San Luis Obispo County Flood Control and Water Conservation District

DATA ENHANCEMENT PLAN

Grant Agreement No. 4600004505

December 2008

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Executive Summary

The Nation possesses abundant water resources and has developed and used those resources extensively. The future health and economic welfare of the region's population are dependent upon a continuing supply of fresh uncontaminated water. Many existing sources of water are being stressed by withdrawals to meet off-stream needs along with increasing in-stream-flow requirements to meet human and environmental needs.

Almost every sector of the Nation's economy has some requirement for water information for planning, developmental, and operational purposes. Accurate information on the condition and trends of a region's water resources is required as a basis for economic and social development, and for maintenance of environmental water quality.

Water resources data serves many purposes. However, the data must be analyzed in order to serve those purposes. Most analysis falls into one of these four categories:

- a.) The quantity of water supplies;
- b.) The quantity of water demands;
- c.) The quality of water for human consumption and use; and
- d.) The quality of water for environmental uses.

Adequate data is required to conduct a sufficient analysis to serve the purposes described above. Consequently, this requires a large variation both in the type of data collected, and the size and complexity of the data collection network, as described below.

In order to determine the desirable water resources data collection network, the kinds of data to be collected and the reasons for collecting data must be considered. The key questions to be addressed in establishing a monitoring program for management are what to measure, where to measure or record each parameter, and why.

In general, a well-designed data collection program provides the necessary information to determine the sources, extent, dependability, and quality of water resources, upon which is based an evaluation of the possibilities for their utilization and control. The proposed regional water monitoring program is designed to provide data for planning, design, and operational, purposes, yet it is also designed to be flexible and to change over time. The aim of this network is to provide a density and distribution of stations in a region so that, by interpolation between data sets at different stations, it will be possible to determine with sufficient accuracy for practical purposes, the characteristics of the basic hydrological and meteorological elements anywhere in the region.

With an understanding of the necessary data collection components needed for a regional water resources data collection network and information on the current regional data collection program, it is possible to identify the regional data gaps, summarized in the following table:

	Additional Gauge needs
Precipitation	
Recording Rain Gauges	12-15
Storage Rain Gauges	30-37
Real-Time Rain Gauges	4
Evaporation	
Evaporation Pans or Weather Stations	2
Streams	
Gauge Sites (with discharge)	7-9
Real-time Stage-only Gauge Sites	6
Groundwater	
Wells	75

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1. Introduction

Water, our most valuable resource, is essential to our daily life. Protecting and managing our water resources is paramount to the continued economic vitality of the County of San Luis Obispo, the health of our residents, and the viability of our environment.

The Nation possesses abundant water resources and has developed and used those resources extensively. The future health and economic welfare of the region's population are dependent upon a continuing supply of fresh uncontaminated water. Many existing sources of water are being stressed by withdrawals to meet off-stream needs along with increasing in-stream-flow requirements to meet human and environmental needs. Recent drought in some areas has accentuated the need to balance water demand with available supply.

To preserve this resource, accurate and comprehensive water resource data are critical to planners and decision-makers at all levels of government, researchers, developers and the business community. Now more than ever, the increasing need to manage our precious natural resources is driving the need for more detailed water and natural resources data for many areas of the region and the Nation.

Managers of water resources systems need to know what is taking place in their systems, both over time and over space. Monitoring provides information on the state of the system. The process of water resources monitoring is more than just measuring system attributes, collecting, storing, analyzing and publishing the measured data, and then acting on the results. It is a sequence of related activities that starts with the identification of information needs, and ends with the use of the information.

In order to determine the desirable water resourced data collection network, the kinds of data to be collected and the reasons for collecting data must be considered. The key questions to be addressed in establishing a monitoring program for management are what to measure, where to measure or record each parameter, and why. The challenge is to know when the information derived from a monitoring program is sufficient to act upon, as well as what action to take.

The regional water monitoring program focuses on monitoring efforts to determine conditions and trends in streams, lakes and reservoirs, groundwater and precipitation for planning, development, and operational purposes.

The regional water monitoring program is designed to provide data for planning, design, and operational, purposes, yet it is also designed to be flexible and to change over time. This is not necessarily contradictory. Rather, it implies that regional water monitoring program data will be frequently interpreted to identify monitoring sites that might be dropped from the network or sampled less frequently, as well as identifying spatial gaps or the need for more frequent data collection. The design also recognizes that there will continue to be improvements in instrumentation that will allow for more in-situ monitoring and the collection of more data by remote sensing. New technologies will be incorporated into the regional water monitoring program when they are ready for operational deployment.

There is a great deal of monitoring in the region that does not fall under the general umbrella of a regional water monitoring program. This monitoring continues to be important and necessary for resource management. For example, the regional water monitoring program will provide critical information at a regional scale. However, there are problems that will not be identified and environmental responses to management actions that will not be tracked simply because they happen at a smaller scale than the regional water monitoring program is designed to detect. Monitoring at this finer scale in small rivers, lakes, reservoirs, local ground water aquifers, and in smaller watersheds will continue to be needed and will be the primary responsibility of particular agencies.

2. Water Resources Data Uses and Requirements

2.1. Purposes for Regional Water Monitoring

Accurate information on the condition and trends of a region's water resources is required as a basis for economic and social development, and for maintenance of environmental water quality. Almost every sector of the Nation's economy has some requirement for water information for the following purposes[1]:

a.) Planning purposes;
b.) Development purposes; and
c.) Operational purposes.

2.1.1. Planning Purposes

Water planning activities are usually motivated by the realization that there are both problems to solve, and opportunities to obtain increased benefits, from the use of water and related land resources. These benefits can be measured in many different ways.

Reducing the frequency and/or severity of the adverse consequences of droughts, floods and excessive pollution are common goals of many planning and management exercises. Other goals include the identification and evaluation of alternative measures that may increase the available water supplies, improve recreation, and enhance the quality of water and aquatic ecosystems.

Some of the multiple purposes served by a water source can be conflicting. A reservoir used solely for water supply is better able to meet its objectives when it is full of water, rather than when it is empty. On the other hand, a reservoir used solely for downstream flood control is best left empty, until the flood comes of course. A single reservoir serving these purposes introduces conflicts over how much water to store in it and how it should be operated. In basins where diversion demands exceed the available supplies, conflicts will exist over water allocations. Finding the best way to manage, if not resolve, these conflicts that occur over time and space are other reasons for planning.[2]

2.1.1.1. Water Resources Planning

Water resources planning involves developing, distributing, and optimally utilizing the regions water resources – under defined water polices and regulations. Water resources' planning on a regional level promotes the beneficial use of water for its people, agriculture, and for the environment.

[1] Report on Water Resources Assessment- Handbook for Review of National Capabilities (WMO/UNESCO, 1997)
[2] Water Resources Systems Planning and Management (UNESCO,2005)

2.1.1.2. Flood Management and Planning

Flood warning systems protect life, property and community assets from flooding, and preserve the natural flood carrying and storage functions of floodplains and waterways. Flood warning systems warn areas of flood danger, and provide agencies with critical rainfall, stream level, and other hydro-meteorological data.

Comprehensive flood management and planning is the most effective way to address flood control issues. It incorporates a variety of engineering, environmental protection and planning measures. It includes flood plain management, flood control maintenance activities, stormwater management, shoreline management, protection of frequently flooded areas, watershed management, other flood hazard mitigation activities, and preparation for flood disasters where mitigation activities cannot prevent flooding.

The basic benefit of a local flood warning program is an increased lead time for watches and warnings at locations subject to flood risk. The information can be used to predict whether a flood is about to occur, when it will arrive, and how severe it will be. Organizations and individuals are given notice by the system so they can protect themselves and their property.

2.1.2. Development Purposes

As populations continually move to urban areas for improved opportunities and a higher standard of living, and as towns merge to form cities, the design of water-related systems serving these areas becomes increasingly important.

In addition to supporting life itself, water is used in the production of goods and services. Development projects that require water resources data include the following:

- Water Supply Network Design
- Transportation Infrastructure Design
- Wastewater Collection Design
- Drainage Design and Storm Water Management
- Flood Control Infrastructure Design

2.1.2.1. Water Supply Network Design

A water supply network is a system of engineered hydrologic and hydraulic components, including storage, delivery, treatment, purification, transmission, and distribution. Each of these components has specific water data needs that range from understanding the supply and quality of water available, to determine peak daily water use.

2.1.2.2. Transportation Infrastructure Design

From a water resources perspective, transportation infrastructure design involves reviewing surface hydrology with an aim to control surface runoff. Designing drainage features that control cross-road drainage and remove runoff from a roadway are two methods used to control runoff.

Data needs vary with the each type of drainage feature and require different methods of hydrologic analysis. For most roadway drainage design purposes, there are three primary categories of hydrologic data:

- Surface water runoff;
- Precipitation, and;
- Drainage basin characteristics.

Other special purpose categories of hydrologic data which may be important to specific problems associated with a road project are sediment and debris transport, groundwater levels and quantity, and water quality.

2.1.2.3.Wastewater Collection Design

Wastewater collection design provides for the safe collection and transmission of wastewater through a region's underground sewer mains, collectors and interceptor lines. The design of a wastewater collection system revolves around understanding the anticipated demand on the system and designing a system to meet those needs.

2.1.2.4.Drainage Design

Good drainage design is a matter of properly balancing technical principles and data with the environment giving due consideration to other factors such as safety and economics. As with some transportation infrastructure designs, drainage features are designed to remove runoff from an area and to convey surface and stream waters originating upstream of that area to the downstream side. Proper drainage design aims to minimize objectionable backwater, excessive velocities, erosion, and to increase traffic safety. A general goal in drainage design should be to perpetuate natural drainage, insofar as practical.

Regardless of the size or cost of the drainage feature the most important step prior to hydraulic design is estimating the discharge (rate of runoff) or volume of runoff that the drainage facility will be required to convey or control. As such, having detailed information on precipitation and surface flows is essential.

2.1.2.5.Flood Control Design

Flood control design addresses the design, development, and implementation of systems that protect people and property from damages, injury, and economic loss caused by storm flows. Facilities that are typically included in this effort are: flood control channels, creeks, rivers, dams, retarding basins, pump stations, and other flood control infrastructure. Coordinated design of flood control facilities maximizes flood water management, while protecting irrigation systems and related agricultural lands from potential adverse impacts.

2.1.2.6. Storm Water Management

The term “storm water management” refers to the cooperative efforts of public agencies and the private sector to mitigate, abate, or reverse the adverse results, both in water quantity and water quality, associated with the altered runoff phenomena that typically accompanies urbanization. Storm water management encompasses a number of control measures, which may be either structural or non-structural (including policy and procedural measures) in nature.

The items presented below describe some of the issues to be considered prior to, and during, the design of any storm water management facility. General issues common to most storm water management strategies that need to be evaluated are:

- The effects of the proposed facility on channel capacities and existing floodways require evaluation. Care must be taken to evaluate the effects related to the delayed release from detention facilities since an increase in downstream peak discharges may result.
- The effects of releasing sediment free “hungry” water into channels and the potential for increased erosion rates downstream must be determined.
- Evaluate the effects of depriving downstream water users of runoff due to retention, percolation or other diversion.
- Access for maintenance must be provided, and the facility must be maintainable.
- Facilities should be designed to “blend in” with their surroundings to the greatest extent possible.

2.1.3. Operational Purposes

Operation of a water resources facility typically involves maintenance of structural and non-structural measures designed to increase the reliability of water supplies, to protect against floods, and to improve water quality. Maintaining these systems involves identifying what, when, and where structural or non-structural measures are needed to ensure ongoing operation of these facilities.

Structural measures may include diversion canals, reservoirs, levees, flood proofing, irrigation delivery and drainage systems, recreational facilities, groundwater wells, and water/wastewater treatment plants along with their distribution and collection systems.

Non-structural measures may include land use controls and zoning, flood warning and evacuation measures, and economic incentives that affect human behavior with regard to water and watershed use.

Some water resource systems that require ongoing maintenance and operation include the following:

- Reservoir Operations
- Irrigation System Management
- Water Treatment Management

2.1.3.1.Reservoir Operations

Reservoirs operated in the region are highly visible elements of the water supply and flood protection efforts, but also provide recreation, habitat, and other beneficial uses. Water data is required for day-to-day operation of these facilities to manage the water supply, provide flood protection, recreation, and habitat for the region.

Examples of reservoir operations include scheduling reservoir releases based on flood-control criteria and water-storage priorities; setting reservoir releases to meet agricultural, municipal, and industrial demands; and maintaining reservoir releases to meet minimum flow requirements for fish and wildlife.

2.1.3.2.Irrigation System Management

As demands for crops continue to increase, the demands for irrigation water also increases. The biggest challenge in irrigation management is to improve the efficiency and productivity of water use in existing systems. In an existing system – with a limited quantity of available water – irrigators are attempting to produce more food with less water.

Irrigation management helps farmers, ranchers, and irrigators conserve water, promote and enhance agricultural production, while protecting valuable water resources and reducing unwanted water quality impacts from leaching or runoff.

Common challenges in irrigation systems are inefficient operations and maintenance, inadequate service delivery that is supply rather than demand-driven, low water productivity, poor cost recovery, degradation of soil and water through waterlogging and salinity, and lost opportunities for sustainable conjunctive surface and groundwater use.

It is necessary to modernize existing systems to promote efficiency in farmers' use of water and to ensure more sustainable development of groundwater irrigation. Collecting data to help irrigators is the primary step in achieving this goal.

2.1.3.3.Water Treatment Management

Water treatment describes those processes used to make water more acceptable for a desired end-use. These end-uses can include use as drinking water, industrial processes, medical water and many other uses. The goal of all water treatment processes is to remove existing contaminants in the water, or to reduce the concentration of such contaminants so that it becomes fit for its desired end-use. One such use is returning water that has been used back into the natural environment without adverse ecological impact.

Management of a water treatment system includes monitoring, operation and maintenance. By providing a high level of management to all systems, communities can meet water quality and cost objectives using a variety of treatment systems. The benefits of good management include; reduced overall costs, longer system life, improved system performance, and increased reliability and overall satisfaction.

2.2. Types of Water Resources Data

2.2.1. Meteorology

No two localities on Earth may be said to have exactly the same climate, but widely separated areas of the world can possess similar climates. These climatic regions have some comparable physical and environmental features as well as having similar weather patterns. Climatic regions are differentiated by weather conditions (including temperature, humidity, precipitation type and amount, wind speed and direction, atmospheric pressure, sunshine, cloud types, and cloud coverage), and by weather phenomena (such as thunderstorms, fog, and frost) that have prevailed there over a long period of time, usually 30 years. These weather conditions and phenomena are important data to water resource engineers, meteorologists, and to others.

Remote sensing, as used in meteorology, is the concept of collecting data from remote weather events and subsequently producing weather information. These measurements give a snapshot of a variety of weather conditions at one single location and are usually collected at automated gauging stations or as part of daily operations of water resources staff.

The measurements taken at meteorological stations can include any number of atmospheric observables; however, the primary focus for water resources analysis involves precipitation and evaporation data, further described below.

2.2.1.1. Precipitation

Precipitation is any product of the condensation of atmospheric water vapor that is deposited on the earth's surface. Precipitation that reaches the surface of the earth can occur in many different forms, including rain, freezing rain, drizzle, snow, ice pellets, and hail. Precipitation is a major component of the water cycle, and is responsible for depositing most of the fresh water on the planet.

The primary aim of any method of precipitation measurement is to obtain representative samples of the fall over the area to which the measurement refers. There is a critical need in hydrology for accurate measurement of precipitation. Therefore, the choice of equipment and location are important considerations.

Direct measurements of precipitation are made by a variety of gauges, all of which have some form of funnel that directs the infalling water to some storage container. Standard types of rain gauges include graduated cylinders, weighing gauges, and tipping bucket gauges. Storage gauges simply store the incident precipitation, and the accumulated water is usually measured on a daily, weekly, or monthly basis. Recording rain gauges allow rates of precipitation to be measured. In some cases, precipitation data from these gauges is automatically transmitted to central computer, and oftentimes then to the internet. These gauges are referred to as ‘real-time’ gauges.

Many factors affect precipitation including: latitude, ocean and atmospheric currents, the proximity to moisture sources (such as oceans or large lakes), the season, the presence of orographic barriers such as the Central California Coast and Transverse Ranges, and the land surface condition.

2.2.1.2.Evaporation

Evaporation is the slow vaporization of a liquid. Evaporation is an essential part of the water cycle. Solar energy drives evaporation of water from oceans, lakes, moisture in the soil, and other sources of water.

Estimates of evaporation from water surfaces and the soil, and transpiration from vegetation are of great importance in hydrological studies. For example, estimates of evaporation may be critical in determining the feasibility of a proposed reservoir site or is used to estimate agricultural water use.

Direct measurement of evaporation from large water or land surfaces is not presently possible. However, several indirect methods for estimating water evaporation have been developed that give acceptable results. There are two common methods used methods for estimating water evaporation. The first and oldest method uses is evaporation pan data. The second and more recent method utilizes weather station data.

An evaporation pan is used to hold water during observations for the determination of the quantity of evaporation at a given location. Such pans are of varying sizes and shapes, the most commonly used being circular or square. Evaporation pans are small containers of water open to the atmosphere so as to allow for the evaporation of water from the pan. Water levels in the pan are measured as the water evaporates over time. Evaporation is measured daily as the depth of water evaporates from the pan. The measurement day begins with the pan filled to an exact height. At the end of 24 hours, the amount of water to refill the pan to that same height is measured. Often the evaporation pans are automated with water level sensors and a small weather station is located nearby.

Weather station data is used to calculate evapotranspiration for a specific crop. Using known site parameters and measured weather parameters, evapotranspiration is estimated. Using a specific crop factor, for each crop in the same microclimate, the actual evapotranspiration for that crop is calculated.

Evaporation pan data are often used to estimate reference evapotranspiration for use in water resource planning and irrigation scheduling. Evapotranspiration is a term used to describe the sum of evaporation and plant transpiration (evaporation of water from the aerial parts of plants) from the earth's land surface to atmosphere and is a significant water loss from a watershed. The types of vegetation and land use significantly affect evapotranspiration, and therefore the amount of water leaving a watershed. Many factors affect evapotranspiration including: weather parameters such as solar radiation, air temperature, relative humidity, and wind speed; soil factors such as soil texture, structure, density, and chemistry; and plant factors such as plant type, root depth and foliar density, height, and stage of growth.

2.2.2. Surface Water

Water collecting on the ground or in rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc. is called surface water. Surface waters include any water that remains on the earth's surface, all waters whose surface is naturally exposed to the atmosphere, and other collectors directly influenced by surface water.

Surface water is naturally replenished by precipitation and naturally lost through discharge to evaporation, sub-surface seepage into the groundwater, and from human-influenced extractions.

2.2.2.1.Water levels

Water level, or stage, is the elevation of the water surface of a stream, lake, or other water body relative to a datum. Stages of rivers, lakes, or reservoirs may be used directly in forecasting flows, to delineate flood hazard areas and to design structures in or near water bodies. When correlated with stream discharge or with the storage volumes of reservoirs and lakes, water levels become the basis for computation of discharge or storage records.

Collection of water level data over time provides information that is vital to understanding the sustainability of water resources, improves our understanding of the supply, and supports protection and conservation of this limited resource.

To measure stage, a stage gauge is used. A gauging station is a collection of instruments placed at a water body to monitor water stage, and potentially other water related data. Stream stage recording devices might be a staff gauge, a crest stage gauge, or any number of electronic stage gauges. Continuous records of stage are obtained with digital recorders, data collection platforms, or data loggers that automatically sample and log stage values at selected time intervals.

2.2.2.1.1. Streams

Monitoring stream stage provides information on the critical link between human activities within a watershed and the regional response to flows. Monitoring stream stage also gives individuals the data they need to design structures, protect recourses, and plan for future growth.

The primary factors that affect stream stage are; channel characteristics, channel geometry, and backwater/flow conditions. Other natural factors that affect water level include: precipitation, evaporation, runoff, groundwater, aquatic growth, meteorological disturbances, tides, and meteorological disturbances.

2.2.2.1.2. Lakes and Reservoirs

Monitoring water levels in lakes and reservoirs helps to control erosion and sediment, to reduce occurrence of flooding, to improve water supply and quality, to enhance fish and wildlife habitat, to create and restore wetlands, and to improve public recreational opportunities.

Fluctuations of lake levels are important to document, whether they result from floods, droughts, or just a normal water year. The levels of all lakes fluctuate, primarily in response to changes in precipitation. Fluctuations can also result from human activities such as the construction or operation of a dam, or from acts of nature such as beaver activity. Fluctuations in water levels in non-tidal areas are the result of several natural factors and may also be influenced by human activities.

The levels of lakes and reservoirs depend on their storage capacity, outflow characteristics of the outlet channels, operating procedures of the regulatory structures, and the amount of water supply received by each lake. The primary natural factors affecting lake levels include precipitation on the lakes, run-off from the drainage basin, evaporation from the lake surface, inflow from upstream lakes, and outflow to the downstream lakes. Man-made factors include diversions into or out of the basin, consumption of water, dredging of outlet channels and the regulation of outflows.

2.2.2.2.Discharge/Flow

Collecting discharge/flow information provides hydrologic data needed to help define, use, and manage a region's water resources. Discharge/flow data are commonly used for the following purposes:

- Enhancing the public safety by providing data for forecasting and managing floods
- Characterizing current water-quality conditions
- Determining input rates of various pollutants into lakes, reservoirs, or estuaries
- Computing the loads of sediment and chemical constituents
- Understanding the biological effects of contamination
- Delineating and managing flood plains
- Operating and designing multipurpose reservoirs
- Setting permit requirements for discharge of treated wastewater
- Designing highway bridges and culverts
- Setting minimum flow requirements for meeting aquatic life goals
- Monitoring compliance with minimum flow requirements
- Developing or operating recreation facilities
- Allocating water for municipal, industrial, and irrigation uses
- Evaluating surface- and ground-water interaction
- Undertaking scientific studies of long-term changes in the hydrologic cycle

Data for one or more of these purposes are needed at some point in time on virtually every water body in the country. The general objective of collecting discharge/flow data is to provide information on or to develop estimates of flow characteristics at any point on any water body in the region.

2.2.2.2.1. Streams

Streamflow data are needed at many sites on a daily basis for forecasting flow extremes, water-management decisions, assessing current water availability, managing water quality, and meeting legal requirements. Trend analysis is another application that requires long records. Streamflow data are needed for immediate decision-making and future planning and project design.

The data obtained at a gauging station on a stream consists of a continuous record of stage (as described above) and individual measurements of discharge throughout a range of stages. These data, together with supplemental information, such as weather records, are used to compute daily discharges.

In order to accurately determine streamflow, measurements must be made of its width, depth, and speed (velocity) of the water at many horizontal and vertical points across the stream. To properly develop a stream-stage/streamflow relation (rating curve), streamflow must be measured at many different stages. Results of individual measurements are plotted against the corresponding stages, and stage-discharge relation curves are then constructed. At some stream-gauging stations, the stage-discharge relation is affected by the backwater from reservoirs, tributary streams, or other sources. A properly-developed rating curve allows for estimation of streamflows at any stream stage.

2.2.3. Groundwater

Groundwater in the broad sense is all water which occurs within the hydrologic cycle below the land surface. It is a pervasive resource, interacting with the land surface, streams and lakes. Ground water is one of the Nation's most valuable natural resources. Surprisingly, for a resource that is so widely used and so important to the health and to the economy of the country, the occurrence of ground water is not only poorly understood but is also, in fact, the subject of many widespread misconceptions.

Groundwater plays a significant role as a resource that is necessary to sustain life, either as a source of water for human use or as water which helps sustain life in surface waters such as streams and wetlands in dry periods. Groundwater is commonly used as a source of domestic, recreational, rural and industrial water – many smaller communities rely on groundwater as their sole source of reliable water. Groundwater bodies not only provide an important source of public water supply and environmental water, but aquifers are with favorable hydraulic properties play other valuable roles in the water supply systems.

Effective groundwater monitoring will help protect the quantity of groundwater and ensure a dependable and affordable supply of groundwater into perpetuity. It will also help protect the water quality to ensure that the groundwater remains suitable for domestic, industrial, agricultural, and environmental uses and it will seek to prevent land subsidence that can damage expensive public and private infrastructure such as water conveyance and flood control facilities, and water wells.

2.2.3.1. Water level

One of the most fundamental skills in groundwater hydrology is the ability to accurately measure and interpret the depth to groundwater.

One of the more valuable pieces of data collected pertaining to longterm trends in ground water basin status is ground water levels. Monitoring water levels in groundwater helps plan for continued beneficial use of ground water, without depleting the supplies, while protecting the quality of the water. Ground-water-level measurements are used to determine hydraulic gradients, directions of flow, rates of flow, locations of ground-water recharge and discharge, the amount of water in storage, the change in storage over time, and aquifer hydraulic characteristics. Repeated measurements of water levels over time provide a history of water-level fluctuations that aids interpretation of water-quality and water-quantity data. For example, seasonal variations in recharge induced by pumping can cause changes in hydraulic gradients that may correspond to changes in water quality and water quantity.

Important benefits and reasons for monitoring groundwater levels include:

- Determining annual and long-term changes of groundwater in storage
- Estimating recharge rates
- Determining direction and gradient of groundwater flow
- Understanding how aquifer systems work

Wells are commonly drilled to depths of tens to hundreds of feet, and measure a few inches to a few feet in diameter. Most wells are constructed to obtain water. However, many small-diameter wells are constructed for foundation engineering, environmental testing, or water monitoring purposes.

Superimposed on natural, climate-related fluctuations in ground-water levels are the effects of human activities that alter the natural rates of ground-water recharge or discharge. For example, urban development, deforestation, and draining of wetlands can expedite surface runoff and thus reduce ground-water recharge. Agricultural tillage, the impoundment of streams, and creation of artificial wetlands can increase ground-water recharge. Long-term water-level monitoring during periods of significant land-use change is important to the protection of aquifers. The effects of such human-induced changes on ground-water recharge and storage are often incremental, and the cumulative effects may not become evident for many years.

2.2.3.2. Flow Rates

Since groundwater is a hidden resource, without appropriate data it's not apparent if there is a reliable groundwater supply of water. "Pump tests" have been used for decades at development sites to evaluate the potential for groundwater production. In addition to determining the optimum pumping rate for the well, aquifer tests provide valuable information on the aquifer including potential for well interference problems, aquifer limitations, connections between water bearing units, and impacts on surface water bodies.

2.2.3.3. Geologic Data and Well Logs

Well logs are created when a well is drilled. They describe the rock formations and materials and indicate the depths at which they are encountered. A well log or well-drilling report often contains valuable information on various factors, including:

- The well location;
- The depth of well;
- The depth to water in the well;
- A description of the geologic materials encountered during drilling; and
- An estimate of the rate at which water can be pumped from the well.

Knowledge of the thickness and spatial distribution of the water-bearing materials, and a rough estimate of the permeability of that material obtained from pumping tests, are paramount in determining the extent of the groundwater resource within an area of interest.

Multiple well logs are used to correlate underground rocks and formations, and to determine the nature of the fluids the groundwater basins contain.

2.2.4. Water Use

The uses of water are many, from drinking and cleaning to irrigating crops and landscapes. Water is used for cooling, for recreation, and dust control. Water is needed for restaurants, most industrial processes, and even some religious ceremonies. On another level, the splash and flow of water in streams and fountains soothes and inspires.

In one way or another, water is a part of almost everything humans make and do. All these water demands are met by various supply sources including surface waters and groundwater pumped from beneath the surface. The main categories of water use are industrial, household, recreational, environmental, and agricultural.

In some cases, water demand in exceeds the reliable supply of surface water and renewable groundwater. Supply and demand have been balanced through excess pumping of groundwater. This overdraft depletes groundwater aquifers and cannot continue indefinitely. Growing competition for scarce water resources coupled with laws restricting water use have led to efforts to conserve water and find alternatives sources of water.

Water-use data are needed to assess the impact of human activities on the natural hydrologic cycle. Sufficient water-use information can assist in planning water supply projects, in evaluating the effectiveness of options for water-demand management. This information is also useful in resolving problems including competing uses for water and water shortages caused by excessive withdrawals and during droughts. High-quality water use data can be used to show spatial and temporal patterns in water use, water intensity, and water stress. At its heart, a water use program is only as good as the quality of its data.

To quantify water demands in a region, the following categories of water use need to be determined:

- Industrial Water Demands
- Household Water Demands
- Recreational Water Demands
- Environmental Water Demands
- Agricultural Water Demands

2.2.4.1.Domestic and Municipal Uses

A secure water supply is of vital importance for the health of the population and for the economy. Domestic and municipal water uses include drinking water, bathing, cooking, sanitation, gardening, and other household uses. Domestic and municipal water demand depends on:

- The number of inhabitants with access to drinking water;
- Meteorological and climatological conditions;
- The price of drinking water;
- The availability of drinking water; and
- Water conservation policies.

2.2.4.2.Agriculture and Irrigation Water Uses

Agriculture is the dominant user of water in the western United States and most other arid regions of the planet. Lacking adequate precipitation during the growing season, agriculture in these areas is dependent on large-scale diversion of surface water and groundwater pumping. It is estimated that 69% of worldwide water use is for irrigation[3]. In some areas of the region, irrigation is necessary to grow any crop at all, in other areas irrigation permits more profitable crops to be grown or enhances crop yield. Also, aquaculture is a small but growing agricultural use of water.

2.2.4.3.Industrial Uses

Industries that produce metals, wood and paper products, chemicals, gasoline, and oils are all major users of water. Probably every manufactured product uses water during some part of the production process. It is estimated that 15% of world-wide water use is industrial. Industrial water use includes water used for such purposes as fabricating, processing, washing, diluting, cooling, or transporting a product; incorporating water into a product; or for sanitation needs within the manufacturing facility. Industries that use large amounts of water produce commodities such as food, paper, chemicals, refined petroleum, and primary metals.

[3] WBCSD Water Facts and Trends

2.2.4.4. Recreational Uses

Recreational water use refers to water needs for recreation. Recreational water use is mostly tied to reservoirs. However, rivers, and other water bodies can have recreational water uses. Nationally, recreational water use is usually a very small but growing percentage of total water use.

2.2.4.5. Environmental Uses

Explicit environmental water use is a very small but growing percentage of total water use. Environmental water usage includes artificial wetlands, artificial lakes intended to create wildlife habitat, fish ladders around dams, and water releases from reservoirs timed to help fish spawn.

Environmental water use is estimated using the calculated acreage of each habitat type and data that is collected from wildlife refuges. Data collected includes the estimated volume of water applied, flood-up and draw-down dates, depth of water applied, and habitat management plans. Habitat management plans are used to estimate water use when volumes of water applied are not available and in between non-survey years. Components used to estimate water use are soil saturation depth and percolation rate, irrigation efficiency, effective precipitation, pan evaporation rates or CIMIS Eto.

2.2.5. Water Quality

Clean water is essential to human survival as well as to aquatic life. Water quality data are essential for the implementation of responsible water quality regulations, for characterizing and remediating contamination, and for the protection of the health of humans and aquatic organisms.

Water quality comprises the physical, chemical, and biological qualities of surface and ground waters. Temperature, turbidity, color, taste, and odor make up the list of physical water quality parameters. Since most ground water is colorless, odorless, and without specific taste, individuals are typically most concerned with its chemical and biological qualities.

Long-term water quality monitoring is essential to determine baselines, measure change, and assess overall ecosystem health. Monitoring is necessary to improve the management and protection of resources, as well as to protect human health. A regional monitoring network will allow the region to track critical factors such as those listed below. A regional monitoring network should help document:

- Concentrations of industrial, municipal, and agricultural contaminants.
- Quantity, quality, and timing of stormwater flows.
- Presence of pathogens and chemical toxins in organisms.
- Rates, locations, and composition of atmospheric deposition.
- Impacts of flooding, coastal hazards, and sea level rise.
- Impacts on ecosystem and human health from pollution.
- Introductions and spread of invasive species.

- Impacts of offshore activities.
- Performance of protected areas.

The types of monitoring sites are determined by the location of known sources of pollution, ease of access to sampling sites, presence of streamflow gauges and required facilities.[4] Selecting what to measure is a complex matter because there are many potential chemical, physical and biological substances that enter freshwaters from natural and human influenced sources, and these may vary from area to area. For the majority of the parameters measured, thresholds have been set by regional and national organizations, depending on the purpose for which the water is being used.

The complexity of water quality as a subject is reflected in the many types of measurements of water quality indicators. Some of the simple measurements can be made on-site (temperature, pH, dissolved oxygen, conductivity), in direct contact with the water source in question. More complex measurements that must be made in a lab setting require a water sample to be collected, preserved, and analyzed at another location.

2.2.5.1. Sampling Surface Water

The water quality of a lake, reservoir or river can vary in space and time according to natural morphological, hydrological, chemical, biological and sedimentological processes. Major storms may cause significant longer-term changes in water quality. Pollution of natural bodies of surface water is widespread because of human activities, such as disposal of sewage and industrial wastes, acidification of rainfall by gas emissions to the atmosphere, land clearance, deforestation, mining, and use of pesticides. Surface-water quality may also be significantly affected by agriculture, industry, mineral and energy extraction, urbanization and other human actions, as well as by atmospheric inputs.

In general, the selection of sampling sites is based on how representative they are. Considerations of the local representativeness of the sampling point at the stream site may be based on preliminary surveys, taking into account the hydrology and morphology of the water body.

2.2.5.1.1. Streams, Lakes and Reservoirs

The quality of surface water in rivers and streams, lakes, ponds and wetlands is determined by the chemistry of precipitation and by interactions of runoff (surface water) with soil and rock, transported solids (organics, sediments), groundwater, and the atmosphere. Records of key parameters in surface waters are of value in detecting trends in environmental quality.

Changes in surface water quality may be quite rapid (e.g. in response to weather variations and flooding). Water samples taken from streams are usually collected at specified intervals of time. Continuous, real-time monitoring systems provide the most complete information, but are restricted to those parameters for which reliable sensors exist. Comprehensive analysis for water-

[4] http://www.lgt.lt/geoin/doc.php?did=cl_surfacew

quality monitoring is, however, expensive, and for most diagnostic purposes sample collection and analysis 4-6 times yearly may suffice, with sampling twice yearly for radionuclides and organic chemicals.

2.2.5.1.2. Estuaries and Wetlands

Lakes, streams, and rivers have been monitored across the U.S. for several years. However, only recently have wetlands been monitored as their environmental and economic benefits have begun to be recognized. Most wetland monitoring programs are less than 10 years old. Therefore, many of the wetland monitoring techniques are still being adapted and developed. Good monitoring programs should be designed to answer questions such as when, where, how, and to what degree do unacceptable wetland conditions occur.

2.2.5.1.3. Oceans and Beaches

Ongoing monitoring is essential to assess the health of ocean and coastal ecosystems and detect changes over time. More than any other measure, monitoring provides accountability for management actions. The region needs a coordinated, comprehensive monitoring network that can provide the information necessary for managers to make informed decisions, adapt their actions as needed, and assure effective stewardship of ocean and coastal resources. In developing such a network, agencies should coordinate and expand their efforts to ensure adequate monitoring in coastal areas and the upland regions that affect them.

Advances in observational technologies and monitoring instrumentation now provide unprecedented ability to monitor changes in our oceans and atmosphere and present new opportunities to understand the role of the oceans in climate change.

2.2.5.2.Sampling Groundwater

Groundwater remains an important resource for many communities in the region. It makes a substantial contribution as a source of water to maintain aquatic environments and is an integral component in the long-term management of water resources on a regional and national scale. Groundwater is an important commodity and a vital input to both urban and rural industries, and our economy.

Important groundwater characteristics include; simple physical and chemical attributes (temperature, pH, and electrical conductivity), mineral composition (cations and anions), isotopes of natural occurring elements, trace elements, and human induced constituents

Groundwater sampling equipment is used to test or continuously monitor water sources for industrial pollutants. Effective groundwater sampling will help protect the water quality to ensure that the groundwater remains suitable for domestic, industrial, agricultural, and environmental uses and it will seek to prevent land subsidence that can damage expensive public and private infrastructure such as water conveyance and flood control facilities, and water wells.

2.2.5.3.Sampling Precipitation

While most water sampling involves collection of the liquid phase in flowing or standing water bodies, the sampling of rainfall, ice, and snow have their own associated sources of variability, which require consideration during the design of a precipitation-sampling program. The importance of collecting data on the chemistry of precipitation is to monitor atmospheric depositions and to monitor geographical and temporal trends.

2.3. Analysis of Water Resources Data

As detailed above, water resources data serves many purposes. However, the data must be analyzed in order to serve those purposes. Most analysis falls into one of these four categories:

a.) The quantity of water supplies;
b.) The quantity of water demands;
c.) The quality of water for human consumption and use; and
d.) The quality of water for environmental uses.

The following table links the purpose of a water resource data collection program to the analysis required to support each purpose. With an understanding of both the quantity and quality of water supplies/demands over time, local agencies water managers, designers, construction staff, environmental assessors, planners, researchers and the general public will be able to adequately ad defensibility manage the region's water resources.

Purposes	Analysis of Water Resources			
	The quantity of water supplies	**The quantity of water demands**	**The quality of water for human consumption and use**	**The quality of water for environmental uses**
Planning Purposes				
- Water Resources Planning	■	■	■	■
- Flood Management and Planning	■	▫	▫	▫
Development Purposes				
- Water Supply Network Design	■	■	■	▫
- Transportation Infrastructure Design	■	▫	▫	□
- Wastewater Collection Design	■	▫	▫	■
- Drainage Design	■	▫	▫	□
- Flood Control Design	■	▫	▫	□
- Storm Water Management	■	▫	▫	■
Operational Purposes				
- Flood Warning Systems	■	▫	▫	□
- Reservoir Operations	■	□	□	■
- Irrigation System Management	■	▫	■	▫
- Water Treatment Management	■	■	■	■

Note: ■ - Primary Analysis
□ - Supplementary Analysis
▫ - n/a

As one can see, data that supports every category of water resources analysis is not necessarily needed to satisfy each water resources data collection purpose. For example, to properly manage and plan for floods, only water data quantifying the supplies of water are needed. Furthermore, there are types of data that are essential to conduct an adequate analysis to meet the purpose, and others that are supplementary (or helpful) in nature, but are not themselves essential.

A general overview of these four categories of analysis is provided below.

2.3.1. Water Quantity

A thorough understanding of the quantity of water required for various uses is critical for developing sustained use of the region's water resources. Sufficient quantities of fresh water are necessary, not only for economic development, agriculture, and recreation, but also for supporting ecosystems. Many programs in government agencies and other organizations use water quantity data and information.

Improving water quantity data and characterization, strengthening cooperation between water management programs, and preparing now for future water quantity issues have been identified key issues that require water quantity data.

Water quantity is also linked to water quality with regards to issues such as pollutant concentration levels, wastewater discharge requirements, and anthropogenic impacts associated with rainfall/recharge events. Environmental and climatic conditions play a major role in the demands for and the availability of water supplies. Effective decisionmaking relies on water quantity data and information from both naturally occurring events and human activities. Tracking data and information on droughts, floods, storm water runoff, instream flows, ground water recharge, water withdrawals, developmentrelated storm drainage, and water diversions is critical. Managing the region's water resources for sustained use cannot be successful without the knowledge and understanding of the hydrologic cycle, the myriad of demands on the resource and fluctuation in ground and surface water supplies.

2.3.1.1.Supply

Understanding the quantity of water available in a region's groundwater basins, streams and reservoirs, and as precipitation is paramount for every water resource related work effort.

To assess the current and future state of water supplies in a region, a hydrologic analysis is performed. A hydrologic analysis is an evaluation of the relationship between surface waters and the various components of the hydrologic cycle. Hydrologic analyses may serve one or more of several purposes, such as:

- Determining the water balance of a region
- Mitigating and predicting flood, landslide, and drought risk
- Predicting geomorphological changes, such as erosion or sedimentation
- Assessing the impacts of environmental change on water resources

Hydrologic analysis may include any of the following parts:

- Estimating basin evapotranspiration
- Estimating lake and reservoir evaporation
- Evaluation of streamflow data
- Flow frequency analysis
- Interpretation of precipitation data
- Low-flow and drought analysis
- Measurement of physiographic characteristics
- Modeling of hydrological systems
- Rainfall frequency and intensity
- Rainfall-runoff relationships
- Storm-rainfall analysis
- Streamflow routing

2.3.1.2. Demand

Water is one of the most valuable natural resources in the region. The need for drinking, cooking, washing, and other domestic uses is obvious, but water is also essential to help the agricultural industry; it is essential for the continued operation of some industrial facilities, it serves as a recreational and tourism base, and as an aesthetic asset of which many communities are proud. With continued increases in population of the region, the competition between these uses will only become more intense. How the region addresses the use, management and allocation of water will have dramatic impacts on the environment, the economy, and the quality of life for all.

2.3.2. Water Quality Monitoring

Water quality management is planning for the protection of a water's quality for various beneficial uses, for the provision of adequate wastewater collection, treatment, and disposal for municipalities and industries, and for activities that might create water quality problems, and regulating and enforcing programs to accomplish the planning goals and laws and regulations dealing with water pollution control.

Water quality is the physical, chemical and biological characteristics of water in relationship to a set of standards. In the United States, Water Quality Standards are created by state agencies for different types of water bodies and water body locations per desired uses[5]. The primary uses considered for such characterization are parameters which relate to drinking water, safety of human contact, and for health of ecosystems.

Water quality must be protected to provide clean drinking water, support viable terrestrial, wetland and aquatic ecosystems, serve as an essential resource for businesses, and provide

[5] Clean Water Act, Section 303, 33 U.S.C. § 1313.

recreational opportunities. Increases in human population and changes in lifestyles are creating new problems around water quality (and quantity).

Water quality data are used to characterize waters, identify trends over time, identify emerging problems, determine whether pollution control programs are working, help direct pollution control efforts to where they are most needed, and respond to emergencies such as floods and spills. Municipal and regional governments, natural resources-based businesses, and other entities (agencies, non-profit organizations) need information to ensure safe and adequate water supply.

Water quality depends on the local geology and ecosystem, as well as human uses such as sewage dispersion, industrial pollution, use of water bodies as a heat sink, and overuse (which may lower the level of the water).

2.3.2.1.Human Consumption and Use

The water that is supplied to residents and businesses comes from different sources, such as lakes, rivers, streams, springs and boreholes. All water supplies that are used for human consumption must meet certain standards. In the United States, the U.S. Environmental Protection Agency (EPA) limits the amounts of certain contaminants in tap water provided by public water systems. The Safe Drinking Water Act authorizes EPA to issue two types of standards: primary standards regulate substances that potentially affect human health, and secondary standards prescribe aesthetic qualities, those that affect taste, odor, or appearance. The U.S. Food and Drug Administration (FDA) regulations establish limits for contaminants in bottled water that must provide the same protection for public health.

For specific human uses, standards may dictate the water quality parameters that need monitoring. Management issues may also dictate the parameters of interest.

2.3.2.2.Environmental Water Quality

Environmental water quality, also called ambient water quality, pertains to water bodies such as lakes, rivers, and oceans. Ambient water quality standards vary significantly due to different environmental conditions, ecosystems, and intended human uses. Toxic substances and high populations of certain microorganisms can present a health hazard for non-drinking purposes such as irrigation, swimming, fishing, rafting, boating, and industrial uses. These conditions may also affect wildlife that use the water for drinking or as a habitat. Modern water quality laws generally specify protection of fishable/swimmable use and anti-degradation of current conditions.

There is some desire among the public to return water bodies to pristine, or pre-industrial conditions. Current environmental laws focus of the designation of uses and therefore allow for some water contamination as long as the particular type of contamination is not harmful to the designated uses. Given the landscape changes in the watersheds of many freshwater bodies, returning to pristine conditions would be a significant challenge. In these cases, environmental scientists focus on achieving goals for maintaining populations of endangered species and protecting human health.

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2.4. Network Design Criteria

Adequate data is required to collect a sufficient analysis to serve the purposes described above. Consequently, this requires a large variation both in the type of data collected, and the size and complexity of the data collection network, as described below.

2.4.1. Planning Purposes

2.4.1.1. Water Resources Planning

Water resources planning data requirements tend to be more general in nature than for flood management or for other purposes. Typically for water resources planning, sensors are required to be placed across an entire region, rather than at specific facilities or project locations. For example, rain gauges that aid in water resources management tend to be evenly distributed across all drainage basins in a region, whereas flood forecasting rain gauges tend to be centered on populated areas.

For water resources planning, it is necessary to collect the following types of data.

Water Resources Monitoring	Analysis of Water Resources			
	The quantity of water supplies	The quantity of water demands	The quality of water for human consumption and use	The quality of water for environmental uses
Meteorology				
- Precipitation	■	▫	▫	▫
- Evaporation	■	□	▫	▫
Surface Water				
Water levels				
- Streams	■	□	▫	▫
- Lakes and Reservoirs	■	▫	▫	▫
- Estuaries and Wetlands	■	□	▫	▫
Discharge/Flow				
- Streams	■	▫	▫	□
Groundwater				
- Water level	■	▫	▫	▫
- Flow Rates	□	▫	▫	▫
- Geologic Data and Well Logs	□	▫	□	□
Water Use				
- Domestic and Municipal Uses	▫	■	▫	▫
- Agriculture and Irrigation Water Uses	▫	■	▫	▫
- Industrial Uses	▫	■	▫	▫
- Recreational Uses	▫	■	▫	▫
- Environmental Uses	▫	■	▫	▫
Water Quality				
Sampling Surface Water				
- Streams Lakes and Reservoirs	▫	▫	■	■
- Estuaries and Wetlands	▫	▫	□	■
- Oceans and Beaches	▫	▫	□	■
Sampling Groundwater	▫	▫	■	□
Sampling Precipitation	▫	▫	▫	■

Note: ■ - Essential Water Resources Data Need
□ - Supplementary Water Resources Data Need
▫ - n/a

2.4.1.1.1. Meteorological Data Needs

Meteorological data is primarily collected to quantify the quantity of water supplies. For example, meteorological data can be used to calculate the quantity of rainfall across a region. Without hydrological data like rainfall, individuals would be unable to properly plan for future uses of water or adequately operate flood control facilities.

Meteorological data can also be used to estimate the quantity of agricultural water demands. When agricultural pumping data are not available, which they usually are not, reasonable estimates of applied irrigation water is a function of evaporation, or more precisely evapotranspiration.

Specific needs for meteorological data collection are provided below.

2.4.1.1.1.1.Precipitation

Measuring Precipitation

The number of gauges required usually increases with the size and topographical complexity of a watershed. The ideal network consists of recording rain gauges, and is supplemented with standard or storage rain gauges. In general, precipitation gauges should be as uniformly distributed as possible. The following table outlines the recommended minimum rain gauge densities in order to measure the supply of precipitation in the region:

Land Use	**Minimum densities per station** (area in mi^2 per station)	
	All Rain Gauges	**Recording Rain Gauges**
Urban Areas (Cities, CSDs, CSAs, etc.)	5	50
Rural Areas (non Rural Areas)	50	500

To ensure that precipitation data are available for extending streamflow records or for hydrologic analysis, coordination of the locations of precipitation gauges with respect to those of stream gauges is of great importance. It is recommended that every stream gauge in the region also has a corresponding recording rain gauge associated with it. These precipitation gauges should be located so that basin precipitation can be estimated for each stream-gauging station. (The gauges will usually be located at or near the stream gauge and in the upper part of the gauged drainage basin. A precipitation gauge can be located at the site of the stream gauge only if the observations will be representative of the general area.)

2.4.1.1.1.2.Evaporation

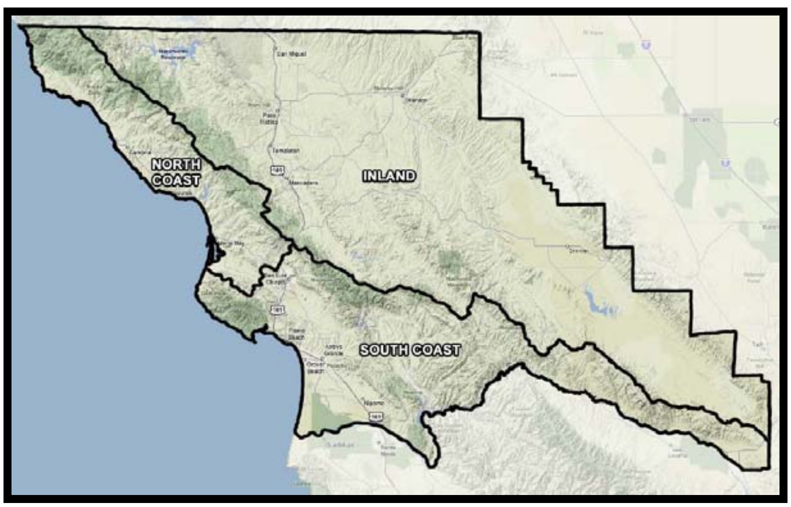
Monitoring Evaporation

Evaporation plays an important role for long-term studies of the water regime of lakes and reservoirs and for water management. The lake water surface behind a dam increases water loss to evaporation compared to evaporation loss from a stream. Reservoir evaporation loss is estimated from pan measurements.

The number and distribution of evaporation pans are determined according to the area and configuration of the lakes and the climatic region or regions involved. Evaporation pans should be established on all large, publicly owned reservoirs that are used for municipal uses. A weather station in place of a traditional evaporation pan is acceptable.

Water use efficiency has become an increasingly important tool for water managers. Accurate information on the amount of water lost from plant and soil surfaces to the atmosphere (evaporation) and the amount of water removed from soil by plants for maintenance and growth (transpiration) is necessary for efficient irrigation management. When efficient use of irrigation water is achieved, crops can produce the highest yields with the most efficient use of energy.

As noted earlier, there are two common methods for estimating crop water use. The first and oldest method for estimating crop water use is evaporation pan data. At a minimum, there should be at least one evaporation station per climatic region, with more in large climatic areas. The three major climatic regions in the area are shown in figure below.



2.4.1.1.2. Surface Water Data Needs

As with meteorological data, surface water data is primarily collected to assess the quantity of water supplies. For example, to assess a reservoirs performance or to evaluate a streams ability to support life, it is essential to collect data on water levels and discharge/flows. For particular water bodies, such as streams that support complex aquatic life, the quantity of flow in those streams helps individuals determine concentrations of critical containments on those water bodies.

Specific needs for surface water data collection are provided below.

2.4.1.1.2.1. Water Levels

Measuring Water Levels in Streams

Spatial representativeness is crucial in the selection of monitoring sites for surface water gauges. In general, a sufficient number of gauging stations should be located along each main creek to permit interpolation of water level and discharge between the stations. Stream gauging stations should be located at:

- The lower reaches of all major creeks, immediately upstream of the creeks mouth or where the creeks cross borders;
- On major creeks near the confluence with significant tributaries;
- On some smaller streams and tributaries;
- On all major lakes and reservoirs, near their outlets, but sufficiently upstream to avoid the influence of drawdown; and
- At major cities along the major creeks.

Stream gauging sites should be located measure streamflow at the outlet of each Hydrologic Catalog Unit within the region. When possible, sites selected will measure streamflow from at least 90 percent of the basin area of each accounting unit.

Measuring Water Levels in Streams

To manage water resources for "in-stream" values and functions such as recreation, aesthetic enjoyment, and habitat for aquatic ecosystems, is important to measure the stages of streams in the region.

Although ideal, it will be nearly impossible to restore all stream flows to pre-human conditions. Through environmental flow management, one can the mimic natural flow regimes in a creek, and provide cues for key life cycle events such as spawning and migration. Mimicking natural flow regimes in regulated streams can also rehabilitate and improve ecosystems.

To determine environmental water demands, the basic network of hydrometric stations will consist of observation points on water courses with a natural regime, as well as with a regime modified by management activities. An adequate stream-gauging network should include (1) gauges that represent most of the region's principal watersheds, (2) various combinations of watershed size, land-use types, and physiography and geology of the State, and (3) gauges that are continuously operated for extended periods of time.

It is vital that flows in the major streams be monitored over time. At least one stream gauge should be placed in each major stream in the region. A stream gauge network should equally gauge all sizes of streams[6] in the region. Larger streams may need gauges in the upper portions of its watershed, or on its tributaries.

There should be at least one stream gauge, mainstem or on tributaries, in each medium or large (one for each Hydrologic Area) watershed, for watersheds that have perennial (year round) or intermittent (partial-year) streams.

It is essential that a base stream gauge network monitor the representative area. As such, stream gauging stations should be placed in such a way such that the watersheds they are monitoring are representative of the whole region. Both large and small streams should be monitored. Streams in developed and undeveloped watersheds should be gauged.

To understand the regional natural flow regime, there should be a number of stream gauges in natural watersheds. Stream gauges in natural watersheds will help water managers mimic pre-human conditions. At a minimum, there should be one stream gauge for each group of comparative watersheds[7] in the region.

To manage environmental flows, a stream gauge is required on each watershed or stream to be monitored. For comparative watersheds, only one stream gauge is needed to estimate the natural flow regime.

Measuring Water Levels in Lakes and Reservoirs

Monitoring reservoir stage is important to ensure that water levels do not recede below minimum levels. Minimum reservoir levels (minimum pool) are generally set to eliminate the risk of environmental losses when water levels drop dangerously low. When waters are below the minimum pool levels, aquatic lives are particularly at danger. Reservoir elevation should be measured (at least daily) on all reservoirs that regulate downstream releases and on those that support aquatic life.

Measuring Water Levels in Estuaries and Wetlands

The purpose of wetland monitoring and assessment is to analyze the condition of wetlands and estuaries, to document trends, and to better protect and manage wetlands and their surrounding habitat. A wetland monitoring program will produce necessary baseline data over time and act as a “screening” tool to help identify problem areas, define reference sites, and document trends.

Most wetland monitoring focuses on water quality parameters, however it is also important to monitor water levels in the regions estuaries and wetlands. The impacts of water withdrawals on

[6]The Strahler Stream Order is a simple hydrology algorithm used to define stream size based on a hierarchy of tributaries. In this stream classification system, as an order 1 stream connects with another order 1 stream, the stream becomes an order 2 stream; as an order 2 stream connects with another order 2 stream, the stream becomes an order 3 stream, and so on.

[7] Comparative watersheds will have similar features including, soil, size, elevation, orientation, etc.

wetlands is an important management consideration at the local and state levels with growing population and increasing demands for water use in the region.

The timing, frequency, and duration of water inputs can be critical to wetland and estuary health. Water fluctuations can be measured in wetlands, and the observation of human-built tidal restrictions can uncover potential impacts on tidal marshes.

A stage gauge should be located in each of the major estuaries and wetlands of the region, particularly those that share watersheds with highly developed urban areas.

2.4.1.1.2.2.Discharge/Flow

Measuring Discharge/Flow in Streams

It is recommended that discharge measurements are taken for every stage gauge site. Factors to be considered in determining the number and distribution of discharge measurements include:

- The stability of the stage-discharge relationship;
- Seasonal discharge characteristics and variability; and
- Accessibility of the gauge in various seasons.

The frequency of measurements depends on the variability of the hydrological characteristics and the response time requirements. Systematic water-level recordings, supplemented by more frequent readings during floods, are appropriate for most streams. At new stations, many discharge measurements at different flow levels are needed to define stage-discharge relationships. At existing stations the frequency of measurements is dictated in part by the number needed to keep the stage-discharge relationship up to date. Adequate determination of discharge during floods can be difficult, but is of prime importance where applicable. In situations where the channel shape can readily change during high-flow conditions, keeping an up-to-date stage-discharge relationship is a challenging (or perhaps indeed unattainable) goal.

Hydraulic conditions are an important factor in site selection on streams, particularly where water levels are used to compute discharge records.

2.4.1.1.3. Groundwater Data Needs

Hydrologic, geologic, and land and water use settings will all influence where and how many locations are established for groundwater monitoring. Hydrologic factors such as presence of surface water supplies for irrigation, sole reliance upon groundwater for irrigation, or a combination of both surface water and groundwater should be considered. Geologic factors should be considered such as known characteristics of the aquifer system being monitored and presence of geological fault lines that may influence groundwater movement.[8]

- Wells should be distributed aerially throughout the permeable sediments of each basin.

[8] http://cetehama.ucdavis.edu/files/37332.pdf

- If continuous confining layers have been identified, wells should be screened in only one aquifer.
- If multiple aquifers have been identified and they are used for water supplies, water levels for each aquifer should be monitored.
- Access to the wells and viability for consistent static level data measurements should be insured.

Changes in land and water use such as new residential, industrial, agricultural, environmental uses, and participation in water transfer programs are examples of land and water use considerations that may influence where and how many locations are established for groundwater monitoring.

2.4.1.1.3.1. Water Levels

It is critical that monitoring systems are properly designed. When establishing monitoring wells it is important to review the distribution of the wells with respect to the extent of the groundwater basin and the aquifer zones present in each main area. A proper distribution of wells provides groundwater level data that represents natural static water levels that are not influenced by transient conditions.

Measuring Groundwater Levels

When establishing wells for a water resources planning, it is important to consider the following:

- Wells included in a groundwater measuring program should be located evenly in a groundwater basin, both horizontally and vertically.
- Selected wells should not pump frequently.
- Program wells should not be within 1,000 feet of a high producing well.
- Wells should not be within 1,000 feet of other wells that tap the same aquifer.
- Two wells that tap different aquifers may be located in close proximity to each other without producing redundant monitoring data.
- There should be separate program wells for basins that tap different aquifers.

Monitoring well distribution should be based on population density and projected population growth, and on current and projected land use because of the greater well pumping impacts in these areas.

Groundwater elevation contour maps are widely used in hydrogeologic studies and are used to determine groundwater flow direction and volumes of groundwater in storage. These maps require a minimum of three wells (completed within the same aquifer). For smaller ground groundwater basins it may be unreasonable to have three wells and just one well may suffice.

Basins and areas within basins previously identified as having declining or rising water levels due to changes in land use should have wells evenly located horizontally and vertically in a basin in order to map the changes of groundwater in storage in those areas.

Water levels in each aquifer should be measured, particularly for aquifers that are used for water supplies. One, centrally located, well is acceptable for small groundwater basins if resources are limited, more might be appropriate for larger basins.

2.4.1.1.3.2.Geologic Data and Well Logs

Collecting Geologic Data and Well Logs

Interpretation of well logs for use in subsurface geology is long-established and remains fundamental to the construction of accurate models. All program wells should have well logs. All measured wells should have well logs and well completion reports on file with the agency that measures the well.

2.4.1.1.4. Water Use Data Needs

Measuring Domestic and Municipal Water Uses

All water users in urban areas, or a representative fraction for residences that do not have water meters, should have their water use metered.

A representative fraction of households in rural areas (those that do not connect to a water system) should have their water use metered using traditional water meters.

Measuring Agriculture and Irrigation Water Uses

Since agricultural water predominately comes from groundwater sources, and is generally not provided – or metered – by a water supply system, a representative percentage of agricultural water users should meter and report their water use.

All meter readings should be reported to a central agency on an annual basis.

Measuring Industrial Water Uses

Given the varied nature of industrial water use, it is recommended that a representative fraction of industrial water users record and report their water use.

2.4.1.1.5. Water Quality Data Needs

In rivers, the bulk of the solutes in the headwaters are derived from soils and groundwater baseflow, where the influence of water-rock interactions is important. Lower down the system or catchment, anthropogenic inputs from diffuse or point sources may be significant. A proper water sampling program will monitor changes in water quality of all waters in the region (starting as rain, ending in the ground, our bodies, or etc.)

The number of sampling points for sediment and water quality monitoring strongly depends on the objectives. For trend detection, a low number of sampling points or mixing samples into composite samples can sometimes yield enough information. If spatial information is to be estimated, the number of sites will increase and composite samples will normally not be used. In general, locations in the main flow of the water bodies will be chosen for water sampling.

Sampling Streams, Lakes, and Reservoirs

All surface waters that are a source of drinking water should be monitored for water quality.

Monitoring should be frequent enough to ensure that water is fit to drink and to document fluctuations of contaminant concentrations that may occur in the water.

A representative fraction of streams in the region should be sampled. A proper sampling network will monitor natural streams outside of the impact of human development, and will monitor creeks and streams in close proximity to the urban interface.

For watersheds where problems are known or suspected, the water quality should be measured using a network of sampling stations.

Sampling for stream water quality should be conducted at or near streamflow gauge stations to allow the computation of contaminant loads.

Sampling Groundwater

In the case of a groundwater quality monitoring system, wells would generally be located in principal aquifers across a region to enable evaluation of the time and spatial variation in quality. Components of this system could also be located within or down gradient of areas of suspected or known contamination to monitor the long term effects on groundwater on the broad scale.

How often one samples depends on the purpose of the sampling and the depth of the aquifer formations from which the well draws water. Some monitoring objectives may require more frequent sampling.

- When screening the water quality in large production wells that pump water from aquifer formations more than 300 feet deep, sampling every year to every few years is sufficient because changes in water quality for such a well will be gradual.
- Shallower wells, particularly domestic wells with smaller pumping rates, should be sampled once or twice a year because they are more prone to short-term variations in groundwater quality and contamination.
- If problems with well bacteria, well degradation, or iron (from a rusting well casing) have been identified and a well maintenance program has been implemented by a licensed contractor, frequent sampling may be necessary regardless of well depth in order to monitor the success of the well rehabilitation program over an extended period of time.

- Finally, shallow monitoring wells that are installed to monitor a potential pollution source may be sampled monthly, quarterly, or semi-annually[9].

All groundwater that is used for human consumption should be monitored to ensure that it is safe for domestic uses.

2.4.1.2. Flood Management and Planning

The criteria when establishing sensors for flood management and planning is quite different than establishing a network for general water resources planning. The primary focus of flood management and planning is to protect people and their property. As such, gauges do not always need to be distributed evenly throughout the region, but concentrated locations that have higher threats to loss of life and or property form flood waters.

For flood forecasting, it is of paramount importance that all observations are promptly available. Therefore, real-time gauges are essential for flood forecasting.

[9] Groundwater Sampling and Monitoring, PUBLICATION 8085, http://groundwater.ucdavis.edu/Publications/Harter_FWQFS_8085.pdf

For flood management and planning, it is necessary to collect the following types of data:

Water Resources Monitoring	The quantity of water supplies	The quantity of water demands	The quality of water for human consumption and use	The quality of water for environmental uses
	Analysis of Water Resources			
Meteorology				
- Precipitation	■	▫	▫	▫
- Evaporation	▫	▫	▫	▫
Surface Water				
Water levels				
- Streams	■	▫	▫	▫
- Lakes and Reservoirs	■	▫	▫	▫
- Estuaries and Wetlands	□	▫	▫	▫
Discharge/Flow				
- Streams	□	▫	▫	▫
Groundwater				
- Water level	□	▫	▫	▫
- Flow Rates	▫	▫	▫	▫
- Geologic Data and Well Logs	▫	▫	▫	▫
Water Use				
- Domestic and Municipal Uses	▫	▫	▫	▫
- Agriculture and Irrigation Water Uses	▫	▫	▫	▫
- Industrial Uses	▫	▫	▫	▫
- Recreational Uses	▫	▫	▫	▫
- Environmental Uses	▫	▫	▫	▫
Water Quality				
Sampling Surface Water				
- Streams Lakes and Reservoirs	▫	▫	▫	▫
- Estuaries and Wetlands	▫	▫	▫	▫
- Oceans and Beaches	▫	▫	▫	▫
Sampling Groundwater	▫	▫	▫	▫
Sampling Precipitation	▫	▫	▫	▫

Note: ■ - Essential Water Resources Data Need

□ - Supplementary Water Resources Data Need

▫ - n/a

2.4.1.2.1. Meteorological Data Needs

Measuring Precipitation

As sated above, people and their property are the primary concern when settings sites and sensors for flood management and planning. To monitor the potential for road flooding, real-time precipitation gauges should be placed near roads with reoccurring drainage problems. These gauges help local roads department staff ensure safe passage of vehicular traffic.

The National Weather Service (NWS), which is part of the National Oceanic and Atmospheric Administration, is widely known as the Federal agency in charge of weather forecasting and warning for the Nation. Many people, however, are not aware that the NWS also is charged by law with the responsibility for issuing river forecasts and flood warnings. The NWS uses many types of data when developing its flood forecasts, but primarily uses precipitation and stream flow data – data that is often provided by local agencies such as the County.

In general, the management and planning (including flood forecasting) required an even distribution of real-time rain gauges thought a region, supplemented by specific gauges in key locations. The following table outlines the recommended minimum rain gauge densities in order to ensure an even aerial distribution of rain gauges:

Land Use	**Minimum densities per station** (area in mi^2 per station)
Urban Areas (Cities, CSDs, CSAs, etc.)	50

Note that these rain gauge density recommendations are the same as for water resources planning.

It is also important to have rain gauges at key locations in a region. Key locations include any watershed(s) that also contains flood control facilities such as reservoirs, large-scale detention and retention basins, or other structures that control the natural flow of storm water. Key locations also contain urbanized areas. The selection of key rain gauge locations are made on a case-by-case basis, as needs become apparent.

Areas and watersheds that regularly flood should have real-time rain gauges in service.

2.4.1.2.2. Surface Water Data Needs

Measuring Water Levels in Streams

To reduce damages to life and property by floods, stage gauges should be placed in and upstream of flood control facilities, roads, and urban areas prone to flooding.

In flood zones and where roads, houses, cities are frequently flooded should have real-time gauges in upstream portions of the watershed for flood warning.

Major and minor streams in the region that have high potential to flood should have real-time stage gauges in operation.

Measuring Water Levels in Lakes and Reservoirs

All on-stream reservoirs indirectly serve as flood control facilities, independent of their original purpose. For example, an empty water supply reservoir will detain storm runoff and can shift a streams natural flow regime during storm events. However, once a reservoir is at capacity and water is pouring over the spillway, the time of concentration and peak storm flows in that watershed may increase in a storm. For these reasons, it is important that these reservoirs have water level sensors in operation, specifically for those that can restrict and/or increase water releases and for those that are up-watershed of developed areas. This is particularly important for the larger-capacity reservoirs in the region that are upstream of property and people who are significantly impacted by floodwaters. For these reservoirs, operators could increase or decrease downstream flows in storms to reduce the potential for downstream flooding of property.

2.4.2. Other Purposes

The requirements for water resources data to meet other purposes can be quite specific. Each purpose likely will need different types data. For these reasons, it can be quite difficult to predict the specific water resources data needs for that purpose. All purposes require similar analysis. Most analysis falls into one of these four categories:

a.) The quantity of water supplies;
b.) The quantity of water demands;
c.) The quality of water for human consumption and use; and
d.) The quality of water for environmental uses.

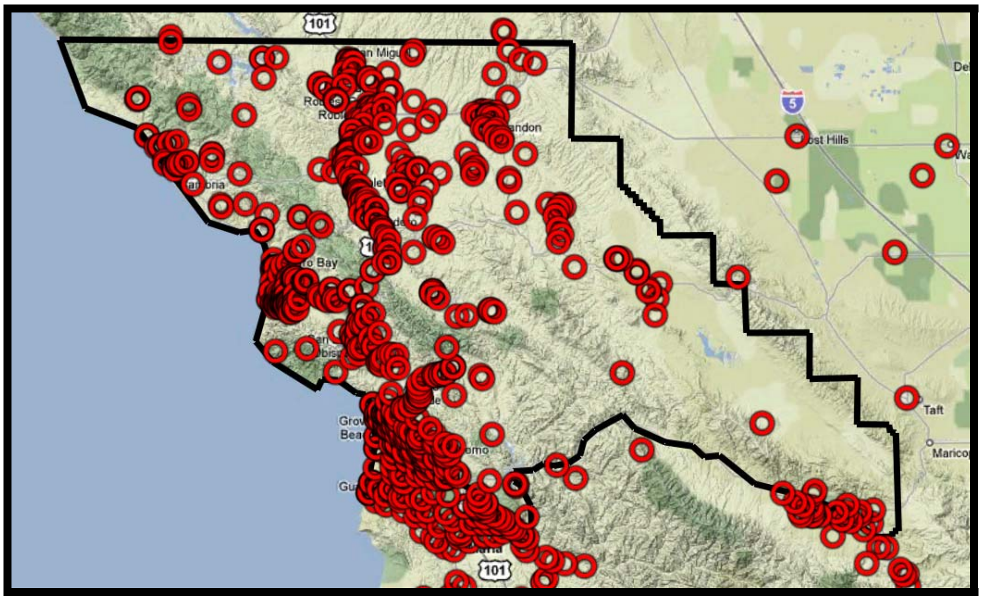
Data required in analyzing the quantity of water supplies, the quantity of water demands, the quality of water for human consumption and use, and the quality of water for environmental uses is all collected to meet planning purposes. Therefore, in collecting data for planning purposes, the foundational data for most every other general purpose is also collected. Local agencies may need to supplement the regional collection program in order to serve their specific project needs.

3. Regional Water Resources Data Collection Program

The current hydrographic network is a collection of sites and sensors maintained by a variety of public and private agencies. There are numerous other agencies (both federal, state, and local) that collect water resources data.

This section provides an overview and description of efforts thought to be of particular importance for planning purposes – including water resources planning, and flood management and planning. This review is not intended as a comprehensive survey of all programs and activities.

For perspective, the following figure illustrates the locations of all water resources data collection sites in the region.



Specific regional monitoring programs are presented in further detail in the following sections.

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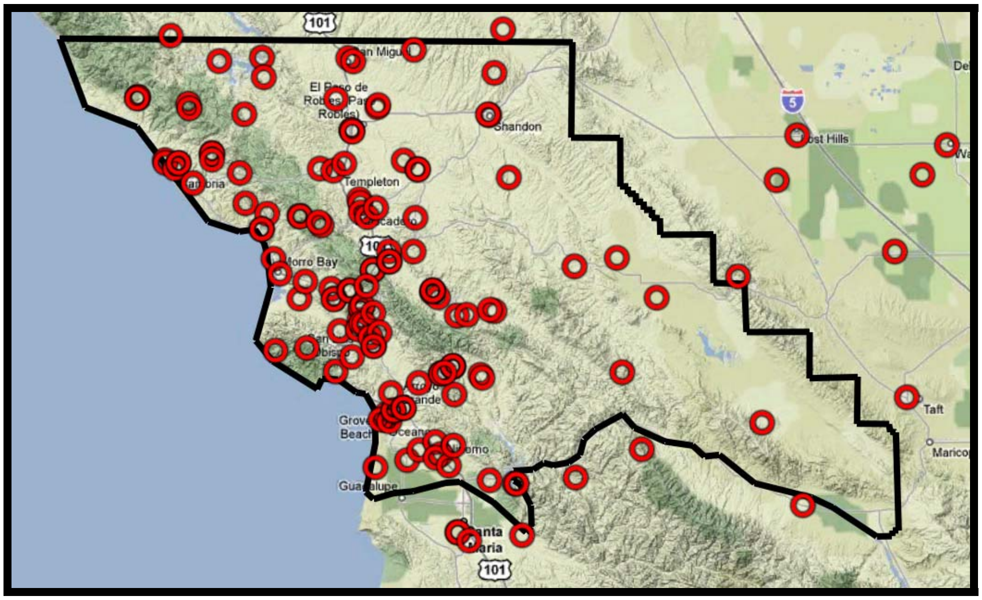
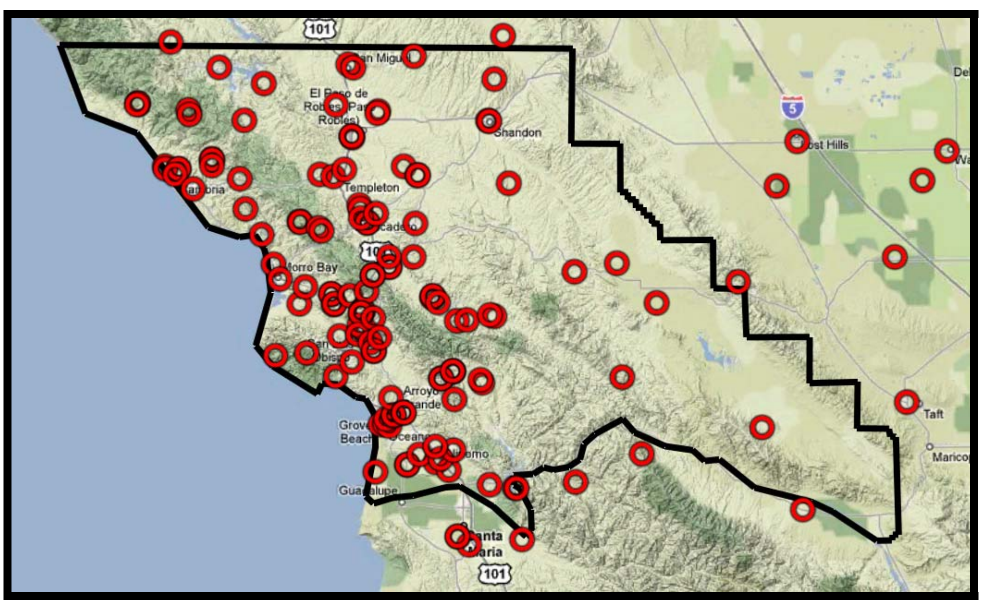
3.1. Meteorological Data

The following figure shows the general location of all rain gauges maintained in the region that are suitable for professional uses. It should be noted that some of these gauges are only suitable for particular purposes, and may not be practical in all situations.



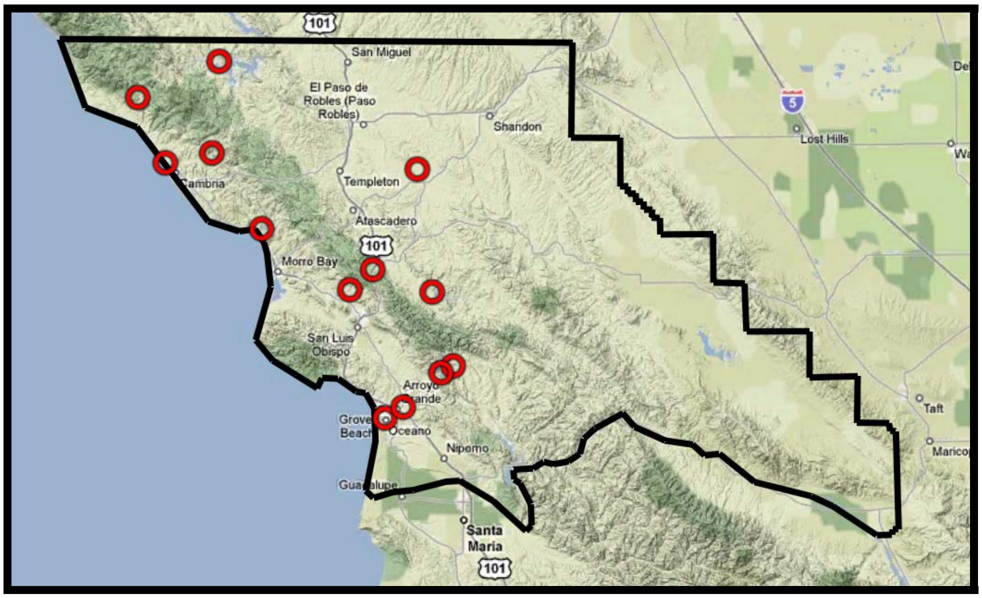
3.1.1. Precipitation

Many agencies collect precipitation data in the region. The major rain gauge networks are shown on the figure below and discussed below.



San Luis Obispo County Recording Rain Gauge Program
There are a number of recording rain gauges in operation in the County. These gauges provide a record of accumulated precipitation versus time. The SLO County Recording Rain Gauge network consists of 13 recording gauges located throughout the region.

The distribution and density of recording rain gauges in the region is fairly limited, and noticeably lacking in the northern and eastern part of the region.

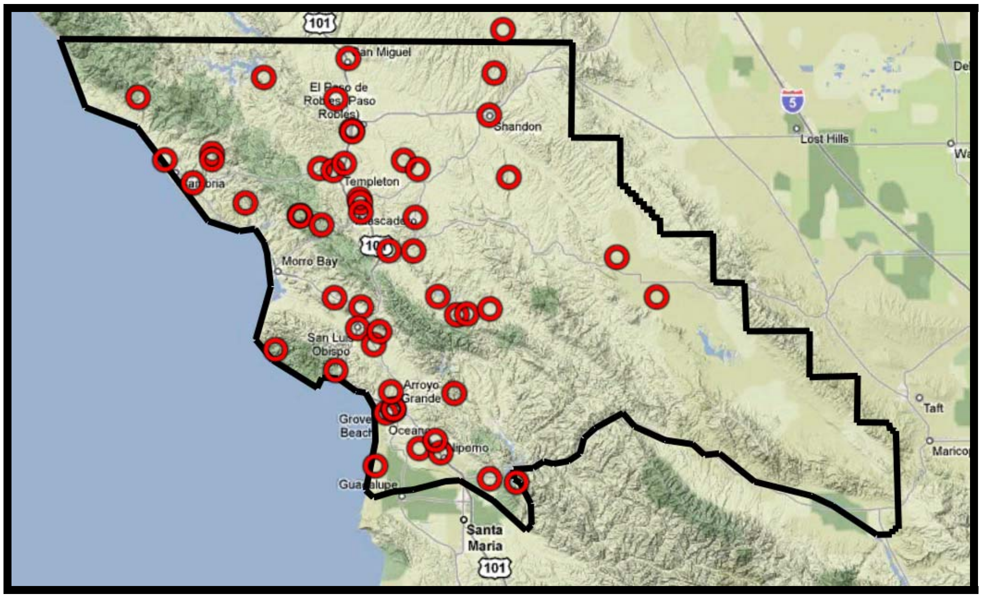


For more information regarding the San Luis Obispo County Recording Rain Gauge Program, go to: http://www.slocountywater.org/site/Water%20Resources/Data/maps/precipitation.htm.

San Luis Obispo County Volunteer Precipitation Program
Precipitation data from approximately 50 stations throughout San Luis Obispo County are collected by the County Public Works Department. These records are usually in the form of daily entries of the precipitation occurring during the preceding 24-hour periods. These daily records are summarized in monthly totals.

Volunteer rain gauges are generally operated at-will, by regional residents, business owners, or local agencies. The volunteers independently collect precipitation data and provide it to the District or other agency on an annual basis.

There are a significant amount of volunteer rain gauges in the region, particularly in urban and suburban areas. As with the County recording rain program, the east portion of the region is particularly under represented.



For more information regarding the San Luis Obispo County Volunteer Precipitation Program, go to: www.slocountywater.org/site/Water%20Resources/Data/maps/precipitation-active-volunteer.htm.

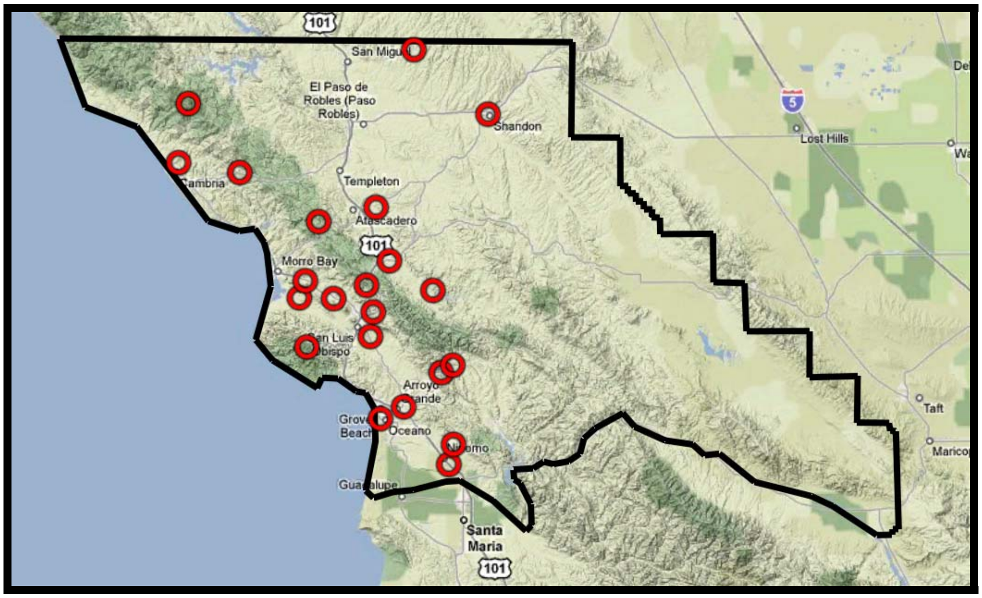
SLO County ALERT Rain Gauge Program

ALERT is an acronym for Automated Local Evaluation in Real Time, which is a method of using remote sensors in the field to transmit environmental data to a central computer in real time. This standard was developed in the 1970's by the National Weather Service and has been used by the National Weather Service, Army Corps of Engineers, Bureau of Reclamation, as well as numerous state and local agencies, and international organizations[10].

The San Luis Obispo County ALERT System was developed in cooperation with the National Oceanic and Atmospheric Administration (NOAA) which is a primary user of the information. The San Luis Obispo County ALERT System consists of one computer base station located at the County Courthouse and radio repeaters that receive and retransmit telemetry from remote sensors located at various locations throughout the County.

[10] Descriptions of the ALERT system are based on information provided in the websites for Orange County and the World Meteorological Organization

Data from these gauges serves to provide real-time information to flood forecasters and engineers during storm events. Due to the inconsistency of ALERT data transmissions, historic data for these gauges is typically unreliable and/or unavailable. For key sites, the County intends to convert some ALERT gauges to recording rain gauges that will provide accurate time-series precipitation data.



For real-time rainfall information from the San Luis Obispo County ALERT rain gauge network, go to: www.SLOCountyWater.org/site/Water Resources/Data/maps/alert.htm.

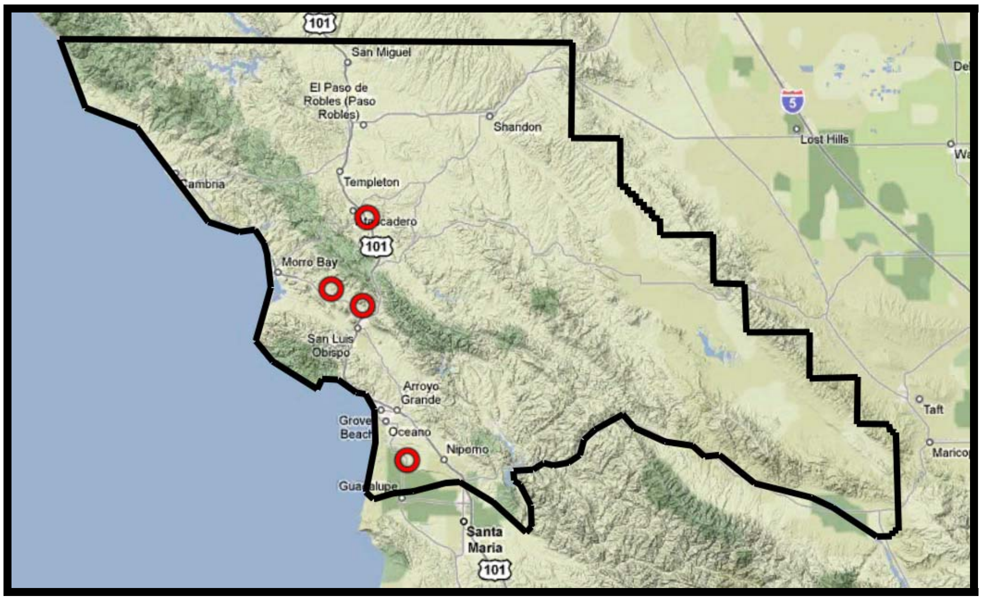
California Irrigation Management Information System (CIMIS) Stations
In 1982, through a joint research and development effort between UC Davis and DWR, a computerized weather station system was established as a more cost effective method for estimating crop water use. This program was given the name "California Irrigation Management Information System" or CIMIS. In 1985, the administration and implementation of the program, and its further development, were turned over to DWR.

The California Irrigation Management Information System (CIMIS) is a program of the Office of Water Use Efficiency, California Department of Water Resources (DWR) that manages a network of over 120 automated weather stations in the state of California. CIMIS was developed in 1982 by DWR and the University of California, Davis to assist irrigators in managing their water resources efficiently. Efficient use of water resources benefits Californians by saving water, energy, and money.

The CIMIS stations gather climatic data (precipitation, temperature, humidity, solar radiation, etc.), which is used to calculate the evapotranspiration (ET). ET is the loss of water to the atmosphere by the combined processes of evaporation (from soil and plant surfaces) and transpiration (from plant tissues). It is an indicator of how much irrigation water is needed (or used) for healthy growth and productivity.

CIMIS stations are maintained by local agencies that use standard equipment and maintenance procedures. The data seems to be reliable, particularly for hourly rainfall information during storms.

As shown on the figure below, there are four (4) CIMIS stations currently in operation throughout the region. Those stations are located in southeast Atascadero, west of Nipomo, 6.5 miles northwest of San Luis Obispo, and on the Cal Poly Campus.



More information on this program and online access to the data for these sites is available at: http://www.cimis.water.ca.gov.

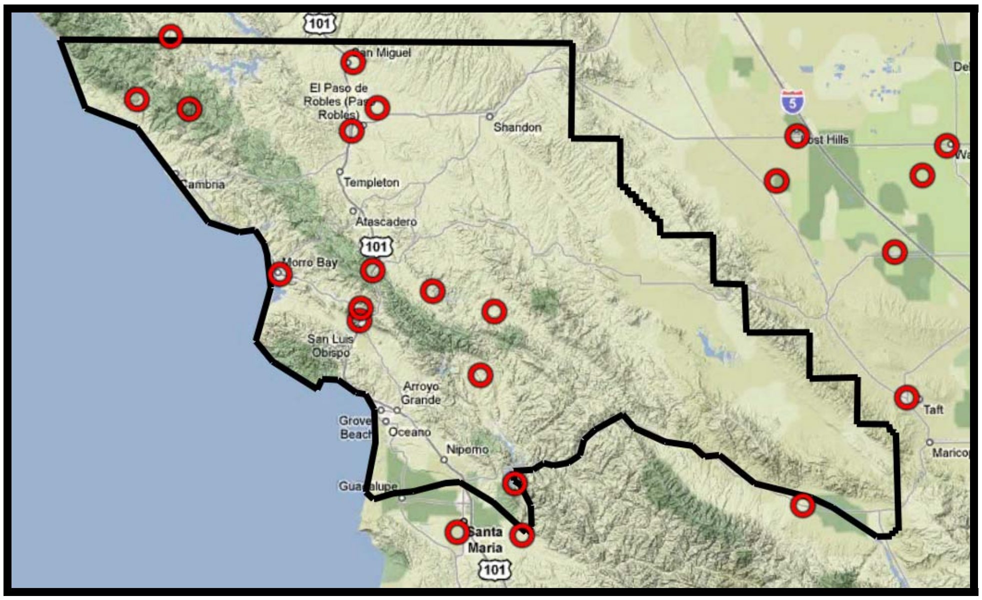
National Oceanic and Atmospheric Administration / National Weather Service Cooperative Observer Network

The National Weather Service Cooperative Observer Program (COOP) was formally created in 1890 under the Organic Act. Its mission is to provide observational meteorological data (usually consisting of daily maximum and minimum temperatures, snowfall, and 24-hour precipitation totals) and to provide observational meteorological data in near real-time to support forecast, warning and other public service programs of the NWS.

More than 11,000 volunteers take observations on farms, in urban and suburban areas, National Parks, seashores, and mountaintops. A cooperative station is a site where observations are taken or other services rendered by volunteers or contractors. A cooperative station may be collocated with other types of observing stations such as standard observations stations, Flight Service Stations, etc.

This network established to provide near real-time to support forecast, warning and other public service programs of the NWS. Unfortunately, the historic dataset for many of these gauges is not complete. It is recommended that data from these gauges not be used for water resources planning. It should be noted that this is a generalization regarding gauges in this network, primarily since these gauges are maintained by different sorts of volunteers and there does not appear to be consistent data maintenance or reporting.

There are twelve active COOP stations in the region, as shown below.



More information about the COOP can be found at: http://www.ncdc.noaa.gov/oa/ncdc.html and at: http://www.nws.noaa.gov/om/coop/.

Citizen Weather Observer Program (CWOP)

The Citizen Weather Observer Program (CWOP) allows users with computerized weather stations to send their information via a website to be included into the United States Mesonet. This data is then used by the Rapid Update Cycle (RUC) forecast model to produce short term forecasts (3 to 12 hours into the future) of conditions across the United States' lower 48 states.

The Citizen Weather Observer Program (CWOP) is a private-public partnership with three main goals: 1) to collect weather data contributed by citizens; 2) to make these data available for weather services and homeland security; and 3) to provide feedback to the data contributors so that they have the tools to check and improve their data quality. In fact, the web address, www.wxqa.com, stands for weather quality assurance. There are over 6,000 registered CWOP members worldwide and roughly 8 in the region.

CWOP is a group of ham radio operators and other private citizens around the country that have volunteered the use of their weather data for education, research and use by interested parties. The APRS-IS collects weather data transmitted from individual stations and communicates these data to the amateur radio findU server where the data are organized and made available to the MADIS Program at 15-minute intervals. The CWOP data also go to the MADIS Quality Control and Monitoring System (QCMS) which checks data quality using a variety of techniques. Based on these checks, data may be declared questionable. Occasional questionable data is normal. However, a high percentage of questionable data may indicate instrument or siting problems.

CWOP members send their weather data by internet alone and internet-wireless combination to the findU server and then every 15 minutes, the entire data set is sent from the findU server to the NOAA MADIS server. The data are checked for quality and then redistributed to users. There are over 500 different user organizations of mesonet data, including the National Weather Service.

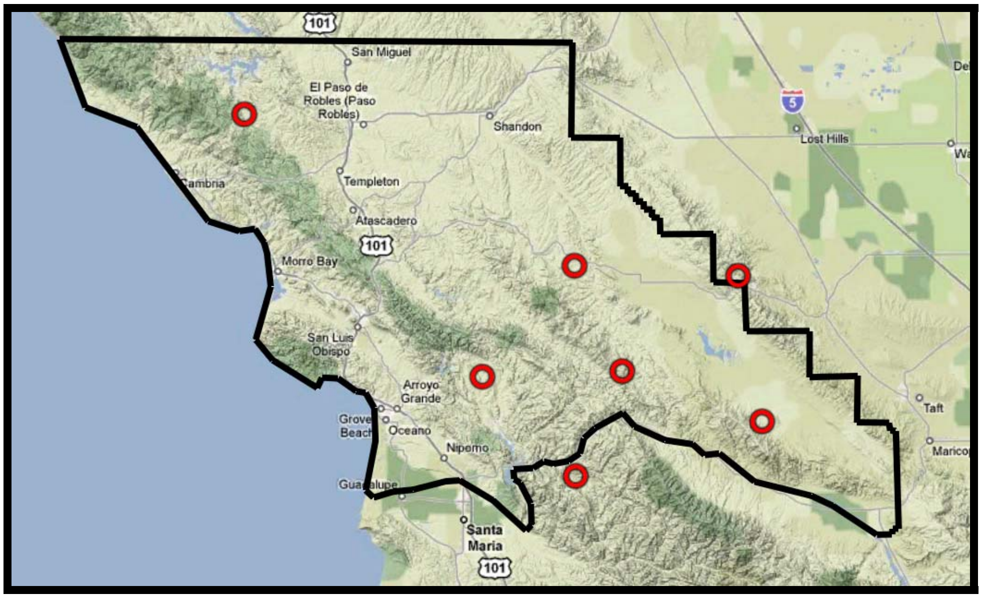
For more information on the Citizen Weather Observer Program, go to: www.wxqa.com.

Remote Automated Weather Station (RAWS) Gauges
There are nearly 2,200 interagency Remote Automated Weather Stations (RAWS) strategically located throughout the United States. These stations monitor the weather and provide weather data that assists land management agencies with a variety of projects such as monitoring air quality, rating fire danger, and providing information for research applications.

Most of the stations owned by the wildland fire agencies are placed in locations where they can monitor fire danger. RAWS units collect, store, and forward data to a computer system at the National Interagency Fire Center (NIFC) in Boise, Idaho, via the Geostationary Operational Environmental Satellite (GOES). The GOES is operated by the National Oceanic and Atmospheric Administration (NOAA). These data are automatically forwarded to several other computer systems including the Weather Information Management System (WIMS) and the Western Regional Climate Center (WRCC) in Reno, Nevada.

Fire managers use these data to predict fire behavior and monitor fuels; resource managers use the data to monitor environmental conditions. Locations of RAWS stations can be searched online courtesy of the Western Regional Climate Center.

The United States Forest Service and National Park Service use RAWS gauges for vegetation mapping, fire fuel mapping, fire risk estimates and fire detection, post-fire severity mapping, insect-infestation mapping, and relative water stress monitoring.



NWS Automated Surface Observing System (ASOS) Stations
Federally funded, ASOS is a joint program of the National Weather Service, the Federal Aviation Administration, and the Department of Defense. The ASOS systems serve as the Nation's primary surface weather observing network. ASOS works non-stop, 24 hours a day, every day of the year. ASOS is installed at more than 900 airports across the country, where they make observations.

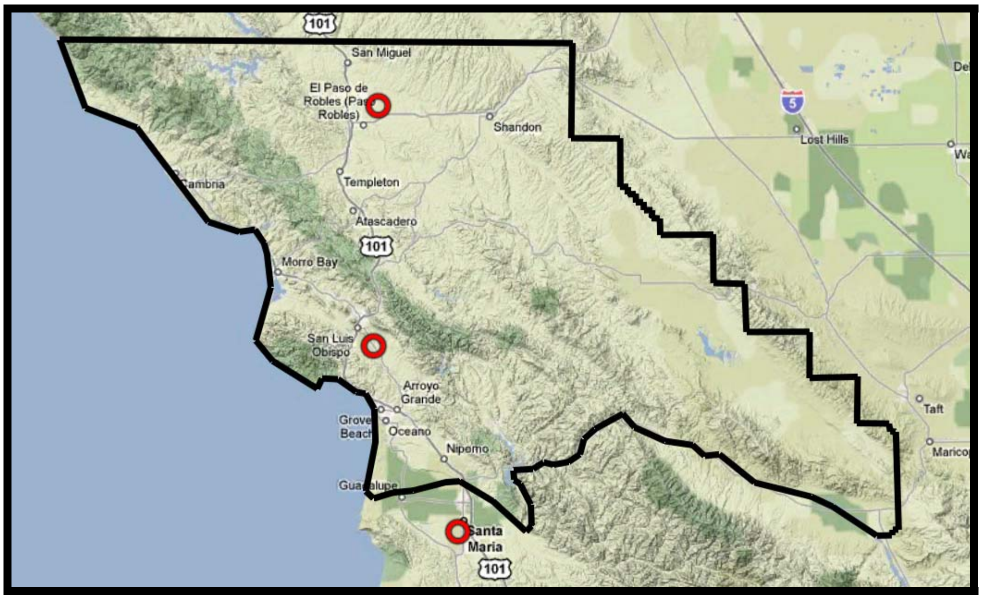
ASOS's constant stream of data benefits the forecast and research communities and promotes more accurate forecasts of all kinds.

ASOS Reports the following basic weather elements:

- Sky conditions such as cloud height and cloud amount up to 12,000 feet,
- Surface visibility up to at least 10 statute miles,
- Basic present weather information such as the type and intensity for rain, snow, and freezing rain,
- Obstructions to vision like fog, haze, and/or dust,
- Sea-level pressure and altimeter settings,
- Air and dew point temperatures,
- Wind direction, speed and character (gusts, squalls),
- Precipitation accumulation, and
- Selected significant remarks including- variable cloud height, variable visibility, precipitation beginning/ending times, rapid pressure changes, pressure change tendency, wind shift, peak wind.

Besides serving aviation needs, ASOS serves as a primary climatological observing network in the United States, making up the first-order network of climate stations. Because of this, not every ASOS is located at an airport; for example, one of these units is located at Central Park in New York City and another is located on Cabbage Hill near Pendleton, Oregon, for the sole purpose of providing climatological observations.

Regionally, there are three ASOS systems. These stations are located at the Paso Robles, San Luis Obispo, and Santa Maria airports, as shown on the figure below.



For more information on FAA ASOS Stations, go to:
http://www.faa.gov/airports_airtraffic/weather/asos/?state=CA.

National Weather Service Precipitation Forecasts (QPF)
The generation of increasingly accurate quantitative precipitation forecasts (QPFs) has been identified as a top priority of the National Weather Service and United States Weather Research Program. The primary applications of QPFs are;

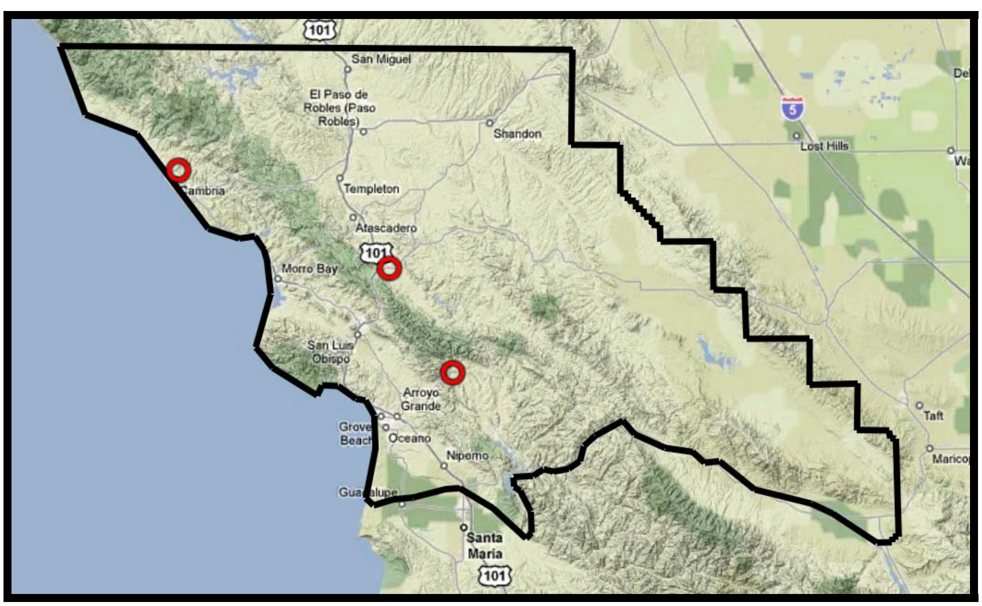
- Flood forecasting,
- Water resource management, and
- Prediction of significant snowfall.

In light of the devastating socioeconomic impacts of flash and river flooding and significant snowfall, QPFs have emerged as a critical facet of the end-to-end forecast process. Timely and accurate flood and winter storm forecasts are essential for the preservation of life and property. In an average year, the number of fatalities and property damage owing to flash and river flooding exceeds that for all weather-related natural phenomena. Although the death toll associated with heavy snow events is typically small, heavy snow can cripple transportation and often has a prolonged economic impact.

Improving QPF and its effect on flood forecasting and water resource management is being recognized as an immense challenge, and will require that the academic and research communities be engaged through the Collaborative Science, Technology, and Applied Research Program and the United States Weather Research Program. Progress in QPF, especially in flash-flood forecasting, will require better understanding of cloud microphysical processes and of land-surface-atmospheric interactions, improved measurements of atmospheric water vapor, better understanding of the dynamics of mesoscale convective systems, better parameterizations of cloud turbulent and microphysical processes, and further development of mesoscale numerical models.

In addition to the many scientific issues relating to QPF, there are also issues in provision of improved, real-time service to users, not the least of which involves the interaction of the important components of the modernized National Weather Service, including the National Centers for Environmental Prediction (NCEP), the Weather Forecast Offices (WFOs), and the River Forecast Centers(RFCs) that constitute an end-to-end forecast process. Several years ago, a Hydrologic Information Working Group was reformed to determine requirement for the production and use of QPF in these NWS components. An operations concept was developed by this working group for the production and use of quantitative precipitation information was developed in the modernized NWS. The next task is to develop a QPF implementation plan based on these concepts which accounts for the role of NCEP Service Centers, the WFOs and RFCs, and the implementation of Advanced Weather Interactive Processing System (AWIPS.)

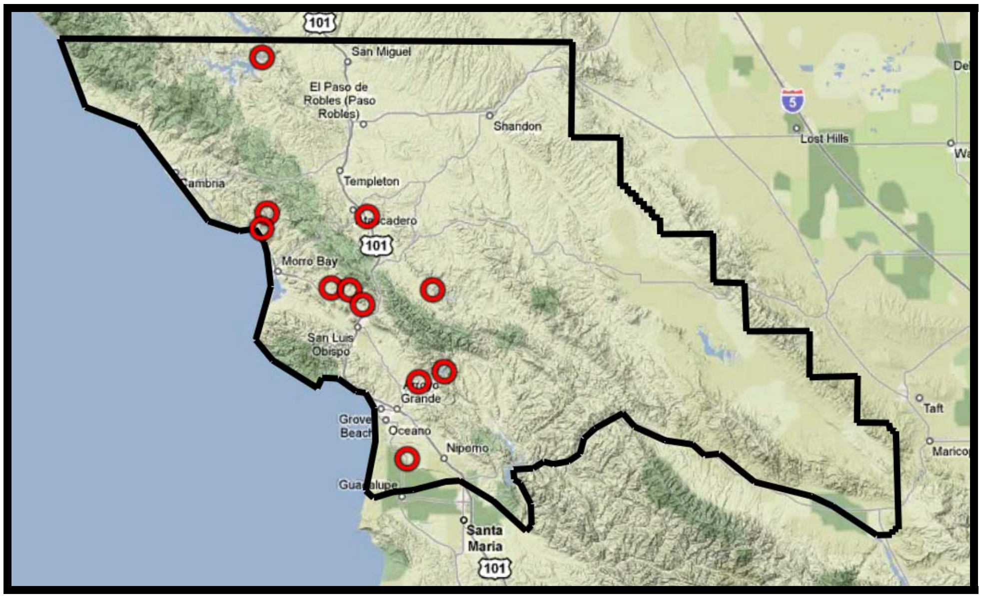
There are three National Weather Service QPF points in the region, as shown below.



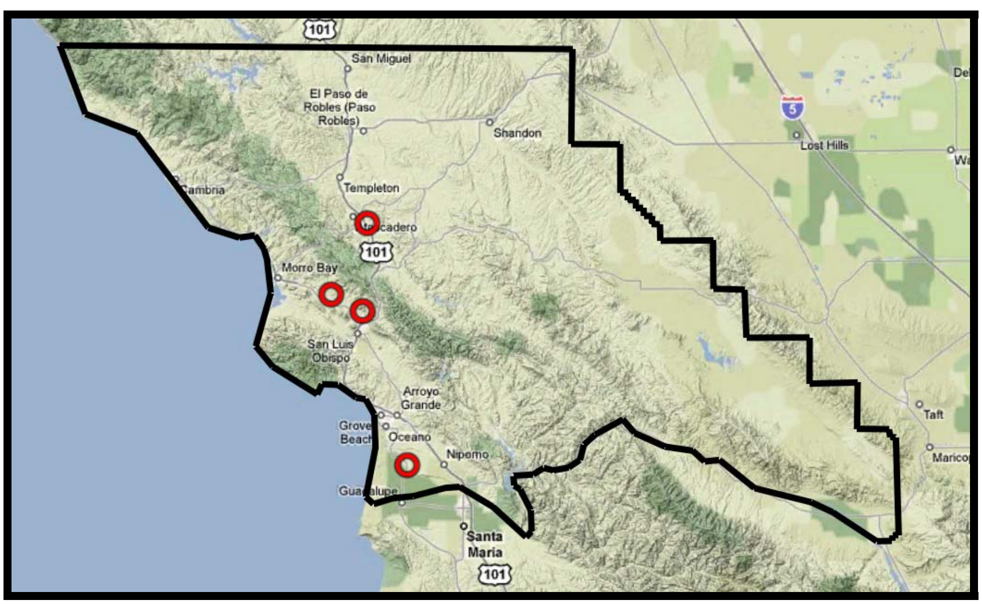
For more information on Local National Weather Service QPFs, go to: www.wrh.noaa.gov/lox/main.php?suite=hydrologyandpage=observations.

3.1.2. Evaporation

The following figure shows the locations in the region where evaporation information is collected. Evaporation data is either collected at reservoirs as part of daily reservoir operations, or by automatic weather stations.



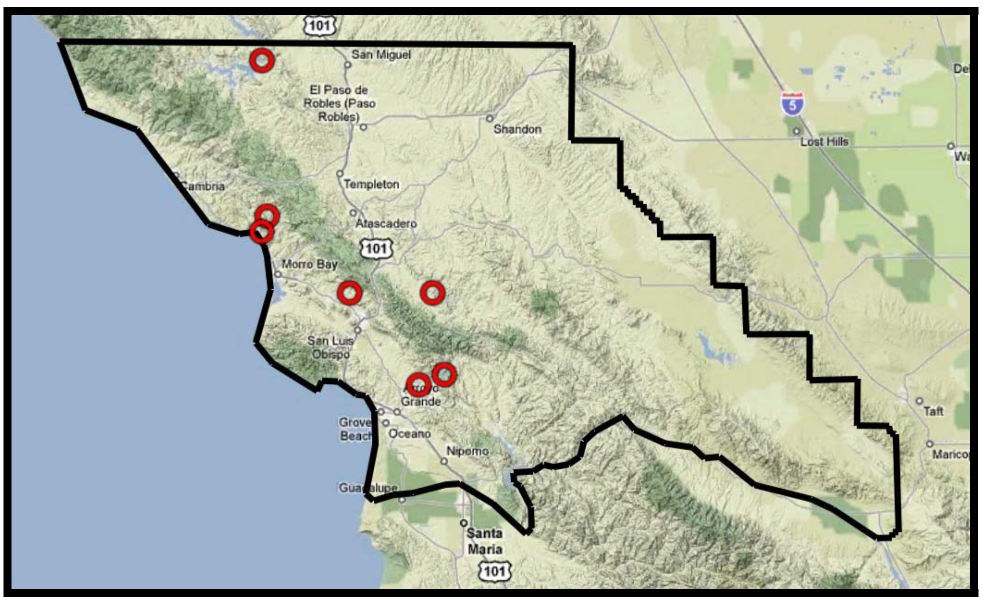
California Irrigation Management Information System (CIMIS) Stations
As discussed in the precipitation section, here are four (4) CIMIS stations currently maintained in the region. As shown on the figure below, there are four (4) CIMIS stations currently in operation throughout the region. Those stations are located in southeast Atascadero, west of Nipomo, 6.5 miles northwest of San Luis Obispo, and on the Cal Poly Campus.



More information on this program and access to the archive of online data for these sites is available at: http://www.cimis.water.ca.gov.

Reservoir Operations
As part of regular reservoir operations, daily pan evaporation values are recorded at the following regional reservoirs:

- Nacimiento Reservoir
- Whale Rock Reservoir (at the dam, and upstream of the reservoir on Cottontail Creek)
- Chorro Reservoir
- Salinas Reservoir (Santa Margarita Lake)
- Lopez Reservoir
- Lopez Terminal Reservoir



Data for each reservoir is available from the agency that operates the reservoir.

3.2. Surface Water Data

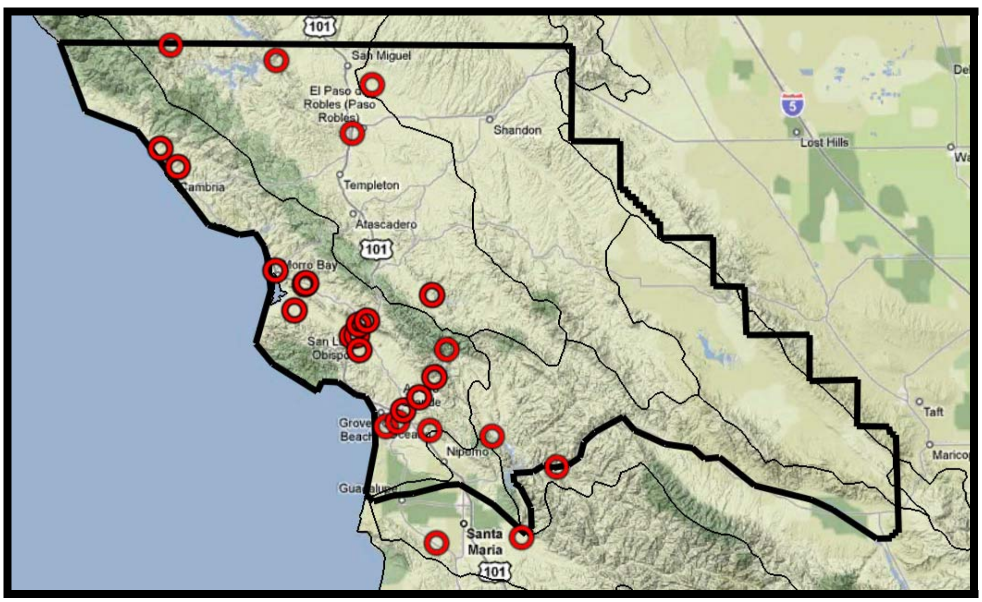
A few agencies in the region collect surface water information. Water level data is most commonly collected. At many sites, flow/discharge information is also collected. The following sections discuss the regional surface water data collection program.

3.2.1. Water levels

Water levels are typically collected in streams as part of a stream flow monitoring program. In addition, water levels are also collected in streams to support flood protection activities, and in reservoirs to assist with daily operations.

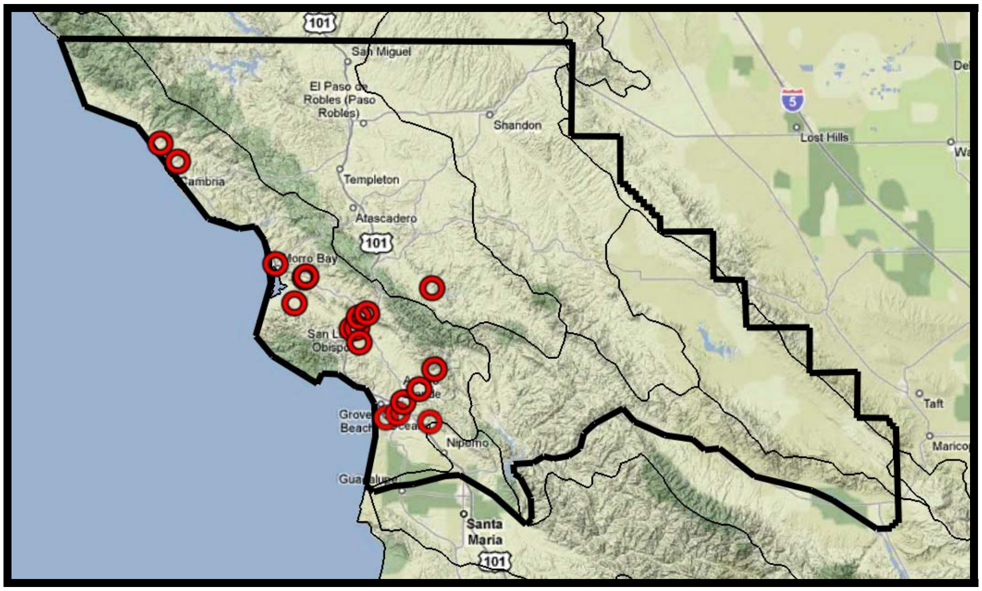
3.2.1.1.Streams

There are two agencies that collect stream flow information in the region: the San Luis Obispo County, and the United States Geological Survey. Regional water level measurement sites are shown in the following figure.



San Luis Obispo County Stream Measuring Program
The County has records of various length from over 30 stream gauging stations, including six stations that were acquired from the USGS. Currently, 18 stream gauge stations located throughout San Luis Obispo County are maintained the County Public Works Department. Each of the gauge stations measure the depth of flow or “stage” of the stream which can be used to estimate the stream discharge at the gauge location.

These sites are maintained to support County reservoir operations, flood control, and other water resources purposes. Most of the County gauges are on coastal creeks and rivers, with the exception one gauge on the Salinas River, just downstream of the Salinas Dam, as shown below.



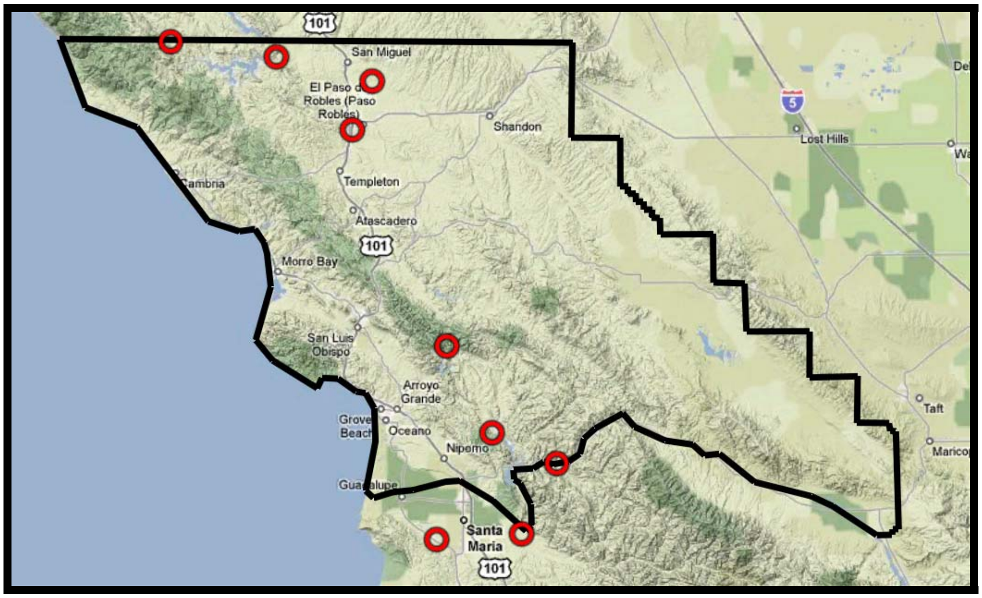
For more information of the County's Stream Gauges, go to: http://www.slocountywater.org/site/Water%20Resources/Data/maps/stream-flow.htm.

U.S. Geological Survey Stream Gauging Program

The U.S. Geological Survey (USGS) stream-gauging program provides streamflow data for a variety of purposes that range from current needs, such as flood forecasting, to future or long-term needs, such as detection of changes in streamflow due to human activities or global warming. The development of data on the flow of the Nation's rivers mirrors the development of the country. From the establishment of the first stream-gauging station operated by the USGS in 1889, this program has grown to include 7,292 stations in operation as of 1994. Data from the active stations, as well as from discontinued stations, are stored in a computer data base that currently holds mean daily-discharge data for about 18,500 locations and more than 400,000 station-years of record. The stream-discharge data base is an ever-growing resource for water resources planning and design, hydrologic research, and operation of water resources projects.

The U.S. Geological Survey's National Streamflow Information Program (NSIP) operates and maintains approximately 7,500 stream gauges which provide long-term, accurate, and unbiased information on streamflow to meet the needs of many diverse users. The mission of NSIP is to provide the streamflow information and understanding required to meet local, State, regional, and national needs.

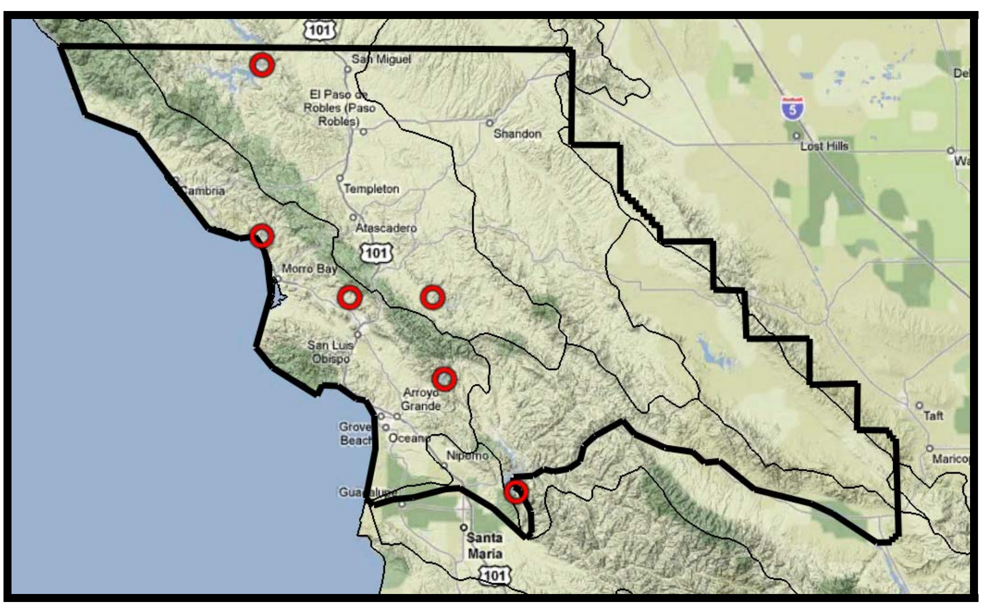
Streams maintained by the USGS tend to be on inland steams and rivers, and are typically funded, at least in part, at a local level. Most stream gauges in the region, if not all, support local reservoir operations.



The USGS collects data at approximately 1.5 million sites in all 50 states. Water resources data collected at those sites is available at: http://waterdata.usgs.gov/nwis.

3.2.1.2.Lakes and Reservoirs

Local Reservoir Operations
Daily surface water levels are measured for most major reservoirs in the region as part of daily reservoir operations. The County maintains reservoir operational records for two reservoirs – Lopez and Salinas. Other agencies collect and maintain reservoir operation data for the other major reservoirs, shown below:



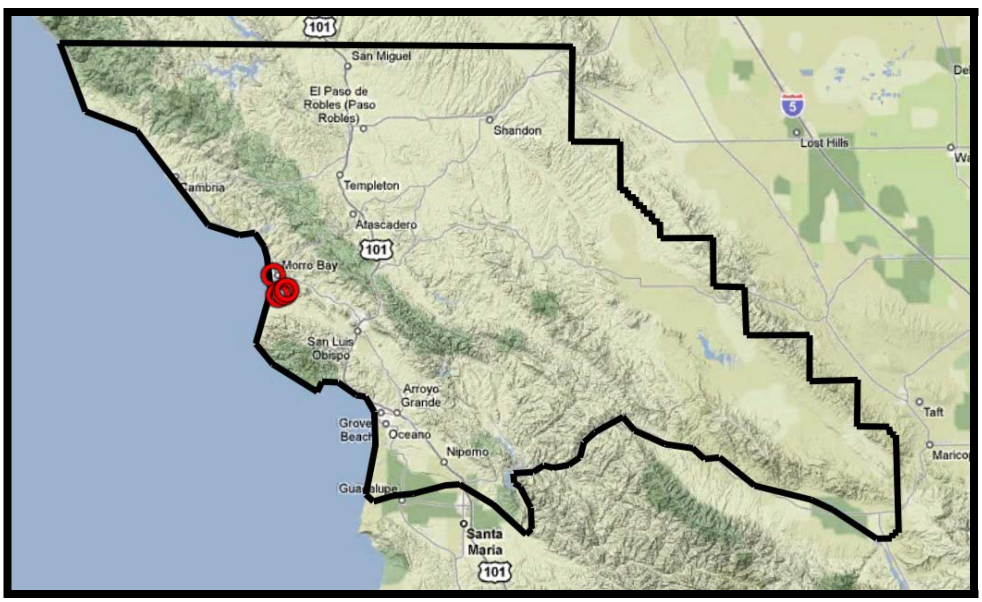
Data for each reservoir is available from the agency that operates the reservoir.

3.2.1.3. Estuaries and Wetlands

San Luis Obispo Science and Ecosystem Alliance (SLOSEA)
The SLOSEA is an integrated group of scientists, resource managers and stakeholders studying and supporting marine resources on the California Central Coast. Six SLOSEA science initiatives together provide the data for improved understanding of the Morro Bay ecosystem.

SLOSEA's Water Quality initiative was designed to map spatial and temporal changes in the physical and chemical characteristics of water quality in the Morro Bay ecosystem. These studies will also help to identify the importance of both natural and human sources in causing those changes. The ultimate goal is to use the knowledge gained to improve management and policy decisions.

In addition to water quality parameters[11], the depth of water is measured at the following sites:



More information on the sites maintained by SLOSEA can be found here: http://www.slosea.org.

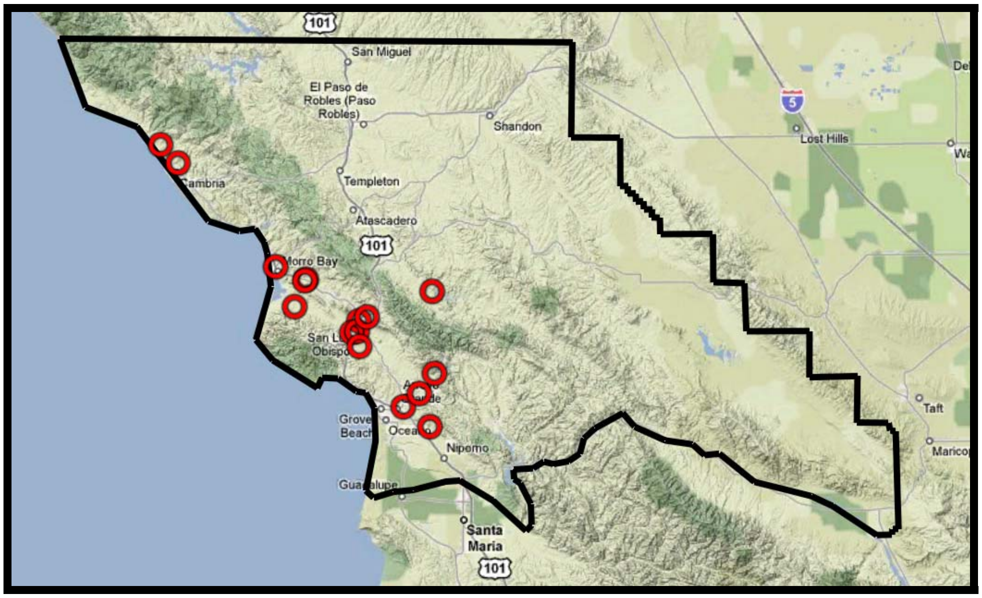
3.2.2. Discharge/Flow

3.2.2.1. Streams

SLO County Stream Measuring Program
In most cases, measuring discharge is one of the measured parameters at County stream gauging sites. A few County stream gauge sites are "stage-only" sites. These sites typically are

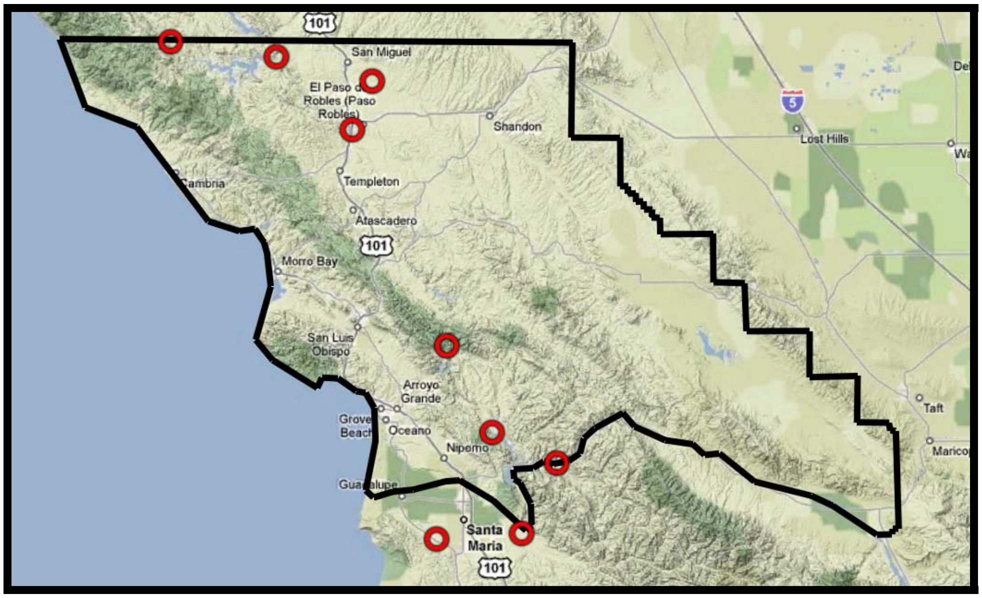
[11] Parameters measured: Conductivity (and Salinity), temperature, dissolved oxygen, oxygen saturation, fluorescence (a proxy for chlorophyll-a), turbidity, nitrate, and current/current profile.

established for flood forecasting purposes and discharge is not measured at these sites. The County stream gauging sites where discharge is regularly measured are shown below:



For more information of the County's Stream Gauges, go to:
http://www.slocountywater.org/site/Water%20Resources/Data/maps/stream-flow.htm.

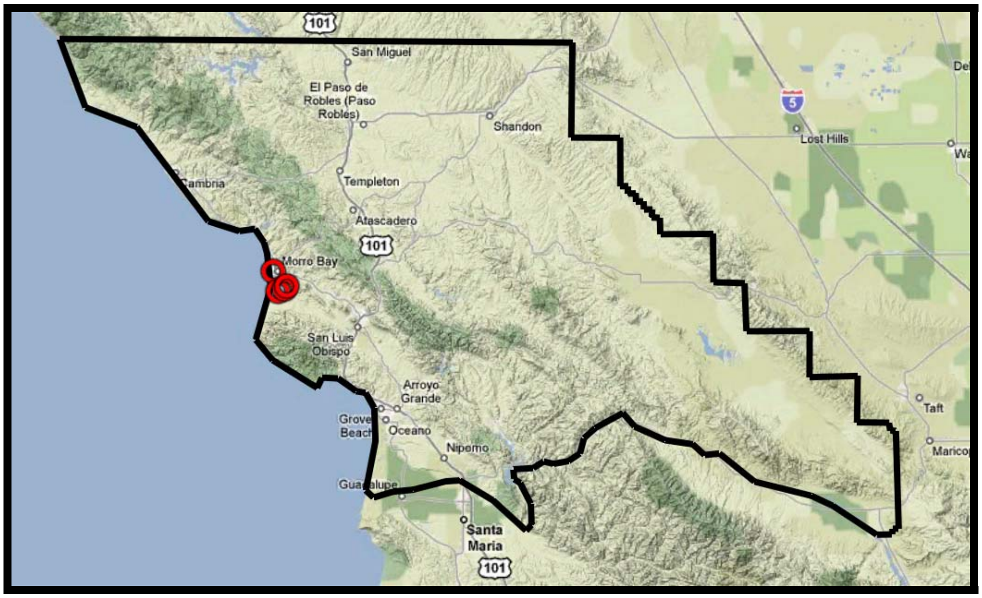
U.S. Geological Survey Stream Gauging Program
All USGS stream gauges in the region also measure discharge. Those sites are shown below:



Water resources data collected at these sites is available at: http://waterdata.usgs.gov/nwis.

3.2.2.2.Estuaries and Wetlands

San Luis Obispo Science and Ecosystem Alliance (SLOSEA)
Three of the four SLOSEA sites (discussed above) have instrumentation to measure the current profile. Using the current profile, one can calculate flow. The three sites, located in the estuary, which can measure the flow of the water system, are shown below:



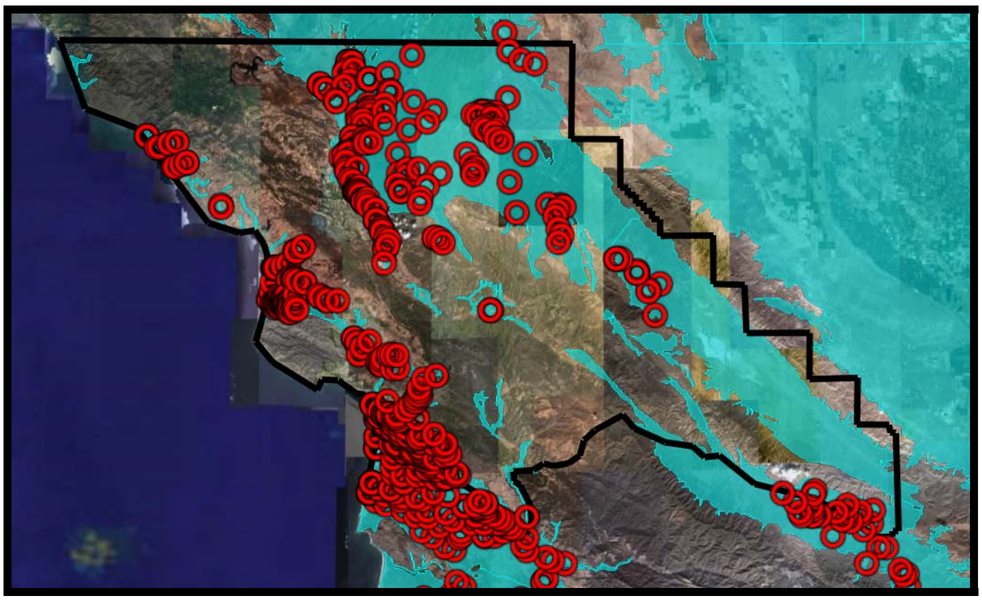
More information on the sites maintained by SLOSEA can be found here: http://www.slosea.org.

3.3. Groundwater Data

Groundwater data has been collected for many years in the region. Primarily the County has been the lead agency to collect this information from water providers, local agencies, and land owners.

3.3.1. Water levels

Water levels throughout the region have been collected in the primary groundwater basins of the region, as shown below. The colored regions delineate the defined groundwater basins of the region. Red circles indicate active well sites.



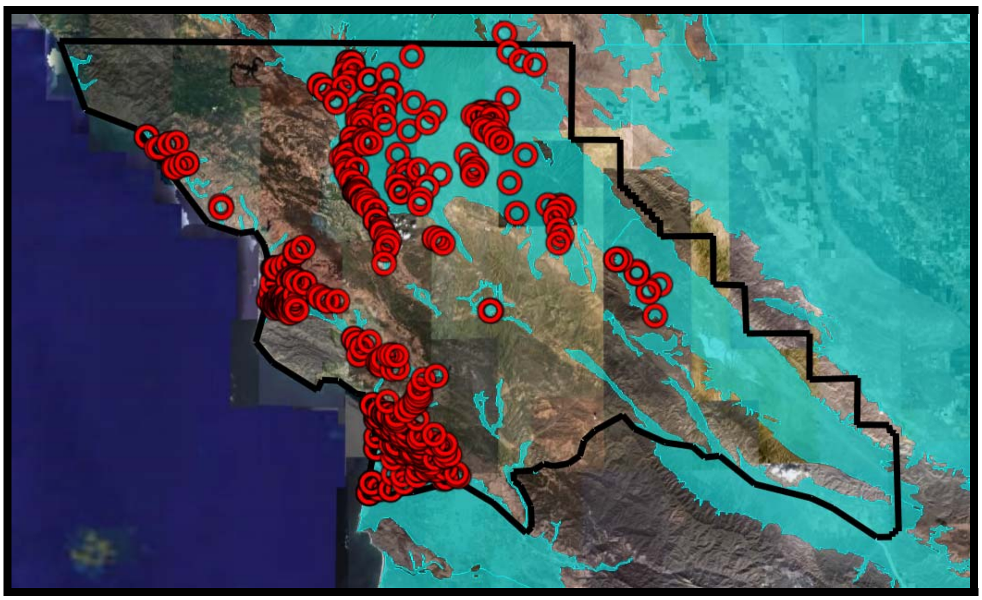
San Luis Obispo County Public Works Department Groundwater Measuring Program
Groundwater levels have been measured by the County of San Luis Obispo in selected wells on a semi-annual basis to provide data for planning and engineering purposes. The monitored wells are located within groundwater basins and subbasins of the Central Coast Hydrologic Region described in Department of Water Resources Bulletin 118. Program wells are selected based on aquifer definition and uniform aerial distribution.

The County maintains a database with hundreds of wells. Readings started in the early 1950's. Water level readings are taken in April and October. Access to wells and ability to measure well levels is getting increasingly difficult. More properties are fenced; gates are locked; more dogs; people want advance notice to access their property, etc. Level readings are taken at active, private and public wells are in operation during the scheduled readings. Well levels are not read if the pump is on.

The groundwater elevation data obtained from this monitoring program collected over time provide a general indication of ground water basin conditions. This information is used in determining groundwater availability and basin yield estimates, and for hydrogeologic and geotechnical impacts and assessment studies on potential projects.

The Salinas River corridor of the Paso Robles Basin, Los Osos Valley, Nipomo Mesa, San Luis Obispo Valley, and the Tri-Cities Mesa have a large number of program wells because of their high population density. The Chorro Valley, Guadalupe hydrologic area, Morro Valley, Creston area, San Juan area, and Shandon areas have a large number of program wells because of their greater agricultural land use.

The current active wells measured in the region, and the regional groundwater basins are shown below:

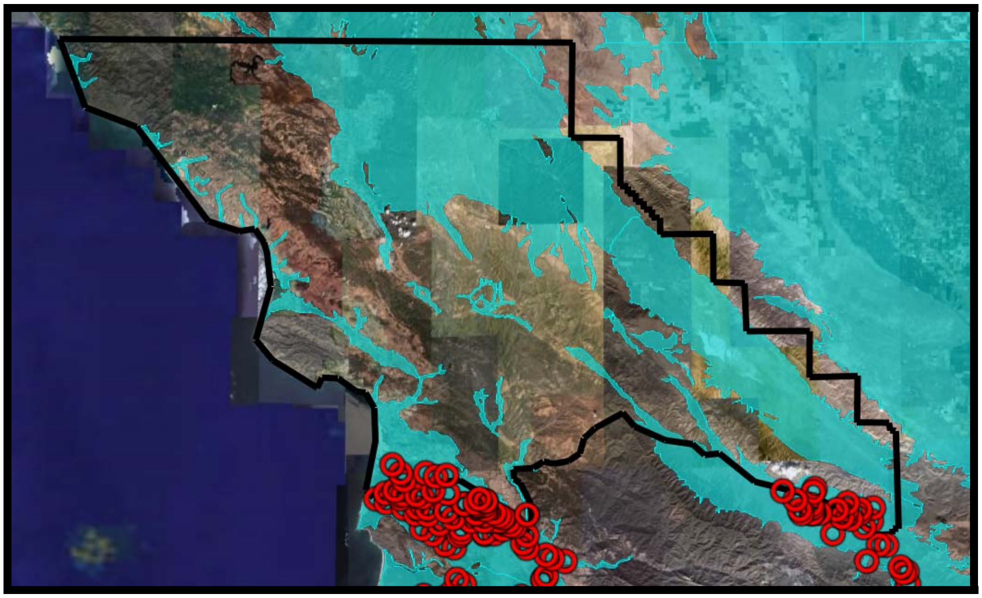


Information on these wells can be obtained from the San Luis Obispo County Public Works Department.

U.S. Geological Survey

The USGS measures depth to groundwater in thousands of wells thought the Nation. Their ground-water database contains records from about 850,000 wells that have been compiled during the course of ground-water hydrology studies over the past 100 years.

The USGS is responsible for measuring the wells in Santa Barbara County's groundwater program. Locally, only a few wells are measured by the USGS, all of which are located on the southern county border in the vicinity of Santa Maria and Cuyama.



Information from these wells is served via the internet through NWISWeb, the National Water Information System Web Interface. NWISWeb provides all USGS ground-water data that are approved for public release. More information can be found at: http://waterdata.usgs.gov.

3.3.2. Geologic Data and Well Logs

Perhaps thousands of well logs are on file for locations throughout the County, although a clear policy is lacking regarding release of the log information. Well logs are on file at both the County Public Works Department, Health Department, and through the Department of Water Resources.

There are certainly far less available well logs than wells, and many of the existing wells are confidential.

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3.4. Water Use Data

Water use is not monitored by a regional authority. It is the responsibility of each water provider to monitor their customers' water use. Fortunately, most water providers in the region meter their customers' water use. Each water provider should have information or their customers' water use. Annually, water use data is requested by the County from these water providers.

Water users that own or use private wells and individuals that live outside of established city limits are typically not required to monitor or report their water use to any agency. One of the largest groups of water users that do not have their water use monitored are agricultural water users, who relatively use a large amount of water.

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3.5. Water Quality Data

Numerous federal, state, and local agencies and organizations have conducted water quality monitoring in the Region over the past several decades. Non-profit organizations and other agencies in San Luis Obispo County are currently monitoring water quality in the County and the Central Coast region. These groups have relatively well-developed programs. Continued monitoring at the regional level will provide a better overall picture of water quality in the County and will make the most efficient use of County resources[12]. Some regional water quality monitoring efforts are described below.

3.5.1. Sampling Surface Water

Water Use Monitoring
Operators of public water systems conduct routine monitoring to ensure that the water they produce complies with Safe Drinking Water Act standards. Results are reported to the State of California Department of Health Services (DHS). Monitoring broadly encompasses several categories of constituents: microorganisms, disinfectants, dsinfection byproducts, inorganic chemicals, organic chemicals, and radionuclides.

Sampling is conducted at treatment plants, within distribution systems, and at the tap, and monitoring results are evaluated to ensure that applicable drinking water quality standards are met. For regulated constituents, results are compared to Primary and Secondary MCLs, and unregulated contaminants are evaluated against DHS Detection Limits for Purposes of Reporting (e.g., color, corrosivity, and odor).

Small water systems[13] are also required to conduct routine monitoring and report to the Environmental Health Services Division of the San Luis Obispo County Public Health Department.

Surface Water Ambient Monitoring Program (SWAMP)
The Surface Water Ambient Monitoring Program (SWAMP) was proposed in a Report to the Legislature to integrate existing water quality monitoring activities of the State Water Resources Control Board and the Regional Water Quality Control Boards, and to coordinate with other monitoring programs.

Ambient monitoring refers to any activity in which information about the status of the physical, chemical and biological characteristics of the environment is collected to answer specific questions about the status, and trends in those characteristics. For the purposes of SWAMP, ambient monitoring refers to these activities as they relate to the characteristics of water quality. Only a small portion of SWAMP can be implemented at its current funding level. As a result, resources are focused where monitoring information is most needed to support regional program

[12] San Luis Obispo County Stormwater Management Plan, June 2006.
[13] Systems having between 15 - 199 service connections and regularly serving 25 or more individuals daily at least 60 days out of the year, or systems that have 5-14 service connections and not regularly serving more than an average of 25 individuals daily for more than 60 days out of the year

priorities, such as maintaining high quality waters, such as Lake Tahoe, or supporting restoring priority watersheds.

SWAMP is a statewide monitoring effort designed to assess the conditions of surface waters throughout the state of California. The program is administered by the State Water Board. Responsibility for implementation of monitoring activities resides with the nine Regional Water Quality Control Boards that have jurisdiction over their specific geographical areas of the state. Monitoring is conducted in SWAMP through the Department of Fish and Game and U.S. Geological Survey master contracts and local Regional Boards monitoring contracts.

SWAMP also hopes to capture monitoring information collected under other State and Regional Board Programs such as the State's TMDL (Total Maximum Daily Load), Nonpoint Source, and Watershed Project Support programs. SWAMP does not conduct effluent or discharge monitoring, which is covered under National Pollutant Discharge Elimination System permits and Waste Discharge Requirements.

Data from sites that are a part of the SWAMP can be obtained online at: http://bdat.ca.gov.

303(d) Clean Water Act
Under section 303(d) of the Clean Water Act, states, territories, and authorized tribes are required to develop lists of impaired waters. These are waters that are too polluted or otherwise degraded to meet the water quality standards set by states, territories, or authorized tribes. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop total maximum daily loads (TMDLs) for these waters. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards.

National Pollutant Discharge Elimination System Compliance Monitoring
As authorized by the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. Point sources are discrete conveyances such as pipes or man-made ditches. Industrial, municipal and other facilities must obtain permits if their discharges go directly to surface waters.

EPA conducts inspections of facilities subject to the regulations to determine compliance. EPA inspections involve:

- Reviewing discharge monitoring reports
- Interviewing facility personnel knowledgeable of the facility
- Inspecting the processes that generate and treat wastewater
- Sampling wastewater discharges to navigable waterways and other points in the Generation or treatment process
- Reviewing how samples are collected and analyzed by the laboratory

3.5.1.1.Streams, Lakes & Reservoirs

Central Coast Ambient Monitoring Program (CCAMP)

The Central Coast Regional Water Quality Control Board (Regional Board) is responsible for maintaining and enhancing water quality throughout central coastal California, including 370 miles of coastline in San Mateo, Santa Cruz, Monterey, San Luis Obispo, and Santa Barbara counties. In 1998, the Regional Board initiated the Central Coast Ambient Monitoring Program (CCAMP), with a broad mandate to gather water quality data in groundwater, rivers, streams, estuaries, and the ocean, throughout the Regional Board's jurisdiction. It is the Regional Boards goal to "collect, assess, and disseminate water quality information to aid decision-makers and the public in maintaining, restoring, and enhancing water quality and associated beneficial uses."

Currently there are 23 river/stream sites in the region, primarily in the Morro Bay Watershed.

SLO County Water Quality Lab
Water sampling and analysis for District-provided water supplies are performed by the San Luis Obispo County Water Quality Laboratory. This lab is certified by the DHS as an environmental testing laboratory for bacteriological and chemical analyses. The lab performs analyses on water and wastewater for all County Special Districts including:

- Cayucos
- County Airport
- Lopez Recreation Area
- Lopez Water Treatment Plant
- Nipomo
- Oak Shores
- Operations Center
- Salinas Project
- San Luis Obispo Country Club
- Santa Margarita
- Shandon
- State Water

Waste Discharge Compliance Monitoring
Under Federal Clean Water Act Section 401, every applicant for a federal permit or license for any activity that may result in a discharge to a water body must obtain state water quality certification that the proposed activity will comply with state water quality standards.

The Regional Board regulates point source discharge of wastewater to land and surface waters of the region so that the highest quality and beneficial uses of these waters are protected and enhanced. Regulation is by issuance of either Waste Discharge Requirements (WDRs) or National Pollutant Discharge Elimination System (NPDES) permits. Both WDRs and NPDES permits contain monitoring requirements to verify compliance with applicable conditions. These requirements vary according to those specific conditions.

All persons or agencies discharging (or proposing to discharge) pollutants from a point source into any waters of the state are required to apply for and have a permit under the NPDES to discharge. Typically publicly owned treatment works are regulated, through NPDES permits, to monitor water quality for all points of water discharge

Key permit conditions applicable to all NPDES permits include those for monitoring. These conditions apply to both stormwater and non-stormwater discharges. Although the state or local authority, or EPA's general permits can impose additional requirements, the permit holder must typically monitor discharges within the following parameters:

- Flow
- Pollutants listed in the terms of the permit conditions
- Pollutants that could have a significant impact on the quality of the receiving streams
- Pollutants specified as subject to monitoring by EPA regulations
- Other pollutants for which the EPA requests monitoring in writing

Each of these monitoring parameters must be measured at the frequency specified in the NPDES permit or at intervals sufficiently frequent to yield data that would characterize the nature of the discharge. Some cities and agencies that are currently operating wastewater collection, treatment and disposal systems under a NPDES permit include:

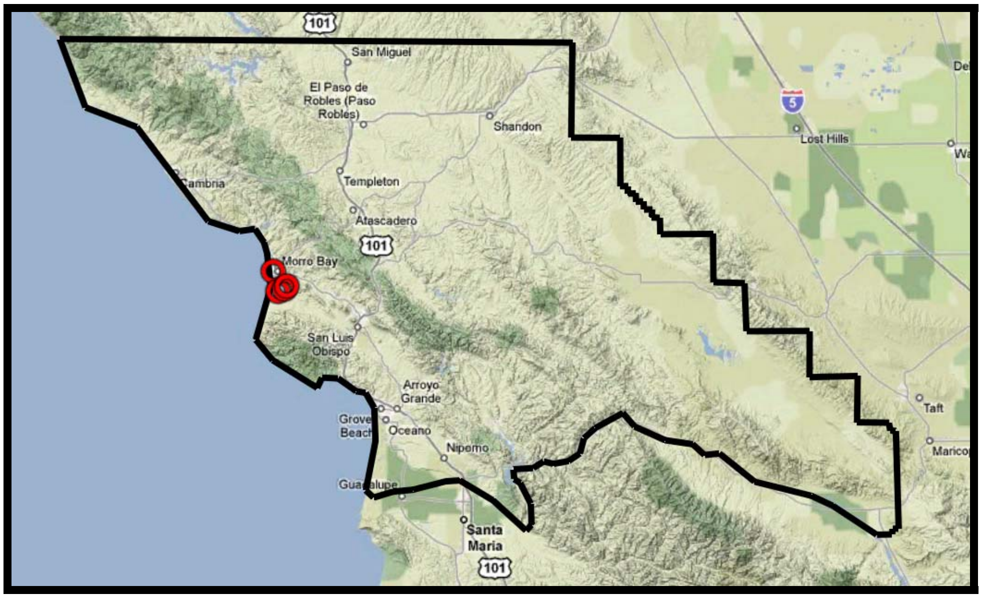
- Paso Robles City
- South San Luis Obispo County Sanitation District
- Pismo Beach City

3.5.1.2.Estuaries and Wetlands

Current monitoring in estuaries and wetlands is summarized below. Note that there is significant estuarine monitoring that is conducted by other federal agencies, state and local agencies, and the academic community that may not be discussed here.

San Luis Obispo Science and Ecosystem Alliance (SLOSEA)
As mentioned above, SLOSEA monitors water quality in the Morro Bay Estuary at the following sites and hopes to map spatial and temporal changes in the physical and chemical characteristics of water quality in the Morro Bay ecosystem.

Conductivity (and salinity), temperature, dissolved oxygen, oxygen saturation, fluorescence (a proxy for chlorophyll-a), turbidity, nitrate, current/current profile, and depth of water are measured at these sites.

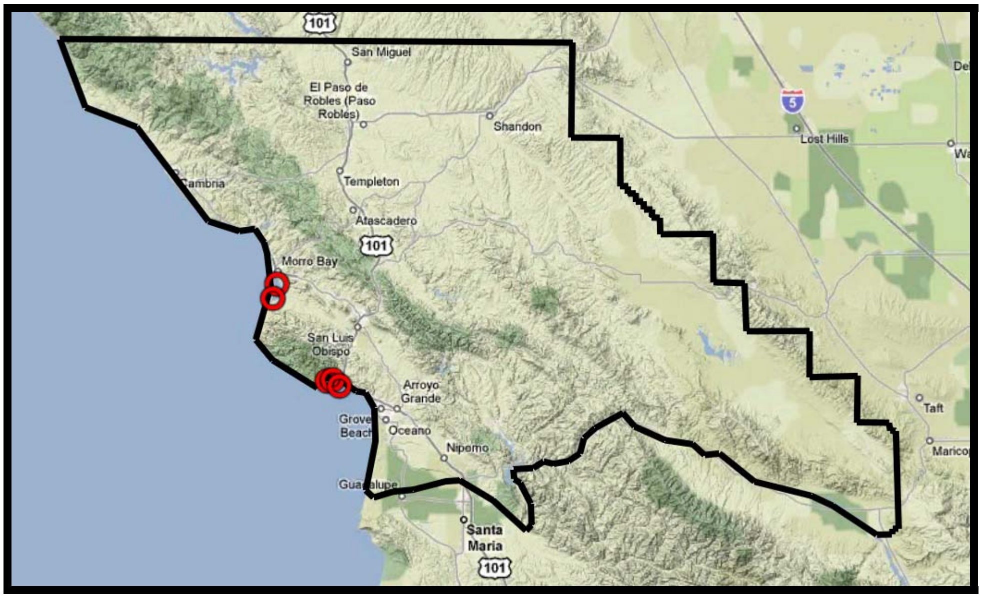


More information on the sites maintained by SLOSEA can be found here: http://www.slosea.org.

EPA's National Coastal Assessment
The US EPA's National Coastal Assessment surveys the condition of the Nation's coastal resources by creating an integrated, comprehensive monitoring program among the coastal states.

To answer broad-scale questions on environmental conditions, EMAP and its partners have collected estuarine and coastal data from thousands of stations along the coasts of the continental United States. EMAP's National Coastal Assessment comprises all the estuarine and coastal sampling done by EMAP beginning in 1990. This includes the sampling done in the biogeographic provinces as well as data from the Regional EMAP (REMAP) studies done by EPA Regional Offices.

Locally there are five stations in the region, as shown below.



These data can be retrieved and stations mapped online at:
http://oaspub.epa.gov/coastal/coast.search.

System-Wide Monitoring Program (SWMP)
A water quality monitoring program has been implemented in each of the 26 reserves of the National Estuarine Research Reserves System (NERRS), some dating back to 1995. The primary emphasis on water quality observations is their relationship with weather observations and coastal use activities and is intended to identify and understand short-term variability and long-term changes in the integrity of representative estuarine ecosystems and coastal watersheds.

3.5.1.3.Oceans and Beaches

California Clean Beaches Program
The Beaches Environmental Assessment and Coastal Health (BEACH) Act of 2000 requires that coastal and Great Lakes states and territories report to EPA on beach monitoring and notification data for their coast recreation waters. The BEACH Act defines coastal recreation waters as the Great Lakes and coastal waters (including coastal estuaries) that states, territories, and authorized tribes officially recognize or designate for swimming, bathing, surfing, or similar activities in the water.

The BEACH Program focuses on the following five areas to meet the goals of improving public health and environmental protection for beach goers and providing the public with information about the quality of their beach water:

- Strengthening beach standards and testing
- Providing faster laboratory test methods
- Predicting pollution

- Investing in health and methods research
- Informing the public

Locally, the Environmental Health Department of San Luis Obispo County conducts the public health beach monitoring and regulatory program. In 2008, seventeen (17) beach sites were analyzed for three indicators: enterococcus, total coliform, and fecal coliform bacteria. Beaches monitored included:

- Avila Beach
- Cayucos Beach
- Hearst Memorial State Beach
- Leffingwell Beach
- Moonstone Beach
- Morro Bay City Beach
- Morro Strand State Beach
- N Morro Strand State Beach
- Oceano Dunes State Rec Area
- Olde Port Beach
- Pismo State Beach
- Pismo State Beach, Oceano
- S Morro Strand State Beach
- San Simeon Beach
- Sewers
- Shell Beach
- Spyglass Park

The Environmental Health Services Department monitors beach water quality for recreational use through a California State grant between April 1 and October 31 of each year. Monitoring includes ocean water samples collected from the County's most visited beaches on a weekly basis. Shoreline samples are analyzed for bacterial indicators.

National Data Buoy Center

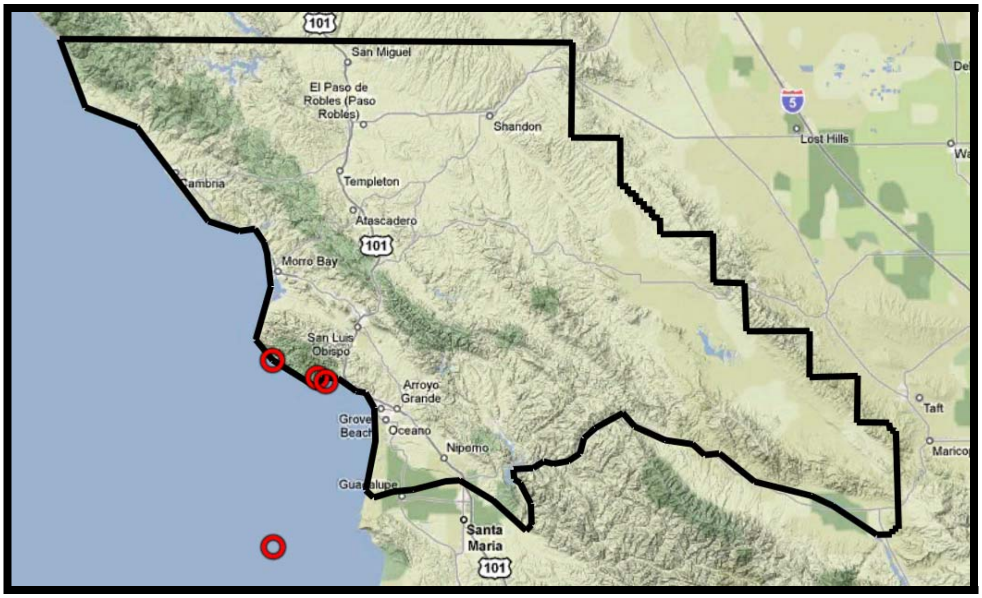
The National Oceanic and Atmospheric Administration (NOAA) National Data Buoy Center (NDBC), a part of the National Weather Service, designs, develops, operates, and maintains a network of data collecting buoys and coastal stations.

The major marine observing systems that form the US National Marine Observations Backbone are:

- NOAA's National Weather Service's NDBC Ocean Observing System (NWS NOOS),
- NOAA's National Ocean Service's (NOS) National Water Level Observation Network (NWLON) and their Physical Oceanographic Real-Time System (PORTS)
- NOAA's Tropical Moored Buoy (TMB) projects
- NOAA's OAR drifting buoy programs.

NWS forecasters need frequent, high-quality marine observations to examine conditions for forecast preparation and to verify their forecasts after they are produced. Other users rely on the observations and forecasts for commercial and recreational activities. NDBC provides hourly observations from a network of about 90 buoys and 60 Coastal Marine Automated Network (C-MAN) stations to help meet these needs. All stations measure wind speed, direction, and gust; barometric pressure; and air temperature. In addition, all buoy stations, and some C-MAN stations, measure sea surface temperature and wave height and period. Conductivity and water current are measured at selected stations.

There are a handful of stations in the region, as shown below.



More information on stations that are a part of the National Data Buoy Center can be found at: http://www.ndbc.noaa.gov.

3.5.2. Sampling Groundwater

Groundwater is often sampled to determine the chemistry of the groundwater for purposes of utilizing the water for human consumption. Public water supply systems are subject to regulation by the California Department of Health Services, which specifies minimum guidelines for sampling frequency and sampling procedures that must be followed by any water system operator.

United States Geological Survey (USGS)
The USGS has conducted water quality sampling at more than 150 sites in the County since the 1920s. Analytical parameters vary, but can include physical measures (e.g., pH and temperature) nutrients, major inorganics (e.g., chloride, potassium, and sulfate), and minor inorganics (e.g., boron and manganese). The USGS also conducts research and special studies to further the development of scientific knowledge and its application to real world management problems.

Waste Discharge Compliance Monitoring
The Regional Board regulates point source discharge of wastewater to groundwaters of the Region so that the highest quality and beneficial uses of these waters are protected and enhanced. Regulation is by issuance of either Waste Discharge Requirements (WDR). WDR permits contain monitoring requirements to verify compliance with applicable conditions. These requirements vary according to those specific conditions.

WDR permit requirements often include groundwater monitoring. For example, the Regional Board has established monitoring programs for recycled water and wastewater operations that discharge to groundwater. Dischargers must periodically collect and analyze groundwater quality samples from wells representative of the receiving groundwater.

For a list of adopted orders, permits, resolutions, and settlements issued by the Central Coast Regional Water Quality Control Board, go to:
http://www.waterboards.ca.gov/centralcoast/board_decisions/adopted_orders/

State Water Resources Control Board Ground-Water Ambient Monitoring and Assessment Program (GAMA)
The Ground-Water Ambient Monitoring and Assessment Program (GAMA) program is a comprehensive assessment of statewide ground-water quality. The program is designed to help better understand and identify risks to ground-water resources. Ground water will be sampled at many locations across California in order to characterize its constituents and identify trends in ground-water quality. The results of these tests will provide information for water agencies to address a variety of issues ranging in scale from local water supply to statewide resource management.

The GAMA program was developed in response to the Ground-Water Quality Monitoring Act of 2001 (Sections 10780-10782.3 of the Water Code): a public mandate to assess and monitor the quality of ground water used as public supply for municipalities in California. The goal of the act was to improve statewide ground-water monitoring and facilitate the availability of information about ground-water quality to the public. The State Water Resources Control Board is implementing the GAMA Program in coordination with the U.S. Geological Survey and Lawrence Livermore National Laboratory.

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4. Data Gap Identification

Because of the growing interest in water management and water planning, the subjects of monitoring networks for both quantitative and qualitative data become more and more in focus. Therefore, a general approach is needed to design and optimize monitoring networks, which explicitly takes into account the important part of the objectives in the optimization process.

In general, a well-designed data collection program provides the necessary information to determine the sources, extent, dependability, and quality of water resources, upon which is based an evaluation of the possibilities for their utilization and control. The aim of a network is to provide a density and distribution of stations in a region so that, by interpolation between data sets at different stations, it will be possible to determine with sufficient accuracy for practical purposes, the characteristics of the basic hydrological and meteorological elements anywhere in the region

In the early stages of development of a hydrological network, the first step should be the establishment of a minimum network. Such a network should be composed of the minimum number of stations which the collective experience of hydrological agencies of many countries has indicated to be necessary to initiate planning for the economic development of the water resources.

The minimum network is one that will avoid serious deficiencies in developing and managing water resources on a scale commensurate with the overall level of economic development of the county. It should be developed as rapidly as possible by incorporating existing stations as appropriate. In other words, a minimum network will provide the basic framework for network expansion to meet future needs for specific purposes. It is emphasized that a minimum network will not be adequate for the formulation of detailed development plans and will not meet the numerous requirements of a developed region for the operation of projects and the management of water resources.

Each hydrologically unique area should be monitored to the best degree possible. A hydrologically unique area is one that is does not exhibit common traits in terms of any of the following areas:

- Climate/Weather
- Solis/Groundcover
- Development (urban and rural)
- Terrain (elevation, slope, and orientation of terrain features)
- Environmental resources

With an understanding of the necessary data collection components necessary for a regional water resources data collection network and information on the current regional data collection program, it is possible to identify the regional data gaps, which are summarized in the following table.

	Water Resources Planning	Flood Management and Planning
Precipitation		
Recording Rain Gauges	12-15*	0
Storage Rain Gauges	30-37*	0
Real-Time Rain Gauges	0	4
Evaporation		
Evaporation Pans or Weather Stations	2	0
Streams		
Gauge Sites (with discharge)	7-9	0
Real-time Stage-only Gauge Sites	0	6
Wetlands & Estuaries		
Stage Gauges	0	0
Reservoirs		
Stage Gauges	0	0
Groundwater		
Wells	75	0

* Depending on the gauge placement, one gauge may meet multiple needs.

This table does not take into account that some sites and sensors can serve dual purposes or that real-time gauges can be collocated with other recording gauges.

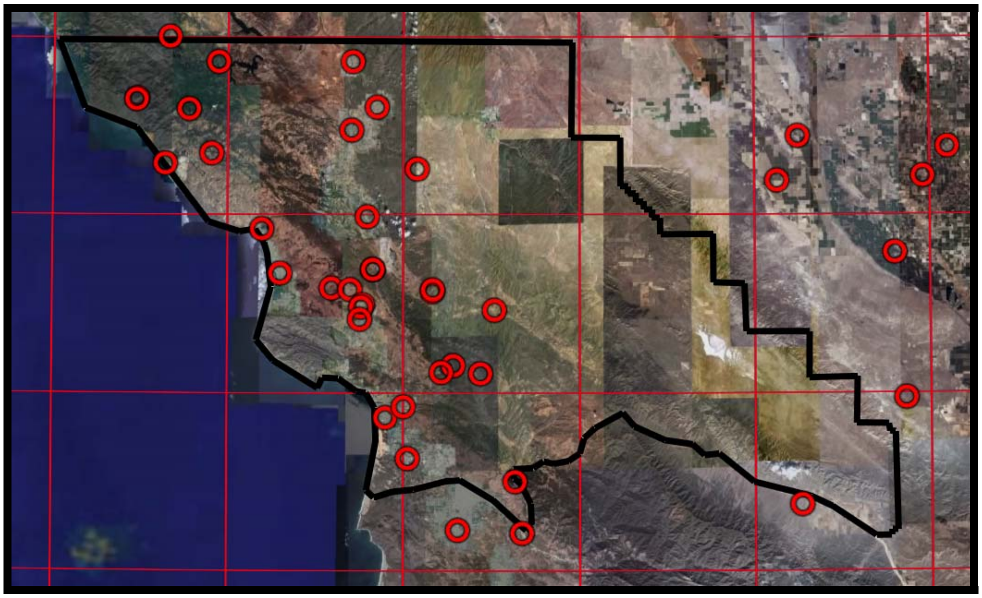
4.1. Planning Purposes

4.1.1. Water Resources Planning

4.1.1.1. Meteorological Data

4.1.1.1.1. Precipitation

For rural water resources planning, it is recommended that there be at least one recording rain gauge per 500 square miles. The figure below shows the recording rain gauge sites in the region. Each square of the red grid is 500 square miles. At this grid size, there should be approximately one recording gauge per square.

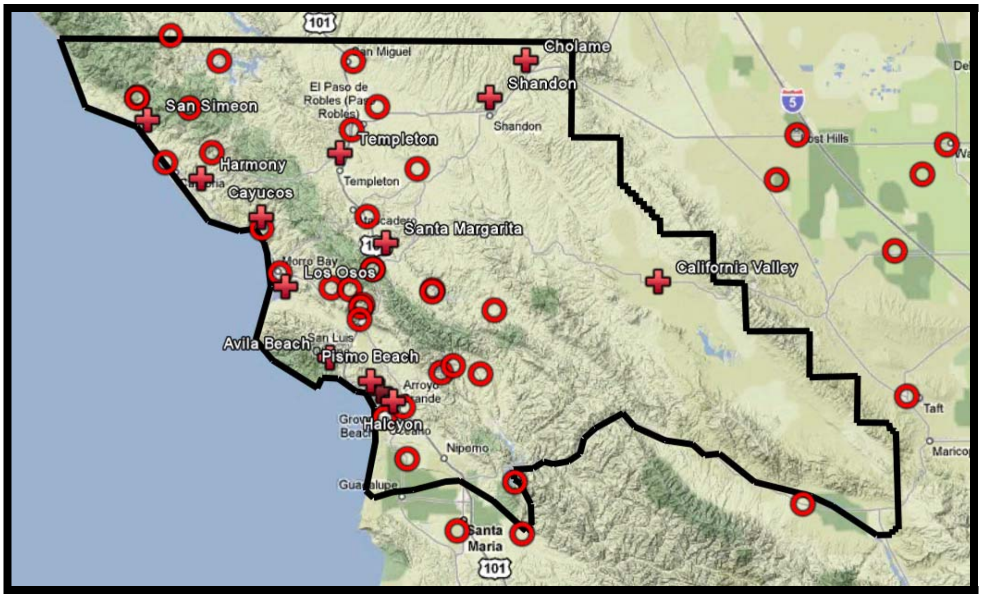


For rural water resources planning, the density of recording rain gauges towards the western portion of the region is more than adequate, whereas the eastern portion of the region is lacking. For rural water resources planning, it is recommended to place at least two additional recording gauges in the following rural areas:

- Shandon
- California Valley

In urban areas, each town, city, or community services area should have at least one centrally located recording rain gauge. The following communities do not currently have any recoding rain gauges within a mile of the following communities:

- Avila Beach
- Baywood/Los Osos
- California Valley
- Cholame
- Grover Beach
- Halcyon
- Harmony
- Pismo Beach
- San Simeon
- Santa Margarita
- Shandon
- Templeton



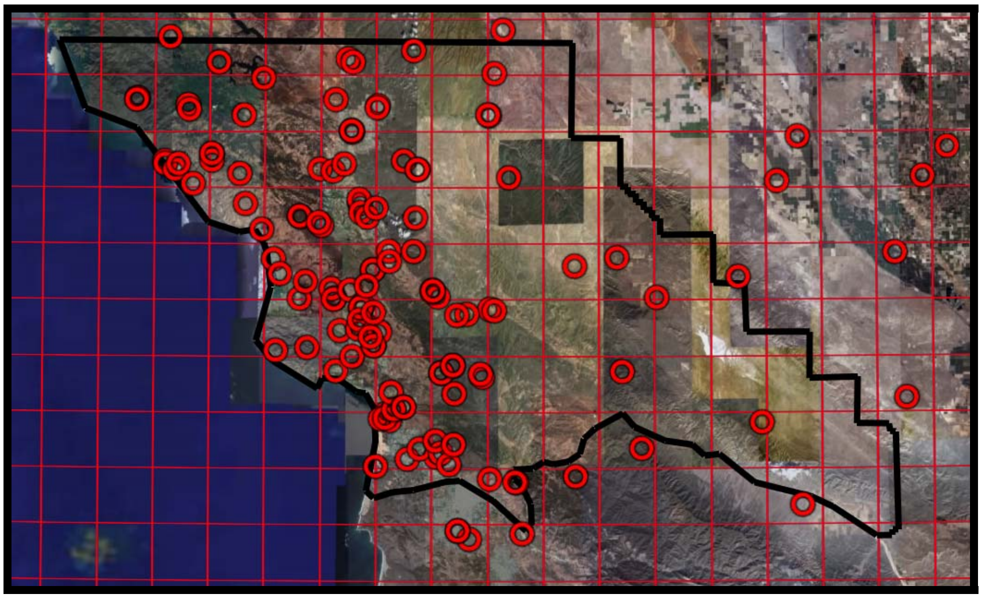
It is recommended that a recording rain gauge be installed at each of these communities, as indicated by the red crosses ("+") in the figure above. (The red circles indicate sites that currently have a recording rain gauge in operation.)

Each stream gauge should have a recording rain gauge associated with it. For this purpose, potentially three (3) gauges need to be installed at the following County stream gauge locations:

- San Simeon Creek
- Los Osos Creek
- Upper Los Berros Creek

Ultimately, these gauges could serve other purposes and may not increase the net number of additional gauges needed to fill the gaps.

For rural water resources planning, it is recommended that there be at least one rain gauge per 50 square miles. The figure below shows all the rain gauge sites in the region. Each square of the red grid is 50 square miles. At this grid size, there should be approximately one rain gauge per square.



For rural water resources planning, the density of total rain gauges (recording and standard) towards the western portion of the region is adequate, whereas the eastern portion of the region is lacking. For rural water resources planning, it is recommended to place approximately 25 rain gauges in the eastern portion of the region. There are also a few areas towards the western part of the region that would benefit from the addition of another rain gauge – about 5 gauges are recommend to fill those areas.

The number of total rain gauges (recording and standard) necessary for water resource planning in urban areas will vary depending on the size of the community. Typically, the minimum recommended number of total rain gauges in smaller communities will range from one to two gauges, and larger urban areas may require upwards of four or six gauges.

The following table illustrates the ideal number of rain gauges that each community in the region should have for water resources planning:

Community	Total Rain Gauges Needed	Additional Gauges Needed*
• Atascadero	5	1
• Paso Robles	4	1
• Pismo Beach	3	3
• San Luis Obispo	3	0
• Nipomo	3	1
• Morro Bay	2	0
• Baywood-Los Osos	2	1
• Cambria	2	0
• Lake Nacimiento	2	0
• Arroyo Grande	1	0
• Grover Beach	1	0
• Cayucos	1	0
• Oceano	1	0
• San Miguel	1	0
• Shandon	1	0
• Templeton	1	0
• Avila Beach	1	0
• California Valley	1	0
• Cholame	1	0
• Halcyon	1	0
• Harmony	1	0
• Los Osos	1	0
• Pozo	1	0
• San Simeon	1	0
• Santa Margarita	1	0
Total	43	7

* This assumes that the proposed addition of the recording rain gauges mentioned above is implemented.

Given the current rain gauge density and the proposed addition of recording rain gauges in these communities, approximately 7 rain gauges should be added in the communities listed above to meet the minimum density requirements.

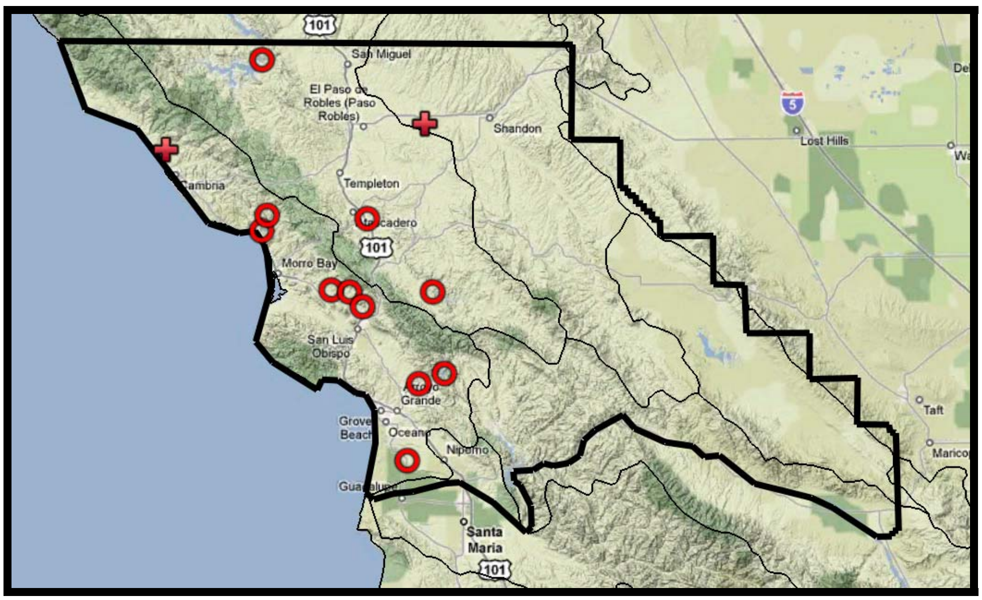
4.1.1.1.2. Evaporation

The large, publically owned reservoirs of the regions are:

- Chorro
- Lopez
- Nacimiento
- Salinas
- Terminal
- Twitchell
- Whale Rock

The County maintains evaporation pans at Lopez, Salinas, and Terminal reservoirs. Evaporation pans are maintained by others at Chorro, Nacimiento, Twitchell, and Whale Rock reservoirs. In light of this, there generally appears to be sufficient evaporative pans for managing reservoir operations.

The CIMIS stations in San Luis Obispo, Nipomo, and Atascadero gather data by which evaporation can be calculated. To help estimate agricultural water use in each climatic region and to supplement evaporation data collected at reservoirs and by weather stations, it is recommended that two additional evaporation pans (or weather stations) are established around Cambria (or further north) and east of Paso Robles, as indicated in the above figure.



Recommended evaporation site are marked by a red cross ("+") on the above figure. (Existing evaporation stations are marked by a red circle.) This distribution of gauges will provide adequate coverage across all the climatic areas of the region, including the cool south coast, the wet north coast, and the hot inland areas.

4.1.1.2.Surface Water Data

4.1.1.2.1. Stream Gauges

In San Luis Obispo County, there are a variety of stream flow monitoring needs, due to the mix of urban and rural watersheds. Information gained from stream flow monitoring is necessary for land use and water resources planning and for flood warnings and forecasts.

Stream flow monitoring may be used to study the effects of recent land use changes in the county due to agricultural and urban development. Heavily irrigated crops such as vineyards have replaced dry-land farming in some areas, increasing the demand on groundwater basins, which rely on recharge from streams. In expanding urban areas, impervious surfaces have replaced open fields and croplands.

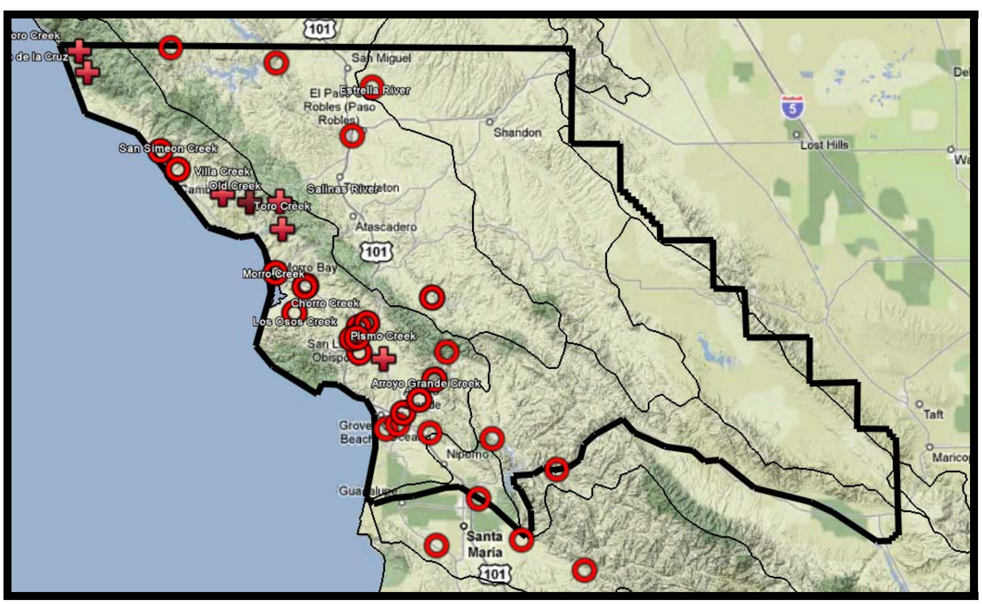
New monitoring stations are necessary to evaluate existing water resources. In areas with a high demand for groundwater, stream flow monitoring is used to create a water balance and to determine a safe yield for the groundwater basin.

Monitoring should be conducted on each of the major streams in the region, particularly in the north coastal part of the region. The coastal communities in the northern portion of the county, in particular, depend on ground water replenished by local streams for water supply.

The major streams and rivers in the region include:

- Arroyo De La Cruz Creek
- Arroyo Grande Creek*
- Cayucos Creek
- Chorro Creek*
- Estrella River*
- Los Osos Creek*
- Morro Creek*
- Old Creek
- Pismo Creek
- Salinas River*
- San Capoforo Creek
- San Luis Obispo Creek*
- San Simeon Creek*
- Santa Rosa Creek*
- Toro Creek
- Villa Creek

Sites marked with an "*" indicate streams that have current gauge stations, and are shown as red circles in the figure below.



There are seven major streams in the region that do not currently have stream gauges, as suggested in the above figure. Those streams are marked by a red cross ("+") on the map above. (Existing streams are marked by a red circle.) Those streams include:

- Arroyo De La Cruz Creek
- Cayucos Creek
- Old Creek
- Pismo Creek
- San Capoforo Creek
- Toro Creek
- Villa Creek

In order to measure stream flow at the outlet of each Hydrologic Catalog Unit within the region, stream gauges should be placed at the outlet of each of the above creeks. The Salinas River, Santa Maria River, and Estrella River watersheds all have USGS stream gauges that measure streamflow from their respective accounting units.

When adding new sites to the stream network, using past, inactive gauges, which may have a period of record that will complement any new data collected, should be considered.

Once each major stream in the region has a stream gauge, it would be worthwhile to gauge some of the smaller tributaries and creeks in the region. County basins that would significantly benefit from enhanced stream flow monitoring conducted for land use and water resources planning include the Paso Robles Basin, San Simeon Basin, Santa Rosa Basin, Los Osos Basin, San Luis Obispo/Edna Valley Basin, Arroyo Grande Basin, Nipomo Mesa Basin, and the Santa Maria Basin. When enhancing the monitoring in these regions, placing gauges on major creeks near the confluence with significant tributaries, on some smaller streams and tributaries, and at major cities along the major creeks should be considered.

To manage water resources for "in-stream" values and functions such as recreation, aesthetic enjoyment, and habitat for aquatic ecosystems, it is important to measure the stages of streams in the region. The recommendations above meet this data requirement.

To understand the regional natural flow regime, there should be a number of stream gauges in natural watersheds. The recommendations above meet this need.

4.1.1.2.2. Reservoir Gauges

Reservoir elevation should be measured daily on all reservoirs that regulate downstream releases and on those that support aquatic life. The following reservoirs in the region regulate downstream releases, support aquatic life, and measure daily reservoir elevation:

- Chorro
- Lopez
- Nacimiento
- Salinas
- Twitchell
- Whale Rock

4.1.1.2.3. Estuary and Wetland Gauges

A stage gauge should be located in each of the major estuaries and wetlands of the region. The Morro Bay Estuary currently has a network of gauges to meet that need. No additional stage gauges are recommended.

4.1.1.3.Groundwater Data

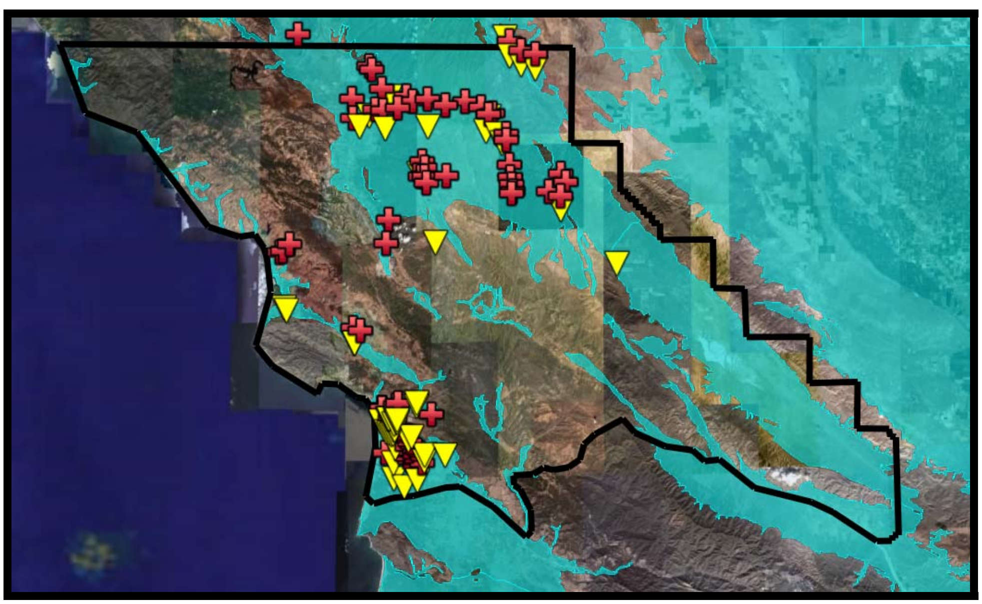
A fundamental purpose for groundwater monitoring is to acquire data necessary for the protection of existing rights and planning to accommodate increased water usage. In some basins, the lack of continuous, long-term groundwater quality and level data makes it difficult to assess trends and manage the resource for current and future needs.

4.1.1.3.1. Water levels

In early 2008, Cleath & Associates evaluated the San Luis Obispo County well measuring program. Their analysis recommended that 48 wells should be eliminated, and 66 wells should be added to the program. The total number of wells in the updated monitoring program would be 485 monitoring wells.

Of the 485 monitoring wells in the updated program, 326 would be monitored by Department of Public Works staff, and 159 would be monitored by municipalities or water purveyors.

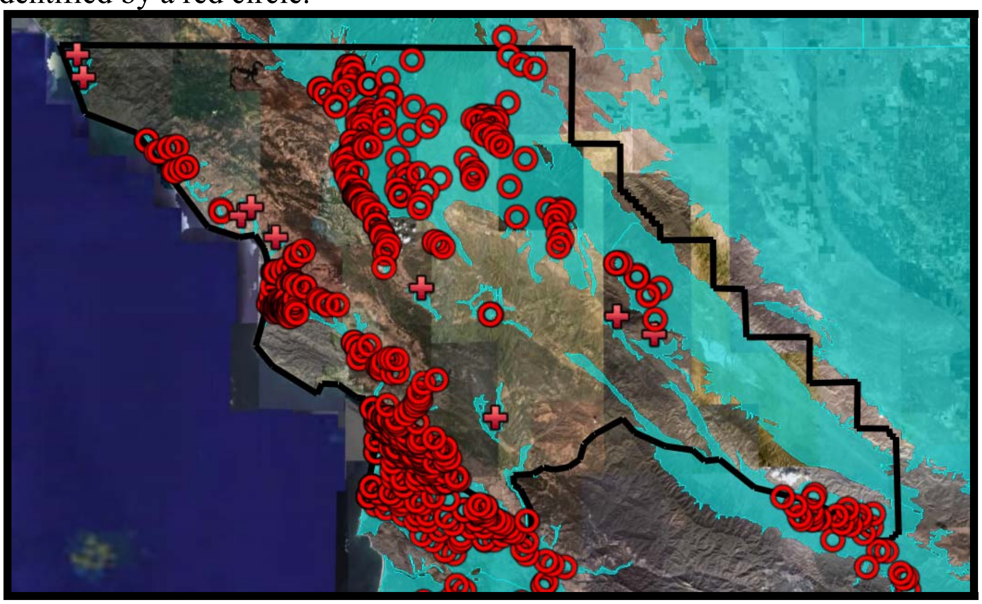
The following figure shows how the changes to the monitoring program, as proposed by Cleath & Associates, would be distributed throughout region. Icons with a red cross ("+") represent wells to be added to the network, while icons with a yellow triangle represent wells to be ultimately removed from the program.



Additionally, one well should be established in each of the un-gauged water basins of the region. The following basins are currently are un-gauged and should have at least one centrally located well:

- Arroyo De La Cruz Valley
- Big Spring Area
- Cayucos Valley
- Huasna Valley
- Old Valley
- Rafael Valley
- Rinconada Valley
- San Capoforo Valley
- Toro Valley

Un-gauged basins are identified in the following figure by a red cross ("+") and existing program wells are identified by a red circle.



4.1.1.3.2. Geologic Data and Well Logs

All program wells should have well logs, however well logs may no longer exist for many program wells. When possible, well logs for any program wells should be collected and made available for analysis. It is not recommended to abandon wells that do not have well logs.

4.1.1.4. Water Use Data

4.1.1.4.1. Domestic and Municipal Water Uses

The region should consider sponsoring a voluntary pilot program that would track actual rural water use for various rural areas throughout the County.

4.1.1.4.2. Agriculture and Irrigation Water Uses

The region should consider sponsoring a voluntary pilot program that would track actual applied water per acre for various agricultural users throughout the County.

4.1.1.4.3. Industrial Water Uses

The region should consider sponsoring a voluntary pilot program that would track industrial water use for various industries throughout the County.

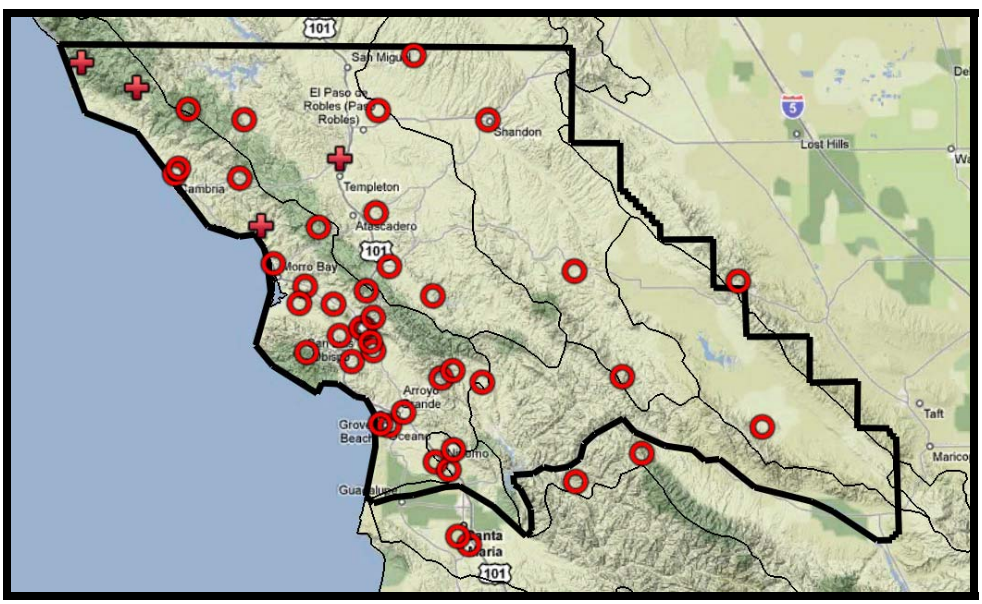
4.1.2. Flood Management and Planning

4.1.2.1.Meteorological Data

4.1.2.1.1. Precipitation

For flood management and planning, it is recommended that there be approximately one real-time rain gauge per 50 square miles in urban areas. The National Weather Service has indicated that the following real-time precipitation sites would be extremity beneficial for developing their flood forecasts and other flood-related products:

- Extreme NW corner of the County
- Hearst Castle area
- Cayucos area
- Templeton area



The locations marked with a red cross ("+") indicate locations that would benefit the National Weather Service and their operations. Red circles indicate the current network of real-time sites available to the National Weather Service.

4.1.2.2. Surface Water Data

4.1.2.2.1. Water levels

4.1.2.2.1.1. Streams

An enhanced flood warning system may be used to some extent in many communities of the region. With adequate warning, property owners may have time to install flood gates or move valuable objects to higher ground. Unfortunately, times of concentration of creeks and rivers in the county are relatively short – only a few hours or less. A flood warning system would only allow enough time for the most basic preparations. Communities with historic flooding that may benefit from a flood warning system include Cambria and other north coast communities, San Luis Obispo to Avila Beach, Five Cities/Arroyo Grande Watershed, Los Osos, Shandon, and old town Nipomo.

In particular, the following roads are consistently flooded in storm events and would benefit from the installation of a real-time stage gauge:

- Airport Road at the Estrella River in Paso Robles
- Buena Vista Drive at Huerohuero Creek in Paso Robles
- San Luis Bay Drive at San Luis Obispo Creek (near Monte Road towards Avila)
- Shell Creek Crossing near Shandon (flash floods potential)
- Turri Road in Los Osos (roughly 1.5 miles upstream of South Bay Drive)
- Upper Santa Rosa Creek Road in Cambria

4.1.2.2.1.2. Lakes and Reservoirs

As part of regular reservoir operations, daily lake elevation values are recorded at the following reservoirs:

- Chorro
- Lopez
- Nacimiento
- Salinas
- Terminal
- Twitchell
- Whale Rock

Daily stage and storage values for these reservoirs are reported to the San Luis Obispo County on a daily basis.