity to toad populations in Caspers Park. However, this reach of San Juan Creek does not appear to support large resident populations of arroyo toad. Opportunities to manage the habitat in this reach and control exotic predators will be coordinated through the NCCP/HCP.

6.2 SAN MATEO CREEK WATERSHED

6.2.1 Gabino

6.2.1.1 Overview of Sub-basin Characteristics

Gabino Canyon is underlain primarily by bedrock of the Williams Formation (Pleasants sandstone and Schulz Ranch members), along with the Santiago, Silverado, Ladd (Baker Canyon member), and Trabuco formations. Surficial geologic units within the project boundaries consist of alluvium, colluvium, nonmarine terrace deposits, and a few landslides. The Mission Viejo fault trends north-south through the southwestern portion of the drainage basin. Although not considered active, this fault affects the terrains and subsurface water movement in the canyon.

The Gabino sub-basin is underlain by clayey and crystalline terrains that generally produce higher runoff volumes per unit area than sandier areas. However, compared to other crystalline terrains in the study area, Gabino Canyon has the highest infiltration capacity of any of the analyzed sub-basins in the San Mateo watershed.[31] Approximately 56 percent of the upper sub-basin is underlain by Type C soils, with 31 percent of the upper basin having the least permeable Type D soils. Infiltration capacity is somewhat lower in the lower portion of the sub-basin and Blind Canyon, with D-type soils being predominant.

Gabino Canyon is 8.3 mi.^{2} and approximately 10 miles long. Along with Talega Canyon, it is the largest sub-basin in the upper San Mateo watershed. Its size, along with its position high in the watershed, and steep terrain produce the highest absolute peak flows and runoff volumes in the upper San Mateo watershed. The crystalline terrains and position in the watershed also result in relatively high drainage density. The 1,274 first order drainages within the Gabino sub-basin account for approximately 51 percent of the stream miles in the sub-basin. At its confluence with La Paz, Gabino Creek is a sixth order stream, until it joins Cristianitos Canyon further downstream. In absolute terms, peak flow rates and volumes at the mouth of Gabino Canyon are at least four times greater than flows entering from the neighboring upper Cristianitos sub-basin, which is a considerably smaller watershed area. However, Gabino Canyon has lower runoff per unit area than either La Paz or Talega Canyons, reflecting the somewhat higher infiltration capacity than these other sub-basins. The simulated hydrographs for Gabino Canyon have a similar shape to the La Paz Canyon hydrographs, with a single distinct peak that rises and falls relatively rapidly. The rising

[31] *Runoff volumes in Gabino Canyon are higher than those for the sandier areas of the San Juan watershed.*

limb of the hydrograph is steeper than the falling limb. This shape is indicative of a somewhat flashy responsive watershed and may be attributable to the crystalline terrain, as well as the shape and slope of the watershed (see Figure 40 on page 136). Flows exiting Gabino Canyon peak about 1.2 hours, 0.8 hours, and 0.4 hours after peak flows have exited the upper Cristianitos sub-basin (upstream of the Gabino confluence) for the 2-year, 10-year, and 100-year events respectively. Interestingly, for the 2-year and 10-year events, storm peaks are somewhat attenuated between the Upper Gabino/La Paz confluence upstream and the Gabino/Cristianitos confluence downstream. This is not the case for the 100-year event, whereby the downstream location has higher peak flows. The proximity of timing of peak flows during more extreme events results in peak flows from Gabino Canyon having the potential to directly add to peak flows in Cristianitos Canyon at the confluence, significantly increasing the downstream hydrograph.

Gabino Canyon was calculated to have the highest sediment yield and transport rate of any sub-basin analyzed in the San Mateo watershed. These high yields are partially attributable to the size of the sub-basin; however, the transport rate per unit area is also high, second only to the Cristianitos sub-basin. Cobbles and other larger particles comprise the majority of sediment produced in this sub-basin; however, unlike La Paz, sand comprises a substantial portion of the sediment produced. The relatively high proportion of underlying sandy substrates (compared to the rest of the crystalline areas in the study area) likely contributes to the high sediment yield predicted for Gabino Canyon. Incision of the channel in the reaches just upstream of the confluence with La Paz also is a likely source of sediment. However, a significant portion of the sediment production is probably associated with erosion caused by historic grazing. Conversion of native habitat to non-native grassland, along with continued grazing, appears to have resulted in extensive gully formation adjacent to Gabino Creek and resultant increases in sediment delivery to downstream areas. A critical feature of the sediment transport characteristics of Gabino Canyon is that most of the sediment is mobilized during extreme episodic events, when the topography, unstable upland soils, and substrate types contribute to produce large quantities of sediment. This sediment is probably very important to downstream channel structure and provides habitat for sensitive species in the middle and lower watershed.

The high proportion of grasslands in the upper watershed represents a potential source of high nitrogen loadings. Similarly phosphate loadings are expected to be moderate, mainly associated with erosion in the upper watershed. Incision in the upper reaches of Gabino Canyon and the naturally confined floodplain in the lower reaches mean that assimilation of nitrate and phosphate loadings are expected to be low to moderate within the riparian floodplain. Baseline metal loadings should be relatively low under existing conditions with most metals transported in particulate form.

Figure 40 2-Year, 10-Year, and 100-Year Event Hydrographs for Gabino Canyon

Groundwater is probably not a significant component of the aquatic ecosystems in the Gabino sub-basin. The channel is typically dry by May or June of even wet years. However, localized groundwater discharge was observed at several active headcuts in the upper watershed. Therefore, there may be localized areas (or sub-surface lenses) that provide localized shallow groundwater. Because the bedrock beneath Gabino Creek is comprised mainly of old, tightly consolidated sediments, any groundwater discharged would have above average specific conductance (i.e., higher salinity).

The dominant habitat types in the upper portion of Gabino Canyon, above the confluence with La Paz Creek, is southern coast live oak riparian woodland. The adjacent uplands are primarily ruderal grasslands with sage scrub on the hillslopes. The upper watershed has been heavily grazed and is incised in places with vegetation that has been cropped or trampled. The riparian zone varies in width from relatively narrow to relatively wide and is well developed (depending on the intensity of grazing). Historically, the stream probably migrated through the floodplain, but now is confined by headcutting and incision processes. In some reaches this incision is in excess of ten feet and appears to have intercepted subsurface flow. A manmade lake/stockpond in upper Gabino canyon, informally known as "Jerome's Pond," captures water from Gabino Creek and three unnamed tributaries. The pond can be characterized as a hemi-marsh mix of open water and bulrush (*S. californicus*). Where Gabino creek flows into the stockpond, there is a delta dominated by mule fat scrub. The pond outlets into a tributary that supports willow riparian habitat and eventually joins the main flows of Gabino Creek. Above the pond, the tributaries are a mix of oak riparian and broad floodplain sycamore habitats. Portions of these tributaries exhibit slumping and erosion, probably resulting from grazing impacts, perhaps in conjunction with fires. A major unnamed tributary flows into Gabino Creek just upstream of its confluence with La Paz Creek. The natural drainage pattern of this tributary has been substantially altered over time by mining activities, including the creation of a series of artificial ponds.

Lower Gabino Creek (below the confluence with La Paz), middle Gabino Creek, and La Paz Creek support structurally diverse, mature oak and southern sycamore riparian woodland with dense chaparral on the adjacent slopes. The center of the stream has a rock cobble substrate overlain by areas of shallow alluvial deposits that support mule fat scrub. The floodplain and riparian zones in the lower sub-basin are confined by the geology of the valley, but contain high topographic complexity (including bars and ponds that were inundated during our site visit), an abundance of coarse and fine woody debris, leaf litter, and a mosaic of plant communities. In many years, the creek flows through the late spring and seasonal pools persist in some locations, but seldom through the summer.

Blind Canyon is a major tributary watershed to Gabino and, as such, was analyzed as part of the lower Gabino system. Blind Canyon is a high gradient, coarse substrate stream, dominated by sycamore and oak riparian gallery forest with a mule fat-dominated understory. The stream contains good topographic complexity, leaf litter, and coarse and fine woody debris. There are numerous high gradient, low order tributaries to Blind Canyon on the site. Some contain scrub oak-dominated riparian forest, others are unvegetated swales. Several of the tributaries appear to pond seasonally at naturally occurring grade changes, but do not exhibit any features of slope wetlands.

6.2.1.2 Summary of Sub-Basin Opportunities and Constraints

Gabino Canyon contains mature oak and sycamore riparian woodlands and provides an important source of sediment to downstream areas. Specific opportunities and constraints are as follows:

- The Gabino sub-basin has a high drainage density and high number of confluence points;

- The floodplain of Gabino Creek is narrow and geologically confined;

- Gabino Canyon provides important sediment yields, though these yields may currently be in excess of natural conditions.

- The crystalline soils in the sub-basin are less sensitive to increases in runoff than sandy soils in other areas, and the lower portion of Gabino Creek has the ability to attenuate increased flows. This pattern is reflected in the hydrographs for the sub-basin (see Figure 40 on page 136).

- The combination of grazing and underlying soils has resulted in incision of upper Gabino Creek (and the associated increase in in-stream sediment production). Remediation of existing upland erosion implementation of a grazing management program and revegetation would improve the current channel instability and reduce sediment loading to the lower watershed over the long term.

- The oak and sycamore gallery forests of lower Gabino Creek represent some of the highest quality riparian habitat in the study area. In addition, portions of upper Gabino Creek supports degraded alkali marsh habitat. This area has high restoration potential, if the channel incision is stabilized.

- A major tributary on the north side of the lower reach of Gabino Canyon has been substantially altered and presents significant restoration opportunities.

- Gabino Creek supports a population of the federally-listed endangered arroyo toad.

6.2.2 La Paz

6.2.2.1 Overview of Sub-Basin Characteristics

La Paz Creek is the major tributary drainage to Gabino Creek, and the two sub-basins share many common characteristics. Approximately two-thirds of the 7.3 $mi.^2$ La Paz sub-basin is within the RMV boundary. The La Paz Canyon drainage basin is underlain by bedrock of the Williams and Trabuco formations and the Santiago Peak Volcanics. Within the boundaries of RMV, the underlying bedrock consists of the Schulz Ranch member of the Williams formation and the Trabuco formation. Surficial geologic units within the project boundaries consist of alluvium, colluvium, nonmarine terrace deposits, and a few landslides.

La Paz creek is a lengthy, fifth order stream and has several fourth order parallel drainages joining it from the eastern hillslopes. Like most of the sub-basins in the upper San Mateo watershed, the steep crystalline terrains produce high drainage density and multiple confluence points. The sub-basin includes 575 first order and 110 second order drainages and has a drainage density of 10 mi/ $mi.^2$. The longest watercourse is approximately 6.8 miles. First order drainages comprise 54 percent of the total streamcourse length in the basin. The narrow western strip of La Paz Canyon is characterized by short, second order streams which drain from the dividing ridge with Upper Gabino Canyon and feed into the main La Paz channel. The fourth order confluence points in the eastern tributaries are associated with dense stands of oak and sycamore woodland and may represent zones of relatively high geomorphic and habitat function.

Runoff and infiltration patterns are similar to those predicted for Gabino Canyon, but at a lower magnitude due to the smaller size of the sub-basin. Runoff per unit area is greater for La Paz Canyon than for Gabino Canyon. This difference results from the fact that the headwaters of La Paz Canyon are approximately 800 feet higher than those of Gabino. The higher portions of the sub-basin receive greater rainfall due to orographic effects. In addition, the upper portions of La Paz Canyon have a high proportion of crystalline terrains and class D soils. Therefore, the portions of La Paz Canyon that receive the most rainfall have the highest expected runoff volumes, resulting high runoff per unit are for the sub-basin as a whole.

The calculated infiltration and loss rates fall in the middle of the calculated range for the reported San Mateo watershed sub-basins. These mid-range rates reflect a balance between poor infiltrating soils in an undeveloped watershed. The majority of the sub-basin is underlain by soils of hydrologic groups C (43.8 percent) and D (47.8 percent) and the sub-basin is nearly entirely undeveloped (99.6 percent). Agricultural and developed lands (mostly roads) cover approximately 0.4 percent of the sub-basin. Therefore, only a very tiny fraction of the basin is impervious to infiltration. Predicted hydrographs for La Paz Canyon display a single distinct peak that rises and falls relatively rapidly. The rising limb of the hydrograph is steeper (convex) than the falling limb (concave). This shape is indicative of a somewhat flashy responsive watershed and may be attributable to the relatively high proportion of low-permeability soils in the watershed. The timing of peak flows is identical to the peak time for upper Gabino Canyon at its confluence with La Paz Canyon. This is not surprising considering that the Upper Gabino Canyon and La Paz Canyon drainages are very similar in size and shape. As a result, peak streamflow from La Paz Canyon directly contributes to increasing peak discharge at Gabino Canyon and further downstream. Runoff per unit area for La Paz Canyon is between 61 percent and 73 percent of the average for the entire San Mateo watershed for the 2-year, 10-year, and 100-year events.

Predicted sediment yields and transport rates for La Paz Canyon are the lowest of any of the sub-basins analyzed in the San Mateo watershed. Rates and yields are comparable to those of the upper Cristianitos sub-basin, which is approximately half the size of La Paz. The low yields may be partially due to the relatively large proportion of very coarse substrates (i.e., large cobbles and boulders) produced from La Paz Canyon. These coarse substrates are likely mobilized very infrequently during large-scale episodic events, at which time they play a significant role in reshaping the geomorphology of the lower portions of the watershed. Groundwater is not a significant contributing factor to the ecology of the riparian systems in the La Paz sub-basin.

Existing nitrogen loadings in the La Paz sub-basin should be relatively low. The lack of well-developed floodplain structure likely limits the ability of the sub-basin to store phosphates and fairly significant quantities are probably mobilized and transported to the main stem of the San Mateo during high flow events. Background metal loadings are likely to be relatively low, with metal speciation favoring particulate forms

La Paz Creek supports dense stands of structurally diverse, mature coast live oak and southern sycamore riparian woodlands. The riparian zones are confined by the geology of the valley, but contain high topographic complexity (including bars and ponds that are inundated late into the spring), an abundance of coarse and fine woody debris, leaf litter, and a mosaic of understory plant communities. In the upper reaches of the sub-basin, the streams are narrow and form tight mosaics with the chaparral and sage scrub of the adjacent uplands. The rock and cobble substrate type that dominates the streambed is reflective of the slope and geologic setting of the sub-basin. Portions of the streams that convey seasonal high velocity flows also retain water for extended periods of time in shallow depressions within the active channel. The seasonal depressions, combined with the open bars and variety of plant communities, likely provide many niches and support complex and inter-related communities.

6.2.2.2 Summary of Sub-Basin Opportunities and Constraints

La Paz Canyon opportunities and constraints are similar to those for Gabino Canyon and include the following:

- The La Paz sub-basin has a high drainage density and high number of confluence points;
- The floodplain of La Paz Creek is narrow and geologically confined;
- La Paz Canyon provides important sediment yields; and
- The oak and sycamore gallery forests of La Paz Creek represent some of the highest quality riparian habitat in the study area.

6.2.3 Cristianitos

6.2.3.1 Overview of Sub-basin Characteristics

The 3.7 $mi.^2$ Cristianitos Canyon drainage basin (upstream of the confluence with Gabino Creek) is underlain by bedrock of the Santiago and Silverado formations. Surficial geologic units within the project boundaries consist of alluvium, colluvium, nonmarine terrace deposits, and a few landslides.

The upper Cristianitos Canyon is a fifth order network with a calculated drainage density of 8 mi/ $mi.^2$. Compared with other sub-basins of this study, the upper Cristianitos watershed has a more rounded, or pear-shaped, configuration. Additionally, the headwater areas are not as steep as many of the other sub-basins. These conditions reflect the physiographic and geologic setting of the upper Cristianitos basin just south of the dividing ridge with the San Juan watershed. As a result of this setting, third and fourth order tributary arms are distributed fairly evenly and have similar lengths. There are 187 first order drainages that account for nearly half of the basin's total stream length.

The majority of the Cristianitos sub-basin is underlain by poorly infiltrating soils of hydrologic groups C (43.9 percent) and D (42.7 percent). However, compared to other sub-basins of the <u>San Mateo watershed</u> studied, the upper Cristianitos Canyon also contains a relatively large portion of the better infiltrating soil group B (12.9 percent). The relatively high proportion of Type B soils and the minimal development in the sub-basin produce relatively high infiltration rates relative to the other reported sub-basins within the San Mateo watershed.[32]

The more gently sloping shape of the headwaters of this drainage, high infiltration rates, and a drainage network which dampens flow peaks results in a less "flashy" hydrograph than observed in other sub-basins of the upper San Mateo watershed. The hydrograph for Cristianitos Canyon has a broader base with lower flow rates. As noted in Section 6.2.1.1, the peak time for Cristianitos is

[32] *Runoff volumes in Cristianitos Canyon are higher than those for the sandier areas of the San Juan watershed.*

identical to the peak time for Gabino Canyon at their confluence. Therefore, peak flows from Gabino Canyon and Cristianitos Canyon combine simultaneously at the confluence, and this significantly increases the hydrograph downstream (see Figure 41 on page 143). In absolute terms, runoff volumes and peak flows from Cristianitos Canyon are the lowest of the studied San Mateo sub-basins, primarily due to the smaller size of this sub-basin. In terms of peak discharge per unit area, upper Cristianitos had the highest rates for the 10-year and 100-year events of the studied San Mateo sub-basins. This higher result for peak discharge per unit area may be somewhat surprising, considering Cristianitos Canyon had more favorable soil and infiltration conditions than the other studied San Mateo sub-basins. It is believed that routing conditions in the Cristianitos Canyon sub-basin, which is the least elongated of the San Mateo sub-basins, enhance flow concentration and generate larger peak flows per unit area. In terms of runoff per unit area, values from Cristianitos Canyon are lower than the other studied sub-basins, only between 43 and 67 percent of the average for the entire San Mateo watershed.

The substrate type in Cristianitos Creek is primarily sands and silts, with a significant portion of clays. However, the lower portion of Cristianitos Creek appears to be actively incising. Review of aerial photographs shows that prior to the extreme flow event of 1938, the reach of Cristianitos Creek upstream from the confluence of Gabino Creek was little more than a swale and seems to have incised 8 to 15 feet since that time. This portion of the creek is likely susceptible to further incision, and associated in-channel sediment generation, during extreme flow events. Sediment transport rate per unit area for the Cristianitos sub-basin is the highest of any San Mateo sub-basin studied. However, because of the small size of the Cristianitos sub-basin, the gross sediment yield and transport rate is the lowest of the studies sub-basins. From a sediment processes perspective, Cristianitos Creek is probably most important as a transport reach, conveying material generated higher in the watershed to downstream areas. Continued incision would interfere with this function.

Pollutant transport and cycling likely occurs predominately within surface waters. The extent of grasslands in the sub-basin strongly suggests that nitrogen loading is currently high, while the high erosion potential indicates that the mobilization of phosphorus sources may be equally high. Metal loadings to the sub-basin are likely low at present and most metal transport can be expected in the particulate form.

Aquatic resources in the Cristianitos sub-basin consist of both riverine and lacustrine (associated with abandoned clay pit mines and stockponds) systems. The upper portions of the sub-basin consist of a ridge or spine with canyons on both sides. These canyons are steep and narrow and contain well-developed, mature oak riparian woodland in a matrix of intact chaparral and coastal sage scrub. Although the total jurisdictional area associated with these drainages may be small, their structure, position in the landscape (in the headwaters), and juxtaposition with intact upland plant communities results in high functioning upland/wetland ecosystems. Cristianitos

Figure 41 2-Year, 10-Year, and 100-Year Event Hydrographs for Cristianitos Canyon

Creek, below an existing stockpond, is a meandering stream that contains alkali marsh communities mixed with willow and mule fat. However this reach is actively incising. Reaches just upstream of Gabino Creek have near-perennial flow, apparently supported by discrete loci of groundwater discharge. The persistent saturation has facilitated development of well-structured hydric soils, and as the gradient flattens, there is a moderate width floodplain associated with the stream. This area supports the highest diversity of wetland species of any of the San Mateo sub-basins studied.

There are several lacustrine wetlands in the sub-basin associated with abandoned clay pits or stockponds. In general, these areas appear to be functioning as intact wetlands. They contain a mix of open water and emergent marsh vegetation. Most are surrounded by a mix of sage scrub and grasslands. One of the stockponds on the lower end of Cristianitos Creek has a stream dominated by mule fat scrub draining into it. The ponds generally appear to have low turbidity and are being used by fish, invertebrates, amphibians, and birds. A large, abandoned claypit exists near the southern boundary of the sub-basin. This pit is approximately 80 to 100 feet deep and dominated by open water with a narrow fringe of emergent marsh habitat. This large, abandoned pit is blue-green in color, and it does not appear to be functioning as a viable ecosystem. Adjacent uplands in the sub-basin have a percentage of clay soils and may support sensitive plant populations.

6.2.3.2 Summary of Sub-Basin Opportunities and Constraints

Cristianitos Canyon includes a significant riparian-upland habitat matrix, alkaline marsh areas, and transport capacity through the system. Specific opportunities and constraints are as follows:

- The upper portion of the sub-basin contains high-quality oak riparian/upland complexes. This matrix of habitat types likely provides high overall biodiversity as an upland-riparian unit.

- The alkali marsh wetlands within the middle portion of the sub-basin are considered regionally significant. The hydrology of lower Cristianitos Creek is not fully understood; however, the dependence of this site on groundwater means that activities in the watershed may affect this resource.

- The riparian zone of Cristianitos Creek likely provides connective function between the upper watershed resources and areas downstream (off Rancho Mission Viejo property).

- Cristianitos Creek has been actively incising since 1938 and is likely susceptible to further incision and associated in-channel sediment generation. This area represents a restoration opportunity.

- The sediment transport capacity of Cristianitos Creek is important as a means to ensure that materials produced in the upper watershed are delivered to downstream areas.

6.2.4 Talega

6.2.4.1 Overview of Sub-Basin Characteristics

The Talega Canyon drainage straddles the boundary of Rancho Mission Viejo and Camp Pendleton. The basin is underlain by bedrock of the Santiago, Silverado, Williams, and Trabuco formations and the Santiago Peak Volcanics. Approximately one-third to one-half of the Talega Canyon drainage basin lies within the project boundary, most of which is occupied by the existing TRW facilities. Within the boundaries of RMV, the underlying bedrock consists of the Santiago and Silverado formations and the Pleasants sandstone and Schulz Ranch members of the Williams formations. Surficial geologic units within the project boundaries consist of alluvium, colluvium, nonmarine terrace deposits and a few landslides.

Talega Creek is a fifth order system where it meets Cristianitos Canyon, downstream of the Gabino Confluence. The 8.3 $mi.^2$ sub-basin has a drainage density of 9 mi/ $mi.^2$, with 501 first order channels. The Talega Canyon sub-basin is extremely elongated, with the longest watercourse over 10.1 miles. The majority of the sub-watershed is underlain by soils of hydrologic groups C (18.8 percent) and D (75.6 percent). Talega Canyon has the highest proportion of poorer infiltrating Type D soils of any of the other sub-basins analyzed in the San Mateo watershed. When considered as a percentage of total storm event rainfall, hydrologic losses in Talega Canyon were the lowest of all reported San Mateo sub-watersheds, for all three modeled storm events. Overall, the low loss rates calculated for Talega Canyon indicate that infiltration rates within the sub-basin are also low, relative to the other reported sub-basins. Although the hydrographs for Talega Creek have a pronounced peak, they are relatively broad (see Figure 42 on page 146). This shape may be attributable to the elongated geometry of the Talega Canyon sub-basin, which tends to attenuate the flood wave as it travels through the sub-basin. While upper tributaries contribute runoff to the main trunk stream, lower tributaries have already conveyed their runoff out of the sub-basin. As a result, elongated basins like Talega Canyon can have dampened hydrographs. In absolute terms, runoff volumes and peak flows from Talega Canyon are in the upper-middle of the range compared to other reported San Mateo sub-basins. Talega Canyon contributes about 33 percent of the runoff volume to Cristianitos Creek at their confluence while it occupies approximately 28.76 percent of the upstream watershed area at that point. Peak flows from Talega Canyon are approximately 25 percent of peak flows in Cristianitos Creek at the confluence. In terms of runoff per unit area, Talega Canyon produced between 66 percent and 78 percent as much runoff on a per-acre basis as the average for the San Mateo Creek watershed as a whole. Talega Canyon is an interesting contrast between runoff peaks which are relatively low and runoff volumes which are relatively high. Higher runoff volumes are generated due to the high proportion of poorly draining soils. However,

Figure 42 2-Year, 10-Year, and 100-Year Event Hydrographs for Talega Canyon

the elongated shape of the sub-basin and long routing distance reduces the magnitude of peak flow rates. Peak discharge rates are attenuated as they travel downstream through the sub-basin.

The lack of available data and the fact that a significant portion of the basin is outside the study area (in Camp Pendleton) prevented analysis of sediment yield or transport rates for this sub-basin.

Nitrogen loading from the Talega sub-basin should be relatively low given the existing land use and cover. However, the potential for generating large amounts of fine sediments indicates that Talega can be a significant source of phosphates. Historical aerial photography shows that a well-vegetated floodplain has often been absent, suggesting that the riparian corridor may play a relatively minor role in cycling of pollutants. However, some sequestration may occur in pockets where sandy substrates are found. Metal partitioning should heavily favor transport in the less biologically available particulate forms.

The riparian zones of Talega Creek are similar to those found in upper Cristianitos and Lower Gabino Creeks. Substrate is rock/cobble dominated with sandbars forming in depositional areas. The riparian habitat consists of dense stands of structurally diverse, mature coast live oak and southern sycamore riparian woodlands. Center portions of the creek support mule fat scrub and open sand bar habitat. The riparian zones are confined by the geology of the valley, but contain high topographic complexity, an abundance of coarse and fine woody debris, leaf litter, and a mosaic of understory plant communities. The creek contains shallow pools that retain water into the late spring and early summer. Some of the highest concentrations of southwestern arroyo toad in the San Mateo watershed are located along Talega Creek.

6.2.4.2 Summary of Sub-Basin Opportunities and Constraints

Talega Canyon includes high quality riparian habitat and a major arroyo toad population. Specific opportunities and constraints are as follows:

- The floodplain of Talega Creek is narrow and geologically confined.
- Talega Creek provides significant sediment yields.
- Talega Creek contains habitat supporting a “core population” of arroyo toads, including adjacent upland habitat and requisite sediment processes.
- The oak and sycamore gallery forests of Talega Creek represent some of the highest quality riparian habitat in the study area.

7.0 MAKING USE OF THE BASELINE CONDITIONS ANALYSIS

Completion of the analysis of baseline hydrologic, geomorphic, and biologic conditions in the San Juan and upper San Mateo Watersheds culminates the first phase of the coordinated SAMP/MSAA, NCCP/HCP, water quality, and local entitlement process. The subsequent phases of this coordinated planning process will: (1) analyze the effect of several proposed land use scenarios on the physical and biological processes of the study watersheds; (2) involve development of specific approaches, guidelines, and criteria for project design elements and BMPs that minimize the effects of land use changes by maintaining the hydrologic, water-quality, and hydrogeologic functions of the watersheds; (3) identify, where practicable, measures necessary to minimize or mitigate the effects of existing uses within the watersheds, but beyond the limits of the study area; and (4) develop specific elements of the aquatic and upland restoration and management programs.

The models and information developed as part of the assessment of baseline conditions will be used during the next phases of the planning process in a predictive manner to evaluate potential impacts and identify impact minimization measures, mitigation measures, and management recommendations. Application of the studies summarized in this Baseline Conditions Report to the SAMP/MSAA, NCCP/HCP, Comprehensive Water Quality Management Plan, and Local Entitlement processes are discussed in detail in Section 1.4 of this report. Examples of how each technical study will be applied to each planning/entitlement process are discussed below. This list is not inclusive, but meant to provide initial recommendations regarding application of the studies. In most cases, specific application of the technical studies will provide input to multiple environmental programs. When considering the application of the technical studies, it is important to be cognizant of the landscape scale and associated spatial accuracy of these studies. Many aspects of the studies affect the resolution and accuracy of the analysis, including field data collection, digitization and photo interpretation, coordinate registration, distortion in images (photos), and precision of the models. In general, the studies are appropriate for use during the alternatives analysis phase. However, certain design applications or detailed impact analyses may require more rigorous analysis.

7.1 APPLICATION OF THE TERRAINS ANALYSIS

SAMP/MSAA – The terrains analysis has identified areas that are conducive to recharge, susceptible to erosion and/or gully formation, and currently possess rapid runoff characteristics. This information will be used during the off-site alternatives analysis to site projects in a manner that has the least overall effect on physical processes in the watersheds, consistent with the overall project purpose. During the on-site alternatives analysis, the terrains analysis will be used to develop design features that minimize or mitigate impacts, in consideration of the intrinsic properties of the landscape.

NCCP/HCP – The terrains analysis will be used to provide recommendations for recharge areas that would help support existing or proposed riparian habitat that may be suitable for least Bell's vireo or southwestern willow flycatcher. Terrains information will also be used to develop management recommendations to: (1) minimize erosion or excessive sediment generation that could affect channel stability; and (2) provide mitigation for impacts to habitat for the arroyo toad or other aquatic species.

Water Quality – Analysis under the SAMP/MSAA and NCCP/HCP, relative to management of sediment generation and optimization of recharge, will also be used as part of the water quality control program to minimize and/or mitigate increases in sedimentation and turbidity by siting development in appropriate areas.

Local Entitlement – The soil and geologic characterizations in the terrains analysis will be used to support siting and design recommendations for specific projects, such as the location of specific structures, basins, and roads.

7.2 APPLICATION OF THE HYDROLOGIC ANALYSIS

SAMP/MSAA – During the off-site alternatives analysis, the results of the hydrologic analysis will be used to evaluate potential changes in flow regimes associated with the various development alternatives and discuss how these potential changes could affect the long-term integrity of wetland and riparian habitats and related species. During the on-site alternatives analysis, these studies will be used to provide recommendations for design features and mitigation measures to offset potential impacts of proposed land use changes. The effect of episodic events on channel stability will be evaluated, and routing of stream flows will be considered during selection of aquatic resource reserve areas to take advantage of natural attenuations of peak flows.

NCCP/HCP – The hydrologic models will be used to analyze the potential effects of land use changes to hydrologic characteristics that may affect the ability of riparian zones to support both sensitive and non-sensitive species. Characteristics to be analyzed include baseflow, annual storm flows, and extreme events.

Water Quality – The hydrologic analysis will provide information for development of stormwater management plans (including formulation of a "treatment train") and Management Measures for control of NPS pollution. These studies will be used to determine appropriate locations, sizes, and designs of water quality control facilities and features, such as basins and swales.

Local Entitlement – The hydrologic analysis will be used to provide input into detailed design of stormwater conveyance systems, detention, and retention facilities for each development area. The relationship of peak flow timing between tributaries and the main stem creeks will be considered during the design of development areas to avoid coincident peaks in downstream areas.

7.3 APPLICATION OF THE SEDIMENT ANALYSIS

SAMP/MSAA – Results of the sediment analysis will be used to evaluate potential impacts of development alternatives on sediment yield, long-term stability and integrity of streams and associated riparian habitat, and the role of floodplains as sediment sources or sinks. During the off-site alternatives analysis, this information will be used to provide guidance on the location of proposed development and reserve areas in a manner that maintains important sediment processes. During the on-site alternatives analysis, these studies will be used to develop design features that maintain appropriate sediment yields and transport rates in the major watercourses. In addition, the sediment analysis will be used to help design restoration strategies for streams that are currently incising.

NCCP/HCP – Analysis of sediment transport and associated stream stability will be used in the NCCP/HCP to ensure that sediment delivery and transport rates are managed in a way that protects aquatic habitats against channel degradation, restores currently degraded streams, and is protective of habitat for sensitive species, such as the arroyo toad. Sediment transport information will also be used to address downstream effects on sediment delivery to sensitive species habitat outside the study area.

Water Quality – The sediment yield and transport models will be used to address rates of sediment entry into channels during both the construction and post-development phases. BMPs and MMs under the NPS Pollution Control program will be developed to manage sediment delivery to streams. Results of the sediment analysis will also be used to help determine appropriate buffer widths adjacent to streams.

Local Entitlement – The sediment analysis will be used to address channel capacity and competence issues, relative to floodflow and sediment conveyance. These studies will also be used in the design and determination of maintenance needs for proposed flood control facilities. Design features (e.g., setbacks, basins, buffers) will accommodate both high frequency and episodic sediment yields.

7.4 APPLICATION OF WATER QUALITY STUDIES

SAMP/MSAA – Analysis of existing water quality constituents and potential future water quality loadings will be used to develop recommendations regarding riparian or wetland areas that could be avoided and/or enhanced. It will also be used to identify areas that could function as both habitat areas and water quality features.

NCCP/HCP – The water quality analysis will be used to evaluate the potential impacts of runoff associated with proposed land use changes on tolerances of aquatic habitats and NCCP/HCP-identified species, such as the arroyo toad.

Water Quality and Local Entitlement – The collection of both dry and wet season water quality data that has been initiated as part of the baseline conditions analysis will be continued. This information will establish the baseline condition for development of water quality control strategies for proposed developments. The water quality analysis will include an investigation of pollutant loadings to receiving waters under different development alternatives. Following this analysis, appropriate BMPs and general urban runoff MMs will be developed to meet State NPS Pollution Control Requirements.

7.5 APPLICATION OF THE GROUNDWATER ANALYSIS

SAMP/MSAA – Information on potential groundwater recharge areas will be used in the selection of development and reserve areas to help provide sufficient shallow subsurface water to support riparian habitats. In areas where perennialization may be of concern, potential recharge areas or other factors will be identified to ensure appropriate baseflow levels are maintained.

NCCP/HCP – The groundwater analysis will be used to identify recharge areas that may contribute to the function of adjacent streams that contain sensitive species or habitats.

Water Quality – The groundwater analysis will be used to develop appropriate infiltration basins that will be a component of the management of urban runoff in a manner that protects water quality and other beneficial uses of the main receiving waters.

Entitlement – The groundwater analysis will be used to help locate and design infiltration strategies (i.e., basins, swales, strips) within proposed development areas.

7.6 APPLICATION OF THE BIOLOGICAL RESOURCES ANALYSIS

SAMP/MSAA – During the off-site alternatives analysis, results of all the baseline technical studies will be used in conjunction with biological data collected as part of the NCCP/HCP, WES/CRRL studies, slope wetlands analysis, and vernal pool analysis to evaluate the areal and functional impact of proposed land use changes. This analysis will include analysis of the effect of upland land use changes on adjacent aquatic resources. During the on-site alternatives analysis phase, the biological analyses will be used to develop impact avoidance, minimization, and mitigation measures. These studies will also be used to prioritize aquatic resource preservation and restoration areas and to develop the aquatic resources restoration and management program.

NCCP/HCP – Application of the biological resources analysis to the NCCP/HCP will be similar and, in most cases, overlap application to the SAMP/MSAA. In addition, the relationship between physical processes and needs of sensitive species will be analyzed. A subsequent report on the hydrologic and geomorphic needs of listed species will be developed that links the known habitat and life history requirements of listed species to the physical processes in the San Juan and San Mateo Creek watersheds. The report will provide management recommendations for long-term management of sensitive species at the watershed and sub-watershed scales. The analysis for the NCCP/HCP will also include more attention to management of upland resources than that for the SAMP/MSAA.

Water Quality – The biological resources analysis will be used to provide recommendations for integration of wetlands and riparian areas, including buffers, into the comprehensive water quality management program.

Local Entitlement – Results of the biological resources analysis under the SAMP/MSAA and NCCP/HCP will be used to document satisfaction of local mitigation requirements under CEQA.

8.0 REFERENCES

Aguirre, G., 2000, Rancho Mission Viejo. Oral communication.

Allen, A. O., 1999, *Urbanization and Dryland Fluvial Systems—Modeling Hydrogeomorphic Change in Ephemeral Streams*. Ph.D. Dissertation. University of California, Los Angeles, pp. 1-240.

Anderson, D. G., 1970, "Effects of Urban Development on Floods in Northern Virginia." U.S. Geological Survey. *Water Supply Paper* 2001-C.

Bolstad, P. V., and J. L. Smith, 1995, "Errors in GIS: Assessing Spatial Data Accuracy." *Journal of Forestry*, 90(11).

Brown, W. M., III, and L. E. Jackson, Jr., 1973, "Erosional and Depositional Provinces and Sediment Transport in South and Central Parts of the San Francisco Bay Region, California," *San Francisco Bay Region Environment and Resources Planning Study*, U.S. Geological Survey Interpretive Report.

Browning, C. R., 1934, *Report on Probable Dependable Water Supply from Piedra de Lumbre Canyon*. Consulting report prepared for Rancho Santa Margarita, Oceanside, California, multi-paged.

Busch, D. E., and S. D. Smith, 1995. "Mechanisms Associated with Decline of Woody Species in Riparian Ecosystems of the Southwestern U.S." *Ecological Monographs* 65(3) pp347-370.

Calcarone, G., and J. Stephenson, 1999, *Southern California Mountains and Foothills Assessment—Habitat and Species Conservation Issues*, General Technical Report GTR-PSW-172, Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, 402 p.

Caldwell, A., 2000, Personal Communication, USGS Field Office, Orange County, September.

California Regional Water Quality Control Board, San Francisco (RWQCB), 1995, *The Water Quality Control Plan (Basin Plan)*, 3rd edition.

Capelli, M., and E. A. Keller, 1993, "Ventura River Flood of February 1992: A Lesson Ignored?" *Water Resources Bulletin*, 28(5) p. 813-832.

Carlson, L., 2000, Marine Corps Base Camp Pendleton. Personal communication.

County of Riverside Flood Control and Water Conservation (RCFCD), 1978, *Riverside County Flood Control and Water Conservation (RCFCWCD) Hydrology Manual 1978*.

DeBano, L. F., 1988, "Effects of Fire on Chaparral Soils in Arizona and California and Post-fire Management Implications" in *Proceedings of the Symposium on Fire and Watershed Management*, sponsored by Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-109.

Dickert, P. F., 1966, Tertiary Phosphatic Facies of the Coast Ranges: in Geology of Northern California, California Division of Mines and Geology, ed. Bailey, E. H. Bulletin 190, p. 289-304.

Dominick, D. S., and M. P. O'Neill, 1998, "Effects of Flow Augmentation on Stream Channel Morphology and Riparian Vegetation: Upper Arkansas River Basin, Colorado," *Wetlands* 18(4):591-607.

Doyle, Martin W., et al., 2000, "Examining the Effects of Urbanization on Streams Using Indicators of Geomorphic Stability." *Physical Geography*, 21, 155-181.

Dunne, T., and L. B. Leopold, 1978, *Water in Environmental Planning*. W. H. Freeman, San Francisco, California.

Edwards, S. W., 1992. Observations on the Prehistory and Ecology of Grazing in California, Fremontia, Vol. 20 (1) pp 3-11.

Faber, P. M., E. A. Keller, A. Sands, and B. M. Massey, 1989, *The Ecology of Riparian Habitat of the Southern California Coastal Region—A Community Profile.* Biological Report 85(7.27), U.S. Fish and Wildlife Service. 152 p.

Ferguson, B. K., 1994, *Stormwater Infiltration.* CRC Press, Boca Raton, Florida.

Fife, D. L., 1979, "Interrelation of Landslides, Fire, Erosion, and Sedimentation in the San Juan Creek Drainage, Southern California," *Guidebook to Selected Geologic Features, Coastal Areas of Southern Orange and Northern San Diego Counties, California*, South Coast Geological Society October 20, 1979, field trip, p. 167-181.

Glysson, G. D., 1977, "Sedimentation in Santa Margarita Lake, San Luis Obispo County, California," U.S. Geological Survey, *Water-Resources Investigations Report* 77-56, 15 p.

Graf, W. L., 1975, "The Impact of Suburbanization on Fluvial Geomorphology," *Water Resources Research*, 11(5):690-692.

Graf, W. L., 1988, *Fluvial Processes in Dryland Rivers*, Springer-Verlag, Heidelberg, Germany.

Hamilton, D. 1992, *Hydrologic Assessment For Riparian Restoration Projects*, Proceedings Environmental Engineering Sessions Water Forum '92, ASCE, Baltimore August 2-6, 1992.

Hammer, T. R., 1972, "Stream Channel Enlargement Due to Urbanization," *Water Resource Research*, 8(6):1530-1540.

Heady H. F. 1968. "Grassland Response to Changing Animal Species." *Journal of Soil Water Conservation* 23:173-176.

Heady H. F. 1977. "Valley Grasslands." Pages.491-514 in Barbour, M. G. and J. Major, eds. *Terrestrial Vegetation of California*. John Wiley and Sons, New York.

Hecht, B., personal communication. Berkeley, California, September 19, 2000.

Hecht, B., 1981, "Sequential Changes in Bed Habitat Conditions in the Upper Carmel River Following the Marble-Cone Fire of August, 1977," *California Riparian Systems: Ecology, Conservation, and Productive Management*, p. 134-141.

Hecht, B., 1983, *Substrate Enhancement and Sediment Management Study for Lagunitas Creek, Marin County*. Consulting report prepared by HEA, a division of J. H. Kleinfelder & Associates for the Marin Municipal Water District, 172 p. plus five appendices.

Hupp, C. R., and W. R. Osterkamp, 1985, "Bottomland Vegetation Distribution Along Passage Creek, Virginia," *Ecology* (66):670-681.

James, L. D., 1965, "Using a Computer to Estimate the Effects of Urban Development on Flood Peaks," *Water Resources Research*, 1:223-234.

Jennings, M. E., W. O. Thomas, Jr., and H. C. Riggs, 1994, "Nationwide Summary of U.S. Geological Survey Regional Regression Equations for Estimating Magnitude and Frequency of Floods for Ungaged Sites, 1993." Prepared in cooperation with the Federal Highway

Administration and the Federal Emergency Management Agency. Reston, Virginia: U.S. Geological Survey, *Water-Resources Investigations Report* 94-4002.

KEA Environmental, Inc., December 1998, *Final San Juan Creek Watershed Baseline Conditions Report*. Consulting report prepared for U.S. Army Corps of Engineers, Los Angeles District, multi-paged, plus three appendices, San Diego, California.

Knudsen, K., and B. Hecht, 1992, *Hydrologic and Geomorphic Factors Affecting Management of the Lower Sisquoc River Alluvial Corridor, Santa Barbara County, California*. Consulting report prepared by Balance Hydrologics, Inc. for SP Milling company, 66 p. plus five appendices.

Kroll, C. G., and G. Porterfield, 1969, *Preliminary Determinations of Sediment Discharge San Juan Drainage Basin, Orange and Riverside Counties, California*, U.S. Geological Survey Open-File Report, 28 p. plus five plates.

Lang, J., B. Oppenheim, and R. Knight, 1998, *Southern Steelhead Oncorhynchus mykiss Habitat Suitability Survey of the Santa Margarita River, San Mateo, and San Onofre Creeks on Marine Corps Base Camp Pendleton, California*. Report prepared by the Department of the Interior U.S. Fish and Wildlife Service Coastal California Fish and Wildlife Office, Arcata, California for the Assistant Chief of Staff, Environmental Security, Environmental and Natural Resources Office of Marine Corps Base Camp Pendleton, 108 p. plus six appendices.

Leopold, L. B., 1968, *Hydrology for Urban Land Planning—A Guidebook on the Hydrologic Effects of Urban Land Use*. Geological Survey Circular, 554:339-353.

Leopold, L. B., 1973, "River Channel Change With Time: An Example." *Geological Society of America Bulletin*, 84:1845-1860.

Lichvar, R., G. Gustina, D. MacDonald, and M. Ericsson, 2000, *Planning Level Delineation and Geospatial Characterization of Riparian Ecosystems of San Juan Creek and Portions of San Mateo Watersheds, Orange County, California*. U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire.

Majmundar, H. H., 1980, Distribution of Heavy Elements Hazardous to Health, Salinas Valley region, California: Sacramento, California, Division of Mines and Geology, Special Report 138.

Montgomery, D., and E. Foufoula-Georgiou, 1994, "Channel Network Source Representation Using Digital Elevation Models," *Water Resources Research*, 29:3925-3934. December.

Morton, P. K., 1970, "Geology of the NE ¼ and NW ¼ Cañada Gobernadora Quadrangle, Orange County, California," *California DMG Preliminary Report 10*.

Morton, P. K., 1974, "Geology and Engineering Geologic Aspects of the South Half of the Cañada Gobernadora Quadrangle, Orange County, California," *California Division of Mines and Geology Special Report 111*, 30 p. plus one plate.

Mount, J. F. 1995. *California Rivers and Streams*, University of California Press, London England.

National Research Council, 1978 and 1980, *Floods, and Debris Flow in Southern California and Arizona*, Committee on Natural Disasters, Environmental Quality Laboratory, California Institute of Technology.

Orange County Environmental Management Agency, 1986, *Orange County Hydrology Manual.* Under contract (D85-078) with Williamson and Schmid, Irvine, California, approved by the Orange County Board of Supervisors on June 18, 1985.

Orange County Environmental Management Agency, 1986, *Orange County Hydrology Manual. Addendum 1*. Under contract (D85-078) with Williamson and Schmid, Irvine, California, approved by the Orange County Board of Supervisors on June 18, 1985.

Orange County Growth Projections, 2000.

PCR Services Corporation, 2000a, *Slope Wetland Functional Assessment.* Irvine, California, June.

PCR Services Corporation, 2000b, *Work Plan for Hydrology and Geomorphology Studies*. Irvine, California.

Philip Williams and Associates (PWA), 1998, *Santa Margarita Watershed Study: Hydrology and Watershed Processes*. PWA Report No. 1132. October 26.

Prestegaard, K., 1979, *Stream and Lagoon Channels of the Los Peñasquitos Watershed, California, with an evaluation of possible effects of proposed urbanization*, M.S. Thesis, University of California, Berkeley, 154 p.

Rantz, S. E., 1971, *Suggested Criteria for Hydrologic Design of Storm-Drainage Facilities in the San Francisco Bay Region, California*, U.S. Geological Survey, Unnumbered Open-file Report.

Richter, B. D., J. V. Baumgartner, J. Powell, and D. P. Braun, 1996, "A Method for Assessing Hydrologic Alteration Within Ecosystems," *Conservation Biology,* January 1996.

Rivertech, Inc., 1987, *San Juan Creek Channel Facility No. L01 Hydrology Study*. Prepared for Orange County, Newport Beach, California.

Roberts, B. R., N. Shanahan, and B. Hecht, 1984, *River Morphology and Behavior—Salinas River Study Phase I Draft Report.* Consulting report prepared by Anderson-Nichols & Co., Inc., for the Monterey County Flood Control and Water Conservation District, 114 p.

Schueler, T. R. and H. K. Holland, 2000, *The Practice of Watershed Protection. Center for Watershed Protection*, Ellicott City, MD, pp.740.

Schumm, S. A., 1956, *Evolution of Drainage Systems and Slopes in Badlands at Perth Amboy, New Jersey*. Geological Society of America Bulletin. 67:597-656.

Scott, M. L., P. B. Shafroth, and G. T. Auble, 1999, "Response of Riparian Cottonwoods to Alluvial Water Table Declines," *Environmental Management* 23(3):347-358.

Shafroth, P. B., G. T. Auble, J. C. Stromber, and D. T. Patten, 1998, "Establishment of Woody Riparian Vegetation in Relation to Annual Patterns of Streamflow, Bill Williams River, Arizona," *Wetlands*. 18(4):577-590

Simon, Li & Associates, Inc. (SLA), August 1988, "River Sediment Discharge Study: San Diego Region," *Coast of California Storm and Tidal Waves Study*, CCSTWS 88-3.

Simons, Li & Associates, Inc. (SLA), 1999, *San Juan Creek Watershed Management Study F3 Feasibility Phase Appendices—Hydraulic and Sedimentation Documentation*, Simons, Li & Associates. Prepared for U.S. Army Corps of Engineers, Los Angeles District. July 1999.

Smith, R. D., 2000, *Assessment of Riparian Ecosystem Integrity in the San Juan and San Mateo Creek Watersheds, Orange County, California*. U.S. Army Corps of Engineers Engineering Research and Development Center, Waterways Experiment Station, Vicksburg, Mississippi 39180.

Smith, S. D., D. A. Devitt, A. Sala, J. R. Cleverly, and D. E. Busch, 1998, "Water Relations of Riparian Plants from Warm Desert Regions," *Wetlands* 18(4):687-696.

Steinitz, C., et al., 1996, "Biodiversity and Landscape Planning: Alternative Futures for the Region of Camp Pendleton, California." *Harvard Business School of Design.* Study supported by SERDP and U.S. EPA.

Strahler, A. N., 1968, "Quantitative Geomorphology," *Encyclopedia of Geomorphology*, edited by R. W. Fairbridge, pp. 898-912. Reinhold Book Corp., New York.

Taylor, B. D., 1981, "Inland Sediment Movements by Natural Processes," *Part B* of *Sediment Management for Southern California Mountains, Coastal Plains, and Shoreline:* Environmental Quality Laboratory, California Institute of Technology, 80 p. plus plates.

Taylor, B. D., 1981, "Sediment Management for Southern California Mountains, Coastal Plains and Shoreline," *Part B Inland Sediment Movements by Natural Processes*. Prepared by Environmental Quality Laboratory, California Institute of Technology, Pasadena, California. EQL Report No. 17-B. October.

Trimble, S. W., 1997, "Contribution of Stream Channel Erosion to Sediment Yield from an Urbanizing Watershed," *Science*, 278:1442-1444. November.

U.S. Army Corps of Engineers, February 1999a, *Scope of Work—Special Area Management Plan, San Diego Creek and San Juan Creek Watersheds, Orange County, California.* Prepared by U.S. Army Corps of Engineers Los Angeles District Regulatory Branch, 25 p.

U.S. Army Corps of Engineers, 1999b, "Aliso Creek Watershed Management Study, Orange County, California—Assessment of Without-Project Conditions," *Los Angeles District Planning Report*, multi-paged plus appendices.

U.S. Army Corps of Engineers, 1999c, "San Juan Creek Watershed Management Study, Orange County, California," *Feasibility Phase, Draft Watershed Management Report*. Los Angeles District, California. December.

United States Department of Agriculture (USDA) and Forest Service in cooperation with University of California Agricultural Experiment Station, September 1978, *Soil Survey of Orange County and Western Part of Riverside County, California*.

Vanoni, V. A., R. H. Born, and H. M. Nouri, 1980, "Erosion and Deposition at a Sand and Gravel Mining Operation in San Juan Creek, Orange County, California," *Proceedings on Storms, Floods, and Debris Flows in Southern California and Arizona 1978 and 1980,* Pasadena California, September 17-18, 1980.

Waldner, L., Stream Gage Operator, Orange County Public Facilities and Resources Department. Personal Communication on July 12, 2000. (714) 567-6370.

Wells, W. G. II, 1981, "Hydrology of Mediterranean-type Ecosystems—a Summary and Synthesis," *Proceedings of the Symposium on Dynamics and Management of Mediterranean-type Ecosystems*, San Diego, California, June 22-26, 1981, p. 426-430.

White, C., E. Foster, E. Ballman, and B. Hecht, 2000, *Final Baseline Hydrology Report Blue Rock Country Club, Walpert Ridge, Hayward, California.* Consulting report prepared by Balance Hydrologics, Inc. for Hayward 1900, Inc. and YCS Investments, Inc. 54 p. plus appendices.

Wilkinson, C., and C. Collier, 2000, *San Juan Creek Watershed Management Feasibility Study, Orange County, California, Planning Aid Report.* Prepared by the U.S. Department of the Interior Fish and Wildlife Service Region 1, Carlsbad Fish and Wildlife Office for the U.S. Army Corps of Engineers, Los Angeles District, 68 p.

Williams, J. W., 1969, *Summary of Gobernadora Test Well, A Portion of the Cooperative Study of the Water Resources of the San Juan Creek Basin* by the Orange County Flood Control District and the State Department of Water Resources. Multipaged.

Wolman, M. G., 1967, "A Cycle of Sedimentation and Erosion in Urban River Channels," *Geografiska Annaler* 49A:385-395.

Wolman, M. G., and R. Gerson, 1978, "Relative Scales of Time and Effectiveness of Climate in Watershed Geomorphology," *Earth Surf. Proc. And Landforms*, 3:189-208.

Wolman, M. G., and L. B. Leopold, 1957, *River Flood Plains; Some Observations on Their Formation*. U.S. Geological Survey Professional Paper 282-C.

Wolman, M. G., and J. P. Miller, 1960, "Magnitude and Frequency of Forces in Geomorphic Processes," *Journal of Geology* 68:54-74.

Wong, T. S., and C. N. Chen, 1993, "Pattern of Flood Peak Increase in Urbanizing Basins with Constant and Variable Slopes," *Journal of Hydrology*, 143:339-354.