Final Report

Task 2A – Conceptual Model Development East and Piru Subbasins

Upper Santa Clara River Chloride TMDL Collaborative Process

Prepared for

Sanitation Districts of Los Angeles County
Los Angeles Regional Water Quality Control Board

October 2006

CH2MHILL

in association with

HGL
HydroGeoLogic, Inc
Exceeding Expectations

This Page Intentionally
Left Blank

Contents

Contents, Continued

Contents, Continued

Contents, Continued

Page

Tables

Contents, Continued

Contents, Continued

Figures

Contents, Continued

Contents, Continued

Contents, Continued

This Page Intentionally
Left Blank

Acronyms and Abbreviations

°F	degrees Fahrenheit
°C	degrees Celsius
acre-ft/month	acre-feet per month
acre-ft/yr	acre-feet per year
AMEC	AMEC Earth & Environmental
ASCE	American Society of Civil Engineers
ASR	Aquifer Storage and Recovery
Basin Plan	Water Quality Control Plan, Los Angeles Region
cfs	cubic feet per second
CHF	channel flow
CIMIS	California Irrigation Management Information System
Cint	canopy storage parameter (units of length)
CLWA	Castaic Lake Water Agency
cm	centimeter
cm/day	centimeters per day
cm/sec	centimeters per second
CY	Calendar Year
DEM	Digital Elevation Model
DWR	California Department of Water Resources
EPA	U.S. Environmental Protection Agency
ET	evapotranspiration
ETc	crop evapotranspiration
ETo	reference evapotranspiration
FAO	Food and Agriculture Organization
ft bgs	feet below ground surface
ft msl	feet above mean sea level
ft/day	foot/feet per day

ft/mi	feet per mile
ft^2/day	square feet per day
GIS	geographic information system
gpd/ft	gallons per day per foot
GSWI	Groundwater/Surface-water Interaction
GSWIM	Groundwater/Surface-water Interaction Model
HFB	Horizontal Flow Barrier
HGL	HydroGeoLogic
HSG	Hydrologic Soil Group
in/hr	inch per hour
ITRC	Irrigation Training and Research Center
Kc	crop coefficient
Kh	horizontal hydraulic conductivity
Kh:Kv	horizontal to vertical hydraulic conductivity
Kv	vertical hydraulic conductivity
LACSD or Districts	Sanitation Districts of Los Angeles County
LADPW	Los Angeles County Department of Public Works
LAI	leaf area index
LFi	fraction of each land use at a given model grid block "i"
LSCE	Luhdorff and Scalmanini Consulting Engineers
LUC	land use code
mgd	million gallons per day
NLF	Newhall Land and Farming Company
OLF	overland flow
P	phosphorus
Pr	precipitation
R^2	Pearson Correlation Coefficient
RCS	Richard C. Slade and Associates
RDF	root-zone distribution function
RMS	root mean squared

Regional Board	Los Angeles Regional Water Quality Control Board
SCAG	Southern California Association of Governments
SCR	Santa Clara River
SCS	Soil Conservation Service
SFi	fraction of each soil type at a given model grid block "i"
Sint	interception storage capacity
SSURGO	Soil Survey Geographic
SWP	State Water Project
TAP	Technical Advisory Panel
TDS	total dissolved solids
TMDL	total maximum daily load
TWG	Technical Working Group
USGS	U.S. Geological Survey
UWCD	United Water Conservation District
VCWPD	Ventura County Watershed Protection District
WFi	model grid block "i" that falls within a given irrigated area divided by the total irrigated area
WQO	water quality objectives
WRP	water reclamation plant
WWTP	wastewater treatment plant

This Page Intentionally
Left Blank

SECTION 1.0

Introduction

1.1 Background

The Santa Clara River (SCR) is the largest river in Southern California that remains in a relatively natural state (Los Angeles Regional Water Quality Control Board [Regional Board], 2006). This river is a source of supply for irrigation and recharge to the underlying groundwater systems as it winds its way through a 100-mile course from the San Gabriel Mountains in Los Angeles County through Ventura County where it meets the Pacific Ocean (see Figure 1-1; tables and figures are located at the end of each section). Portions of the SCR drainage area have undergone significant growth over the last couple of decades. One such area is the Santa Clarita Valley (including the City of Santa Clarita and surrounding communities in Los Angeles County), with a population that has more than tripled between 1980 and 2004 from about 69,000 to 230,303 people[1]. Significant growth in this region is expected to continue, and residents and regulatory agencies are concerned about the consequences of increased development to beneficial uses of the SCR system. One consequence of increased urbanization has been increased loading of salts to the SCR hydrologic system. The sources of these salts include imported water, point-source discharges from industrial and commercial entities to the SCR and its tributaries, irrigation runoff, groundwater discharge to streams, local use of water softeners, atmospheric deposition from rainfall and dustfall, and other sources.

The Regional Board has been evaluating chloride water quality objectives (WQO) for the SCR since 1976 (Regional Board, 2002). The Regional Board assigned river reach numbers to the SCR in the Santa Clarita Valley and adjacent areas as follows (see Figure 1-1):

- Reach 4 extends from the A Street bridge (Highway 23) in Fillmore, California, to Blue Cut near the Ventura-Los Angeles County boundary.
- Reach 5 extends from Blue Cut in Ventura County to the west pier of the Highway 99 bridge in Los Angeles County, near the Valencia Water Reclamation Plant (WRP).
- Reach 6 extends from the west pier of the Highway 99 bridge to the west pier of Bouquet Canyon Road in Los Angeles County, near the Saugus WRP.
- Reach 7 extends from the west pier of Bouquet Canyon Road to a subbasin boundary located near the Lang stream gage in the SCR in Los Angeles County.

These Regional Board reach designations roughly correspond to Reaches 6, 7, 8, and 9 as designated by the U.S. Environmental Protection Agency (EPA). References made to SCR reach numbers in the remainder of this report follow the convention of the Regional Board.

In Reaches 5 and 6, chloride was assigned a WQO of 100 milligrams per liter by the Regional Board in the Water Quality Control Plan, Los Angeles Region (Basin Plan) (Regional Board, 1994). This WQO was assigned in an attempt to protect downstream agricultural uses,

[1] http://gis.esri.com/library/userconf/proc01/professional/papers/pap710/p710.htm

including irrigation of salt-sensitive crops. However, in 1998, the Regional Board determined that portions of the SCR were impaired with respect to chloride pursuant to Section 303(d) of the Clean Water Act, because the 100-milligrams per liter chloride WQO was being exceeded. After a surface-water body is listed on the 303(d) list, the Clean Water Act requires that a Total Maximum Daily Load (TMDL) be established to restore the impaired water body and implement the established WQO for a given contaminant. The Upper SCR chloride TMDL officially became effective on May 5, 2005 (Regional Board, 2006).

1.2 Problem Statement

Chloride concentrations in Reaches 5 and 6 of the Upper SCR frequently exceed WQO standards associated with agricultural supply. Furthermore, chloride concentrations in portions of the groundwater systems that underlie the SCR occasionally exceed WQO standards associated with groundwater recharge (Regional Board, 2002 and 2006).

1.3 Scope

The chloride TMDL includes special studies to determine the chloride threshold for salt-sensitive crops in Ventura County and the chloride loading from surface water to underlying groundwater basins along the affected reaches. The latter study is referred to as the "Groundwater/Surface-water Interaction (GSWI) Study." The Sanitation Districts of Los Angeles County (LACSD or Districts) and Regional Board are working jointly on the GSWI Study. The Districts own and operate the Valencia and Saugus WRPs in Los Angeles County that discharge tertiary-treated effluent to the Upper SCR. Modeling of ground Transport water/surface-water interactions will help evaluate the impact of chloride and total dissolved solids (TDS) loading from the WRPs outfalls and other sources to downstream receiving water stations, as well as assess the impacts of chloride loading sources on underlying groundwater in the Upper SCR. In combination with the results of the other TMDL studies, this study will provide information to assist the Regional Board in consideration of revising the chloride WQO or establishing a site-specific objective for chloride in the Upper SCR that is protective of surface-water and groundwater resources.

For the GSWI Study, the Districts, along with their consultant team, CH2M HILL and HydroGeoLogic (HGL), are developing a numerical model for a portion of the SCR watershed to evaluate chloride fate and transport from surface water to groundwater basins underlying the Upper SCR. In accordance with the TMDL collaborative process, the Districts included Regional Board staff, stakeholders, and an independent review committee called the "GSWI Technical Advisory Panel" (TAP) in the process of developing the numerical model.

The GSWI model will aid in the understanding of the interaction between surface water and groundwater and the linkage between surface-water quality and groundwater quality with respect to chloride and TDS. The GSWI model will also allow for the assessment of the assimilative capacity of the surface water and groundwater systems within Reaches 4, 5, and 6 of the SCR in relation to existing Basin Plan WQOs for groundwater and surface water.

Portions of Reach 7 of the SCR will also be included in the study area to account for groundwater and surface-water conditions upstream of the Saugus WRP.

1.3.1 Overview of GSWI Tasks

The GSWI Study includes the following principal tasks:

- **Task 1A - Evaluate Existing Models, Literature, and Data** - Compile and evaluate available information from which to develop a GSWI numerical model.
- **Task 1B - Conduct Additional Studies/Monitoring and Enhance Monitoring Network, as Necessary** - Address data gaps identified in Task 1A and subsequent tasks.
- **Task 2A - Conceptual Model Development** - Use the information compiled in Task 1A to develop a physical description of the study area and processes governing the sources, fate, and transport of chloride and TDS; this is the subject of this report.
- **Task 2B - Numerical Model Development and Calibration** - Develop a numerical model, initially based on the conceptual model described in this report, to simulate the concentration and movement of chloride and TDS in surface water and groundwater in the study area, historically since Calendar Year (CY) 1975, and projected to CY 2030.
- **Task 3 - Public Review Strategy** - Ensure that information and analyses are made available to stakeholders in the watershed.
- **Task 4 - Reporting, Presentations, and Documentation** - Document and present information, analyses, and results of the GSWI Study and get appropriate input from the GSWI Technical Working Group (TWG), GSWI Modeling Subcommittee, GSWI TAP, and other project stakeholders. Reports will be prepared for each of Tasks 1A, 1B, 2A, 2B, and 3, with a Final Summary Report covering all tasks at the end of the study. Thus, there will be an opportunity to revise the content in the "final" versions of the individual task reports before submittal of the Final Summary Report at the conclusion of the project.

1.3.1.1 Status of Task 1A

To date, the GSWI consultant team has collected data and information from multiple stakeholders and organizations, including the following:

- Districts
- Regional Board
- Ventura County Watershed Protection District (VCWPD)
- United Water Conservation District (UWCD)
- U.S. Geological Survey (USGS)

- Upper Basin Water Purveyors[2]
- Los Angeles County Department of Public Works (LADPW)
- AMEC Earth & Environmental (AMEC) (specifically, data from AMEC database and AMEC, 2005)
- Fillmore Fish Hatchery
- U.S. Army Corps of Engineers
- Systech Engineering
- Ventura Regional Sanitation District
- Los Angeles Department of Water and Power
- Newhall Land and Farming Company (NLF)
- City of Santa Clarita
- Agricultural Commissioner of Ventura County
- University of California Cooperative Agricultural Extension
- Geomatrix Consultants

Pertinent data received from these organizations are being compiled on a routine basis. The consultant team compiled available information and completed the Draft Task 1A Report (CH2M HILL, 2006) in March 2006. The report presented the evaluations of existing models, literature, and data for the Upper SCR. A Final Task 1A Report has not been prepared because of the ongoing nature of data collection. Final results of Task 1A will be rolled into the Final Summary Report at the end of the GSWI project, which is currently scheduled for November 2007.

1.3.1.2 Status of Task 1B

As previously indicated, Task 1B is composed of two main subtasks, including conducting additional studies and routine monitoring. Task 1B is designed to create the opportunity to fill data gaps and provide additional monitoring data with which to facilitate development of the GSWI model. Following is a brief update on the status of Task 1B.

Additional Studies. During development of the Task 1A and Task 2A reports, data gaps were identified that fall into one of the following three general categories:

- Data gaps associated with surface and subsurface characterization (e.g., aquifer properties and alluvium geometry at subbasin boundaries) within the GSWI Study area
- Data gaps associated with water quantity (e.g., streamflow, diversions, groundwater levels, stage of surface-water bodies, and groundwater use)

[2]The Upper Basin Water Purveyors consist of the Castaic Lake Water Agency (CLWA), the Newhall County Water District, the Santa Clarita Water Division of CLWA, and the Valencia Water Company. The Santa Clarita Water Division of CLWA was acquired by CLWA in 1999. It was formerly called the "Santa Clarita Water Company".

- Data gaps associated with water quality (e.g., chloride and TDS concentrations in surface-water, groundwater, and point-source discharges, and the associated mass loading of chloride and TDS)

Identification of data gaps, and implementation of associated field activities to fill data gaps, will be ongoing throughout the GSWI Study. However, during development of the Task 1A and 2A reports, it was discovered that few subsurface characterization data and groundwater level and quality data are available for the western portion of the SCR Valley East Subbasin (hereafter referred to as the "East Subbasin") (near Blue Cut) and the eastern portion of the Piru Subbasin (near the county line). General observations and existing descriptions for the county line area indicate that rising groundwater, perennial surface-water flows, and then percolation into the Piru Subbasin all occur in this general area. The conceptual and numerical models for the GSWI Study will be developed with greater certainty if subsurface conditions in this area are better understood and quantified. Specifically, this particular area lacks definition of alluvium geometry, groundwater levels, groundwater quality (specifically chloride and TDS), and aquifer properties. Because of the importance of this area to the study, Task 1B activities were prioritized to begin characterizing this data-poor area. As a result, Geomatrix Consultants was tasked with development and implementation of a work plan to provide subsurface characterization data near the county line.

To help better characterize groundwater conditions in the Blue Cut area, both exploratory borings and installation of monitoring wells are planned. To date, Geomatrix Consultants has been working through technical and land access issues with NLF and Camulos Ranch, the property owners of the land on which drilling activities are planned. For the exploratory borings, it is anticipated that four soil borings will be drilled to bedrock in areas shown on Figure 1-2 during fall 2006. Continuous core will be collected from the borings such that geologic logs that document observations of soil type with depth can be developed. Borehole geophysical logs (e-logs) will be run in at least one of the borings to provide basic data to use in conceptualizing the alluvial geometry in the GSWI model. Surface geophysical methods might also be implemented near the four boring locations to further delineate the alluvium thickness across the SCR channel, if information from the borings indicates that additional data are needed and that surface geophysical methods would likely be successful.

Additionally, Geomatrix Consultants is also coordinating the installation of dedicated monitoring wells at four locations (different from the four exploratory soil boring locations). Figure 1-3 shows the planned locations of these monitoring wells. The purpose of these monitoring wells is to provide ongoing access for measurement of groundwater levels, collection of water quality samples, and assessment of aquifer properties in the county line area, as described in the following subsection.

Routine Monitoring. A general scope for monitoring groundwater and surface-water conditions was provided in the Districts' Request for Proposals that included the following:

- Groundwater quality and groundwater level monitoring at eight existing and up to five new monitoring wells
- Surface-water quality and flow monitoring at six existing and two new locations along the Upper SCR, including monthly sampling at the current LACSD receiving water stations (RA, RB, RC, RD, RE, and RF) and the two new locations

The calibration period for the GSWI model includes CYs 1975 through 2005. The purpose of the routine monitoring is to provide higher frequency monitoring data during the post-calibration period to use in gaining insights into seasonal hydrologic system behavior that could facilitate development of the GSWI model. In addition, the data will be used to further enhance the model's ability to replicate seasonal fluctuations of hydrologic system dynamics in historical and future periods.

Geomatrix Consultants developed a Groundwater and Surface Water Sampling Plan (Geomatrix Consultants, 2006), derived from information resulting from Task 1A and 2A activities. Figure 1-3 shows the routine monitoring locations currently planned under Task 1B. Locations were selected because of perceived value to the GSWI project, access, and coordination with ongoing sampling activities conducted by UWCD, LACSD, and the Upper Basin Water Purveyors to avoid duplication of efforts. For further information, the reader is referred to the Groundwater and Surface Water Sampling Plan (Geomatrix Consultants, 2006) for a more detailed description of the sampling plan details, methods, and protocol.

Potential Additional Data Gaps. As higher priority data gaps identified in Section 1.3.1.2 are filled during initial Task 1B activities, other geographic areas of uncertainty might need to be assessed throughout execution of the GSWI Study. These data gaps are considered to have lower short-term priority than those associated with the Blue Cut and county line area described above, but might be important for the ultimate development of conceptual and GSWI models. Potential data gap areas for additional consideration include the following:

- Portions of Reach 7 near the Saugus WRP or potentially farther upstream
- Reach 6 downstream of the Saugus WRP
- Reaches 5 and 4 downstream of the Valencia WRP
- Water quantity and quality data associated with major diversions along the SCR
- Water quantity and quality associated with less-studied tributaries to the SCR (e.g., Salt Canyon near the county boundary)
- Water quality in Bouquet Reservoir

It is anticipated that as the higher priority data gaps are filled, the potential importance and value of obtaining additional data from these other areas will be assessed using the output from early versions of the GSWI model. In this way, knowledge gained from early stages of the GSWI Study can be used to assess the benefit of filling other data gaps identified in later stages of the GSWI Study. The need for this type of phased approach to data collection was agreed upon by GSWI TWG and stakeholders in early stages of the study.

1.3.2 Task 2A Report Objectives

This report describes the results of Task 2A of the GSWI Study. A Draft Task 2A Report was submitted in June 2006 to the GSWI TWG and stakeholder members. Formal comments were provided by members from these groups and formal responses were provided and discussed in a GSWI Modeling Subcommittee meeting in August 2006. Responses to the GSWI TWG and stakeholder comments are provided in Appendix A of this report.

Upon completion of the response to GSWI TWG and stakeholder comments, the Draft Task 2A Report and the responses to comments provided in Appendix A were given to members of the GSWI TAP for their review. Appendix B of this report contains the responses to the GSWI TAP members' comments. Thus, the content of this Final Task 2A Report provides all responses to formal comments received and incorporates agreed-upon revisions and other additional content that further clarifies the conceptual model development.

The main objectives of Task 2A are as follows:

1. Develop a conceptual GSWI modeling framework to incorporate the necessary elements for development and implementation of the numerical model.
2. Provide conceptualization of model structure and functioning.
3. Assess information and data gathered under Task 1A for climate, land use, hydrogeological, hydrological, groundwater level, groundwater pumpage, groundwater quality, and surface-water quality for model development.
4. Identify sources and sinks impacting the chloride and TDS concentrations in the Upper SCR and the underlying groundwater basin. Prepare flow and loading inputs from the loading sources identified in a format that the model will use.

1.4 GSWI Conceptual Model Overview

The Districts and Regional Board have determined that development of a numerical model is required for the GSWI Study. Prior to developing the GSWI numerical model, a theoretical construct that represents the field problem was initially developed. This theoretical construct is known as a "conceptual model," and its development involves simplifying the field problem into fundamental components that can be represented mathematically, so that the field problem can be evaluated using a numerical model. The numerical model then serves as the tool that houses the mathematical framework and solves the governing flow and transport equations that simulate aspects of the field problem that can be independently evaluated for a range of situations. Simplification of the field problem is a necessary step during conceptual model development because complete reconstruction of the field problem is not possible using the best available technologies. Thus, one goal of developing conceptual and numerical models is to simplify the field problem as much as possible, while retaining enough complexity so that evaluations of the hydrologic system behavior can be conducted for a variety of field conditions.

The GSWI model will be a deterministic-process model designed to aid in the understanding of the linkages between sources and fate of chloride and TDS. The GSWI conceptual modeling framework is illustrated on Figure 1-4, including the effects of climate, flow, and loading from various sources to the chloride and TDS concentration in the SCR and the underlying groundwater basins. One goal of the conceptual model is to identify the linkages that are necessary to evaluate the relationships between salt loads and the water quality of the SCR with respect to chloride and TDS.

For this study, the conceptual and numerical models will hereafter be referred to as "the GSWI conceptual model" and "GSWIM," respectively. Following is an overview of the

GSWI conceptual model, which will describe the overall purpose of GSWIM and the framework within which GSWIM will be constructed and used to aid in decisionmaking.

1.4.1 Overview of Geographic Area

Figures 1-5 and 1-6 show schematic representations of the Santa Clarita Valley and Piru Valley, respectively. Santa Clarita Valley is located in Los Angeles County along Reaches 5, 6, and 7; and the Piru Valley is located in Ventura County along Reach 4 (see Figure 1-1). The Santa Clarita Valley is located 35 miles north of downtown Los Angeles off the Golden State Freeway (Interstate 5), serving largely as a bedroom community to the greater Los Angeles area. The Piru Valley is located downstream and west of the Santa Clarita Valley and is predominantly an agricultural area along Reach 4 of the SCR. Significant surface-water features that exist upstream and north of both valleys are surface-water reservoirs including Bouquet Reservoir, Pyramid Lake, and Castaic Lake and Lagoon located in Los Angeles County, and Lake Piru located in Ventura County.

In both valleys, tributaries in canyons located north and south of the SCR contribute intermittent streamflow to the river during short-term storm runoff or reservoir-release events. Streamflow in Reach 7 of the SCR, located upstream of the Saugus WRP, is also intermittent. Streamflow in most of Reaches 6 and 5, located downstream of the Saugus and Valencia WRPs, is perennial, owing much of its flow to groundwater discharge from the underlying alluvial aquifer and from discharge of tertiary-treated wastewater from the WRPs (see Figure 1-5). Streamflow remains perennial in the SCR in a westerly direction over the county line, where it begins to infiltrate into the aquifer system underlying the Piru Valley in Ventura County. A short distance downstream of the Las Brisas Bridge, streamflow in Reach 4 of the SCR typically disappears into the streambed except during storm runoff events. The location at which streamflow disappears marks the beginning of the dry gap in the SCR in the Piru Valley, which typically extends downstream to the Piru Narrows where groundwater begins to daylight into the SCR streambed near the Fillmore Fish Hatchery (see Figure 1-6). Streamflow is occasionally present in the SCR upstream of the Fillmore Fish Hatchery to the confluence with Piru Creek during releases or spills from Lake Piru.

1.4.2 Model Purpose

Following the convention of Anderson and Woessner (1992), hydrologic modeling studies typically fall within one or more of the following three categories:

- **Generic.** Conducted to evaluate hypothetical hydrologic system behavior under a set of assumed physical properties and boundary conditions. Does not necessarily require calibration of an analytical or numerical model, but calibration to field-measured data is common. Can be useful to facilitate technical discussions or as a screening tool to aid in framing management or regulatory questions or guidelines.

- **Interpretive.** Conducted to evaluate site-specific hydrologic system behavior. Does not necessarily require calibration of an analytical or numerical model, but calibration to field-measured data is common. Can serve as a framework for data collection aimed at gaining insights into site-specific controlling parameters and formulating hypotheses for hydrologic system dynamics.

- **Predictive.** Conducted to predict site-specific future hydrologic system behavior. Frequently aimed at forecasting consequences to proposed actions. Typically requires calibration of an analytical or numerical model to a set of calibration targets, such as groundwater levels measured in wells, streamflow measured at stream gages, or solute concentrations detected at specific locations, for an appropriate historical period prior to conducting the predictive analysis. Predictive analysis can also contain elements of both generic and interpretive analyses.

GSWIM, after calibrated to historical conditions from CYs 1975 through 2005, will be a predictive model that will ultimately provide the following:

- A forecast of the chloride concentration gradient from the Saugus and Valencia WRP discharge locations to the downstream LACSD receiving-water locations (SCR-RA, SCR-RB, SCR-RC, SCR-RD, and SCR-RE; shown on Figure 1-3) and the surface-water diversion at Camulos Ranch under assumed (yet-to-be-determined) hydrology, land use, water use, and water quality discharge conditions to CY 2030.

- Insights into the interaction (linkage) between surface-water flow and quality and groundwater flow and quality, and the resulting mixing, assimilative capacity, and attenuation with respect to chloride and TDS, in relation to the existing Basin Plan WQOs.

- Insights into an appropriate WQO or site-specific objective for chloride compliance in the surface-water and groundwater systems located within the GSWI study area.

- Guidance for selection of an appropriate averaging period over which future chloride TMDL compliance can be evaluated by the Regional Board (e.g., daily, monthly, or annual rolling average chloride concentrations).

1.4.3 Model Code

GSWIM will be built using a code called "MODHMS" (HGL, 2001) that has its origins in the popular USGS Modflow model (McDonald and Harbaugh, 1988). However, MODHMS has been enhanced and further developed by HGL to include numerous features that are not included in the original USGS code. MODHMS is a physically based, spatially distributed numerical model that includes several packages for simulation of fully integrated ground-water and surface-water flow (including saturated and unsaturated flow) and solute transport. This particular code was selected for the following reasons:

- Project scope requires a code that is capable of simulating unconfined subsurface flow interacting with a stream channel flow domain, and the associated solute transport therein.

- The code needs to be capable of handling drying and re-wetting of both surface and subsurface domains to allow for evaluations of unsteady flow and transport resulting from temporal and spatial wet and dry conditions (e.g., drought or wet periods, and the extents of the dry gaps in the SCR and its tributaries).

- MODHMS treats the flow of water and transport of solutes in a hydrologic system in a rigorous and mechanistic manner by mathematically representing surface and sub-surface domains as one holistic system whose matrix is solved simultaneously. Therefore, it is not necessary to estimate locations of losing or gaining portions of the SCR outside of the model for each stress period. Furthermore, it is not necessary to manually link approximations of the surface-water and groundwater systems separately. Thus, key processes that control groundwater/surface-water interaction are inherently simulated as part of the numerical solution.

- MODHMS is the product of over 15 years of development and is built upon the USGS Modflow model. Modflow has been used extensively in groundwater evaluations worldwide for over 20 years.
- MODHMS has been benchmarked and verified, meaning that the numerical solutions generated by the code have been compared with one or more analytical solutions, been subject to scientific review, and been used on previous modeling projects (e.g., Vrugt et al., 2004; Schoups et al., 2005; Werner et al., 2006). Verification of the code ensures that MODHMS can accurately solve the governing equations that constitute the mathematical model.

For additional information on the MODHMS code, the reader is referred to the user's manual (HGL, 2001).

1.4.4 Model Design Overview

The GSWIM design is the result of translating the GSWI conceptual model into a form that is suitable for numerical modeling. Steps associated with the GSWIM design include the following:

1. Establishing study area boundaries (i.e., model domain) and developing a numerical grid.
2. Selecting a time discretization (i.e., stress period durations) appropriate for evaluation of the field problem and fulfilling the model purpose.
3. Establishing boundary conditions for flow and water quality (i.e., water budget and chloride loading terms for each stress period).
4. Spatially distributing the initially assumed parameter values (e.g., aquifer properties, layers thicknesses, land surface properties, and initial conditions) that will be subject to calibration.

The following subsections describe results of these four design steps.

1.4.4.1 Model Domain and Grid

In the real world, space is continuous, but a numerical model must use discrete space to represent the hydrologic system. The simplest way to discretize space is to subdivide the study area into many subregions (i.e., grid-blocks) of the same size. However, it is typically advantageous to use relatively small grid-blocks in key areas of the modeling domain where more resolution in the numerical solution is desired, but having small grid-blocks across the entire modeling domain can lead to very long simulation runtimes. Therefore, use of larger grid-blocks in areas of the modeling domain that are located away from the main areas of interest, and that are less critical to the evaluation of the overall field problem, is a typical grid-building strategy, especially when the study area encompasses a large geographic area.

This strategy seeks to maximize the resolution of the numerical solution in areas of interest within the modeling domain, while minimizing model runtimes.

A preliminary GSWIM grid that will mathematically represent the 418-square-mile GSWI study area has been developed, and its aerial extent is shown on Figure 1-7. This particular grid is a curvilinear grid, which means that it is topologically a uniform Cartesian grid, but is geometrically warped in space. This particular grid type was chosen because of compatibility with MODHMS and the ability to warp the grid along nonlinear features of interest, such as the domain boundary. This allows one to maximize the number of grid-blocks in key areas of the modeling domain, while minimizing the number of grid-blocks in areas of the modeling domain that are less important.

The outer geographic boundary of the GSWIM domain, as shown on Figure 1-7, follows natural hydrologic divides around an area located downstream of three local surface-water reservoirs. The vertical discretization (layering) of GSWIM is described in Section 4.0. GSWIM simulations will target the portion of the SCR watershed downstream of large surface-water reservoirs that contribute water and salts to Reaches 4, 5, 6, and 7.

Western Boundary. At the GSWI TWG and Modeling Subcommittee meetings held during the first and second quarters of 2006, it was agreed that the most downstream location at which GSWIM calibration will be focused will coincide with the Piru-Fillmore Groundwater Subbasin boundary (as designated by USGS) in Reach 4 of the SCR. Figure 1-8 shows the western limit of the calibration area (at the subbasin boundary) and the western boundary of GSWIM. The Piru-Fillmore Subbasin boundary is located in an area of significant groundwater pumpage by local irrigators and from Fillmore Fish Hatchery operations. To simulate responses of groundwater levels to this nearby pumping in GSWIM and to minimize numerical model boundary effects at this location, the western boundary of GSWIM is located farther downstream at the A Street bridge, which also marks the end of Reach 4 of the SCR.

Northern Boundary. A portion of the SCR watershed located north of Reaches 4, 5, 6, and 7 contains such features as surface water reservoirs. The larger reservoirs include Bouquet Reservoir, Pyramid Lake, and Castaic Lake and Lagoon in Los Angeles County, and Lake Piru in Ventura County. These surface-water bodies accumulate water that is drained from a large portion of the SCR watershed and, in some cases, serve as terminal reservoirs for the State Water Project (SWP). A detailed understanding of the hydrology in areas tributary to these reservoirs is not considered necessary for the GSWI Study because the timing, magnitude, and quality of water downstream of these reservoirs is controlled and measured. Therefore, to further refine the GSWIM domain, the areas upstream of Bouquet Reservoir, Pyramid Lake, Castaic Lake and Lagoon, and Lake Piru were not considered for the GSWI study area, as is consistent with the approach taken by Systech Engineering (2002b) during development of the WARMF (Watershed Analysis Risk Management Framework) model.

Eastern Boundary. Reach 6 of the Upper SCR begins at the west pier of Bouquet Canyon Road in Los Angeles County near the Saugus WRP. Selection of an eastern boundary for the GSWI study area considered the upstream distance and extent of the drainage area east of Reach 6, up to the headwaters of the Upper SCR, and the locations of stream gages in the Upper SCR upstream of Reach 6. The portion of the SCR watershed located east of the Lang community in Los Angeles County, where a USGS stream gage exists in the Upper SCR, was not considered for the GSWI study area. The selection of an eastern boundary that corresponds to the location of the Lang stream gage also coincides with the beginning of Reach 7 and is consistent with previous modeling of the region conducted by CH2M HILL (2004a, 2004b, and 2005b). Streamflow data recorded at the Lang stream gage will be used to account for streamflow and chloride and TDS entering the modeling domain from the Acton Subbasin of the SCR watershed, which is located east of this stream gage.

Southern Boundary. The southern boundary of GSWIM was extended to the southern boundary of the SCR watershed.

1.4.4.2 Model Time Discretization

In the real world, time is continuous, but a numerical model must use transient parameter values that describe the field problem at discrete intervals of time. The duration of each discrete time interval is carefully selected for the numerical model in an attempt to input transient parameter values that represent time-continuous hydrologic processes of the field problem and allow the model solution to be output at a time scale appropriate for the field problem being evaluated.

As previously discussed in Section 1.4.2, one purpose of GSWIM is to provide guidance for selection of an appropriate averaging period over which future chloride TMDL compliance can be evaluated by the Regional Board (e.g., daily, monthly, or annual rolling average chloride concentrations). For the current study, transient parameter values will initially be discretized using monthly stress periods. Monthly stress-period durations have been initially selected according to the availability of measured chloride and TDS concentration data, and attempts to balance anticipated GSWIM runtimes (which could be significant given the multi-decade calibration period duration and large geographic area) with sufficient resolution in model output. By starting with monthly stress periods, initial calibration efforts can focus on improving the model's overall ability to simulate observed seasonal variability in hydrologic processes. As development of GSWIM progresses over the life of the project, sensitivity analyses will be conducted to evaluate the relative importance of refining stress-period durations for selected transient input parameters. The outcome of sensitivity analyses coupled with the LACSD and Regional Board's development of future scenarios to be simulated will provide the technical justification for incorporating additional complexities or refinement of stress-period durations.

1.4.4.3 Boundary Conditions

GSWIM will consist of governing flow and transport equations, boundary conditions, and initial conditions. Discussion of the governing flow and transport equations used with the MODHMS code can be found in the MODHMS user's manual (HGL, 2001). Boundary conditions are mathematical statements (i.e., rules) that specify water elevation, water flux, solute concentration, and/or solute flux at particular locations within the model domain, which can vary in time. Five types of boundary conditions will be used with GSWIM, including the following:

1. **Specified-head boundary** – Water elevation is prescribed.
2. **Specified-flux boundary** – Water flux is prescribed.

3. **Head-dependent flux boundary** – Given head values, a water flux is computed across the boundary using an appropriate governing flow equation. It is anticipated that GSWIM will be set up to solve Richard's Equation for variably saturated subsurface flow and the Diffusion Wave Equation and Manning's Equation for overland flow. See the MODHMS user's manual (HGL, 2001) for additional details regarding how governing equations are implemented into MODHMS.
4. **No-flow boundary** – Water flows parallel to the boundary and not across it.
5. **Inflow solute concentration boundary** – Solute concentration is assigned as inflow boundaries to simulate solute loading to the modeling domain. Assigning concentrations to outflow boundary conditions is not necessary because solute outflow will be computed as part of the numerical solution.

The locations and conditions of each of the five boundary conditions are allowed to vary with each stress period in GSWIM, except for the no-flow boundaries, which simulate surface and subsurface water divides associated with the outer GSWIM domain boundaries. Table 1-1 summarizes the boundary conditions selected for GSWIM.

1.4.4.4 Initial Conditions

The establishment of GSWIM as a predictive model in Section 1.4.2 necessitates establishment of initial conditions in the hydrologic system from which to simulate hydrologic conditions in a forward-in-time manner. Initial conditions in this context refer to the initial distribution of groundwater elevations, streamflow locations, and solute concentrations throughout the modeling domain that are representative of January 1975 (the beginning of the calibration period).

Water Flow. Typically, the initial distribution of water levels and flow is computed in a "charge-up" simulation run prior to starting the actual calibration simulation. There are many ways to implement this charge-up period. For GSWIM, it is anticipated that establishment of initial conditions for the calibration simulations will involve simulating 1975 surface and subsurface conditions in a steady-state manner, and then qualitatively comparing the steady-state solution with observed conditions (e.g., groundwater levels and streamflow locations versus dry gap locations) in the mid 1970s. The steady-state condition will then be used for simulating transient conditions from CYs 1975 through 2005. Because the influence of the initial conditions on the numerical solution diminishes as the simulation progresses in time, consequences associated with selection of potentially erroneous initial conditions will be small overall, provided that sufficient simulation time has elapsed (Anderson & Woessner, 1992).

Water Quality. Discussion of the initial conditions with respect to water quality is focused on chloride in this report and does not specifically address TDS concentrations. The planned approach for the early versions of GSWIM is to focus calibration efforts on improving the match between simulated and measured calibration targets that relate to flow and chloride concentrations (Section 9.0 provides more detail on calibration targets). As calibration improvements are made during development of the early versions of GSWIM, an approach for handling TDS will be developed and presented at GSWI TWG, GSWI Modeling Subcommittee, and GSWI TAP meetings. Thus, details of TDS loading estimates will be discussed in a later report under Task 2B and/or the Final Summary Report at the end of the project.

An initial chloride concentration was selected based on examination of both the raw data and chemograph trends. To come up with an initial distribution that takes advantage of as much of the available data as possible, initial chloride concentration values were selected from CYs 1970 through 1978. The initial distribution of chloride in the alluvial aquifer is presented on Figure 1-9. This figure shows that groundwater quality data were more readily available for the Piru and Eastern Fillmore Subbasins in Ventura County than for the East Subbasin in Los Angeles County. Because of the high density and nonuniform distribution of data in the Piru and Eastern Fillmore Subbasins, the Thiessen Polygon (1911) method was selected to areally distribute the point-concentration data. This approach subdivides the subbasins into polygons centered on a data point such that all grid-blocks located within each polygon are assigned the value of the corresponding point concentration. Because of the much lower density of available chloride data in the East Subbasin in Los Angeles County, this area was subdivided by assigning each drainage a chloride concentration value based on the nearest data point. Insufficient data were available to generate a spatially variable distribution of groundwater quality in the Saugus Formation in Los Angeles County; therefore, an average value of 37 milligrams per liter for chloride will be assigned to all model grid-blocks representing this formation.

TABLE 1-1
Summary of Boundary Conditions
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Hydrologic Process[a]	Specified-head Boundary	Specified-flux Boundary	Head-dependent Flux Boundary	Inflow Solute Concentration Boundary
Stream Inflow at Lang Stream Gage		X		X
Groundwater Inflow at Lang Stream Gage	X			X
Dams Underflow		X		X
Precipitation		X		X
Evapotranspiration			X	
Applied Water		X		X[b]
Point-source Discharges		X		X
Reservoir Releases and Spills		X		X
Groundwater Pumping		X		X[b]
Surface-water Diversions		X		X[b]
Discharges to Septic Systems		X		X[b]
Stream Outflow at A Street Bridge	X[c]			
Groundwater Outflow at A Street Bridge	X			

[a]See Figures 1-5 and 1-6 to facilitate conceptualization and general locations of hydrologic processes.

[b]Concentrations will be specified by MODHMS as part of the numerical solution, as is discussed in Section 8.0.

[c]More specifically, a zero-depth gradient boundary condition.

This page intentionally left blank.

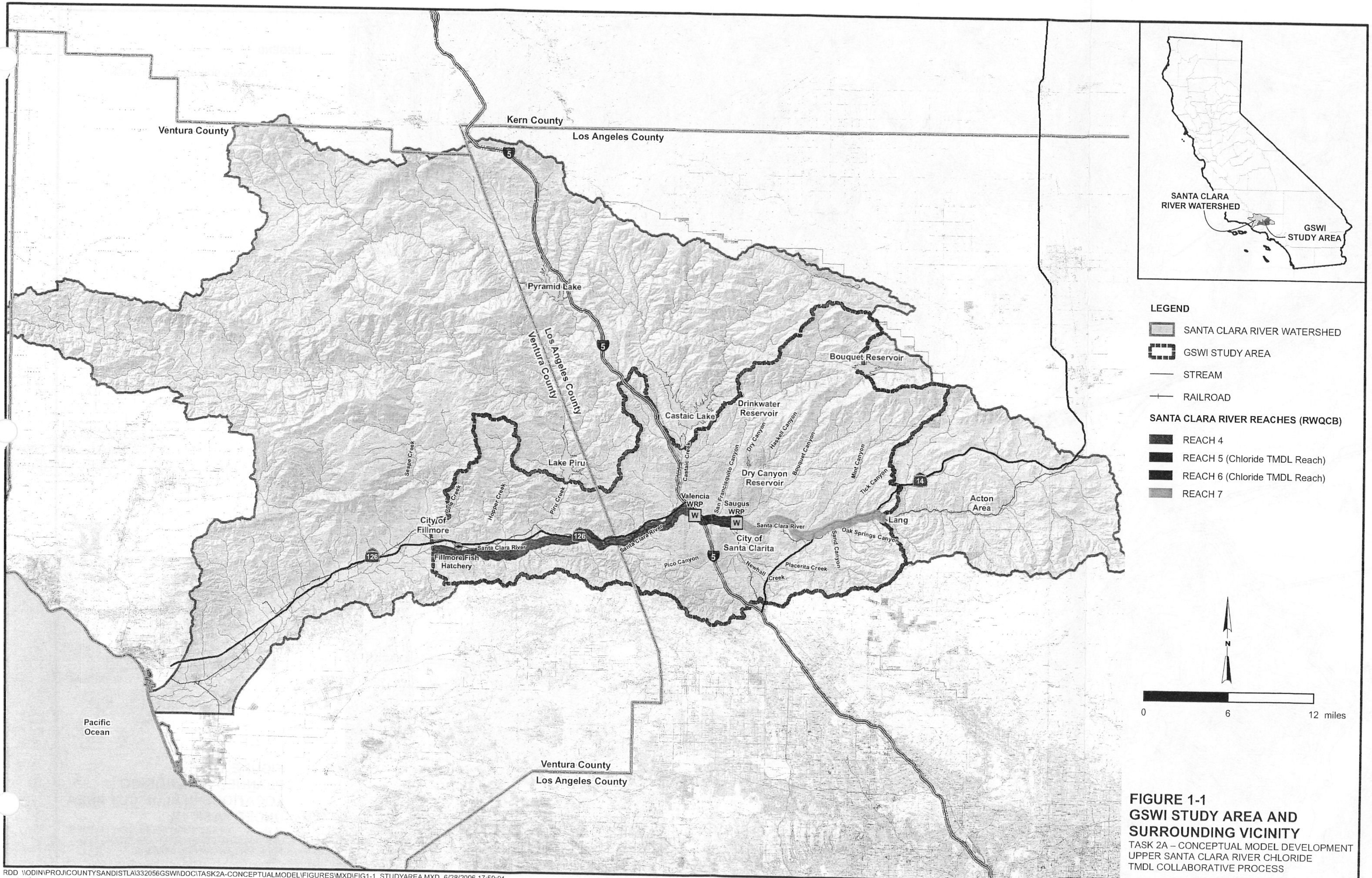
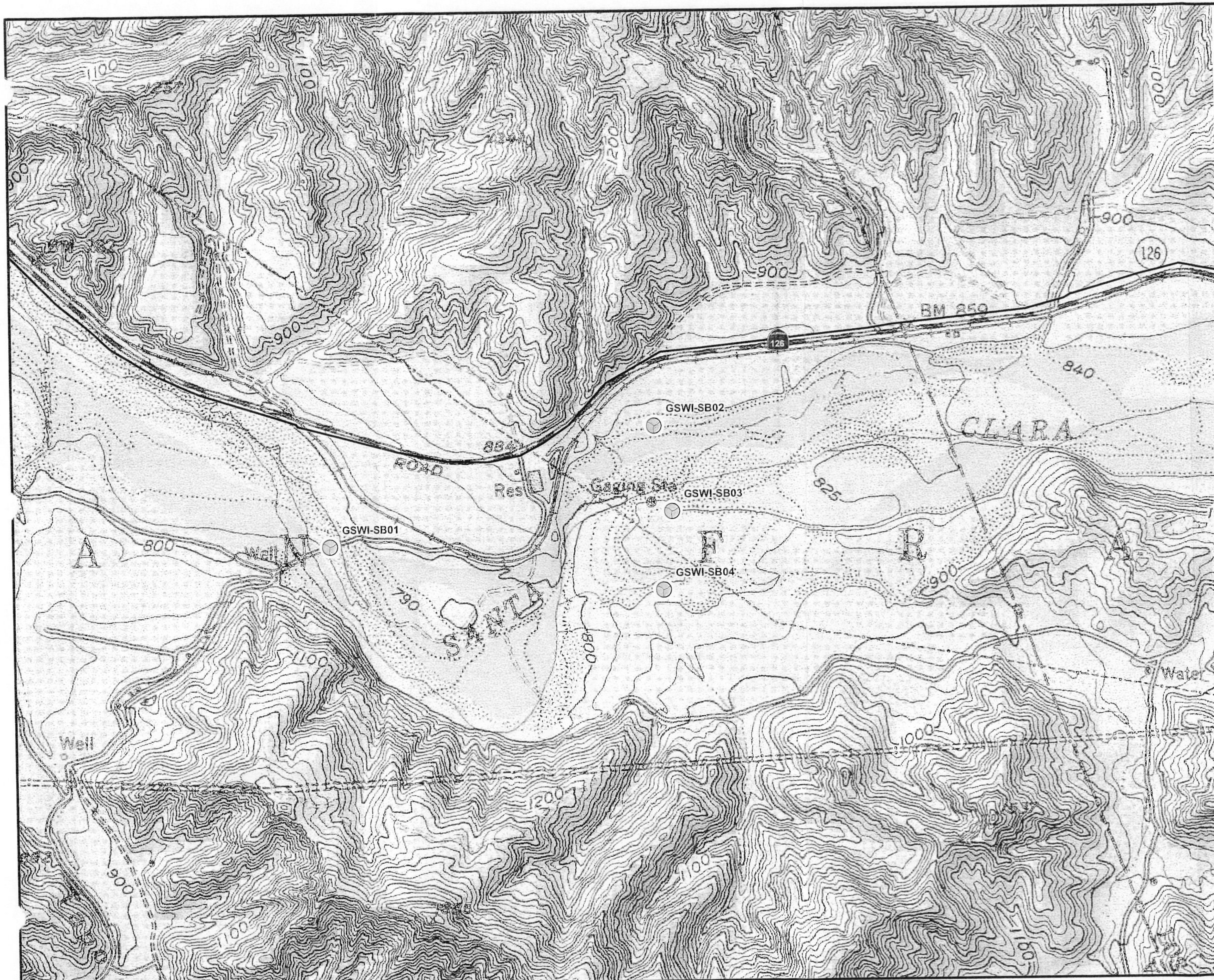


FIGURE 1-1
GSWI STUDY AREA AND SURROUNDING VICINITY
TASK 2A – CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS

RDD \\ODIN\PROJ\COUNTYSANDISTLA\332056GSWI\DOC\TASK2A-CONCEPTUALMODEL\FIGURES\MXD\FIG1-1_STUDYAREA.MXD 6/28/2006 17:59:01



LEGEND

PLANNED SOIL BORING LOCATION

N

0 1,000 2,000 Feet

FIGURE 1-2
PLANNED SOIL BORING LOCATIONS IN BLUE CUT AREA UNDER TASK 1B

TASK 2A – CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS

CH2MHILL

RDD \\ODIN\PROJ\COUNTYSANDISTLA\332056GSWI\DOC\TASK2A-CONCEPTUALMODEL\FIGURES\FINALREPORT\MXD\FIG1-2_TASK1B_COUNTYLINE_SOILBORINGS.MXD 9/6/2006 11:38:12

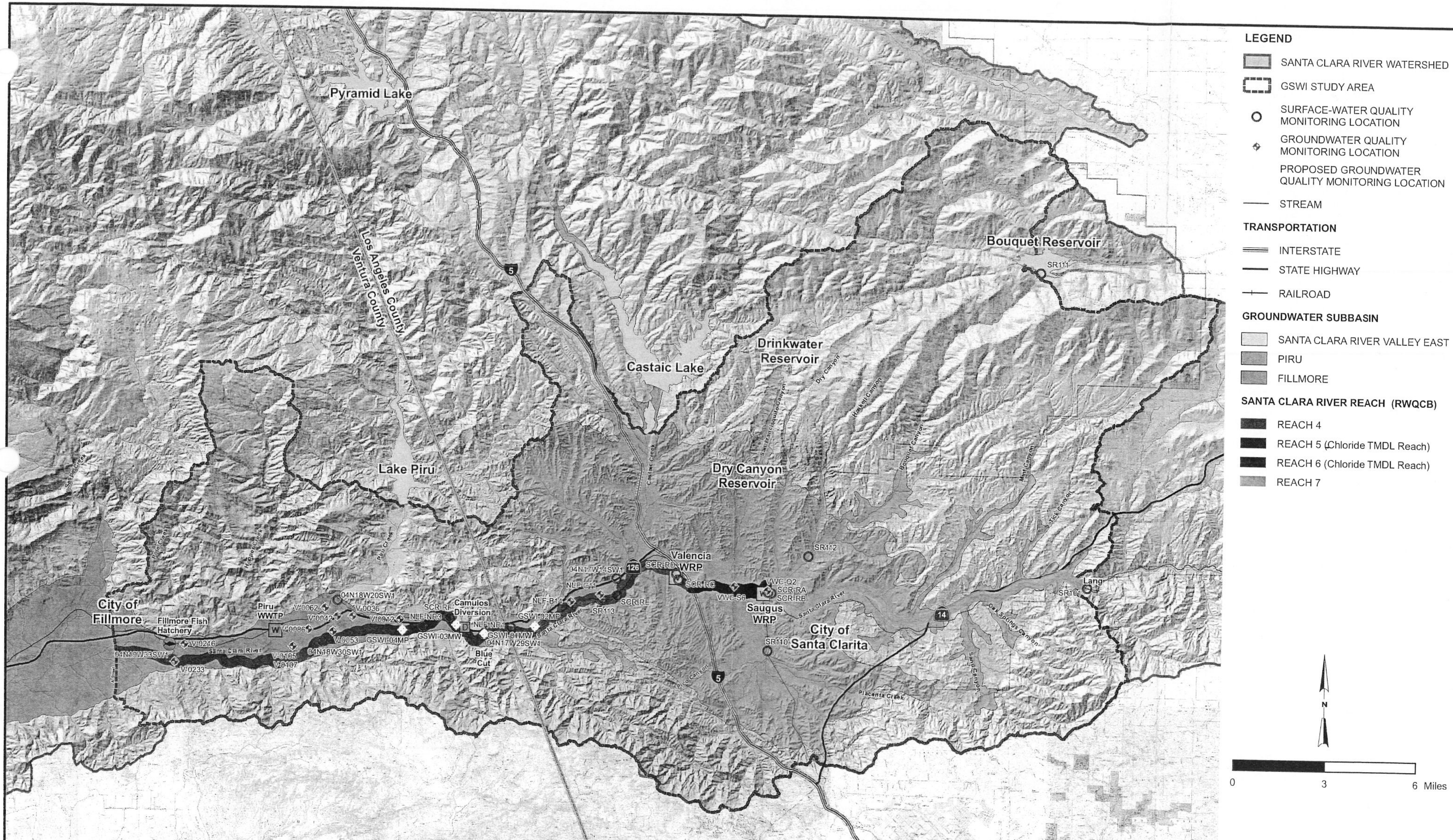


FIGURE 1-3
PLANNED MONITORING LOCATIONS UNDER TASK 1B
TASK 2A – CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL

RDD \\ODIN\PROJ\COUNTYSANDISTLA\332056GSWI\DOC\TASK2A-CONCEPTUALMODEL\FIGURES\FINALREPORT\MXD\FIG1-3_TASK1BMONITORINGLOCS.MXD 10/4/2006 16:44:51

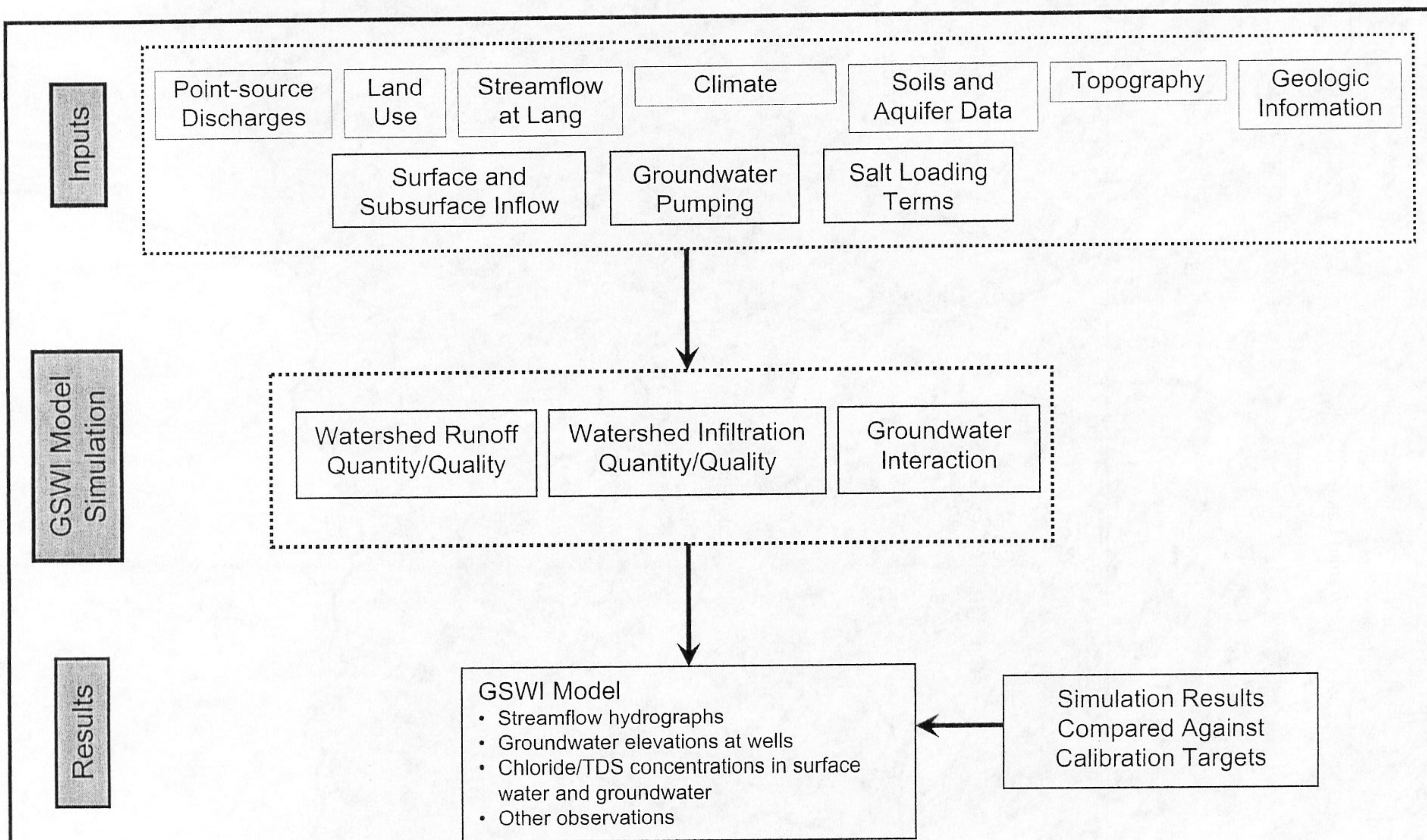
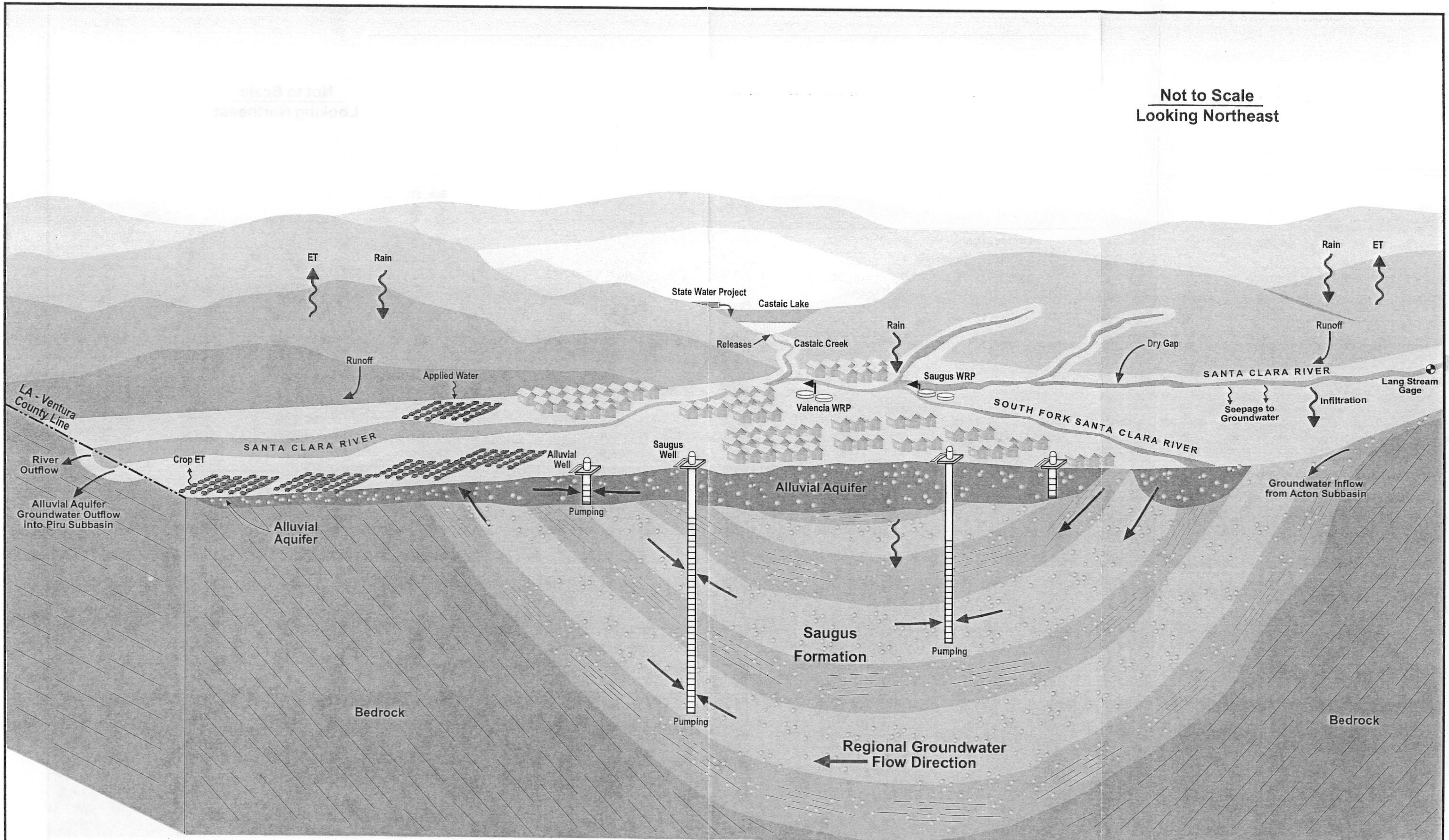


FIGURE 1-4
CONCEPTUAL MODELING FRAMEWORK
TASK 2A – CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS

CH2MHILL

FIG1-4_CONCEPTUALMODELFLOWDIAGRAM.PPT



ES052006011RDD_03 (10/2/06)

FIGURE 1-5
SANTA CLARITA VALLEY SCHEMATIC
TASK 2A – CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS

CH2MHILL

5-1387

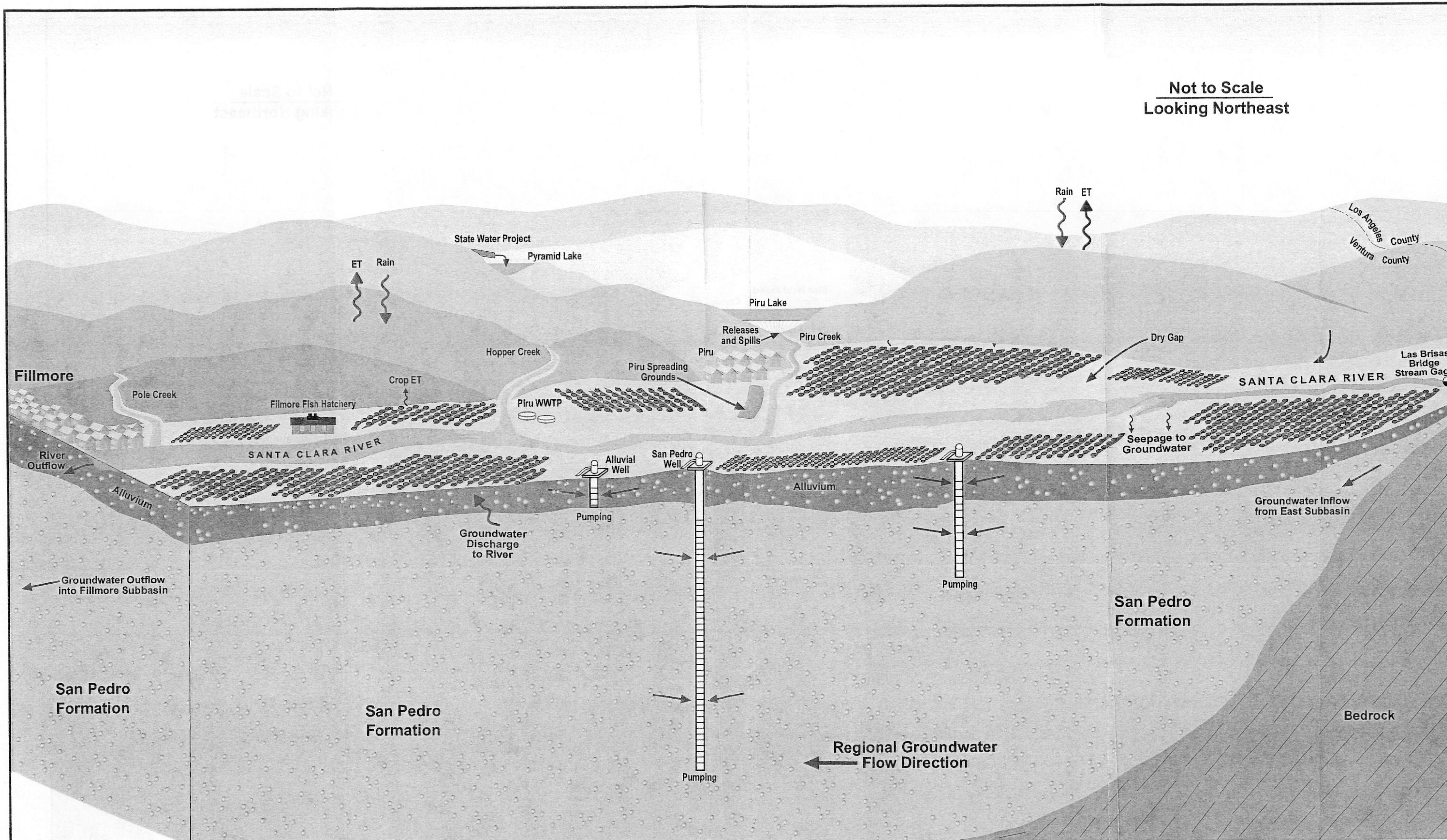


FIGURE 1-6
PIRU VALLEY SCHEMATIC
TASK 2A – CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS
CH2MHILL

ES052006011RDD_02 (10/2/06)

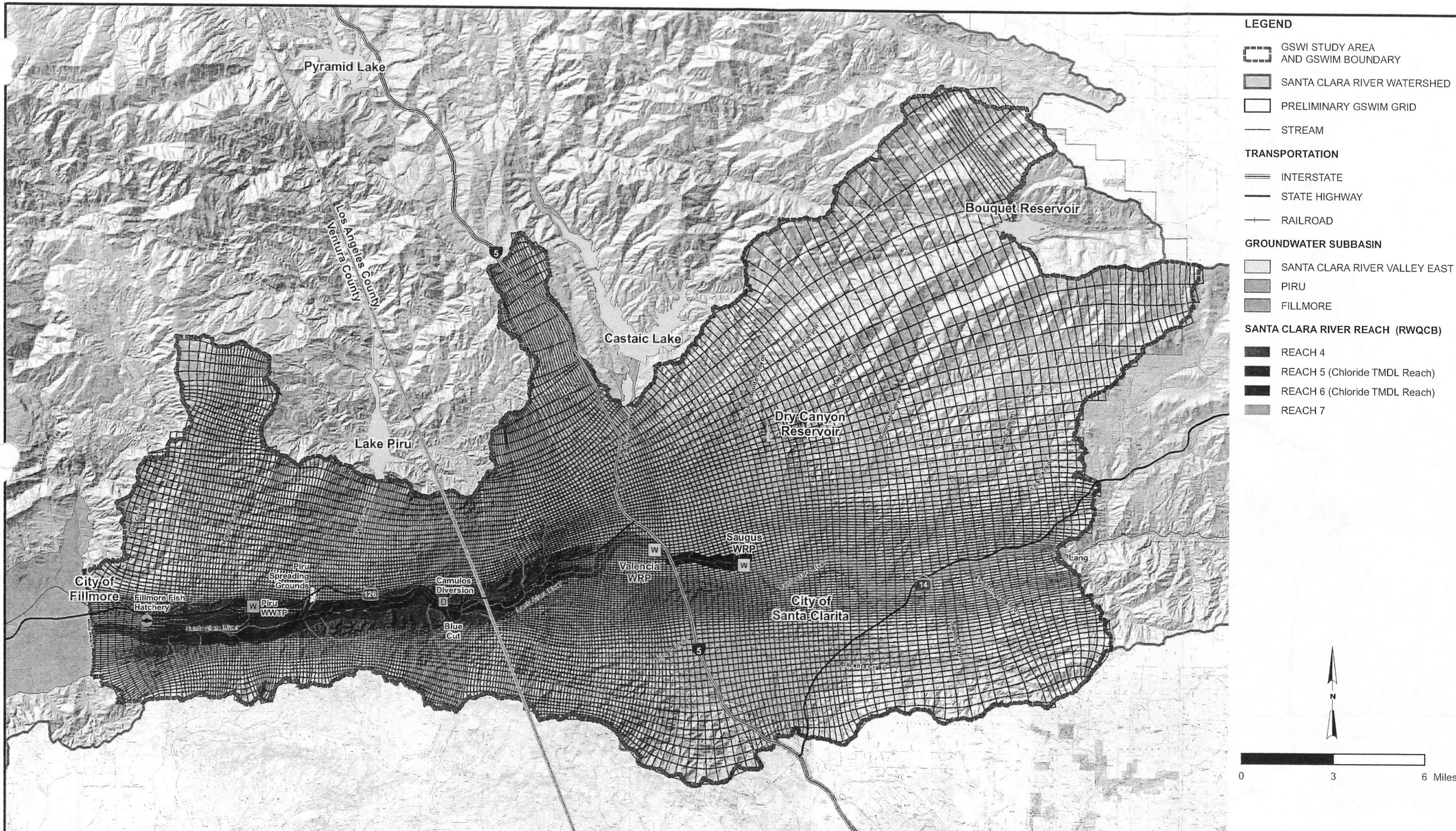


FIGURE 1-7
PRELIMINARY GSWIM CURVILINEAR GRID
TASK 2A – CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS

CH2MHILL

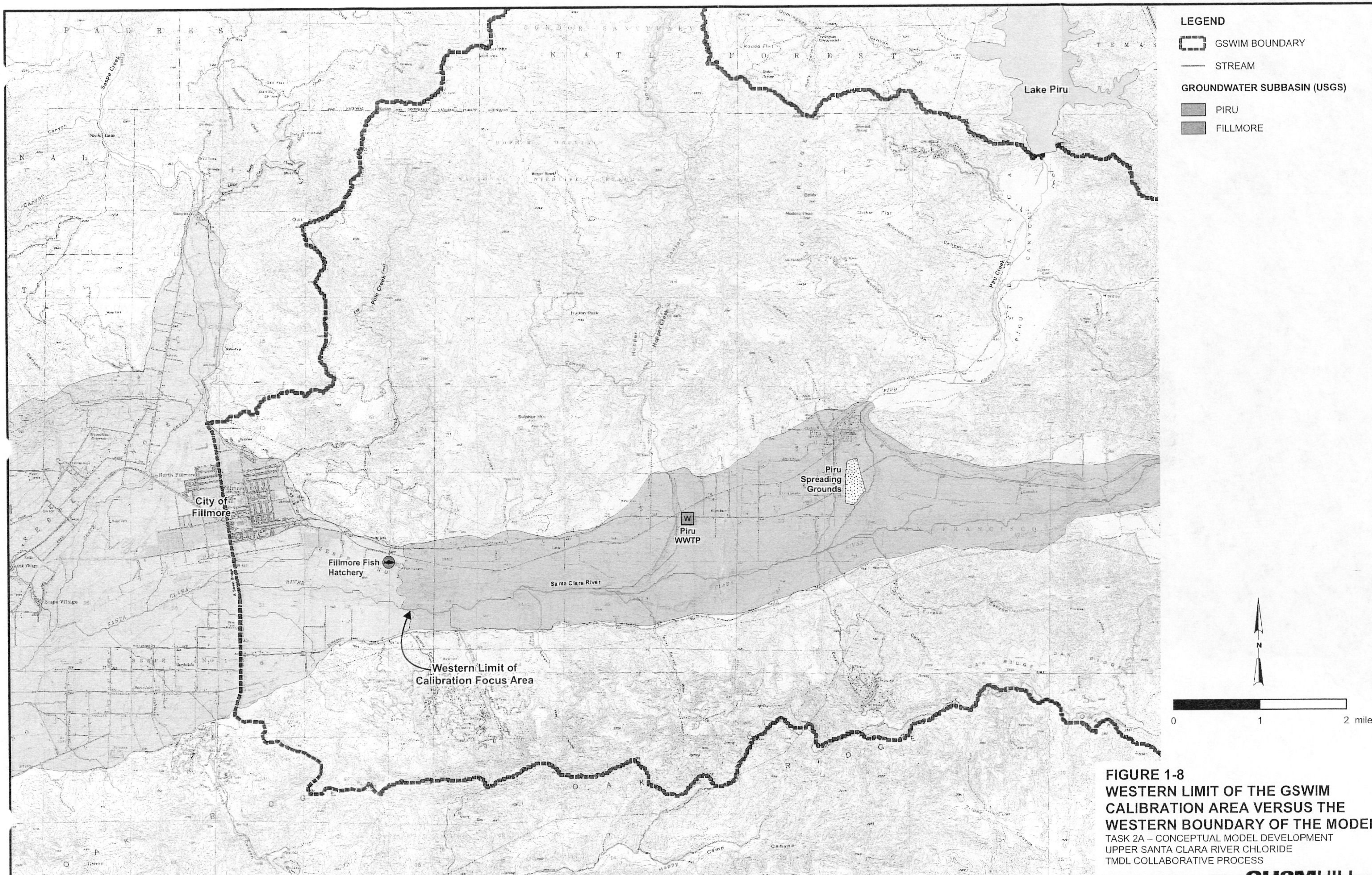


FIGURE 1-8
WESTERN LIMIT OF THE GSWIM CALIBRATION AREA VERSUS THE WESTERN BOUNDARY OF THE MODEL
TASK 2A – CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS

CH2MHILL

RDD \\ODIN\PROJ\COUNTYSANDISTLA\332056GSWI\DOC\TASK2A-CONCEPTUALMODEL\FIGURES\FINALREPORT\MXD\FIG01-08_WESTERNBOUNDARYAREA.MXD 10/2/2006 11:02:26

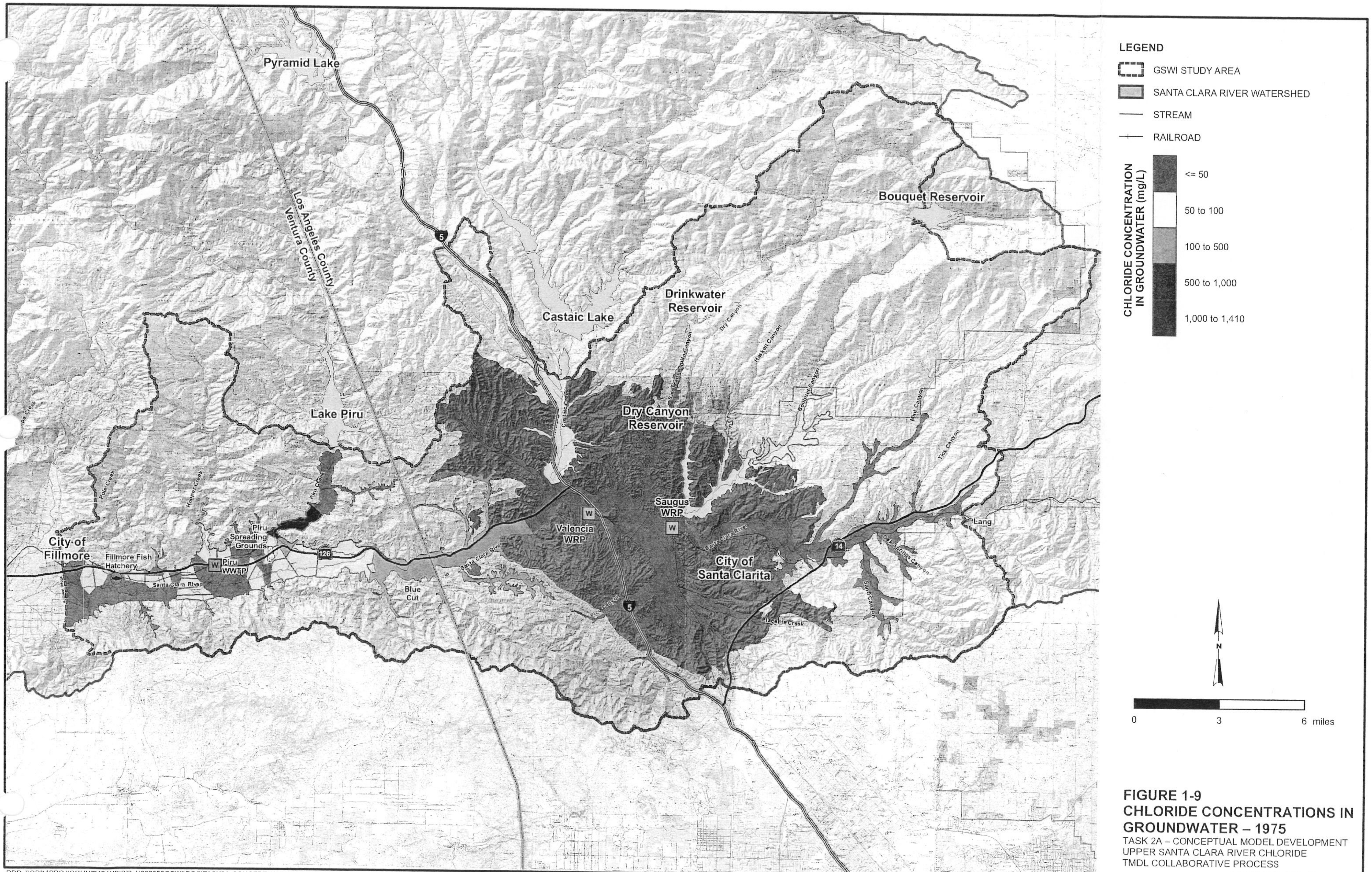


FIGURE 1-9
CHLORIDE CONCENTRATIONS IN GROUNDWATER – 1975
TASK 2A – CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS

CH2MHILL

RDD \\ODIN\PROJ\COUNTYSANDISTLA\332056GSWI\DOC\TASK2A-CONCEPTUALMODEL\FIGURES\FINALREPORT\MXD\FIG01-09_INITIALCONDITIONSCHLORIDE.MXD 10/2/2006 11:55:26

This Page Intentionally
Left Blank

SECTION 2.0

Climate

Climatic factors such as precipitation and evapotranspiration represent sources and sinks of water in the GSWI study area. GSWIM will simulate detailed mechanisms related to precipitation falling onto the land surface, and evaporation and transpiration from the surficial soil and vegetation.

The weather in Southern California is characterized by coastal, inland, mountain, and desert climate zones that have distinct characteristics and are located close to each other. Characteristics of these climate zones depend on proximity to the Pacific Ocean, latitude, and terrain (i.e., land surface elevation). The GSWI study area has a semi-arid Mediterranean-type climate, characterized by long, dry summers with short, and sometimes wet, winters. Mean monthly temperatures in the Santa Clarita and Piru Valleys have historically ranged from approximately 35 degrees Fahrenheit (°F) to 95°F. Record temperatures in the area have ranged from 15°F in Santa Clarita in 1968, to 116°F in Piru in 1985.

2.1 Precipitation

Precipitation data collected largely from LADPW and Ventura County are presented in Appendix B of the Draft Task 1A Report (CH2M HILL, 2006). Locations of rainfall gages in the GSWI study area and surrounding areas are shown on Figure 2-1, where daily precipitation data are available.

2.1.1 Temporal Trends

Precipitation data have been recorded since 1927, at the Piru-Newhall Ranch rain gage (shown on Figure 2-1 with a location identifier of "25"), located near the Blue Cut area just west of the Los Angeles–Ventura County line. Figure 2-2 shows the measured annual precipitation since 1928 (the first calendar year with complete recorded totals). Evaluation of historical precipitation at this particular rain gage was made because this gage has a long period of record and is conveniently located near the center of the GSWI study area. The mean annual precipitation at this gage was 17.55 inches from CY 1928 to 2006 (similar for water years). As shown on Figure 2-2, annual precipitation is highly variable. During this period, the highest and lowest calendar-year precipitation was 41.72 inches in 1983, and 3.16 inches in 1947, at the Piru-Newhall Ranch rain gage. Precipitation is not only variable on an annual basis, but is also highly seasonal. On average, over 80 percent of the annual precipitation at the Piru-Newhall Ranch rain gage falls between November and March (inclusive). Most of the precipitation falls during winter storms that last a few days and are separated by relatively long periods of clear weather.

Also shown on Figure 2-2 is the cumulative departure from the mean annual precipitation from CY 1928 to 2006. Cumulative departure refers to the cumulative amount of annual precipitation that is greater than or less than the long-term mean annual precipitation. The slope of the cumulative departure plot provides insights into long-term trends in precipitation over successive years. Figure 2-2 shows the following trends in precipitation near the Blue Cut area:

- 1928 through 1935: Dry conditions except for a single above-average year in 1931 (a nearly continual decrease in cumulative departure values)
- 1936 through 1946: Wet conditions except for occasional below-average years (general increase in cumulative departure values)
- 1947 through 1951: Dry conditions (decrease in cumulative departure values)
- 1952 through 1955: Average conditions (relatively flat cumulative departure values except for single above- and below-average years in 1952 and 1953)
- 1956 through 1957: Wet conditions (increase in cumulative departure values)
- 1958 through 1964: Dry conditions (decrease in cumulative departure values)
- 1965 through 1969: Fluctuating wet and dry conditions (fluctuating trends in cumulative departure values)
- 1970 through 1972: Dry conditions (decrease in cumulative departure values)
- 1973 through 1974: Average conditions (relatively flat cumulative departure values)
- 1975 through 1977: Dry conditions (decrease in cumulative departure values)
- 1978 through 1983: Wet conditions except for single below-average year in 1982 (increase in cumulative departure values)
- 1984 through 1990: Dry conditions except for a single above-average year in 1986 (decrease in cumulative departure values)
- 1991 through 1998: Highly variable conditions from year to year, but overall increase in cumulative departure values
- 1999 through 2005: Highly variable conditions from year to year, but overall decrease in cumulative departure values

2.1.2 Spatial Trends

Precipitation data are available at several rain gages from as early as 1916, with some gages having a continuous precipitation record and others having a noncontinuous precipitation record. Furthermore, some gages have come online only recently, whereas others have been discontinued. The calibration period for GSWIM extends from CY 1975 through 2005, so gages with data available since January 1, 1975, were considered for further evaluation.

A regression study was initially conducted to examine the correlation of measured daily precipitation values between nearby gages. Figures 2-3 and 2-4 show the regression trends between nearby gages within and outside (respectively) of the GSWI study area for days on which data were available from January 1, 1975 through December 31, 2005. Precipitation data within the GSWI study area that were previously available through September 1, 2005, were augmented with additional data within and adjacent to the GSWI study area, made available by the data providers discussed in the Draft Task 1A Report (CH2M HILL, 2006) or downloaded from the Internet to bring the GSWI dataset current through 2005. Each plot on Figures 2-3 and 2-4 shows the regression at a gage with its nearest-neighbor gage to the left and with the second nearest-neighbor gage to the right. This sequence is followed for all gages shown on Figure 2-1. The best correlation with a Pearson Correlation Coefficient (R^2) greater than 0.9 occurs between Stations 171 and 199; 171 and 94c; and 171 and 36a for stations located within the GSWIM domain, and between Stations 172 and 160; 191 and 206b; and 191 and 250 for stations located outside of the GSWIM domain. The poorest correlation with R^2 values less than 0.1 occurs between Stations 101r and 1040; 25 and 1012b; 1040 and 25; 372 and 127b; 1184a and 372; 1022a and 25; and 25 and 493d. Stations 493d and al402 do not have any records that fall on a common day; the same is true between Stations al402 and 1009a. The trend-line slopes for several of the regressions are not close to unity, further denoting that the general precipitation magnitudes are also different between the gages. The poor correlation for measured daily precipitation between several of the gages along with trend-line slopes not being close to unity suggests that precipitation patterns are spatially variable at the scale of a given gage with its nearest and second nearest neighbor.

Orographic effects in the spatial precipitation patterns occur within the GSWI study area resulting from effects of elevation, proximity to the Pacific Ocean, microclimates, and the way precipitation events typically move across the local terrain. During model development, these combined effects will be evaluated to assess spatial variability of precipitation and to provide spatial resolution via assignment of "orographic gages" in regions where gage density is sparse. Orographic gages, in this context, are virtual rain gages assigned to locations where rain gages do not exist. Their purpose is to serve as surrogate rain gages whose precipitation values will be based on the spatial pattern of precipitation as determined by the precipitation data from the available rain gages shown on Figure 2-1.

2.1.3 Conceptualization of Precipitation

For modeling purposes, a temporally and spatially continuous daily precipitation record is needed. A temporally continuous record of daily rainfall is available only at a few gages located within and surrounding the GSWI study area. Gages with less than 5 percent missing daily precipitation data include Stations 1005B, 125B, 252C, 32C, 372, and Piru #101 located within the GSWIM domain, and Stations 395B, 405B, 261F, and 446 located outside but adjacent to the GSWIM domain. Conversely, gages 25, 94C, 224A, 39, 206B, 250, and 196B have more than 90 percent missing daily precipitation data. To obtain a temporally continuous record of precipitation at a given rain gage, the gaps in the period of record need to be filled. Several methods have been described in the literature to do this, including, but not limited to, the following:

1. Performing spatial interpolation of all measured data and using the interpolated value at the locations of missing data for each day
2. Filling missing data with zero or the mean monthly value at that gage
3. Using the value from the adjacent watershed/rain gage at the locations of missing data
4. Using the arithmetic mean daily value of all stations with measured daily data at the locations of missing data

5. Dividing the next measured daily data by the number of consecutive missing data days plus one, and assigning this number to the consecutive missing data days and the next measured data day
6. Creating a regression plot with data from adjacent gages to evaluate the degree to which they correlate and using the station with good correlation and available data to scale for missing data via the trend-line slope of the regression line
7. Using Fourier Series and cubic splines
8. Using Artificial Neural Networks
9. Using multivariate regression through space and time
10. Using spectral methods
11. Using graphical inspection
12. Using multiple imputation, which involves a Gaussian Markov Random Field Model
13. Using polynomial regression
14. Using Bayesian techniques

Some of the techniques mentioned above are overly simplistic, and others are more research oriented. Spatial interpolation is an attractive method for obtaining missing data; however, it is not appropriate in the current modeling effort because of lack of spatial correlation between most gages with the nearest and second nearest neighbor. To provide the best estimate of temporally continuous precipitation at every gage, a combination of methods is used for this study. Following this combined methodology, the missing data are first filled using available data via the regression methodology noted above as the sixth item. Following this regression methodology, the correlation is considered good if the R^2 value of the regression plot (see Figures 2-3 and 2-4) for the nearest- and second nearest-neighbor gages is at least 0.7. Table 2-1 shows how missing data are filled at rain gages by this regression methodology. When filling gaps in a given data set with the regression method based on data from multiple nearby rain gages, the priority of filling the missing data is given to the gage with the higher R^2 to provide the most reliable fill values.

After the data gaps are filled for rain gages that show good correlation, the averaging methodology noted above as the fourth item, is used to fill any remaining data gaps. Following this averaging methodology, the filled daily precipitation value at a given gage for a given day is computed as the arithmetic mean of the measured (not filled) daily precipitation values available at the other gages. This is a suitable second step considering the poor correlation and trends of precipitation data that were not filled by the regression methodology. In this manner, the combined methodology of filling gaps in rain gage data provides an optimal technique of taking into consideration gages with good correlations as well as gages at which precipitation data do not correlate well with nearby rain gages. The filled precipitation data are further evaluated below for suitability. Furthermore, it is subject to change during calibration.

Figures 2-5 and 2-6 show the complete temporally continuous precipitation record at each gage within and outside of the GSWIM domain, respectively. The filled data are plotted in a different color than the measured data to enable determination of which data were created versus measured. Table 2-2 provides some summary statistics of the filled data. The portion of the precipitation data set that was filled because of missing daily values at a given gage varies from about 1 to 90 percent and averages about 50 percent across all rain gages. Of this data set, 5 percent are filled by the regression methodology, and 45 percent are filled by the averaging methodology. Across all gages listed in Table 2-2, it is noted that about 75 percent of all filled data are zeros, indicating that daily precipitation data is often not recorded during dry periods. Furthermore, assuming the zeros as known data, only about 12 percent of all the data represents nonzero data that are missing and filled, of which 1 percent are filled by the regression methodology and 10 percent are filled by the averaging methodology. Use of this combined approach to fill missing values for rain gages is adequate for the current study.

To evaluate the average orographic effects inherent in the rain gage information over the GSWIM calibration period, the temporally continuous data set (that includes measured and filled precipitation data) is summed into annual rates and then averaged over the study period (CYs 1975 through 2005) at each gage and plotted on Figure 2-7. Spatial patterns in the precipitation distribution shown on Figure 2-7 are variable, including local highs and lows.

The nearest-neighbor interpolation method is used to spatially distribute the point-precipitation data from each rain gage throughout the GSWIM domain. The zones of rainfall thus created are shown on Figure 2-8. Sparsity of data and orographic effects will be evaluated from Figures 2-8 and 2-7 as part of the numerical model development task (Task 2B) to generate data for "orographic gages" in regions where gage density is sparse and where orographic effects are considerable. For GSWIM, the temporally continuous daily precipitation data that were assimilated as discussed above will be summed into monthly rates at each gage (including "orographic gages") and applied to the numerical model during each monthly stress period.

2.1.4 Interception of Precipitation

Interception is the process of retention of a certain amount of precipitation on the leaves, branches, and stems of vegetation or on built-up surfaces in urban areas. For the GSWI study, interception is conceptualized via a "bucket model," whereby precipitation occurs on the canopy of surfaces covered by vegetation or structures, and the interception storage is first filled to capacity before the rainfall reaches the ground surface. The interception storage capacity depends on canopy type and its stage of development and is calculated as indicated in Equation 2-1:

$$Sint = Cint \times LAI \qquad (2\text{-}1)$$

Where Sint is the interception storage capacity, Cint is the canopy storage parameter (units of length), and LAI is the leaf area index. The LAI is defined as the leaf surface area per unit of land surface area. This conceptualization is consistent with the conceptualization used in the WARMF model (Systech Engineering, 2002a and 2002b). To take advantage of previous modeling work, Cint and LAI will be assigned in GSWIM with data from the WARMF model (Systech Engineering, 2002a and 2002b) that provides correlations between Land Use Codes (LUC) and the parameters Cint and LAI. Furthermore, these values will be distributed throughout the GSWIM domain using an area-weighted average of the various LUCs that exist at a given location (which is calculated as discussed later in Section 3.3).

2.2 Evapotranspiration

ET is a parameter that accounts for the vaporization of water to the atmosphere through the processes of evaporation (from plant, soil, and water surfaces) and transpiration (water uptake by plant roots). The occurrence of ET depends on the availability of both water and energy to convert the water into vapor. Specifically, the rate at which ET occurs depends on several factors including, but not limited to, the following:

- **Weather Factors** – solar radiation, air temperature, relative humidity, and wind speed. The weather factors affect the reference ET, which is the maximum ET that can occur if water availability is not a constraint. "Reference ET" (ETo) is defined as the ET that occurs from a standardized "reference" crop such as clipped grass or alfalfa that is clipped to a constant height, provided with nutrition requirements, irrigated regularly, and not affected by disease (see Section 2.2.1 for additional information on weather factors).
- **Plant Factors** – plant type, root depth, plant density, plant height, and stage of growth. The plant factors include the crop coefficient, the root-zone distribution function (RDF), and the LAI (see Section 2.2.2 for additional information on plant factors).
- **Soil Factors** – soil moisture, texture, density, structure, and chemistry. The soil factors affecting ET are primarily the soil moisture (which depends on the capillarity of the soil under unsaturated conditions), the field-capacity moisture content (above which moisture from the soil is freely available for ET), and the wilting point moisture content (below which the moisture availability constrains ET flux) (see Section 2.2.3 for additional information on soil factors).

GSWIM will input ET each month as described below. The reader is referred to the following three references for a much more detailed description of evapotranspiration processes:

- *Vegetative Water Use in California, 1974* (also known as Bulletin 113-3) by the California Department of Water Resources (DWR) (1975)
- *Crop Evapotranspiration. Guidelines for Computing Crop Water Requirements* (also known as Food and Agriculture Organization [FAO] 56) by Allen et al. (1998)
- *California Crop and Soil Evapotranspiration* (also known as ITRC Report 03-001) by the Irrigation Training and Research Center (ITRC) at the California Polytechnical State University (ITRC, 2003)

2.2.1 Weather Factors

Reference ET data for various locations in California can be downloaded from the California Irrigation Management Information System (CIMIS) Web site[3]. CIMIS is a program of the Office of Water Use Efficiency within DWR, which manages a network of over 100 auto-

[3] http://wwwcimis.water.ca.gov/cimis/welcome.jsp

mated weather stations within California. In 1982, DWR and the University of California, Davis developed CIMIS. One CIMIS station, Piru #101[4], is located within the GSWI study area, and its location is shown on Figure 2-1 (because it is also a rain gage location). The period of record for daily data collected at this particular station includes August 27, 1991 through January 1, 2005. Thus, ETo data for the remainder of the GSWIM calibration period was calculated, as discussed below.

The tool used to calculate daily ETo values for the portion of the GSWIM calibration period over which there is an absence of data is called "REF-ET" (Allen, 2002)[5]. REF-ET is a compiled, stand-alone computer program that calculates ETo by various methods currently in use. The REF-ET program supports ETo computation guidelines and procedures that were recommended in American Society of Civil Engineers (ASCE) Manuals and Reports on Engineering Practice No. 70, "Evapotranspiration and Irrigation Water Requirements" edited by Jensen, et al. (1990) through efforts by the Committee on Evapotranspiration in Irrigation and Hydrology of the Irrigation and Drainage Council of the Environmental and Water Resources Institute of ASCE. Below is a brief discussion of the steps used to calculate ETo for portions of the calibration period during which no daily measured data were available at the Piru #101 station:

Step 1 – Compile available minimum and maximum daily air temperature data for the Piru #101 station. The period of record for daily air temperature data collected at this particular station includes August 27, 1991 through January 1, 2005.

Step 2 – Calculate ETo using REF-ET for the time period when air temperature data are available and compare calculated ETo with measured ETo. The REF-ET calculator was programmed to calculate ETo using the 1985 Hargreaves Method (Hargreaves et al., 1985; Allen, 2002). This method uses a simple equation, which requires input of minimum and maximum air temperatures (T_{min} and T_{max}, respectively) over the period of interest as shown in Equation 2-2.

$$ETo = 0.0023(T_{max} - T_{min})^{0.5} (T_{mean} + 17.8)R_a \qquad (2\text{-}2)$$

Where:

R_a = Extraterrestrial solar radiation in units of millimeters per day

Units for ETo in Equation 2-2 also need to be expressed in millimeters per day, and the temperatures need to be expressed in units of degrees Celsius (°C). The T_{mean} term is internally computed by REF-ET as $(T_{max} + T_{min}) \div 2$.

The daily calculated ETo values were summed into monthly rates and compared with the measured daily ETo that were also summed into monthly rates. Monthly rates were compared because ET will be varied monthly in GSWIM. Figure 2-9 shows the comparison between measured and calculated ETo values for the Piru #101 station using REF-ET calculator. As can be seen on Figure 2-9, the calculated ETo data closely matches the measured data over the same period ($R^2 = 0.92$).

4 http://wwwcimis.water.ca.gov/cimis/frontStationDetailInfo.do?stationId=101

5 http://www.kimberly.uidaho.edu/ref-et/

Step 3 – Develop time series for minimum and maximum temperature and calculate ETo for portions of calibration period during which measured ETo data are not available. The following approach was used to fill in the temporal gaps in the Piru #101 period of record:

- Minimum and maximum air temperature data from a Santa Paula weather station were downloaded.
- Minimum and maximum air temperature data from a Camarillo weather station were also downloaded and used to fill holes in period of record at the Santa Paula station to prepare a complete air temperature time series for the Santa Paula station for the calibration period.
- Correlation functions were developed between the minimum and maximum temperatures measured at the Santa Paula station with those measured at the Piru #101 station for time-coincident data. This step was performed to account for orographic effects on ETo because the Piru #101 station is located at an elevation of 640 feet above mean sea level (ft msl), whereas the Santa Paula and Camarillo stations are located at elevations of 273 and 130 ft msl, respectively. Differences as large as about 25°F were observed in the minimum and maximum temperatures between these two stations. Figure 2-10 shows the correlation plots of air temperature minimum and maximum between the Santa Paula and Piru #101 stations for days at which measured temperatures were available. The correlation functions are then used to develop continuous time series for minimum and maximum air temperature at the Piru #101 station for the missing portion of the calibration period. From data shown on Figures 2-9 and 2-10, it is concluded that the monthly ETo as computed by REF-ET is not particularly sensitive to the range of minimum and maximum air temperatures observed in the Camarillo, Santa Paula, and Piru Valley.
- Calculate ETo using the air temperature time series and the REF-ET calculator.

For a more complete description of the REF-ET software and calculation methods, the reader is referred to the REF-ET Web site at http://www.kimberly.uidaho.edu/ref-et/.

Table 2-3 summarizes the monthly ETo data for the Piru #101 station over the GSWIM calibration period that will be used for the model.

2.2.2 Plant Factors

Reference ET is an important parameter because it is used along with crop coefficient (Kc) values to compute crop ET (ETc) for crops located within the GSWIM domain. The Kc is a factor that is empirically determined and relates the ETo to ETc for specific crops, as indicated in Equation 2-3.

$$ETc = Kc \times ETo \qquad (2\text{-}3)$$

5-1400

ETo and ETc for specific crop types in different regions of California were compiled from the ITRC Report 03-001 (ITRC, 2003) and associated Web pages[6]. These regional ETc values were used to estimate the ETc for crops located within the GSWI study area as follows:

Step 1. **Identify major crops located in the GSWI study area.** The major crops that have existed in the GSWI study area since 1975, include citrus crops, strawberries, avocados, nursery crops, small vegetables (e.g., lettuce, cabbage, broccoli, cauliflower, carrots, celery, parsley, cilantro, and radishes), and peppers.

Step 2. **Identify ETc for major crops located in the GSWI study area.** Figure 2-11 shows a statewide ETo zone map. The GSWI study area is located mostly within Zone 14 (Mid-Central Valley, Southern Sierra Nevada, Tehachapi, and High Desert Mountains) across the Los Angeles–Ventura County boundary. Monthly ETc for each crop identified in Step 1 along with the monthly ETo data used for the calculation of ETc are obtained for Zone 14 from ITRC (2003) and associated Web pages.

Step 3. **Compute crop coefficients.** By rearranging Equation 2-3 and solving for Kc, the monthly ETo and ETc data compiled from Step 2 are used to calculate monthly Kc data for each crop type in Zone 14 shown on Figure 2-11. Table 2-4 lists the Kc values for crops identified in Step 1. The magnitude of a crop's Kc value for a given month depends on the crop's stage of growth in comparison to that of the reference crop of grass. Kc values greater than 1 indicate that the ET capacity of the associated crop or land cover is greater than that of grass and consequently these crops or land cover features would consume more water than grass when Kc > 1. The transient Kc values listed in Table 2-4 reflect the timing of planting, plant growth, and harvesting for the indicated crop type. These values are distributed areally throughout the model using the area-weighted average of the various crop types that exist at a given location (which is calculated as discussed later in Section 3.3), and are used to initially parameterize GSWIM. These values will be subject to change during calibration.

Another important plant factor affecting ET is the LAI. A larger LAI allows for more transpiration (more leaf surface from which transpiration occurs), but less evaporation (more leaves prevent energy from penetrating to the ground). As noted in Section 2.1.4, the LAI will be parameterized initially using values from the WARMF model and will be subject to change during calibration.

The RDF is defined as the fraction of all roots at a location that are active and lie at a particular depth. The RDF is dependent on the crop type and stage of growth and can be correlated to the LUC. However, this will ultimately be treated as a calibration parameter.

2.2.3 Soil Factors

Soil factors that affect ET including the field capacity and wilting point moisture contents will be obtained via correlations from the Soil Conservation Service (SCS) soil type (Carsel et al., 1988) as noted in Table 2-5. These values will be distributed areally throughout the model using an area-weighted average of the various soil types that exist at a location

[6] http://www.itrc.org/etdata/waterbal.htm

(which is calculated as discussed later in Section 3.2). These values will be used to initially parameterize the model and are subject to change during calibration because of their large uncertainty and the large spatial averaging of moisture within the model. The actual soil moisture for unsaturated conditions is related to the capillarity of the soil that is discussed further in Section 5.5.1.

2.2.4 Evapotranspiration Computation

The ETo value is conceptualized as the maximum ET flux that can be extracted from the model. The ETc value, when distributed throughout the model according to the land use mapping, is the maximum ET flux that can be extracted from any location within the model. This ET is first extracted from available water in the canopy. The remaining ET is extracted via transpiration and evaporation, which are scaled as follows.

- Transpiration is a function of the LAI that is one at maximum LAI and zero at minimum LAI, the available moisture (subject to a maximum of one at field capacity and a minimum of zero at the wilting point moisture content), and the root-zone distribution (which should vertically sum to one or less at any location).
- Evaporation is a function of the LAI that is zero at maximum LAI and one at minimum LAI (denoting that leaf cover hinders evaporation from the surface and subsurface), the moisture content between field capacity and wilting point moisture contents, and an Evaporation Distribution Function that should sum to one or less at any location. The Evaporation Distribution Function denotes energy penetration through the soil and decreases rapidly from the soil surface to zero at the extinction depth. Thus, the actual ET flux at any given location can be equal to or less than the ETc value at that location.

TABLE 2-1
Summary of Regression Terms Used to Partially Fill Missing Data at Rain Gages
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Rain Gage Data Set Being Filled	Rain Gage Data Set Used for Regression	Slope[a]	Y-Intercept[a,b]
Within the GSWI Study Area			
199	171	0.9470	0.0328
171	94c	1.0149	-0.0156
171	199	1.0560	-0.0328
94c	171	0.9853	0.0156
94c	36a	1.1632	-0.0298
94c	25	0.9522	0.0890
36a	94c	0.8597	0.0298
36a	25	0.9892	-0.0030
36a	101r	0.8914	0.0630
101r	25	0.9275	0.0344
101r	36a	1.1218	-0.0630
25	36a	1.0109	0.0030
25	101r	1.0782	-0.0344
25	94c	1.0502	-0.0890
1012b	200	0.8321	0.0053
1012b	1022a	0.7171	0.0073
200	1022a	0.7171	0.0027
200	1012b	1.2018	-0.0053
1022a	200	1.3945	-0.0027
1022a	1012b	1.3945	-0.0073
Outside of the GSWI Study Area			
160	172	0.9294	0.0890
160	224a	0.7794	-0.0566
172	160	1.0760	-0.0890
172	224a	0.6631	0.0341
172	39	1.1840	-0.0942

TABLE 2-1
Summary of Regression Terms Used to Partially Fill Missing Data at Rain Gages
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Rain Gage Data Set Being Filled	Rain Gage Data Set Used for Regression	Slope[a]	Y-Intercept[a,b]
224a	172	1.5081	-0.0341
224a	160	1.2831	0.0566
224a	39	1.2935	0.0950
224a	206b	1.9877	-0.1150
39	206b	1.0584	0.0212
39	172	0.8446	0.0942
39	191	1.2410	-0.0986
39	224a	0.7731	-0.0950
206b	191	0.9436	0.0157
206b	250	0.9645	-0.0381
206b	39	0.9448	-0.0212
206b	224a	0.5031	0.1150
191	250	0.9017	0.0277
191	206b	1.0598	-0.0157
191	39	0.8058	0.0986
191	196b	1.0820	-0.0809
250	191	1.1090	-0.0277
250	206b	1.0368	0.0381
250	196b	0.9303	0.0533
196b	191	0.9242	0.0809
196b	250	1.0749	-0.0533
AL301	395b	0.9539	-0.0053
395b	AL301	1.0483	0.0053

[a]Linear regression equation of the form: y=mx+b, where:
x = daily mean precipitation value measured at the indicated rain gage (2nd column)
y = daily mean precipitation value being filled at the indicated rain gage (1st column)
m = slope of the linear regression equation
b = y-intercept of the linear regression equation

[b]Regression equation output is constrained by a value of zero to avoid negative filled values when the measured precipitation value at the nearby gage (2nd column) is zero.

TABLE 2-2
Summary of Filled Precipitation Data
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Rain Gage	Percent of Total Data Set Filled by Regression Scheme	Percent of Total Data Set Filled by Averaging Scheme	Percent of Total Data Set that Is Filled	Percent of Filled Data Set that Equal Zero	Percent of Total Nonzero Filled Data	Percent of Data Set Filled by Regression Scheme that Equal Zero	Percent of Data Set Filled by Averaging Scheme that Equal Zero[a]	Percent of Total Data Set Filled by Regression Scheme with Nonzeros	Percent of Total Data Set Filled by Averaging Scheme with Nonzeros
1005b	0.00	3.55	3.55	72.06	0.99	0.00	72.06	0.00	0.99
1009a	0.00	68.38	68.38	70.19	20.38	0.00	70.19	0.00	20.38
1012b	0.00	5.31	5.31	63.01	1.96	0.00	63.01	0.00	1.96
101r	2.78	87.91	90.69	78.73	19.29	43.75	79.84	1.56	17.72
1022a	77.59	5.31	82.90	91.02	7.44	92.94	63.01	5.48	1.96
1040	0.00	45.25	45.25	69.26	13.91	0.00	69.26	0.00	13.91
1104c	0.00	36.25	36.25	70.50	10.69	0.00	70.50	0.00	10.69
125b	0.00	2.64	2.64	66.45	0.89	0.00	66.45	0.00	0.89
127b	0.00	52.28	52.28	69.64	15.87	0.00	69.64	0.00	15.87
171	2.13	87.67	89.80	79.72	18.21	69.80	79.96	0.64	17.57
199	1.30	87.89	89.19	78.61	19.08	0.00	79.76	1.30	17.79
200	34.37	5.31	39.68	90.32	3.84	94.54	63.01	1.88	1.96
25	3.06	87.63	90.69	78.15	19.82	22.44	80.09	2.37	17.45
252c	0.00	3.44	3.44	72.22	0.96	0.00	72.22	0.00	0.96
32c	0.00	1.58	1.58	67.58	0.51	0.00	67.58	0.00	0.51
36a	1.79	87.63	89.42	78.49	19.24	0.00	80.09	1.79	17.45
372	0.00	0.60	0.60	57.97	0.25	0.00	57.97	0.00	0.25

TABLE 2-2
Summary of Filled Precipitation Data
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Rain Gage	Percent of Total Data Set Filled by Regression Scheme	Percent of Total Data Set Filled by Averaging Scheme	Percent of Total Data Set that Is Filled	Percent of Filled Data Set that Equal Zero	Percent of Total Nonzero Filled Data	Percent of Data Set Filled by Regression Scheme that Equal Zero	Percent of Data Set Filled by Averaging Scheme that Equal Zero[a]	Percent of Total Data Set Filled by Regression Scheme with Nonzeros	Percent of Total Data Set Filled by Averaging Scheme with Nonzeros
493d	0.00	28.73	28.73	67.11	9.45	0.00	67.11	0.00	9.45
94c	4.49	87.45	91.94	77.49	20.70	23.60	80.26	3.43	17.26
al402	0.00	82.21	82.21	70.44	24.30	0.00	70.44	0.00	24.30
Piru #101	0.00	4.42	4.42	66.34	1.49	0.00	66.34	0.00	1.49
1184a	0.00	80.69	80.69	69.05	24.97	0.00	69.05	0.00	24.97
160	2.62	87.21	89.83	79.46	18.45	45.51	80.47	1.43	17.03
172	3.10	86.80	89.91	79.62	18.32	45.10	80.85	1.70	16.62
224a	4.26	86.12	90.38	79.23	18.77	33.47	81.50	2.83	15.93
39	6.66	85.84	92.50	77.69	20.64	25.20	81.76	4.98	15.66
206b	4.36	86.29	90.65	78.08	19.87	13.57	81.33	3.76	16.11
191	2.92	87.05	89.97	78.80	19.07	24.40	80.63	2.21	16.86
250	3.59	87.48	91.07	77.80	20.22	18.64	80.23	2.92	17.30
196b	2.91	88.28	91.19	77.37	20.64	12.84	79.50	2.54	18.10
AL301	53.20	3.45	56.65	90.39	5.44	90.88	82.87	4.85	0.59
395B	0.24	3.45	3.69	77.41	0.83	0.00	82.87	0.24	0.59
405B	0.00	4.48	4.48	70.87	1.30	0.00	70.87	0.00	1.30
261F	0.00	3.72	3.72	78.97	0.78	0.00	78.97	0.00	0.78
722C	0.00	37.94	37.94	69.14	11.71	0.00	69.14	0.00	11.71

TABLE 2-2

Summary of Filled Precipitation Data

Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Rain Gage	Percent of Total Data Set Filled by Regression Scheme	Percent of Total Data Set Filled by Averaging Scheme	Percent of Total Data Set that Is Filled	Percent of Filled Data Set that Equal Zero	Percent of Total Nonzero Filled Data	Percent of Data Set Filled by Regression Scheme that Equal Zero	Percent of Data Set Filled by Averaging Scheme that Equal Zero[a]	Percent of Total Data Set Filled by Regression Scheme with Nonzeros	Percent of Total Data Set Filled by Averaging Scheme with Nonzeros
1245	0.00	37.56	37.56	69.91	11.30	0.00	69.91	0.00	11.30
321	0.00	6.36	6.36	71.72	1.80	0.00	71.72	0.00	1.80
128BF	0.00	19.85	19.85	68.52	6.25	0.00	68.52	0.00	6.25
1262	0.00	35.74	35.74	70.23	10.64	0.00	70.23	0.00	10.64
446	0.00	1.16	1.16	91.73	0.10	0.00	91.73	0.00	0.10
33a	0.00	35.74	35.74	70.23	10.64	0.00	70.23	0.00	10.64
542	0.00	35.74	35.74	70.23	10.64	0.00	70.23	0.00	10.64
Average	5.03	44.58	49.61	74.57	11.47	15.64	73.84	1.09	10.37

[a]The average of all daily precipitation data measured at rain gages shown on Figure 2-1 equaling zero on a particular day.

TABLE 2-3
Reference Evapotranspiration at Piru #101 Station
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Calendar Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
1975	***2.37***	***2.45***	***3.46***	***3.98***	***5.38***	***5.71***	***7.05***	***6.48***	***5.75***	***3.68***	***2.53***	***2.44***	***51.28***
1976	***2.76***	***2.71***	***4.38***	***4.73***	***5.96***	***7.45***	***7.26***	***6.95***	***5.62***	***4.75***	***3.50***	***2.48***	***58.55***
1977	***2.31***	***3.49***	***3.97***	***5.10***	***5.30***	***6.15***	***7.69***	***6.68***	***5.43***	***4.33***	***3.41***	***2.19***	***56.05***
1978	***2.03***	***2.49***	***3.71***	***4.13***	***7.05***	***7.09***	***7.23***	***6.45***	***6.02***	***4.25***	***2.66***	***1.96***	***55.07***
1979	***1.78***	***2.39***	***3.48***	***5.10***	***6.00***	***7.21***	***7.13***	***6.48***	***6.35***	***4.03***	***2.86***	***2.49***	***55.30***
1980	***2.03***	***2.96***	***3.90***	***5.28***	***5.02***	***6.60***	***7.44***	***6.56***	***4.85***	***4.25***	***2.98***	***2.49***	***54.36***
1981	***2.32***	***3.13***	***3.77***	***5.23***	***6.11***	***6.59***	***7.36***	***6.97***	***5.64***	***4.37***	***2.94***	***2.33***	***56.76***
1982	***2.46***	***2.80***	***4.08***	***5.33***	***6.11***	***6.59***	***7.36***	***7.11***	***5.57***	***4.76***	***2.70***	***2.18***	***57.05***
1983	***2.65***	***2.70***	***3.80***	***4.84***	***6.09***	***5.89***	***7.93***	***7.69***	***5.91***	***4.76***	***2.61***	***2.12***	***56.99***
1984	***2.92***	***3.40***	***4.92***	***5.66***	***7.45***	***6.57***	***7.98***	***7.26***	***6.79***	***4.32***	***2.57***	***1.85***	***61.69***
1985	***2.36***	***2.95***	***3.90***	***5.57***	***5.88***	***7.06***	***8.04***	***7.12***	***5.54***	***4.46***	***2.42***	***2.69***	***57.99***
1986	***2.84***	***2.76***	***4.16***	***5.39***	***5.99***	***6.42***	***6.93***	***6.65***	***4.74***	***4.37***	***3.25***	***2.31***	***55.81***
1987	***2.14***	***2.55***	***3.76***	***5.57***	***5.53***	***5.50***	***6.11***	***5.90***	***5.12***	***3.75***	***2.57***	***1.57***	***50.07***
1988	***2.23***	***3.24***	***4.88***	***4.77***	***6.44***	***6.49***	***7.00***	***6.34***	***5.35***	***4.03***	***2.68***	***2.17***	***55.62***
1989	***2.48***	***2.52***	***4.41***	***5.84***	***6.06***	***6.41***	***7.24***	***6.21***	***5.65***	***4.23***	***3.37***	***2.92***	***57.34***
1990	***2.61***	***2.67***	***4.08***	***5.26***	***6.28***	***7.00***	***7.88***	***6.70***	***6.10***	***4.82***	***3.26***	***2.34***	***59.00***
1991	***2.53***	***2.80***	***3.41***	***5.71***	***6.19***	***6.21***	***7.09***	***6.93***	***5.64***	***4.75***	***3.10***	***2.27***	***56.63***
1992	3.62	2.66	2.53	5.89	5.45	6.45	6.96	7.69	6.03	4.40	4.79	2.73	59.20
1993	2.75	2.29	4.86	6.43	7.14	7.86	7.26	7.65	6.47	5.33	4.24	3.67	65.95
1994	4.30	3.56	4.80	5.56	5.20	7.36	7.39	7.44	5.62	5.04	3.86	3.36	63.49
1995	2.51	3.80	4.26	5.16	5.00	6.61	8.47	8.61	6.56	5.17	3.62	2.71	62.48
1996	2.97	2.38	4.12	6.69	7.05	7.37	8.20	7.86	5.77	5.01	3.68	2.59	63.69
1997	2.07	3.47	5.40	6.30	7.61	6.27	7.15	7.38	6.21	5.31	2.73	3.29	63.19
1998	2.02	1.86	3.49	4.95	5.51	6.30	8.35	8.30	4.66	5.22	3.61	3.90	58.17
1999	3.57	3.50	3.91	4.96	5.93	6.96	8.07	7.72	5.63	6.51	3.48	4.53	64.77
2000	2.56	2.27	4.70	5.58	7.14	7.84	8.14	8.03	5.92	3.79	3.65	3.83	63.45
2001	3.10	2.26	3.53	4.06	6.38	7.16	7.07	6.99	6.05	4.42	2.70	2.65	56.37
2002	3.31	4.81	5.29	5.28	7.24	7.85	8.54	7.87	6.96	4.11	4.49	2.36	68.11
2003	4.70	3.18	5.32	4.81	5.94	5.43	8.16	8.96	6.59	5.63	3.19	2.96	64.87
2004	3.41	3.13	5.70	6.36	7.89	7.34	8.39	7.69	6.77	3.99	3.09	3.66	67.42
2005	***2.16***	***2.67***	***4.05***	***5.59***	***6.37***	***6.12***	***6.95***	***6.57***	***5.49***	***4.07***	***3.32***	***2.19***	***55.55***

Notes:

Values in ***bold italicized font*** were calculated using REF-ET software (Allen, 2002).

ETo data are available for download at http://www.cimis.water.ca.gov/cimis/ftonStationDetailData.do?stationId=101

Values expressed in units of inches.

TABLE 2-4
Coefficients for Major Crops in the GSWI Study Area
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Crop Coefficients, Kc[a]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Drip Irrigation - Typical Year												
Strawberries	1.10	0.36	0.39	0.24	0.35	0.89	0.90	0.37	0.05	0.19	0.46	0.86
Nursery[b]	1.08	0.36	0.27	0.40	0.81	0.88	0.86	0.87	0.85	0.63	0.44	0.86
Peppers[b]	1.10	0.36	0.34	0.14	0.49	0.99	0.82	0.13	0.05	0.19	0.46	0.86
Sprinkler Irrigation - Typical Year												
Nursery[b]	1.08	0.36	0.32	0.49	0.79	0.81	0.83	0.84	0.78	0.65	0.44	0.85
Citrus (no groundcover)	1.11	0.92	0.80	0.76	0.73	0.74	0.68	0.74	0.74	0.90	0.84	1.13
Immature Citrus	1.11	0.63	0.51	0.49	0.48	0.50	0.47	0.50	0.52	0.62	0.77	1.00
Avocados	1.08	0.36	0.32	0.49	0.79	0.81	0.83	0.84	0.78	0.65	0.44	0.85
Small Vegetables[c]	1.11	0.65	0.93	1.63	0.36	0.04	0.01	0.19	0.34	0.65	1.01	1.07

[a]Computed according to ITRC (2003) and tables located at http://www.itrc.org/etdata/waterbal.htm. Values for other vegetative covers such as native vegetation will be arrived at during the calibration process.

[b]Crops are irrigated using either drip/microspray or sprinkler or some combination thereof. Crop coefficients for these crops will be evaluated further during the calibration of GSWIM.

[c]Includes effects of double-cropping and the following crops: lettuce, cabbage, broccoli, cauliflower, carrots, celery, parsley, cilantro, and radishes.

TABLE 2-5
Field Capacity and Wilting Point Moisture Content Values for Different Soil Types
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Hydrologic Soil Group[a]	Field Capacity Moisture Content[b]	Wilting Point Moisture Content[b]	Total Porosity[b]	Saturation at Field Capacity[c]	Saturation at Wilting Point[c]
A	0.118	0.041	0.41	0.29	0.10
B	0.195	0.09	0.43	0.45	0.21
C	0.224	0.108	0.39	0.57	0.28
D	0.241	0.146	0.45	0.54	0.32

[a]**A** – Low runoff potential. These soils have a high infiltration rate even when thoroughly wetted. They chiefly consist of deep, well-drained to excessively drained sands or gravels. They have a high rate of water transmission (greater than 0.30 inch per hour [in/hr]). **B** – These soils have a moderate infiltration rate when thoroughly wetted. They chiefly are moderately deep to deep, moderately well-drained to well-drained soils that have moderately fine to moderately coarse textures. They have a moderate rate of water transmission (0.15 to 0.30 in/hr). **C** – These soils have a slow infiltration rate when thoroughly wetted. They chiefly have a layer that impedes downward movement of water or have moderately fine to fine texture. They have a slow rate of water transmission (0.05 to 0.15 in/hr). **D** – High runoff potential. These soils have a very slow infiltration rate when thoroughly wetted. They chiefly consist of clay soils that have high swelling potential, soils that have a permanent high water table, soils that have a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. They have a very slow rate of water transmission (0 to 0.05 in/hr). Section 3.2 provides additional discussion of the Hydrologic Soil Group designations.

[b]Mean values from Carsel et al. (1988).

[c]Saturation = Moisture Content/Total Porosity.

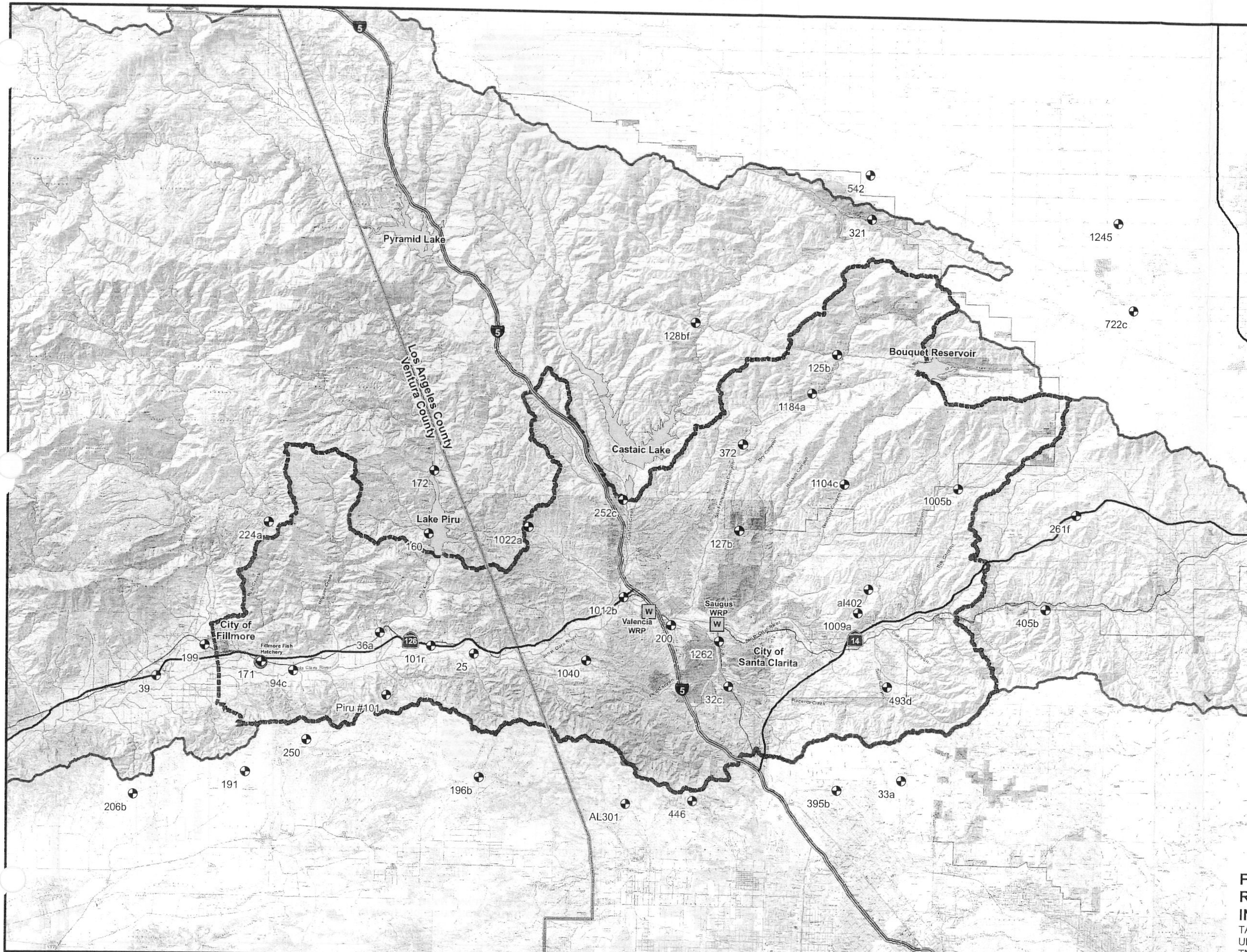


FIGURE 2-1
RAIN GAGE LOCATIONS USED IN THE GSWI STUDY VICINITY
TASK 2A – CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS

CH2MHILL

RDD \\ODIN\PROJ\COUNTYSANDISTLA\332056GSWI\DOC\TASK2A-CONCEPTUALMODEL\FIGURES\FINALREPORT\MXD\FIG2-1_RAINGAGES.MXD 9/21/2006 14:02:55

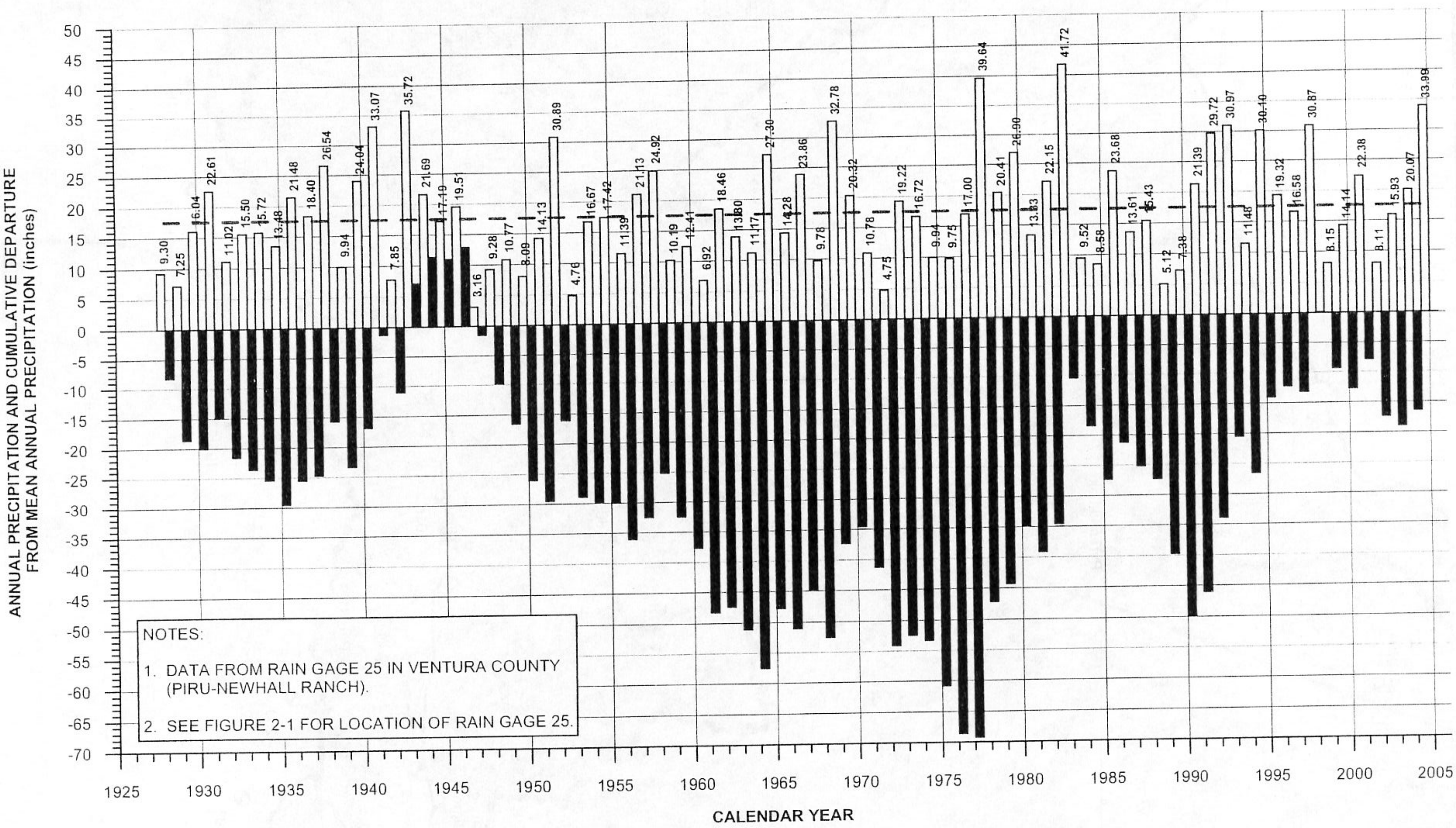
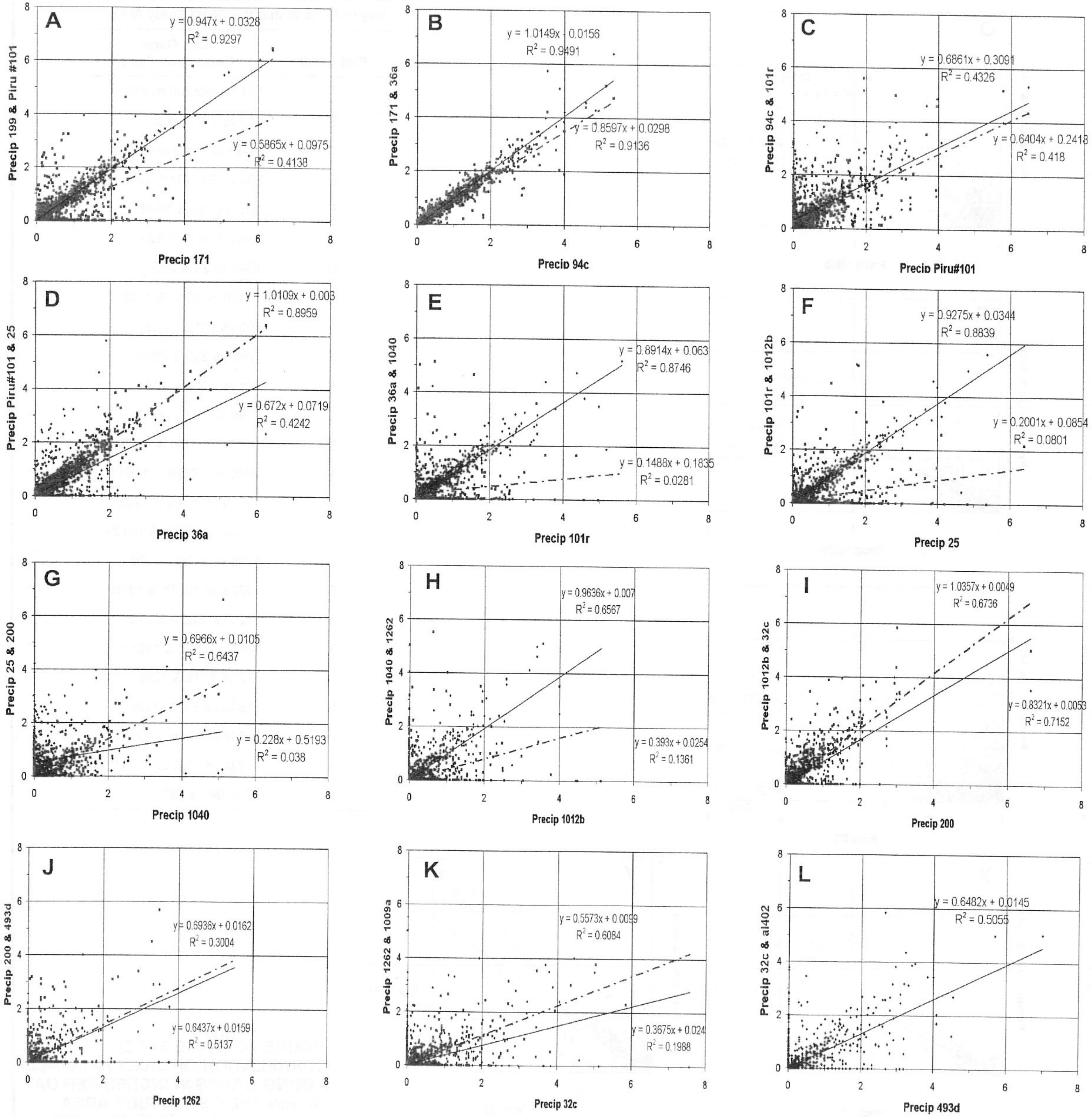


FIGURE 2-2
ANNUAL PRECIPITATION AND CUMULATIVE DEPARTURE FROM MEAN ANNUAL PRECIPITATION
TASK 2A – CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS

CH2MHILL

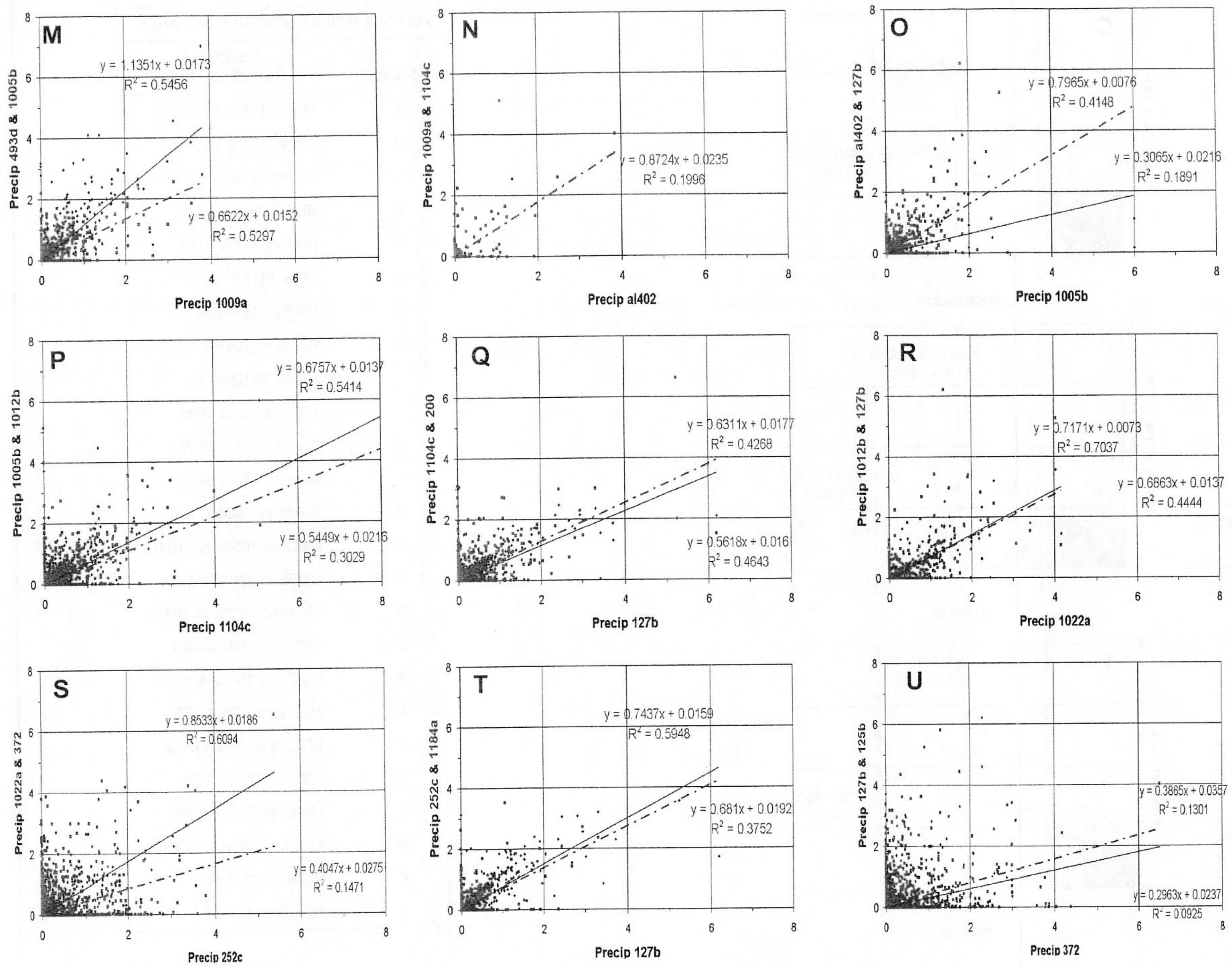
RDD \\ODIN\PROJ\CountySanDistLA\332056GSWI\Doc\Task2A-ConceptualModel\Figures\FinalReport\Grapher\Fig2-2_Precip@25.grf

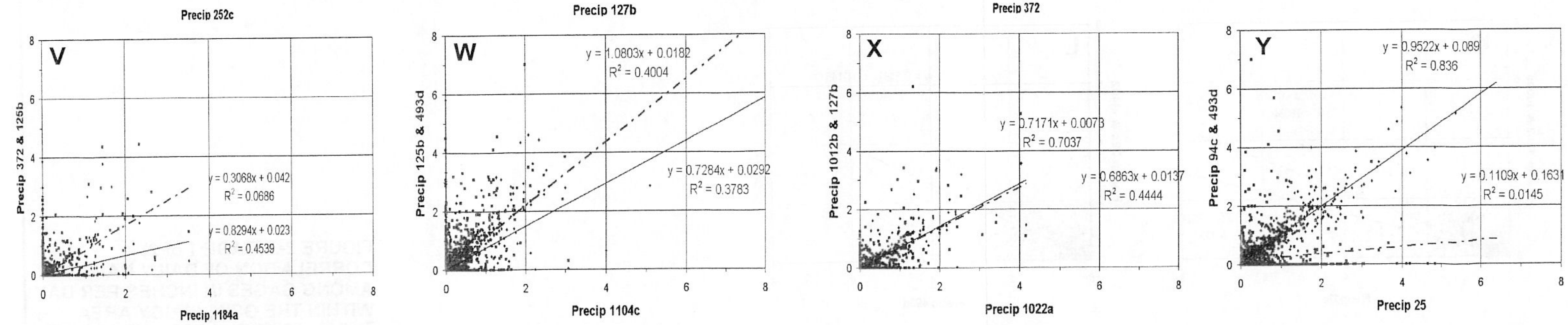


Key to Plots Within the GSWI Study Area

Plot Label	Rain Gage Correlation Pairs
A	171 vs 199 & Piru #101
B	94c vs 171 & 36a
C	Piru #101 vs 94c & 101r
D	36a vs Piru101 & 25
E	101r vs 36a & 1040
F	25 vs 101r & 1012b
G	1040 vs 25 & 200
H	1012b vs 1040 & 1262
I	200 vs 1012b & 32c
J	1262 vs 200 & 493d
K	32c vs 1262 & 1009a
L	493d vs 32c & al402
M	1009a vs 493d & 1005b
N	al402 vs 1009a & 1104c
O	1005b vs al402 & 127b
P	1104c vs 1005b & 1012b
Q	127b vs 1104c & 200
R	1022a vs 1012b & 127b
S	252c vs 1022a & 372
T	127b vs 252c & 1184a
U	372 vs 127b & 125b
V	1184a vs 372 & 125b
W	1104c vs 125b & 493d
X	1022a vs 25 & 200
Y	25 vs 94c & 493d

FIGURE 2-3 (PAGE 1 of 2)
CORRELATION OF DAILY RAINFALL AMONG GAGES IN INCHES PER DAY WITHIN THE GSWI STUDY AREA
TASK 2A – CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS





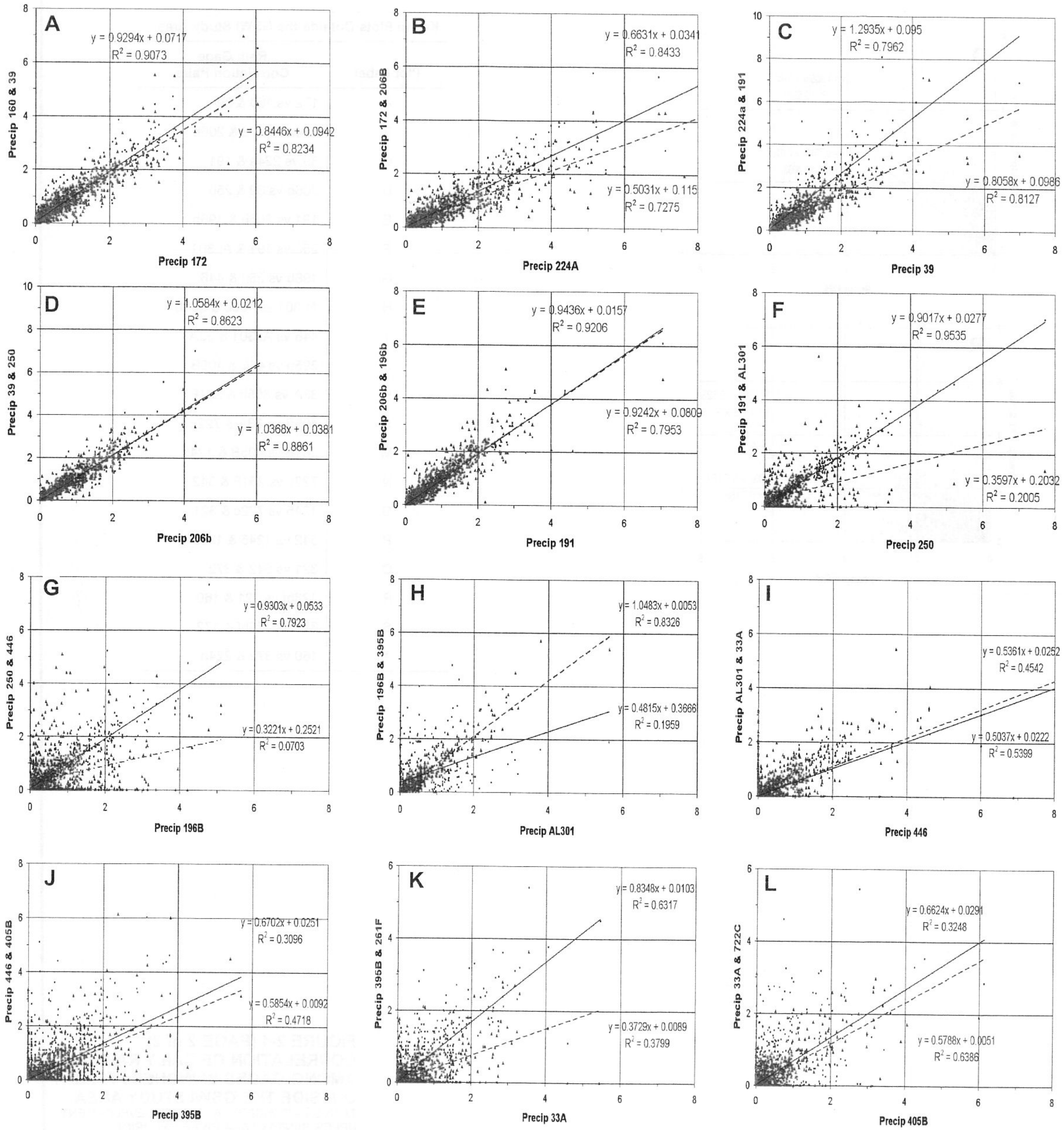
Key to Plots Within the GSWI Study Area

Plot Label	Rain Gage Correlation Pairs
A	171 vs 199 & Piru #101
B	94c vs 171 & 36a
C	Piru #101 vs 94c & 101r
D	36a vs Piru101 & 25
E	101r vs 36a & 1040
F	25 vs 101r & 1012b
G	1040 vs 25 & 200
H	1012b vs 1040 & 1262
I	200 vs 1012b & 32c
J	1262 vs 200 & 493d
K	32c vs 1262 & 1009a
L	493d vs 32c & al402
M	1009a vs 493d & 1005b
N	al402 vs 1009a & 1104c
O	1005b vs al402 & 127b
P	1104c vs 1005b & 1012b
Q	127b vs 1104c & 200
R	1022a vs 1012b & 127b
S	252c vs 1022a & 372
T	127b vs 252c & 1184a
U	372 vs 127b & 125b
V	1184a vs 372 & 125b
W	1104c vs 125b & 493d
X	1022a vs 25 & 200
Y	25 vs 94c & 493d

FIGURE 2-3 (PAGE 2 of 2)
CORRELATION OF DAILY RAINFALL AMONG GAGES IN INCHES PER DAY WITHIN THE GSWI STUDY AREA
TASK 2A – CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS

CH2MHILL

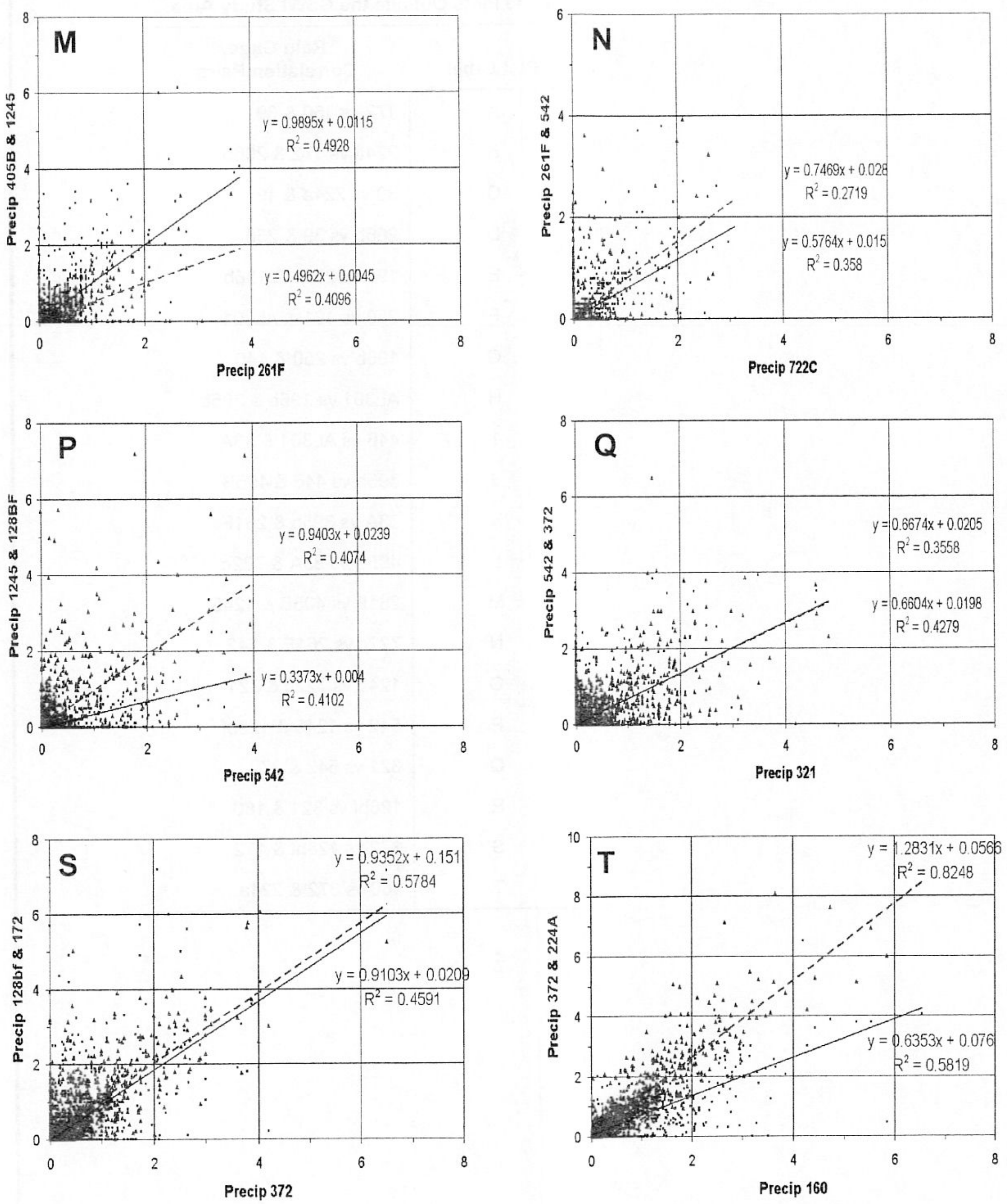
Fig2-3_Rainfall.GRF



Key to Plots Outside the GSWI Study Area

Plot Label	Rain Gage Correlation Pairs
A	172 vs 160 & 39
B	224a vs 172 & 206b
C	39 vs 224a & 191
D	206b vs 39 & 250
E	191 vs 206b & 196b
F	250 vs 191 & AL301
G	196b vs 250 & 446
H	AL301 vs 196b & 395b
I	446 vs AL301 & 33A
J	395b vs 446 & 405B
K	33A vs 395b & 261F
L	405B vs 33A & 722c
M	261F vs 405B & 1245
N	722c vs 261F & 542
O	1245 vs 722c & 321
P	542 vs 1245 & 128bf
Q	321 vs 542 & 372
R	128bf vs 321 & 160
S	372 vs 128bf & 172
T	160 vs 372 & 224a

FIGURE 2-4 (PAGE 1 of 2)
CORRELATION OF DAILY RAINFALL AMONG GAGES IN INCHES PER DAY OUTSIDE THE GSWI STUDY AREA
TASK 2A – CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS



Key to Plots Outside the GSWI Study Area

Plot Label	Rain Gage Correlation Pairs
A	172 vs 160 & 39
B	224a vs 172 & 206b
C	39 vs 224a & 191
D	206b vs 39 & 250
E	191 vs 206b & 196b
F	250 vs 191 & AL301
G	196b vs 250 & 446
H	AL301 vs 196b & 395b
I	446 vs AL301 & 33A
J	395b vs 446 & 405B
K	33A vs 395b & 261F
L	405B vs 33A & 722c
M	261F vs 405B & 1245
N	722c vs 261F & 542
O	1245 vs 722c & 321
P	542 vs 1245 & 128bf
Q	321 vs 542 & 372
R	128bf vs 321 & 160
S	372 vs 128bf & 172
T	160 vs 372 & 224a

FIGURE 2-4 (PAGE 2 of 2)
CORRELATION OF DAILY RAINFALL AMONG GAGES IN INCHES PER DAY OUTSIDE THE GSWI STUDY AREA
TASK 2A – CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS
CH2MHILL

Fig2-3_Rainfall.GRF

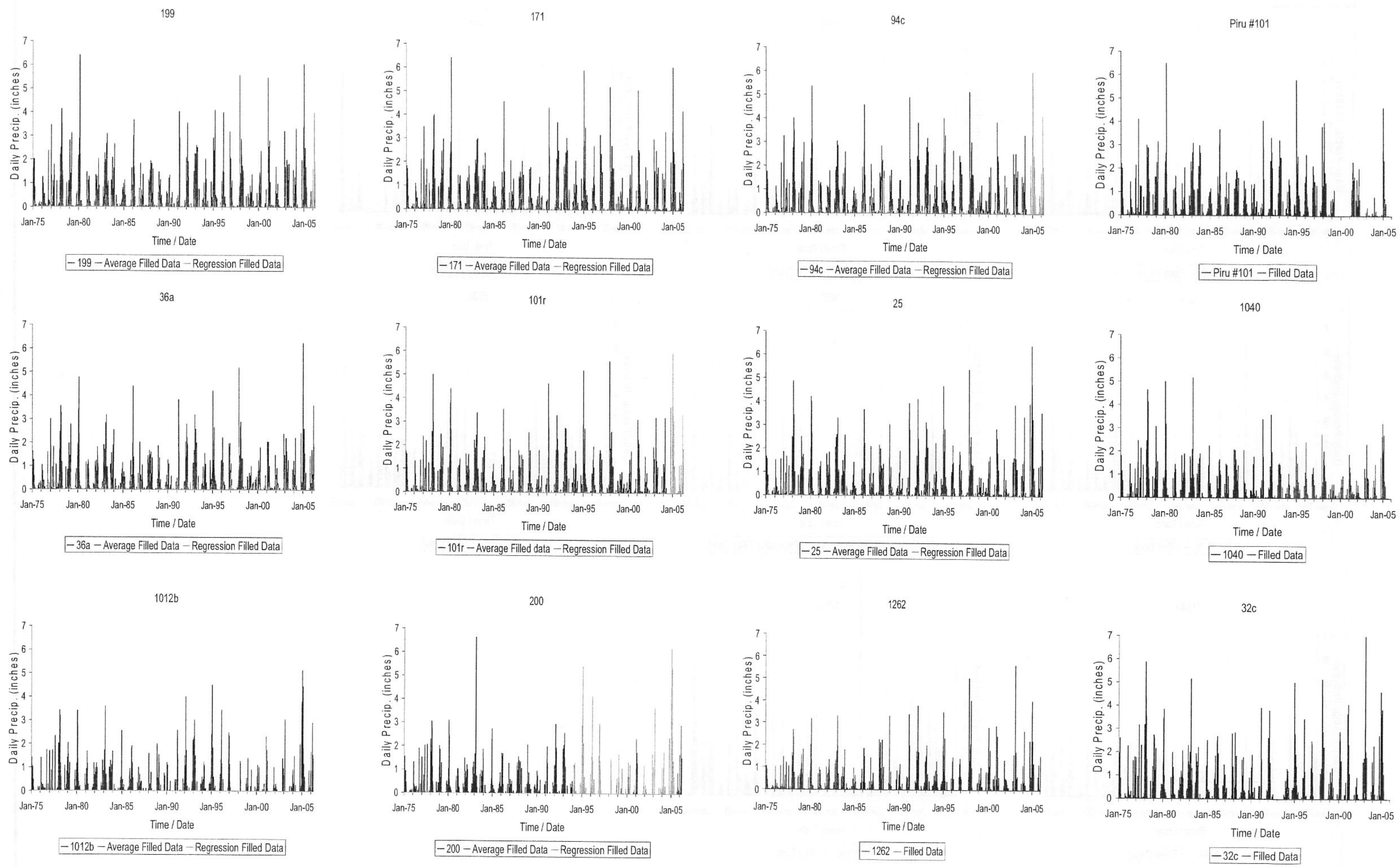


FIGURE 2-5 (PAGE 1 of 2)
TEMPORALLY CONTINUOUS PRECIPITATION RECORD AT EACH GAGE WITHIN THE GSWI STUDY AREA

TASK 2A - CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS

CH2MHILL

Fig2-5_TemporalPrecip_1.GRF

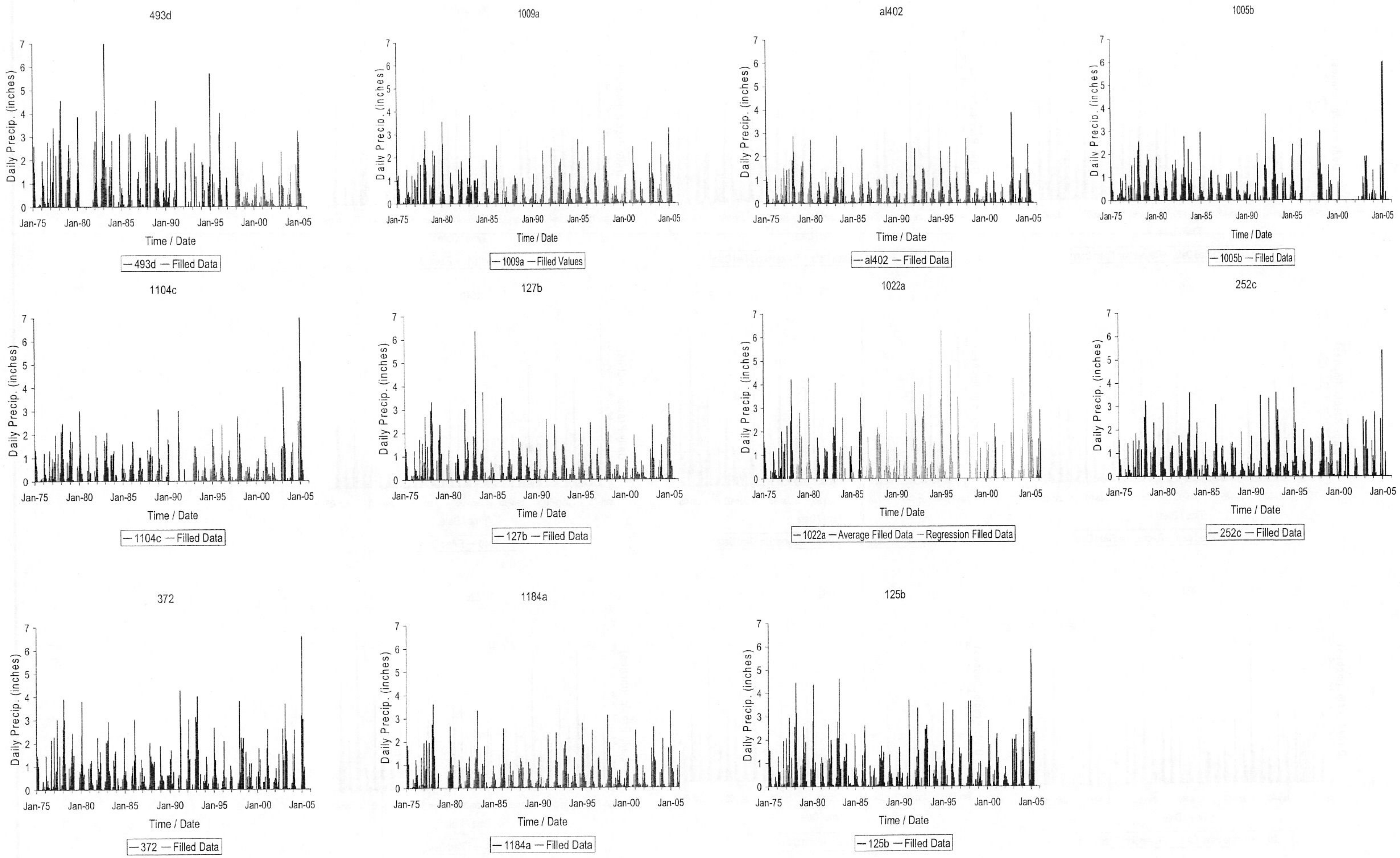


FIGURE 2-5 (PAGE 2 of 2)
TEMPORALLY CONTINUOUS PRECIPITATION RECORD AT EACH GAGE WITHIN THE GSWI STUDY AREA
TASK 2A - CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS
CH2MHILL

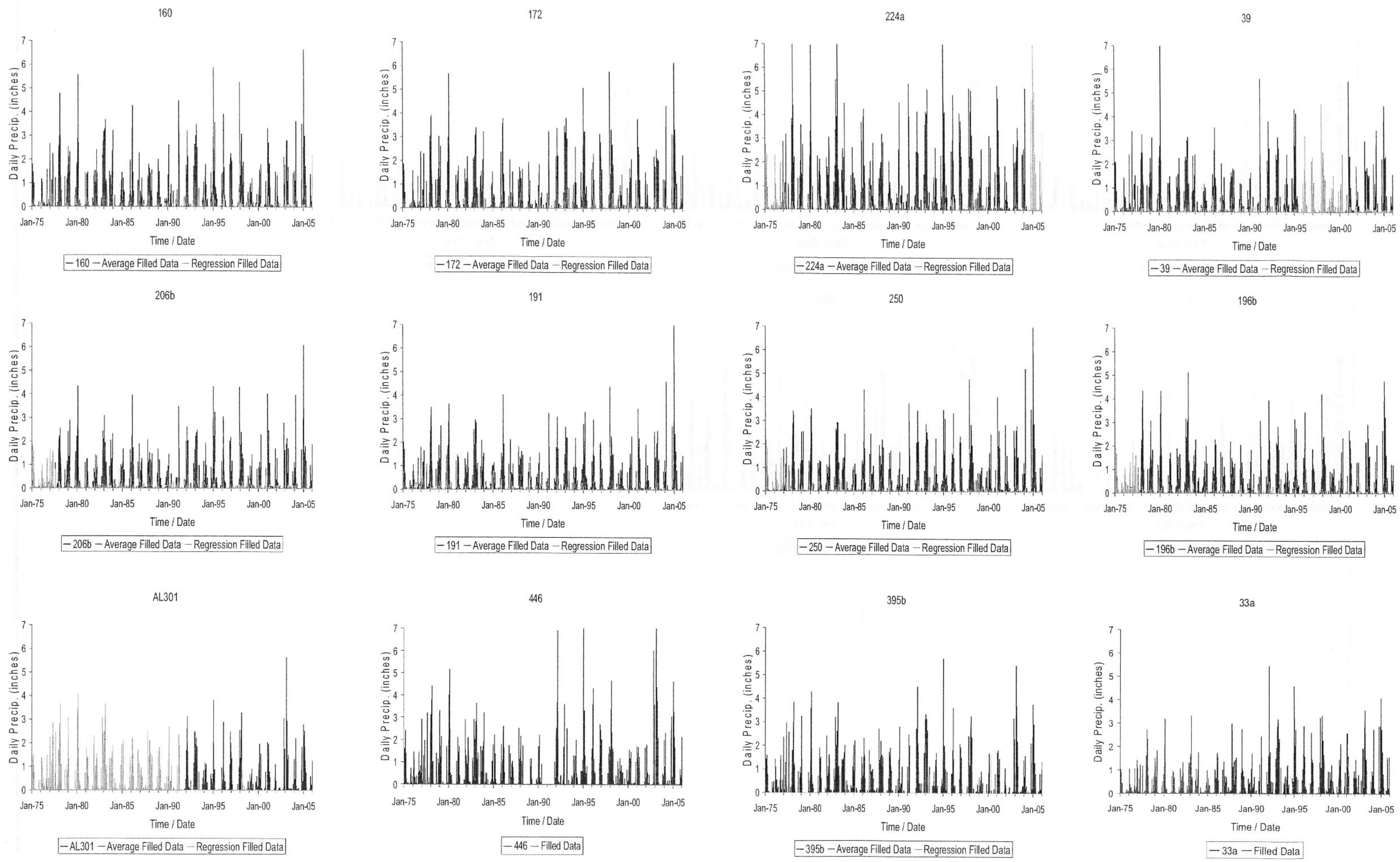


FIGURE 2-6 (PAGE 1 of 2)
TEMPORALLY CONTINUOUS PRECIPITATION RECORD AT EACH GAGE OUTSIDE THE GSWI STUDY AREA
TASK 2A - CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS

CH2MHILL

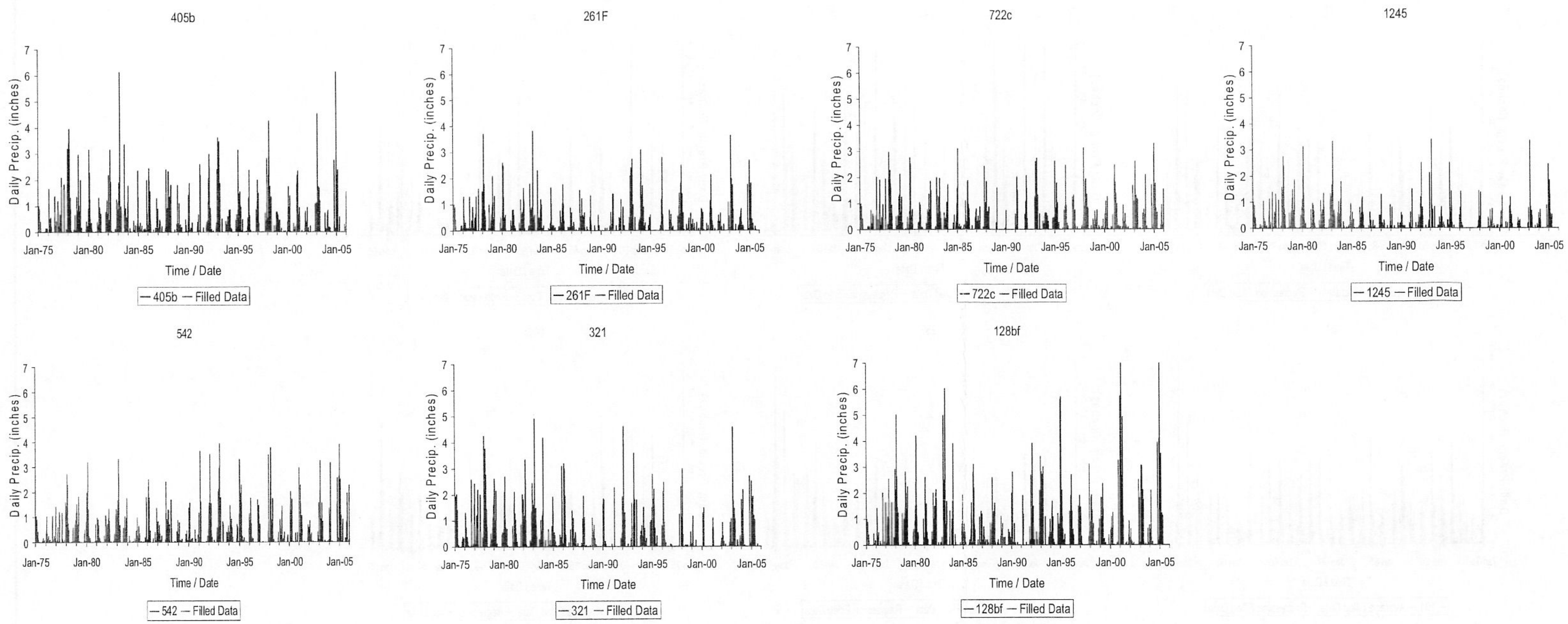


FIGURE 2-6 (PAGE 2 of 2)
TEMPORALLY CONTINUOUS PRECIPITATION RECORD AT EACH GAGE OUTSIDE THE GSWI STUDY AREA

TASK 2A - CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS

CH2MHILL

3-1420

Fig2-6_TemporalPrecip_2.GRF

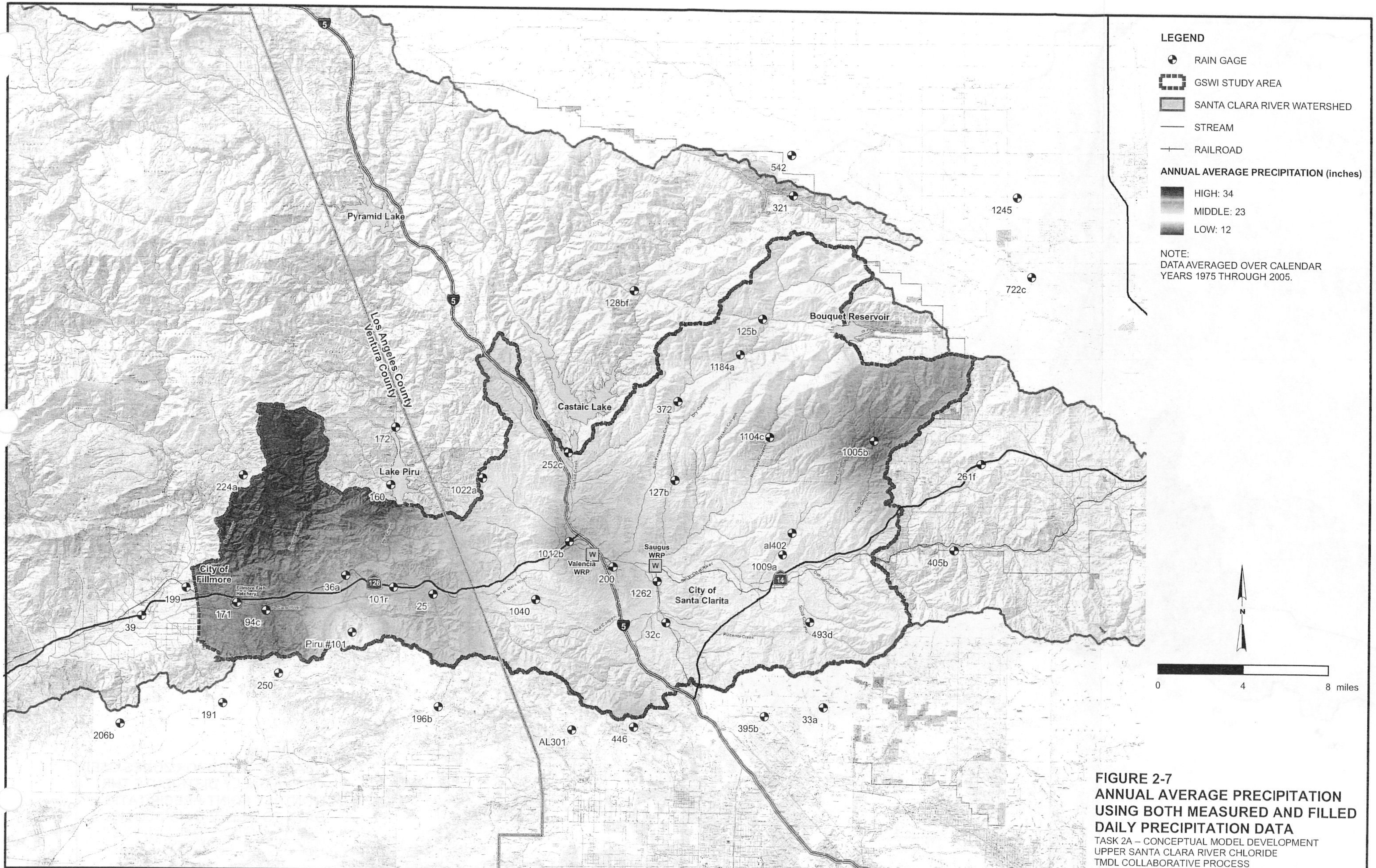


FIGURE 2-7
ANNUAL AVERAGE PRECIPITATION USING BOTH MEASURED AND FILLED DAILY PRECIPITATION DATA
TASK 2A – CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS

CH2MHILL

RDD \\ODIN\PROJ\COUNTYSANDISTLA\332056GSWI\DOC\TASK2A-CONCEPTUALMODEL\FIGURES\FINALREPORT\MXD\FIG2-7_FILLEDOROGRAPHY.MXD 9/29/2006 10:23:21

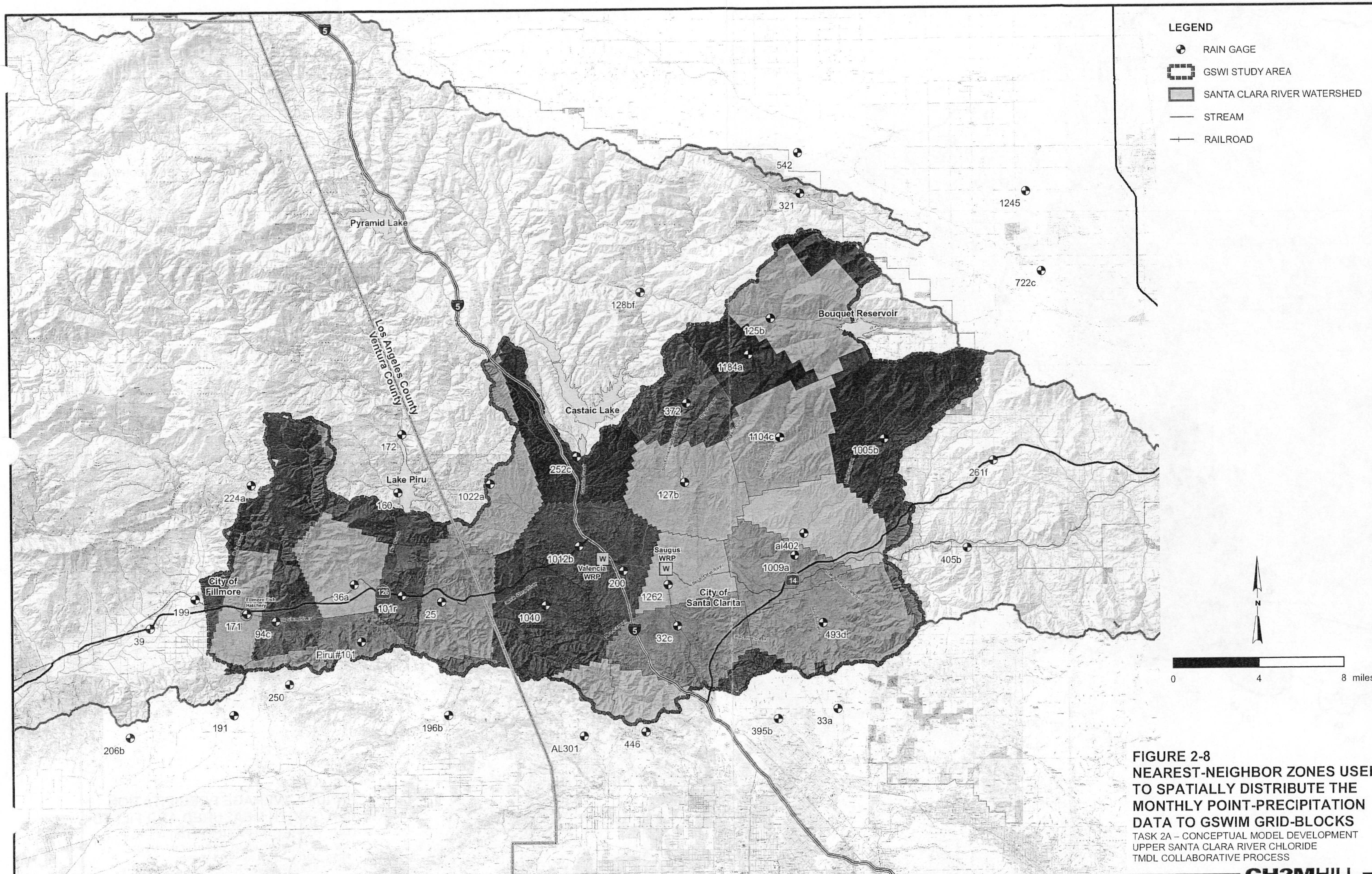
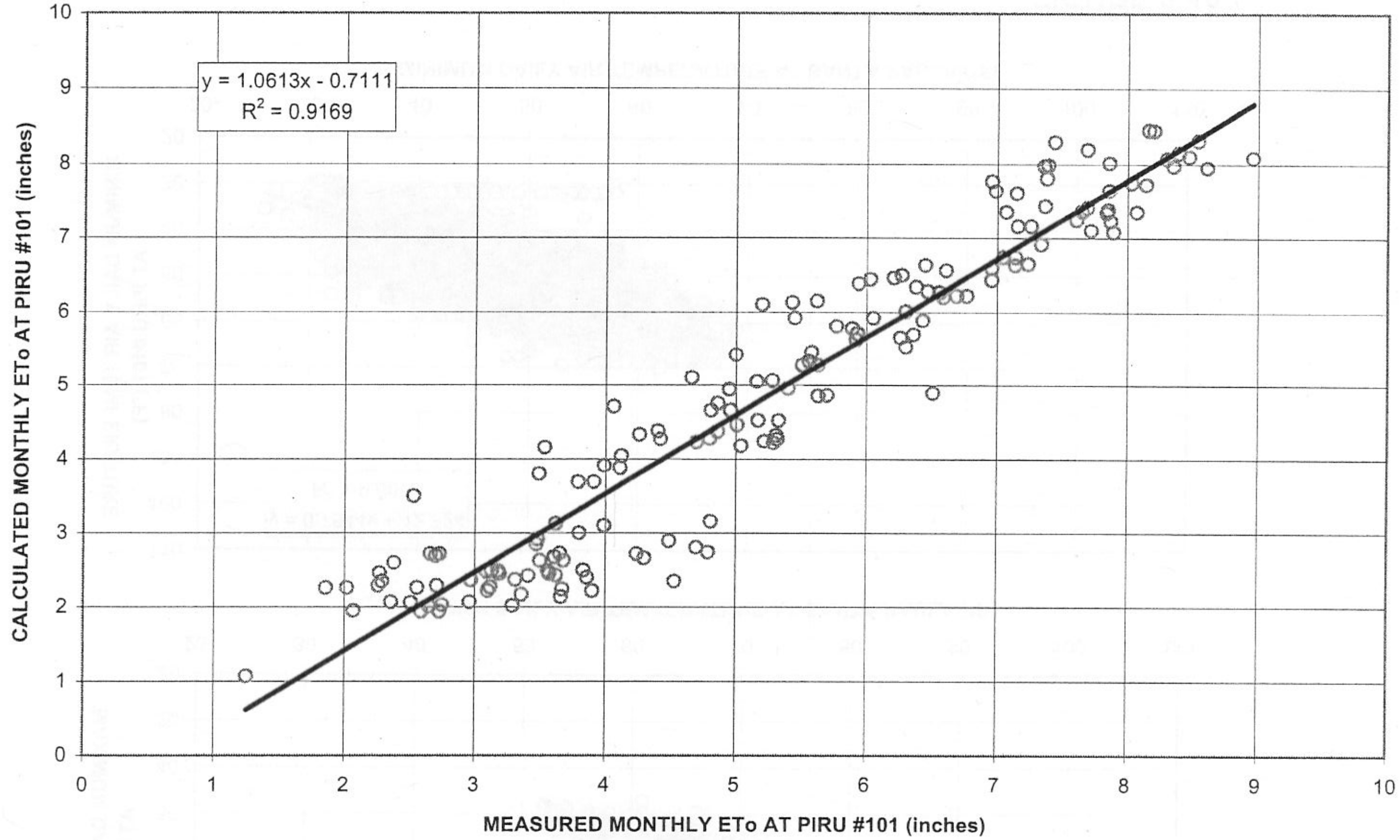


FIGURE 2-8
NEAREST-NEIGHBOR ZONES USED TO SPATIALLY DISTRIBUTE THE MONTHLY POINT-PRECIPITATION DATA TO GSWIM GRID-BLOCKS
TASK 2A – CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS

CH2MHILL

RDD \\ODIN\PROJ\COUNTYSANDISTLA\332056GSWI\DOC\TASK2A-CONCEPTUALMODEL\FIGURES\FINALREPORT\MXD\FIG02-08_OROGRAPHICZONES.MXD 10/2/2006 12:09:30

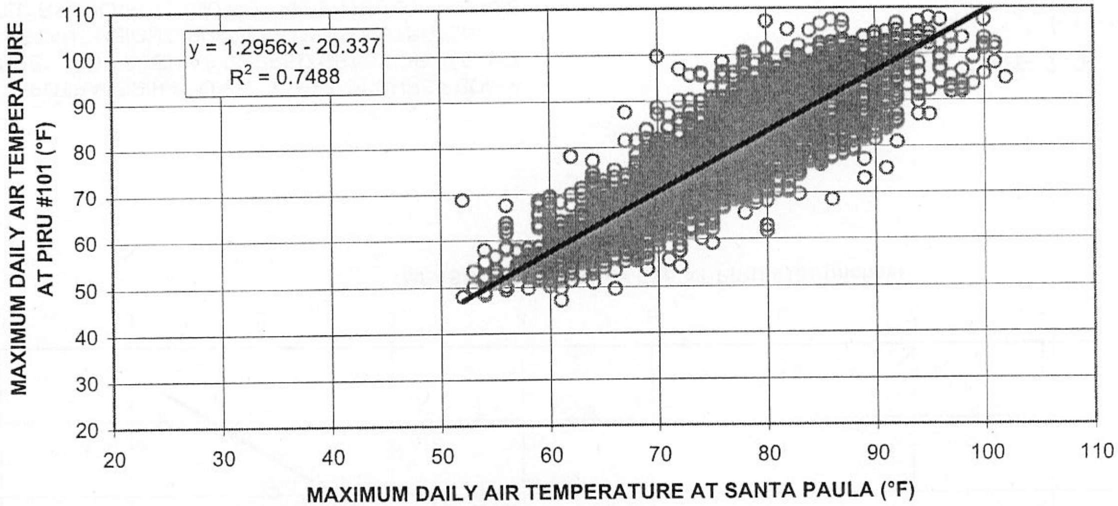


NOTE:
ETo IS DEFINED AS THE EVAPOTRANSPIRATION (ET) THAT OCCURS FROM A STANDARDIZED "REFERENCE" CROP SUCH AS CLIPPED GRASS OR ALFALFA THAT IS CLIPPED TO A CONSTANT HEIGHT, PROVIDED WITH NUTRITION REQUIREMENTS, IRRIGATED REGULARLY, AND NOT AFFECTED BY DISEASE.

FIGURE 2-9
CALCULATED VERSUS MEASURED ETo AT PIRU #101
TASK 2A - CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS

Fig02-09_Piru101_ETo_1991_2004.xls/Fig2-9

CH2MHILL



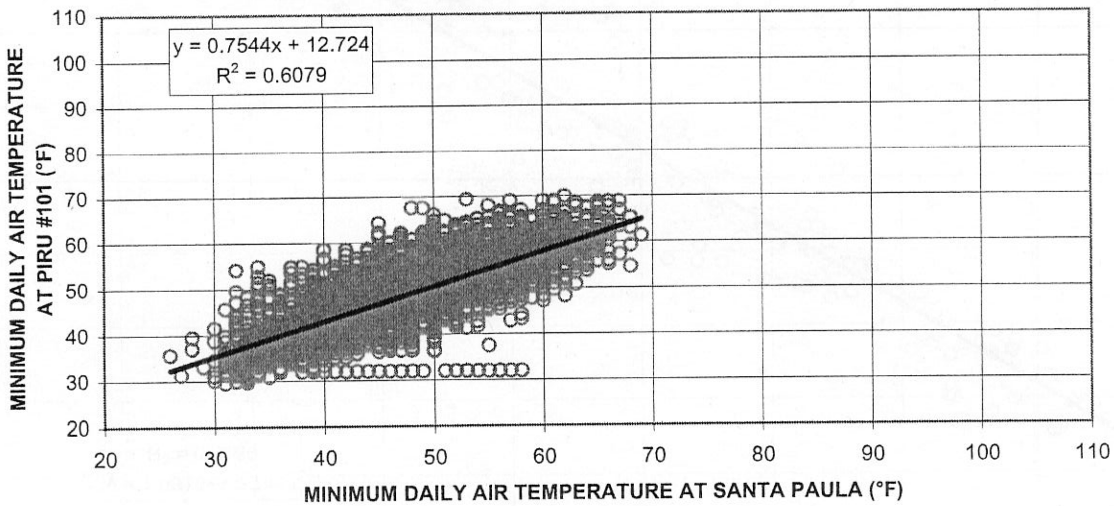
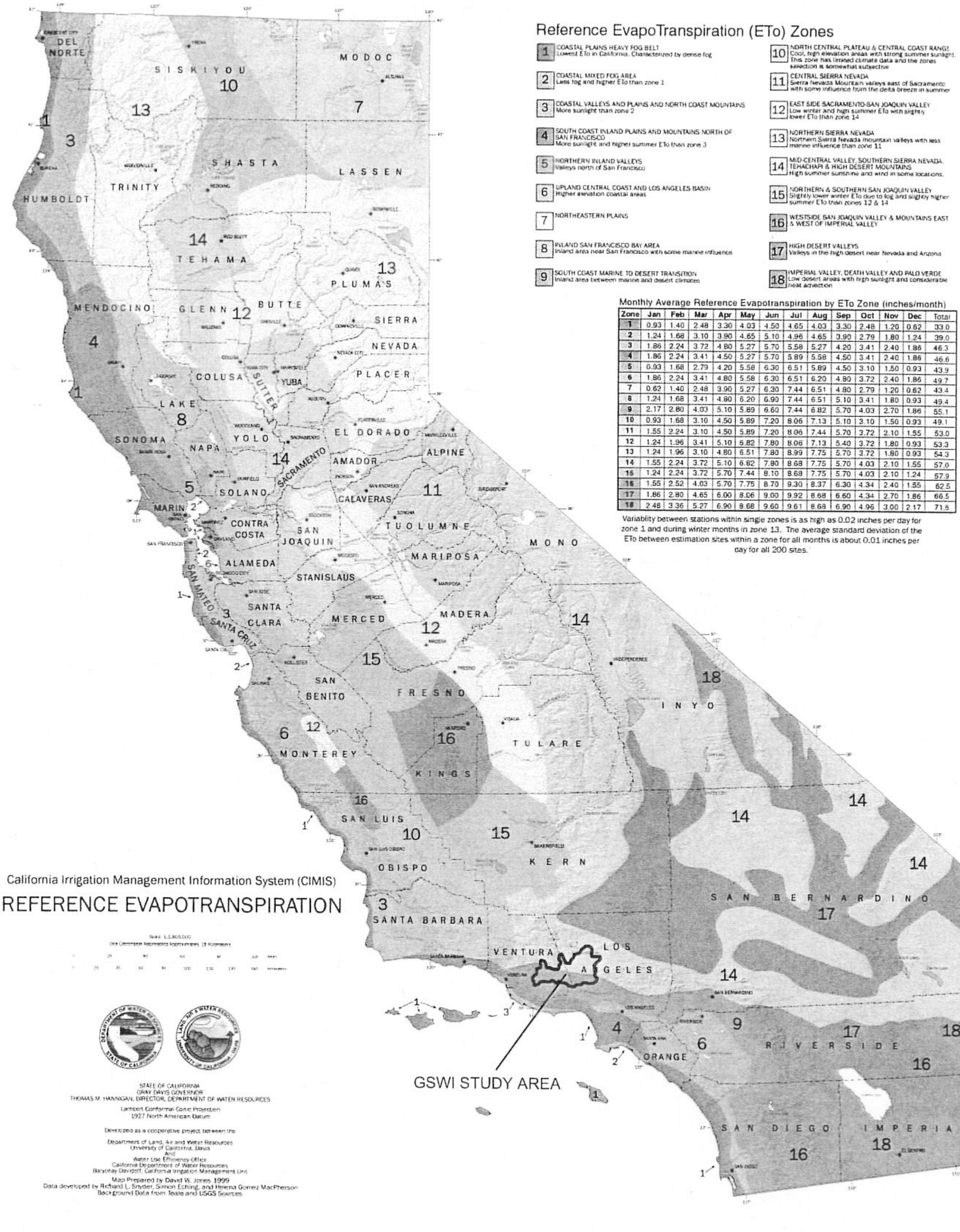


FIGURE 2-10
CORRELATION OF DAILY AIR TEMPERATURE BETWEEN SANTA PAULA AND PIRU #101 STATIONS
TASK 2A - CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS



Reference EvapoTranspiration (ETo) Zones

1. COASTAL PLAINS HEAVY FOG BELT — Lowest ETo in California. Characterized by dense fog
2. COASTAL MIXED FOG AREA — Less fog and higher ETo than zone 1
3. COASTAL VALLEYS AND PLAINS AND NORTH COAST MOUNTAINS — More sunlight than zone 2
4. SOUTH COAST INLAND PLAINS AND MOUNTAINS NORTH OF SAN FRANCISCO — More sunlight and higher summer ETo than zone 3
5. NORTHERN INLAND VALLEYS — Valleys north of San Francisco
6. UPLAND CENTRAL COAST AND LOS ANGELES BASIN — Higher elevation coastal areas
7. NORTHEASTERN PLAINS
8. INLAND SAN FRANCISCO BAY AREA — Inland area near San Francisco with some marine influence
9. SOUTH COAST MARINE TO DESERT TRANSITION — Inland area between marine and desert climates
10. NORTH CENTRAL PLATEAU & CENTRAL COAST RANGE — Cool, high elevation areas with strong summer sunlight. This zone has limited climate data and the zones selection is somewhat subjective
11. CENTRAL SIERRA NEVADA — Sierra Nevada Mountain valleys east of Sacramento with some influence from the delta breeze in summer
12. EAST SIDE SACRAMENTO-SAN JOAQUIN VALLEY — Low winter and high summer ETo with slightly lower ETo than zone 14
13. NORTHERN SIERRA NEVADA — Northern Sierra Nevada mountain valleys with less marine influence than zone 11
14. MID-CENTRAL VALLEY, SOUTHERN SIERRA NEVADA, TEHACHAPI & HIGH DESERT MOUNTAINS — High summer sunshine and wind in some locations.
15. NORTHERN & SOUTHERN SAN JOAQUIN VALLEY — Slightly lower winter ETo due to fog and slightly higher summer ETo than zones 12 & 14
16. WESTSIDE SAN JOAQUIN VALLEY & MOUNTAINS EAST & WEST OF IMPERIAL VALLEY
17. HIGH DESERT VALLEYS — Valleys in the high desert near Nevada and Arizona
18. IMPERIAL VALLEY, DEATH VALLEY AND PALO VERDE — Low desert areas with high sunlight and considerable heat advection

Monthly Average Reference Evapotranspiration by ETo Zone (inches/month)

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62	33.0
2	1.24	1.68	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	4.50	3.41	2.40	1.86	46.6
5	0.93	1.68	2.79	4.20	5.58	6.30	6.51	5.89	4.50	3.10	1.50	0.93	43.9
6	1.86	2.24	3.41	4.80	5.58	6.30	6.51	6.20	4.80	3.72	2.40	1.86	49.7
7	0.62	1.40	2.48	3.90	5.27	6.30	7.44	6.51	4.80	2.79	1.20	0.62	43.4
8	1.24	1.68	3.41	4.80	6.20	6.90	7.44	6.51	5.10	3.41	1.80	0.93	49.4
9	2.17	2.80	4.03	5.10	5.89	6.60	7.44	6.82	5.70	4.03	2.70	1.86	55.1
10	0.93	1.68	3.10	4.50	5.89	7.20	8.06	7.13	5.10	3.10	1.50	0.93	49.1
11	1.55	2.24	3.10	4.50	5.89	7.20	8.06	7.44	5.70	3.72	2.10	1.55	53.0
12	1.24	1.96	3.41	5.10	6.82	7.80	8.06	7.13	5.40	3.72	1.80	0.93	53.3
13	1.24	1.96	3.10	4.80	6.51	7.80	8.99	7.75	5.70	3.72	1.80	0.93	54.3
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68	7.75	5.70	4.03	2.10	1.24	57.9
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30	8.37	6.30	4.34	2.40	1.55	62.5
17	1.86	2.80	4.65	6.00	8.06	9.00	9.92	8.68	6.60	4.34	2.70	1.86	66.5
18	2.48	3.36	5.27	6.90	8.68	9.60	9.61	8.68	6.90	4.96	3.00	2.17	71.6

Variability between stations within single zones is as high as 0.02 inches per day for zone 1 and during winter months in zone 13. The average standard deviation of the ETo between estimation sites within a zone for all months is about 0.01 inches per day for all 200 sites.

SOURCE:
http://wwwcimis.water.ca.gov/cimis/images/etomap.jpg

FIGURE 2-11
STATEWIDE MAP OF REFERENCE EVAPOTRANSPIRATION

TASK 2A - CONCEPTUAL MODEL DEVELOPMENT
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS

This Page Intentionally
Left Blank

Physical Setting

The SCR drains an area of approximately 1,600 square miles in the Transverse Mountain Range along its 100-mile course from the San Gabriel Mountains in the east, through Los Angeles and Ventura Counties, where it empties into the Pacific Ocean at its western limit. The focus of the GSWI Study is on groundwater/surface-water interactions along Reaches 4, 5, 6, and 7 (as designated by the Regional Board) of the SCR in western Los Angeles County and eastern Ventura County.

3.1 Topography

Digital Elevation Model (DEM) data obtained from the National Elevation Dataset[7] form the basis for land surface elevations for GSWIM. The 30-meter DEM data are the best available data for land surface elevation covering the study domain, given the large extent of the GSWI study area. The topography can have significant control on the infiltration-runoff processes that are conceptualized for this study in a physically based, spatially distributed manner. As shown on Figure 3-1, land surface elevations in the GSWI study area range from approximately 5,200 ft msl near Bouquet Reservoir to approximately 420 ft msl at the downstream end of Reach 4, at the A Street bridge in Fillmore. Drops in elevation along the chloride TMDL reaches of the Upper SCR average about 35 to 40 feet per mile (ft/mi) in Reach 6 and about 30 ft/mi in Reach 5, according to the DEM data. The DEM data are also used as input into the Arc Hydro model[8] of ESRI® ArcGIS™ Version 9.1[9] to delineate stream locations (also shown on Figure 3-1) for this study.

3.2 Soils

Soils play an important role in groundwater/surface-water interaction studies. Thus, an understanding of physical soil characteristics of various soil types and their geographic distribution is an important data need for the GSWI Study.

As a starting point, GSWIM will use geographic information system (GIS)-based soils data provided in Soil Survey Geographic (SSURGO) data sets[10]. SSURGO data are produced, maintained, and distributed by the National Resources Conservation Service within the U.S. Department of Agriculture. SSURGO is the most detailed level of soil mapping done by the National Resources Conservation Service, with mapping scales generally ranging from 1:12,000 to 1:63,360. This level of mapping is designed for use by landowners, townships, and county natural resource planning and management agencies. The SSURGO data set includes detailed information on soil properties and distribution.

7 http://ned.usgs.gov/

8 http://support.esri.com/index.cfm?fa=downloads.dataModels.filteredGateway&dmid=15

9 http://www.esri.com/software/arcgis/index.html

10 http://soildatamart.nrcs.usda.gov/County.aspx?State=CA

One of the most important soil characteristics for the GSWI Study is a soil's resistance to surface-water infiltration during storm events. The Hydrologic Soil Group (HSG) code, provided in the SSURGO GIS, groups soils having similar runoff potential under similar storm and cover conditions. Soil properties that influence runoff potential also influence infiltration for a bare soil after prolonged wetting and when not frozen. These properties include depth to a seasonally high water table, saturated hydraulic conductivity after prolonged wetting, and depth to a layer with a very slow water transmission rate. In the definitions of the classes, infiltration rate is the rate at which water enters the soil at the surface and is controlled by the surface conditions. Transmission rate is the rate at which water moves in the soil and is controlled by soil properties. The influence of ground cover is treated independently[11].

The soils in the United States are placed into four groups - A, B, C, and D - and three dual classes - A/D, B/D, and C/D. Definitions of the four main groups are as follows:

- A - These soils have low runoff potential and a high infiltration rate even when thoroughly wetted. They consist of deep, well-drained to excessively drained sands or gravels. They have a high rate of water transmission (greater than 0.30 in/hr).
- B - These soils have a moderate infiltration rate when thoroughly wetted. They are moderately deep to deep, moderately well-drained to well-drained soils that have moderately fine to moderately coarse textures. They have a moderate rate of water transmission (0.15 to 0.30 in/hr).
- C - These soils have a slow infiltration rate when thoroughly wetted. They have a layer(s) that impedes downward movement of water or have moderately fine to fine texture. They have a slow rate of water transmission (0.05 to 0.15 in/hr).
- D - These soils have high runoff potential a very slow infiltration rate when thoroughly wetted. They consist of clay soils that have high swelling potential, soils that have a permanent high water table, soils that have a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. They have a very slow rate of water transmission (0 to 0.05 in/hr).

The dual classes, A/D, B/D, and C/D, have a combination of the infiltration properties of the main soil classes. Figure 3-2 shows the spatial distribution of soils according to the HSG codes provided in the SSURGO GIS, obtained from the National Resources Conservation Service. Soils data that are deemed incomplete or suspect from the SSURGO data set will be checked against soil data and distributions generally known to occur in the GSWI study area and changes will be made accordingly so the final calibrated soil property distribution will likely represent some combination of data from SSURGO, WARMF, UWCD, and professional judgment.

Information on soil distributions and properties is also extracted from the WARMF model data sets to investigate the correlation with SSURGO GIS distributions and to provide initial estimates of several property values that are related to soil types. The WARMF model provides soil information according to subcatchment, including soil layering, layer thickness, field capacity and saturated moisture contents, horizontal hydraulic conductivity

[11] http://soils.usda.gov/technical/handbook/contents/part618p2.html#35

(Kh) and vertical hydraulic conductivity (Kv), and a root distribution function (RDF) among the soil layers. This information was generally examined to categorize the soils into Soil Types A, B, C and D. After observing the spatial distribution of all parameters, the layer 3 Kh was used to distinguish the WARMF Soil Types as follows:

- Soil Type A was assigned to soils with a Kh range of 560 to 860 centimeters per day (cm/day) – the highest of the data set.
- Soil Type B was assigned to soils with a Kh of 200 cm/day.
- Soil Type C was assigned to soils with a Kh range of 40 to 56 cm/day.
- Soil Type D was assigned to soils with a Kh of 25 cm/day – the lowest of the data set.

The areal distribution of the WARMF Soil Type classifications is shown on Figure 3-3; when compared to HSGs presented on Figure 3-2, there is no definite relationship between the two maps. However, Soil Type A from the WARMF model generally correlates with HSG-A soils along the SCR in Ventura County; Soil Type B correlates with HSG-B along the SCR in western Los Angeles County; Soil Type C correlates with HSG-C in portions of the northern and eastern regions of the domain; and Soil Type D correlates with HSG-D in portions of Bouquet and Mint Canyons. Thus, the WARMF model included general soil type classifications within the model area averaged over each of the subcatchments.

With this classification of soil types, the soil properties that will be used to aid in the initial parameterization of soil properties in GSWIM are shown in Table 3-1. The parameters extracted from the WARMF model are within range of literature values and are used to initially parameterize GSWIM to provide consistency between the models; however, the distribution of HSG zones shown on Figure 3-2 will be used to spatially distribute these parameter values as follows.

The spatial distribution of the HSGs shown on Figure 3-2 will initially be used to evaluate the fraction of each soil type at any given location (i.e., within each spatially discretized model grid-block) to parameterize properties that are related to soil type. The fraction of each soil type at a given model grid-block (SFi) is the area of model grid-block "i" that is covered by that soil type, divided by the total area of grid-block "i." Figure 3-4 illustrates the concept of calculating the SFi terms. These calculations are performed using scripts developed for use within ESRI® ArcGIS™ Version 9.1[12]. The sum of all SFi terms within each grid-block equals one. Properties that are related to soil type are then evaluated for a model grid-block via an area-weighted average of the value of the property for each soil type in that grid-block, by using the SFi values as weighting factors for the individual property values related to the soil types shown in Table 3-1. Table 3-2 shows an example calculation for averaging a soil property areally over a given grid-block.

Properties that relate to soil type include the field capacity and wilting point moisture contents that govern the ET process (discussed in Section 2.2), the Kh and Kv of the surface soils, and the moisture retention properties for unsaturated conditions discussed in Section 5.0.

---

12 http://www.esri.com/software/arcgis/index.html

3.3 Land Use

GIS mapping that defines subareas within the GSWI study area by vegetation and land use will be used to assign appropriate land cover properties throughout the GSWIM domain. Land use mapping data are available for specific years and from multiple organizations, including, but not limited to the EPA, Southern California Association of Governments (SCAG), UWCD, DWR, and the City of Santa Clarita. Digital land use mapping was obtained as follows (land use mapping covers both Los Angeles and Ventura Counties unless otherwise noted):

- 1980: BASINS[13] (EPA) (see Figure 3-5)
- 1990: SCAG (see Figure 3-6)
- 1993: SCAG (see Figure 3-7)
- 1997: UWCD (Ventura County agriculture only) (see Figure 3-8)
- 2000: DWR[14] (Ventura County only) (see Figure 3-9)
- 2001: SCAG (see Figure 3-10)
- 2001: City of Santa Clarita (City of Santa Clarita only) (see Figure 3-11)
- 2002: UWCD (Ventura County agriculture only) (see Figure 3-12)
- 2004: City of Santa Clarita (City of Santa Clarita only) (see Figure 3-13)
- 2005: City of Santa Clarita (City of Santa Clarita only) (see Figure 3-14)
- 2005: SCAG (see Figure 3-15)

Land use data available from the Division of Land Resource Protection Farmland Mapping and Monitoring Program[15] also will be used to provide general land use information. Technical soil ratings use soil physical and chemical properties to determine a soil's suitability for different crops and types of agricultural practice and management. The Farmland Mapping and Monitoring Program mapping system uses farmland map categories, which are determined by agricultural productivity. The system includes the following categories:

- Prime farmland
- Farmland of statewide importance
- Unique farmland
- Farmland of local importance
- Grazing land
- Urban and built-up land
- Other
- Water

These categories, largely derived from the soil survey, are mapped at a fairly coarse scale and are not particularly useful for determining water usage because they are not crop specific. The purpose of this land mapping system is to determine the productivity and, therefore, the potential land use. Thus, qualitative information might be obtained from the

13 http://www.epa.gov/ost/basins/

14 http://www.landwateruse.water.ca.gov/basicdata/landuse/counties/survey_years/vector_quads/00ve.cfm

15 http://www.consrv.ca.gov/DLRP/fmmp/index.htm

Farmland Mapping and Monitoring Program mapping to supplement the mapping from BASINS, DWR, SCAG, City of Santa Clarita, and UWCD.

Some of these land use data are more detailed than the standardized codes and some are less detailed. In some cases, the level of detail varies within the mapping system. For example, the BASINS data (described below) separate out native vegetation into several categories, whereas there is only one category for cropland and pasture. In most other sources of land use data, crops are separated out into crop type categories.

3.3.1 Standardized Land Use Codes

The LUCs provided in the GIS database by the organizations listed above were standardized into a smaller set of LUCs for the GSWI Study. Standardization of LUCs is an important step, because many of the LUCs provided in the original GIS data sets might represent geographic areas with similar features of interest for GSWIM. Table 3-3 lists standardized LUCs that are planned for the GSWI Study. The ability to assign some of the LUCs listed in Table 3-3 depend on the availability of information in the original LUC designations and aerial photographs through time. Table 3-4 shows how the original LUC classifications were standardized into the LUCs listed in Table 3-3.

If the original LUC was more detailed than the standardized LUC (i.e., if there were more categories in the original data source than in the standardized list), then some of those LUCs from the original data source were aggregated into one standardizes LUC. For example, if the data source included several types of riparian vegetation, all were coded with the "Riparian Vegetation" standardized LUC, thereby losing some of the detail in the original LUC. If the original data source was less detailed, then the original data source LUC was coded with the standardized LUC that was most similar. For example, one data source included only one LUC for all crops and pasture land. This standardized LUC was coded as "Improved Pasture" because that is the category that would capture the irrigated and managed aspects of agricultural land. Following is a discussion related to specific land use data sources and examples of how the original LUCs were standardized.

3.3.1.1 U.S. Environmental Protection Agency

Land use data obtained from BASINS were originally collected by the USGS and converted to ARC/INFO by EPA. These data are useful for environmental assessment of land use patterns with respect to water quality analysis and growth management. The BASINS data are detailed with respect to native vegetation, but are not detailed with respect to agricultural crops. Several LUCs for different types of natural vegetation, such as deciduous forest land, mixed forest, and nonforest wetland, are provided. However, all agricultural crops and pasture types are aggregated into one LUC. In this case, the subclasses of natural vegetation used in the BASINS system were aggregated into the standardized LUCs of "Native Vegetation" and "Riparian Vegetation." In general, wetland vegetation categories were standardized into the "Riparian Vegetation" standardized LUC, and nonwetland vegetation was standardized into the "Native Vegetation" standardized LUC, as noted in Table 3-4. The cropland and pasture category was standardized into the "Improved Pasture" LUC, because this category captures the irrigated and managed aspect of agricultural land.

3.3.1.2 California Department of Water Resources

The DWR land use data are relatively detailed. They are explained in the Standard Land Use Legend developed and published by the Land and Water Use Section, Statewide Planning Branch, Division of Planning. This legend is revised on an irregular schedule (every few years), so it is important to use the appropriate version of the legend to interpret the data.

In general, the DWR land use survey data are as detailed as or more detailed than the standardized LUCs developed for this study. For example, most of the subclasses under the pasture category represent some type of managed, irrigated pasture, and were thus coded "Improved Pasture" in the standardized list. However, because one subclass, native pasture, represents nonirrigated, nonimproved pasture and is more similar to "Native Vegetation," it was standardized as such.

3.3.1.3 Southern California Association of Governments and City of Santa Clarita

This land use classification system is derived from the Anderson Land Use Classification, Level III/IV. The land use descriptions are specific to Southern California and might not apply in other geographical areas.

There is considerable detail in the urban LUCs. Several types of residential, industrial, and commercial uses are distinguished. However, the criteria used for these subclasses are not typical of urban land use mapping. The main difference between this classification system and typical urban land use mapping is the criteria used to distinguish low- and high-density residential urban areas. In this system, less than two units per acre in a single-family detached residential area is considered low density and more than two units per acre is considered high density. This is a very low criterion for high-density detached residences. The highest density that can be achieved in detached single-family residences is 10 to 15 units per acre – beyond that density, housing is necessarily multi-family (e.g., duplexes or apartments). Typically, 5 to 20 units per acre is considered medium density and more than 20 units per acre is considered high density. Thus, it is unlikely that single-family residential areas are actually high-density residential areas as provided by this land use classification system.

This observation is significant with respect assigning appropriate land cover properties that affect runoff versus infiltration. High-density areas are assumed to have greater coverage of low-permeability land cover (e.g., paved areas) than low-density areas. If single-family residential areas are considered high-density areas, then they would be assumed to have large areas of impervious land cover, which would be incorrect. Therefore, categories were coded in Table 3-4 according to the likelihood that they would include significant impervious land cover areas, not according to their original codes. For example, apartments, condominiums, and townhouses were coded as high-density residential, whereas single-family and mixed multi-family residential were coded as low-density residential, because it is likely that this coding will serve the GSWI Study more realistically than the original coding in the data source.

3.3.1.4 United Water Conservation District

The land use survey conducted by UWCD included agricultural descriptions only. No urban LUCs were included. These categories translated easily to the standardized LUCs.

3.3.2 Conceptualization of Land Use

The spatial distribution of LUCs will be used to evaluate the fraction of each LUC at any given location (i.e., within each spatially discretized model grid-block) to parameterize properties that are related to the LUCs. The fraction of each LUC at a given location or discretized model grid-block (LFi) is the area of model grid-block "i" that is covered by that LUC divided by the total area of model grid-block "i." The sum of all LFi terms within each grid-block equals one. Figure 3-16 illustrates the concept of calculating land use area fractions. These calculations are performed using the same GIS scripts written for use with ESRI® ArcGIS™ Version 9.1 used to compute SFi terms for soil types discussed in Section 3.2.

As noted earlier, LUC distributions will be available for specific years between 1980 and 2005 (inclusive) for GSWIM. The LFi values for each of these years will be computed to represent the fractional area of a grid-block covered by each LUC for each of the years when the LUC distributions are available. The LUC distributions will then be conceptualized as varying annually in a linear manner, through linear interpolation of the LFi values for each grid-block, between the available LFi values. The assumption inherent in this approach is that temporal land use changes, such as urbanization or crop changes, occur in a linear manner between periods for which land use mapping is available.

Short-term effects of fires on the infiltration properties of the land cover are initially assumed to be negligible. If, during calibration, there is a technical justification to consider such effects, this topic can be discussed at a future GSWI Modeling Subcommittee meeting to gain consensus on an appropriate approach for conceptualizing these effects.

3.3.3 Computation of Properties Related to Land Use

Several hydrologic properties are related to land use and cover, including parameters related to ET (e.g., LAI, Kc, and RDF) as discussed in Section 2.0 and parameters related to surface hydrology (e.g., surface leakance and Manning's friction coefficient) as discussed in Section 5.0. LUC properties will be evaluated at a given model grid-block via an area-weighted average of the property value for each LUC at that grid-block at the given time. The LFi values are used as weighting factors for the individual LUC property values.

3.3.4 Conceptualization of Applied Water Related to Land Use

Another important consideration of land use is how water is used within specific areas. Water is supplied by either public or private utilities or by individual domestic wells. Some of that water is used indoors and then conveyed to wastewater treatment plants (WWTP) or WRPs, or to individual septic systems, and some is used outdoors for irrigation. Water used for irrigation is applied to vegetation on the land surface at rates and frequencies that depend on the portion of a crop's ET demand that is not met by precipitation alone and the irrigation efficiency associated with the irrigation method (e.g., sprinklers versus drip). Regardless of the source of irrigation water (imported water, surface water, or groundwater), this applied water needs to be accounted for with an appropriate distribution and rate within the modeling domain that depends on the areal water application demands. To facilitate these computations, a method was developed to spatially apply water to grid-blocks falling within a given water use area. Following are two examples that illustrate the challenge of appropriately applying water in the modeling domain:

- Water delivered to specific water purveyor service areas and used outdoors can only be applied to appropriate land uses that are located within that service area. In addition, the total volume of applied water within that service area must be consistent with the outdoor water fraction of water delivered to that service area through time.
- A field crop that is irrigated with water produced from a local production well(s) must receive an appropriate areal distribution of applied water in the modeling domain (according to crop type and irrigation method) that is also consistent with the volume of water pumped from the production well(s) associated with that field crop.

The method for addressing these modeling challenges is described below.

3.3.4.1 Delineation of Irrigated Areas

Using available land use mapping, parcel maps, and input from local entities such as the Upper Basin Water Purveyors, LACSD, UWCD, or contacts from the local agricultural extension, irrigated areas will be delineated using the best understanding of applied water locations and the sources of water for those areas. For example, CH2M HILL will work with UWCD to identify pumping locations that are associated with specific large-scale crops because the source of irrigation water in many areas of the Piru Subbasin is groundwater delivered by local production wells. The identification method will include intersecting parcel maps with known production well locations and land use mapping, and linking production wells (water source) to crops served by those production wells. If multiple production wells fall within a given parcel, it will be initially assumed that the combined water supplied by all production wells located within that parcel is used to irrigate crops located within that parcel. These associations between water source and irrigated areas will also vary with time (e.g., urbanization, or changing cropping patterns or water requirements).

3.3.4.2 Node-link Method

After the associations between water source and irrigated areas are established, these associations will be conceptualized within the GSWIM domain. A description of the planned method to account for this follows.

WFi is defined as the area of model grid-block "i" that falls within a given irrigated area divided by the total irrigated area. Note that the sum of WFi values at grid-blocks that fall within a particular irrigated area equals one. Figure 3-17 illustrates the concept of calculating the grid-block fraction of a total irrigated area. These calculations are performed using GIS scripts written for use with ESRI® ArcGIS™ Version 9.1. The WFi values will be computed for years at which land use mapping is available.

After the WFi terms are computed for a given snapshot in time, node-links will be identified within MODHMS. A node-link is a set of instructions that are input into MODHMS that establishes a link between water sources and irrigated areas. For example, a grid-block representing a pumping well will be associated (linked) with all grid-blocks that represent the irrigated area to which water is applied from that well. Table 3-5 shows an example calculation using this node-link concept, whereby a hypothetical well supplies irrigation water to the grid-block areas shown on Figure 3-17 at a hypothetical total rate of 15 acre-feet per month (acre-ft/month). The applied water rate for each irrigated area is distributed over the surficial layer of the modeling domain using the WFi weighting factors for each of the irrigated areas.

TABLE 3-1
WARMF Soil Parameters
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

WARMF Soil Parameter	Soil Type A	Soil Type B	Soil Type C	Soil Type D
Layer 1 Thickness (cm)	37, 46.5	37	37	45
Layer 1 Field Capacity	0.25, 0.3	0.3, 0.25	0.19, 0.25	0.24
Layer 1 Saturated Moisture Content	0.4	0.4	0.4	0.4
Layer 1 Kh (cm/day)	720, 1,500	1000	600, 720, 1,200	72
Layer 1 Kv (cm/day)	5.5, 72	8, 80	7, 7.5, 8, 72	8.2
Layer 1 RDF	0.75	0.75	0.6, 0.69, 0.75	0.6
Layer 2 Thickness (cm)	46.8, 54	54	40, 52, 54	62
Layer 2 Field Capacity	0.15, 0.23	0.23	0.154, 0.23	0.21, 0.23
Layer 2 Saturated Moisture Content	0.35, 0.355	0.35	0.35, 0.359	0.35, 0.37
Layer 2 Kh (cm/day)	800, 1500	700	80, 120, 240, 600	50.003, 80
Layer 2 Kv (cm/day)	80	80	78.665, 80	78.5, 79.25, 80
Layer 2 RDF	0.15	0.2	0.2, 0.21, 0.24, 0.25	0.2
Layer 3 Thickness (cm)	28, 29	78	78, 128, 130, 140	150
Layer 3 Field Capacity	0.175, 0.19	0.19	0.19, 0.191	0.17
Layer 3 Saturated Moisture Content	0.327, 0.35	0.35	0.349, 0.35	0.35, 0.37
Layer 3 Kh (cm/day)	560, 860	200	40, 56	25
Layer 3 Kv (cm/day)	56	56	10, 56	9.999, 56
Layer 3 RDF	0.1	0.05	0.01, 0.1, 0.15, 0.2	0.2
Layer 4 Thickness (cm)	NA, 10,000	NA, 1000	NA, 10,000	NA, 10,000
Layer 4 Field Capacity	NA, 0.2	NA, 0.2	NA, 0.2	NA, 0.2
Layer 4 Saturated Moisture Content	NA, 0.3	NA, 0.3	NA, 0.3	NA, 0.3
Layer 4 Kh (cm/day)	NA, 0	NA, 0	NA, 0	NA, 0
Layer 4 Kv (cm/day)	NA, 56	NA, 56	NA, 10, 56	NA, 9.999
Layer 4 RDF	NA, 0	NA, 0	NA, 0	NA, 0
Soil Type Classification Parameter	560	200	40	25

Notes:

cm = centimeter

See the *Final Task 1 Report for Santa Clara River Nutrient TMDL Analysis: Source Identification and Characterization* (Systech Engineering, 2002a) for further details on soil parameters listed here.

TABLE 3-2
Example Calculation of an Area-weighted Soil Property for a Given Model Grid-block
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Hydrologic Soil Group	Kv of Soil Group (cm/sec)	SFi of Soil Group within Grid-block	Area-weighted Kv (cm/sec)
A	10^{-2}	0.10	1.00×10^{-3}
B	10^{-6}	0.05	5.00×10^{-8}
C	10^{-5}	0.33	3.30×10^{-6}
D	10^{-3}	0.52	5.20×10^{-4}
	Sum	1.00	1.52×10^{-3} (assigned to model grid-block)

Notes:

Area-weighted Kv = (Kv of LUC) x (SFi of LUC within grid-block), where:
Kv = vertical hydraulic conductivity
cm/sec = centimeters per second

TABLE 3-3
Standardized List of Land Use Codes for the GSWI Study
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Standardized Land Use Code	Definition
Nonirrigated	
Native Vegetation	Nonirrigated grasslands, brush, and forest located outside of riparian corridors.
Riparian Vegetation	Nonirrigated shrubs, grasses, and trees located within riparian corridors.
Barren	Nonirrigated areas lacking vegetation.
Vacant	Nonirrigated paved areas, including parking lots, roads, tennis courts, sales lots, and runways.
Water	Surfaces of reservoirs, perennial streams, and canals.
Irrigated	
Improved Pasture	Irrigated alfalfa, clover, and grass.
Strawberries	Irrigated strawberry crops.
Nursery Crops	Irrigated tree farms and flower crops.
Truck Crops	Irrigated small vegetable crops, including lettuce, cabbage, broccoli, cauliflower, carrots, celery, parsley, cilantro, radishes, and peppers for the GSWI Study.
Citrus and Avocados	Irrigated crops of oranges, grapefruits, lemons, and avocados.
Golf Course	Irrigated golf courses.
Urban Commercial/Industrial	Partially irrigated commercial/industrial areas serviced by sewerage systems, such as WWTPs or WRPs. Includes offices, hotels, institutions, schools, businesses, parks, facilities, warehouses, mills, airports, installations, and refineries.
Rural Commercial/Industrial	Partially irrigated commercial/industrial areas not serviced by sewerage systems (use septic tanks). Includes offices, hotels, institutions, schools, businesses, parks, facilities, warehouses, mills, airports, installations, and refineries.
Urban High-density Residential	Partially irrigated residential areas serviced by sewerage systems, such as WWTPs or WRPs, located in areas with multiple units per acre.
Urban Low-density Residential	Partially irrigated residential areas serviced by sewerage systems, such as WWTPs or WRPs, located in areas with few units per acre.
Rural High-density Residential	Partially irrigated residential areas not serviced by sewerage systems (use septic tanks), located in areas with multiple units per acre.
Rural Low-density Residential	Partially irrigated residential areas not serviced by sewerage systems (use septic tanks), located in areas with few units per acre.

TABLE 3-4
Standardization Key of Original Land Use Codes
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Source	Original LUC	Original LUC Description	GSWI Standardized LUC
BASINS 1980	11	Residential	Urban Low-density Residential
BASINS 1980	12	Commercial and Services	Urban Commercial/Industrial
BASINS 1980	13	Industrial	Urban Commercial/Industrial
BASINS 1980	14	Trans, Comm, UTIL	Urban Commercial/Industrial
BASINS 1980	15	Indust & Commerc CMPLXS	Urban Commercial/Industrial
BASINS 1980	16	MXD Urban or Built-up	Urban Low-density Residential
BASINS 1980	17	Other Urban or Built-up	Urban Commercial/Industrial
BASINS 1980	21	Cropland and Pasture	Improved Pasture
BASINS 1980	22	Orch, Grov, Vnyrd, Nurs, Orn	Nursery Crops
BASINS 1980	23	Confined Feeding Ops	Rural Commercial/Industrial
BASINS 1980	24	Other Agricultural Land	Improved Pasture
BASINS 1980	31	Herbaceous Rangeland	Native Vegetation
BASINS 1980	32	Shrub & Brush Rangeland	Native Vegetation
BASINS 1980	33	Mixed Rangeland	Native Vegetation
BASINS 1980	41	Deciduous Forest Land	Native Vegetation
BASINS 1980	42	Evergreen Forest Land	Barren
BASINS 1980	43	Mixed Forest Land	Native Vegetation
BASINS 1980	51	Streams and Canals	Water
BASINS 1980	52	Lakes	Water
BASINS 1980	53	Reservoirs	Water
BASINS 1980	54	Bays and Estuaries	Barren
BASINS 1980	61	Forested Wetland	Riparian Vegetation
BASINS 1980	62	Nonforested Wetland	Riparian Vegetation
BASINS 1980	71	Dry Salt Flats	Barren
BASINS 1980	72	Beaches	Barren
BASINS 1980	73	Sandy Area (Non-Beach)	Barren
BASINS 1980	74	Bare Exposed Rock	Barren
BASINS 1980	75	Strip Mines	Barren
BASINS 1980	76	Transitional Areas	Barren

TABLE 3-4
Standardization Key of Original Land Use Codes
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Source	Original LUC	Original LUC Description	GSWI Standardized LUC
DWR: 1998 to present	C	Citrus and Subtropical - All subclasses	Citrus and Avocado
DWR: 1998 to present	D	Deciduous Fruits and Nuts	Citrus and Avocado
DWR: 1998 to present	F	Field Crops	Native Vegetation
DWR: 1998 to present	G	Grain and Hay Crops	Improved Pasture
DWR: 1998 to present	I	Idle	Barren
DWR: 1998 to present	I1	Idle – Fallow	Barren
DWR: 1998 to present	I2	Idle - New land being prepared for crop production	Barren
DWR: 1998 to present	NB	Barren and Wasteland - All subclasses	Native Vegetation
DWR: 1998 to present	NC	Native Classes - No subclasses	Native Vegetation
DWR: 1998 to present	NR	Native Riparian - All subclasses	Native Vegetation
DWR: 1998 to present	NV	Native Vegetation - All subclasses	Native Vegetation
DWR: 1998 to present	NW	Water Surface - All subclasses	Water
DWR: 1998 to present	P	Pasture	Improved Pasture
DWR: 1998 to present	P1	Pasture - Alfalfa and alfalfa mixtures	Improved Pasture
DWR: 1998 to present	P2	Pasture – Clover	Improved Pasture
DWR: 1998 to present	P3	Pasture - Mixed pasture	Improved Pasture
DWR: 1998 to present	P4	Pasture - Native pasture	Native Vegetation
DWR: 1998 to present	P5	Pasture - Induced high water native pasture	Improved Pasture
DWR: 1998 to present	P6	Pasture - Misc. grasses (normally grown for seed)	Improved Pasture
DWR: 1998 to present	P7	Pasture - Turf farms	Golf Course
DWR: 1998 to present	RC	Recreational Commercial	Urban Low-density Residential

TABLE 3-4
Standardization Key of Original Land Use Codes
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Source	Original LUC	Original LUC Description	GSWI Standardized LUC
DWR: 1998 to present	RR	Recreational Residential	Urban Low-density Residential
DWR: 1998 to present	RT	Recreational Vehicle and Camp Sites	Urban Low-density Residential
DWR: 1998 to present	RV	Recreational Vacant	Vacant
DWR: 1998 to present	S	Semiagricultural and Incidental to Agriculture	Rural Low-density Residential
DWR: 1998 to present	S1	Semiagricultural and Incidental to Agriculture - Farmsteads	Rural Low-density Residential
DWR: 1998 to present	S2	Semiagricultural and Incidental to Agriculture - Feedlots	Rural Commercial/Industrial
DWR: 1998 to present	S3	Semiagricultural and Incidental to Agriculture - Dairies	Rural Commercial/Industrial
DWR: 1998 to present	S4	Semiagricultural and Incidental to Agriculture - Lawn areas	Golf Course
DWR: 1998 to present	SR	Suburban Residential	Urban High-density Residential
DWR: 1998 to present	T	Truck, Nursery and Berry Crops	Truck Crops
DWR: 1998 to present	T1 through T-15	Truck	Truck Crops
DWR: 1998 to present	T16	Flowers, Nursery and Christmas Tree Farms	Nursery Crops
DWR: 1998 to present	T17 through T-19	Truck	Truck Crops
DWR: 1998 to present	T20	Strawberries	Strawberries
DWR: 1998 to present	T21	Peppers	Truck Crops
DWR: 1998 to present	T22 through T25	Truck	Truck Crops
DWR: 1998 to present	U	Urban	Urban Low-density Residential
DWR: 1998 to present	UC	Urban Commercial	Urban Commercial/Industrial
DWR: 1998 to present	UI	Urban Industrial	Urban Commercial/Industrial
DWR: 1998 to present	UL	Urban Landscape	Golf Course
DWR: 1998 to present	UL1	Urban Landscape - Lawn area, irrigated	Golf Course

TABLE 3-4
Standardization Key of Original Land Use Codes
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Source	Original LUC	Original LUC Description	GSWI Standardized LUC
DWR: 1998 to present	UL2	Urban Landscape - Golf course, irrigated	Golf Course
DWR: 1998 to present	UL3	Urban Landscape - Ornamental landscape (excluding lawns), irrigated	Golf Course
DWR: 1998 to present	UL4	Urban Landscape - Cemeteries, irrigated	Improved Pasture
DWR: 1998 to present	UL5	Urban Landscape - Cemeteries, not irrigated	Native Vegetation
DWR: 1998 to present	UR1	Urban Residential - Single family large lot	Urban Low-density Residential
DWR: 1998 to present	UR2	Urban Residential - Single small lot	Urban Low-density Residential
DWR: 1998 to present	UR3	Urban Residential - Multiple family	Urban High-density Residential
DWR: 1998 to present	UR4	Urban Residential - Trailer courts	Urban Low-density Residential
DWR: 1998 to present	UV	Urban Vacant	Vacant
DWR: 1998 to present	V	Vineyards	Native Vegetation
DWR: before 1993	C	Subtropical Fruits - All	Citrus and Avocado
DWR: before 1993	I1	Idle - Fallow	Barren
DWR: before 1993	I2	Idle - New land being prepared for crop production	Barren
DWR: before 1993	NB	Barren and Wasteland - All subclasses	Native Vegetation
DWR: before 1993	NC	Native Classes - No subclasses	Native Vegetation
DWR: before 1993	NR	Native Riparian - All subclasses	Native Vegetation
DWR: before 1993	NV	Native Vegetation - All subclasses	Native Vegetation
DWR: before 1993	NW	Water Surface - All subclasses	Water
DWR: before 1993	P1	Pasture - Alfalfa and alfalfa mixtures	Improved Pasture
DWR: before 1993	P2	Pasture - Clover	Improved Pasture
DWR: before 1993	P3	Pasture - Mixed pasture	Improved Pasture

TABLE 3-4
Standardization Key of Original Land Use Codes
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Source	Original LUC	Original LUC Description	GSWI Standardized LUC
DWR: before 1993	P4	Pasture - Native pasture	Native Vegetation
DWR: before 1993	P5	Pasture - Induced high water native pasture	Improved Pasture
DWR: before 1993	P6	Pasture - Misc. grasses (normally grown for seed)	Improved Pasture
DWR: before 1993	P7	Pasture - Turf farms	Golf Course
DWR: before 1993	RC	Recreational Commercial	Urban Low-density Residential
DWR: before 1993	RR	Recreational Residential	Urban Low-density Residential
DWR: before 1993	RT	Recreational Vehicle and Camp Sites	Urban Low-density Residential
DWR: before 1993	RV	Recreational Vacant	Vacant
DWR: before 1993	S1	Semiagricultural and Incidental to Agriculture - Farmsteads	Rural Low-density Residential
DWR: before 1993	S2	Semiagricultural and Incidental to Agriculture - Feedlots	Rural Commercial/Industrial
DWR: before 1993	S3	Semiagricultural and Incidental to Agriculture - Dairies	Rural Commercial/Industrial
DWR: before 1993	S4	Semiagricultural and Incidental to Agriculture - Lawn areas	Golf Course
DWR: before 1993	S5	Semiagricultural and Incidental to Agriculture - Cemeteries	Improved Pasture
DWR: before 1993	SR	Suburban Residential	Urban High-density Residential
DWR: before 1993	T1 through T-3	Truck	Truck Crops
DWR: before 1993	T4	Truck, Nursery and Berry Crops - Cole crops (misc. cruciferous)	Truck Crops
DWR: before 1993	T5 through T-15	Truck	Truck Crops
DWR: before 1993	T16	Truck, Nursery and Berry Crops - Nursery	Nursery Crops
DWR: before 1993	T17	Truck	Truck Crops
DWR: before 1993	T18	Truck, Nursery and Berry Crops - Miscellaneous truck	Truck Crops
DWR: before 1993	T19	Truck	Truck Crops

TABLE 3-4
Standardization Key of Original Land Use Codes
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Source	Original LUC	Original LUC Description	GSWI Standardized LUC
DWR: before 1993	T20	Strawberries	Strawberries
DWR: before 1993	T21	Truck, Nursery and Berry Crops - Peppers	Truck Crops
DWR: before 1993	T22 through T25	Truck	Truck Crops
DWR: before 1993	UC	Urban Commercial	Urban Commercial/Industrial
DWR: before 1993	UI	Urban Industrial	Urban Commercial/Industrial
DWR: before 1993	UR1	Urban Residential - Single family large lot	Urban Low-density Residential
DWR: before 1993	UR2	Urban Residential - Single small lot	Urban Low-density Residential
DWR: before 1993	UR3	Urban Residential - Multiple family	Urban High-density Residential
DWR: before 1993	UR4	Urban Residential - Trailer courts	Urban Low-density Residential
DWR: before 1993	UV	Urban Vacant	Vacant
SCAG	1111	High Density Single Family Residential	Urban Low-density Residential
SCAG	1112	Low Density Single Family Residential	Urban Low-density Residential
SCAG	1121	Mixed Multi-Family Residential	Urban Low-density Residential
SCAG	1122	Duplexes, Triplexes, and 2- or 3-Unit Condominiums and Townhouses	Urban Low-density Residential
SCAG	1123	Low-Rise Apartments, Condominiums, and Townhouses	Urban High-density Residential
SCAG	1124	Medium-Rise Apartments and Condominiums	Urban High-density Residential
SCAG	1125	High-Rise Apartments and Condominiums	Urban High-density Residential
SCAG	1131	Trailer Parks and Mobile Home Courts, High Density	Urban Low-density Residential
SCAG	1132	Mobile Home Courts and Subdivisions, Low Density	Urban Low-density Residential
SCAG	1140	Mixed Residential	Urban Low-density Residential
SCAG	1151	Rural Residential High Density	Rural High-density Residential

TABLE 3-4
Standardization Key of Original Land Use Codes
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Source	Original LUC	Original LUC Description	GSWI Standardized LUC
SCAG	1152	Rural Residential Low Density	Rural Low-density Residential
SCAG	1211	Low- to Medium-Rise Major Office Use	Urban Commercial/Industrial
SCAG	1212	High-Rise Major Office Use	Urban Commercial/Industrial
SCAG	1213	Skyscrapers	Urban Commercial/Industrial
SCAG	1221	Regional Shopping Center	Urban Commercial/Industrial
SCAG	1222	Retail Centers (Nonstrip w/Contiguous Interconnected Off-Street Parking)	Urban Commercial/Industrial
SCAG	1223	Modern Strip Development	Urban Commercial/Industrial
SCAG	1224	Older Strip Development	Urban Commercial/Industrial
SCAG	1231	Commercial Storage	Urban Commercial/Industrial
SCAG	1232	Commercial Recreation	Urban Commercial/Industrial
SCAG	1233	Hotels and Motels	Urban Commercial/Industrial
SCAG	1234	Attended Pay Public Parking Facilities	Urban Commercial/Industrial
SCAG	1241	Government Offices	Urban Commercial/Industrial
SCAG	1242	Police and Sheriff Stations	Urban Commercial/Industrial
SCAG	1243	Fire Stations	Urban Commercial/Industrial
SCAG	1244	Major Medical Health Care Facilities	Urban Commercial/Industrial
SCAG	1245	Religious Facilities	Urban Commercial/Industrial
SCAG	1246	Other Public Facilities	Urban Commercial/Industrial
SCAG	1247	Non-Attended Public Parking Facilities	Urban Commercial/Industrial
SCAG	1251	Correctional Facilities	Urban Commercial/Industrial
SCAG	1252	Special Care Facilities	Urban Commercial/Industrial

TABLE 3-4
Standardization Key of Original Land Use Codes
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Source	Original LUC	Original LUC Description	GSWI Standardized LUC
SCAG	1253	Other Special Use Facilities	Urban Commercial/Industrial
SCAG	1261	Pre-Schools/Day Care Centers	Urban Commercial/Industrial
SCAG	1262	Elementary Schools	Urban Commercial/Industrial
SCAG	1263	Junior High Schools	Urban Commercial/Industrial
SCAG	1264	Senior High Schools	Urban Commercial/Industrial
SCAG	1265	Colleges and Universities	Urban Commercial/Industrial
SCAG	1266	Trade Schools	Urban Commercial/Industrial
SCAG	1271	Base (Built-Up Area)	Urban Commercial/Industrial
SCAG	1272	Vacant Area	Native Vegetation
SCAG	1273	Air Field	Vacant
SCAG	1274	Former Military Base (Built-Up Area)	Urban Commercial/Industrial
SCAG	1275	Former Military Vacant Area	Native Vegetation
SCAG	1276	Former Military Air Field	Vacant
SCAG	1311	Manufacturing, Assembly, and Industrial Services	Urban Commercial/Industrial
SCAG	1312	Motion Picture and Television Studio Lots	Urban Commercial/Industrial
SCAG	1313	Packing Houses and Grain Elevators	Urban Commercial/Industrial
SCAG	1314	Research and Development	Urban Commercial/Industrial
SCAG	1321	Manufacturing	Urban Commercial/Industrial
SCAG	1322	Petroleum Refining and Processing	Urban Commercial/Industrial
SCAG	1323	Open Storage	Barren
SCAG	1324	Major Metal Processing	Urban Commercial/Industrial
SCAG	1325	Chemical Processing	Urban Commercial/Industrial
SCAG	1331	Mineral Extraction - Other Than Oil and Gas	Barren
SCAG	1332	Mineral Extraction - Oil and Gas	Barren

TABLE 3-4
Standardization Key of Original Land Use Codes
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Source	Original LUC	Original LUC Description	GSWI Standardized LUC
SCAG	1340	Wholesaling and Warehousing	Urban Commercial/Industrial
SCAG	1411	Airports	Urban Commercial/Industrial
SCAG	1412	Railroads	Vacant
SCAG	1413	Freeways and Major Roads	Vacant
SCAG	1414	Park and Ride Lots	Vacant
SCAG	1415	Bus Terminals and Yards	Vacant
SCAG	1416	Truck Terminals	Vacant
SCAG	1417	Harbor Facilities	Urban Commercial/Industrial
SCAG	1418	Navigation Aids	Barren
SCAG	1420	Communication Facilities	Native Vegetation
SCAG	1431	Electrical Power Facilities	Urban Commercial/Industrial
SCAG	1432	Solid Waste Disposal Facilities	Urban Commercial/Industrial
SCAG	1433	Liquid Waste Disposal Facilities	Urban Commercial/Industrial
SCAG	1434	Water Storage Facilities	Urban Commercial/Industrial
SCAG	1435	Natural Gas and Petroleum Facilities	Urban Commercial/Industrial
SCAG	1436	Water Transfer Facilities	Urban Commercial/Industrial
SCAG	1437	Improved Flood Waterways and Structures	Water
SCAG	1438	Mixed Wind Energy Generation and Percolation Basin	Barren
SCAG	1440	Maintenance Yards	Urban Commercial/Industrial
SCAG	1450	Mixed Transportation	Native Vegetation
SCAG	1460	Mixed Transportation and Utility	Native Vegetation
SCAG	1500	Mixed Commercial and Industrial	Urban Commercial/Industrial
SCAG	1600	Mixed Urban	Urban Commercial/Industrial
SCAG	1700	Under Construction	Barren
SCAG	1810	Golf Courses	Golf Course
SCAG	1820	Local Parks and Recreation	Golf Course
SCAG	1821	Developed Local Parks and Recreation	Golf Course

TABLE 3-4
Standardization Key of Original Land Use Codes
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Source	Original LUC	Original LUC Description	GSWI Standardized LUC
SCAG	1822	Undeveloped Local Parks and Recreation	Native Vegetation
SCAG	1830	Regional Parks and Recreation	Improved Pasture
SCAG	1831	Developed Regional Parks and Recreation	Golf Course
SCAG	1832	Undeveloped Regional Parks and Recreation	Native Vegetation
SCAG	1840	Cemeteries	Improved Pasture
SCAG	1850	Wildlife Preserves and Sanctuaries	Native Vegetation
SCAG	1860	Specimen Gardens and Arboreta	Nursery Crops
SCAG	1870	Beach Parks	Barren
SCAG	1880	Other Open Space and Recreation	Improved Pasture
SCAG	1900	Urban Vacant	Vacant
SCAG	2110	Irrigated Cropland and Improved Pasture Land	Improved Pasture
SCAG	2120	NonIrrigated Cropland and Improved Pasture Land	Native Vegetation
SCAG	2200	Orchards and Vineyards	Citrus and Avocado
SCAG	2300	Nurseries	Nursery Crops
SCAG	2400	Dairy and Intensive Livestock, and Associated Facilities	Rural Commercial/Industrial
SCAG	2500	Poultry Operations	Rural Commercial/Industrial
SCAG	2600	Other Agriculture	Rural Commercial/Industrial
SCAG	2700	Horse Ranches	Improved Pasture
SCAG	3100	Vacant Undifferentiated	Native Vegetation
SCAG	3200	Abandoned Orchards and Vineyards	Native Vegetation
SCAG	3300	Vacant with Limited Improvements	Vacant
SCAG	3400	Beaches (Vacant)	Barren
SCAG	4100	Water, Undifferentiated	Water
SCAG	4200	Harbor Water Facilities	Water
SCAG	4300	Marina Water Facilities	Water
SCAG	4400	Water Within a Military Installation	Water
SCAG	4500	Area of Inundation (High Water)	Water
SCAG	9999	No Photo Coverage	Native Vegetation
UWCD 1997 and 2002	Berry	Berry	Strawberries
UWCD 1997 and 2002	NC	Avocado	Citrus and Avocado
UWCD 1997 and 2002	NC	Citrus	Citrus and Avocado

TABLE 3-4
Standardization Key of Original Land Use Codes
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

Source	Original LUC	Original LUC Description	GSWI Standardized LUC
UWCD 1997 and 2002	NC	Dairy	Rural Commercial/Industrial
UWCD 1997 and 2002	NC	Duck Club	Native Vegetation
UWCD 1997 and 2002	NC	Horse Ranch	Improved Pasture
UWCD 1997 and 2002	NC	Nursery	Truck Crops
UWCD 1997 and 2002	NC	Pasture	Native Vegetation
UWCD 1997 and 2002	NC	Poultry	Rural Commercial/Industrial
UWCD 1997 and 2002	NC	Row	Truck Crops
UWCD 1997 and 2002	NC	Sod	Golf Course
UWCD 1997 and 2002	NC	Strawberry	Strawberries
UWCD 1997 and 2002	NC	Transition	Barren
UWCD 1997 and 2002	NC	Unkn-Orch	Native Vegetation

TABLE 3-5
Example Calculation of Area-weighted Irrigation by Grid-block
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

MODHMS Row of Grid-block[a]	MODHMS Column of Grid-block[a]	WFi of Irrigated Area within Grid-block[a]	Area-weighted Applied Water Rate[b] (acre-ft/month)
4	2	0.003	0.05
4	3	0.018	0.27
4	4	0.026	0.39
4	5	0.020	0.30
4	6	0.007	0.11
5	1	0.003	0.05
5	2	0.025	0.38
5	3	0.032	0.48
5	4	0.032	0.48
5	5	0.032	0.48
5	6	0.031	0.47
5	7	0.014	0.21
6	1	0.014	0.21
6	2	0.032	0.48
6	3	0.032	0.48
6	4	0.032	0.48
6	5	0.032	0.48
6	6	0.032	0.48
6	7	0.024	0.36
7	1	0.020	0.30
7	2	0.032	0.48
7	3	0.032	0.48
7	4	0.032	0.48
7	5	0.032	0.48
7	6	0.032	0.48
7	7	0.030	0.45
8	1	0.011	0.17
8	2	0.032	0.48
8	3	0.032	0.48
8	4	0.032	0.48
8	5	0.032	0.48
8	6	0.032	0.48
8	7	0.025	0.38
9	1	0.001	0.02
9	2	0.015	0.23
9	3	0.030	0.45

TABLE 3-5
Example Calculation of Area-weighted Irrigation by Grid-block
Task 2A – Conceptual Model Development, Upper Santa Clara River Chloride TMDL Collaborative Process

MODHMS Row of Grid-block[a]	MODHMS Column of Grid-block[a]	WFi of Irrigated Area within Grid-block[a]	Area-weighted Applied Water Rate[b] (acre-ft/month)
9	4	0.032	0.48
9	5	0.032	0.48
9	6	0.023	0.35
9	7	0.004	0.06
10	3	0.005	0.08
10	4	0.006	0.09
10	5	0.005	0.08
	Sum	**1.000**	**15.00**

[a]See Figure 3-17.

[b]Assume 15 acre-ft/month applied water requirement for example.

Note:

Area-weighted applied water rate = (15 acre-ft/month) x (WFi of irrigated area within grid-block).

This page intentionally left blank.