California Statewide
Groundwater Elevation
Monitoring Program

CASGEM Monitoring Plan

for

High and Medium Priority Groundwater Basins

in the

San Luis Obispo County Flood Control & Water Conservation District

---

San Luis Obispo County Flood Control
& Water Conservation District

September 2014

[This page intentionally left blank]

TABLE OF CONTENTS

[This page intentionally left blank]

LIST OF TABLES

LIST OF FIGURES

[This page intentionally left blank]

LIST OF ACRNONYMS & ABREVIATIONS

CASGEM	California Statewide Groundwater Elevation Monitoring
County	San Luis Obispo County
District	San Luis Obispo County Flood Control and Water Conservation District
DWR	California Department of Water Resources
Program	District Groundwater Level Measuring Program
SMVMA	Santa Maria Valley Management Area
USGS	United States Geological Survey

[This page intentionally left blank]

1. Introduction

Purpose

The purpose of this plan is to comply with the California Department of Water Resources (DWR) California Statewide Groundwater Elevation Monitoring (CASGEM) Program by creating a plan to monitor groundwater elevations of California's alluvial groundwater basins and sub-basins identified in DWR Bulletin 118 that are located within the San Luis Obispo County Flood Control and Water Conservation District (District) boundaries.

As part of the CASGEM Program, DWR was required to prioritize California groundwater basins. This monitoring plan will focus on the High and Medium priority groundwater basins, with the intent that a separate monitoring plan (or plans) will be developed for Low and Very-Low priority groundwater basins within the District.

Background

DWR developed the CASGEM Program in response to Part 2.11 (Groundwater Monitoring), Division 6 of the California Water Code, which was added in 2009 by the passage of Senate Bill 6, 7th Extraordinary Session. The law directs that groundwater elevations in all groundwater basins and sub basins in California be regularly and systematically monitored, preferably by local entities, with the goal of demonstrating seasonal and long-term trends in groundwater elevations. The intent of the CASGEM program is to rely and build on the many established long-term groundwater monitoring and management programs, and for the role of DWR to be data coordination, data maintenance, and data dissemination in a readily and widely available public database. DWR is also mandated to continue its current statewide groundwater level monitoring and data dissemination efforts, as funding allows.

Through the CASGEM program, local monitoring parties with appropriate authority may notify DWR of their intent to be a Monitoring Entity. On December 30, 2010, under authority of the District, the County of San Luis Obispo applied to DWR to become the countywide Monitoring Entity which would designate wells as appropriate for monitoring and reporting groundwater elevations for purposes of the CASGEM program. Following confirmation of DWR's acceptance of the District as the Monitoring Entity, the District proceeded to identify the wells to be included in the monitoring program network and to prepare this CASGEM Monitoring Plan as required by DWR.

Groundwater Basin Coverage & Responsibility

DWR Bulletin 118 identifies twenty two (22) groundwater basins located fully or partially within San Luis Obispo County, the District's jurisdictional boundary is one and the same with San Luis Obispo County's boundary (see Figure 1 for basin and jurisdictional boundaries, and Section 2 for the list of groundwater basins in the county).

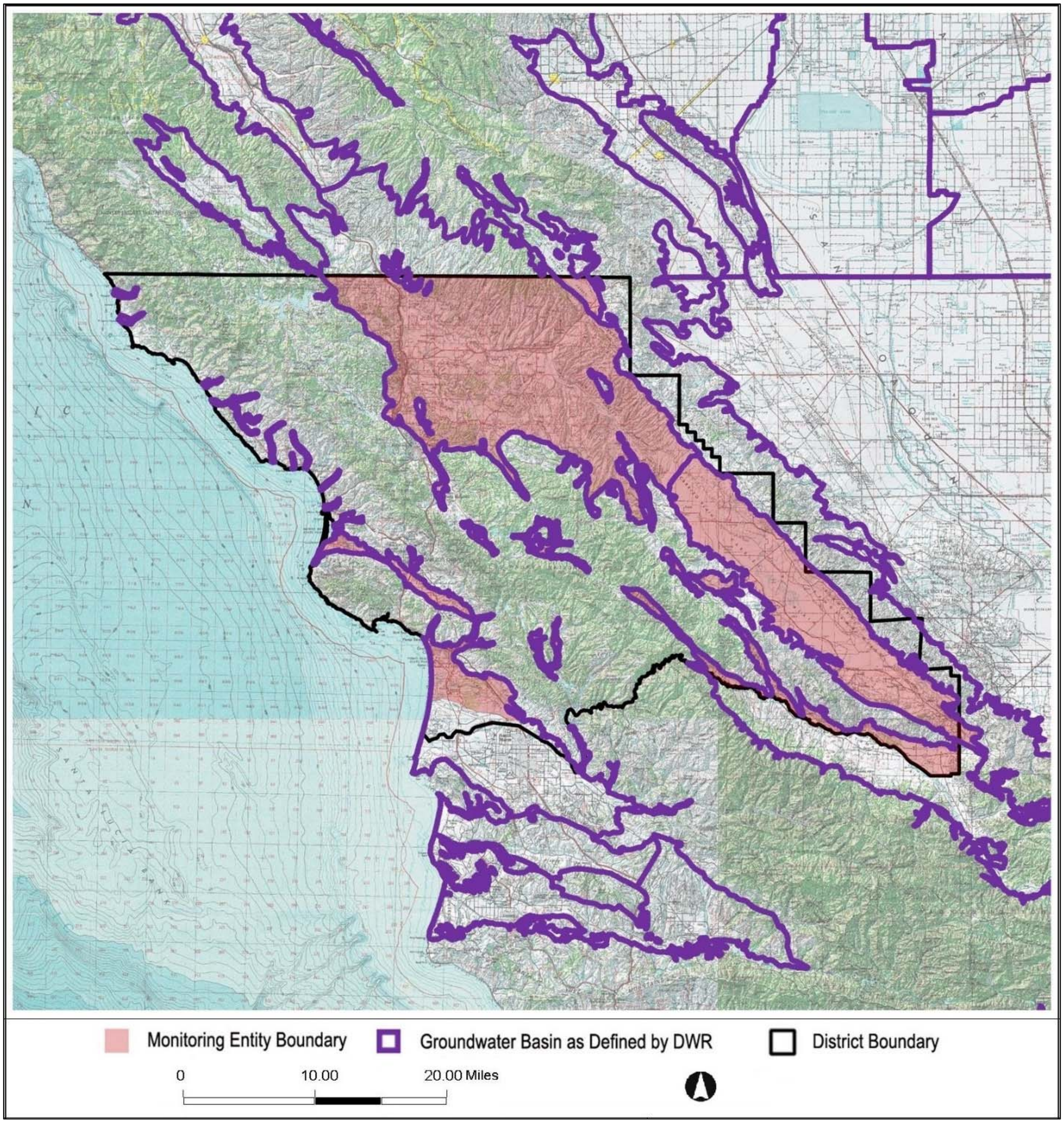

FIGURE 1: Groundwater Basin Delineations and Monitoring Entity Boundary in San Luis Obispo County Flood Control & Water Conservation District

The District is the only entity that has submitted their intent to serve as a Monitoring Entity for two (2) of the five (5) High and Medium priority groundwater basins in the District. The remaining three (3) basins will require Monitoring Plans from multiple Monitoring Entities in order to address the entire basin. Basins that require multiple Monitoring Entities for basin-wide coverage are as follows:

- The Salinas Valley Groundwater Basin: This basin spans San Luis Obispo and Monterey counties. This Plan will address only portions of the Salinas Valley Groundwater Basin that exist within the District.

- The Cuyama Valley Groundwater Basin: This basin spans San Luis Obispo, Santa Barbara, and Kern counties. Originally Santa Barbara County intended to monitor the entire Cuyama groundwater basin, even though portions of the basin extend into neighboring counties. In mid-2014, Santa Barbara County found it necessary to reapply for acceptance through CASGEM as a partial basin, and only be responsible for the portion of the basin within Santa Barbara County. This Plan addresses portions of the Cuyama Valley Groundwater Basin within the District.

- The Santa Maria Groundwater Basin: This basin spans San Luis Obispo and Santa Barbara counties. The Santa Maria Valley Management Area (SMVMA) was established by the courts to administer a final judgment determining rights to groundwater. The SMVMA comprises approximately one third of the southern portion of the Santa Maria Groundwater Basin. The northern part of the SMVMA extends into San Luis Obispo County. The Twitchell Management Authority submitted their intent to serve as the Monitoring Entity for areas under their jurisdiction. In September 2014, DWR designated the Twitchell Management Authority as the Monitoring Entity for this portion of the basin. Per a request from DWR, this Plan only addresses portions of the Santa Maria Groundwater Basin that exist outside of the jurisdiction of the Twitchell Management Authority and within the District.

Approach to Groundwater Monitoring

The remaining sections of this Monitoring Plan present an overview and description of each High and Medium priority groundwater basin and subbasin, a description of the proposed monitoring programs, including maps displaying the spatial distribution of the wells and remaining data gap areas, and procedures for collecting and reporting the groundwater-level data.

This Plan is a dynamic document that will be evaluated and updated as the monitoring network is refined or enhanced to address specific program needs and data gaps. Revisions will be submitted to DWR when additions or removal of wells from the monitoring network occur.

[This page intentionally left blank]

2. Basin Descriptions & Proposed CASGEM Monitoring Plan

State & Regional Setting

There are currently 431 groundwater basins delineated by the State Department of Water Resources (DWR), underlying about 40 percent of the surface area of the State. Of those, 24 basins are subdivided into a total of 108 sub basin, giving a total of 515 distinct groundwater systems (Source: DWR Bulletin 118, update 2003).

For planning purposes, DWR divides California into 10 Hydrologic Regions, which correspond to the State's major drainage areas (Figure 2). The Central Coast Hydrologic Region covers approximately 7.22 million acres (11,300 square miles) in central California. This Hydrologic Region includes all of Santa Cruz, Monterey, San Luis Obispo, and Santa Barbara counties, most of San Benito County, and parts of San Mateo, Santa Clara, and Ventura counties.

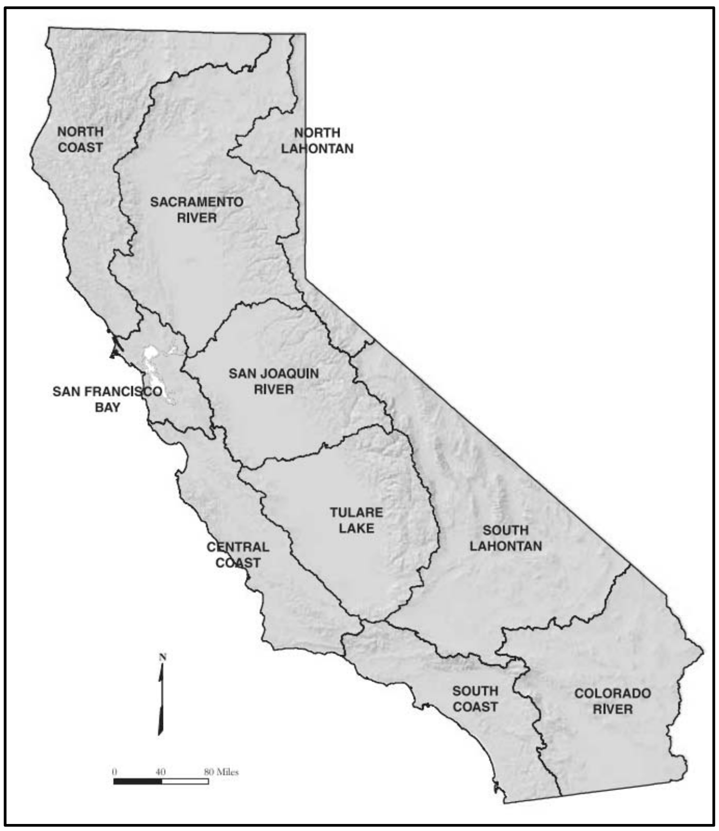

FIGURE 2: California's Hydrologic Regions

Significant geographic features in San Luis Obispo County includes the Salinas, Santa Maria, and Cuyama valleys; and the Coastal Mountain Range. Major drainage ways in the region include the Salinas, Cuyama, Santa Maria, San Antonio, and Nacimiento Rivers.

DWR delineates 50 groundwater basins in the Central Coast Hydrologic Region. Of those, there are currently 22 groundwater basins that are fully or partly within the San Luis Obispo County. Those basins are shown on Figure 1 and on Figure 3, and on subsequent figures for each individual basin.

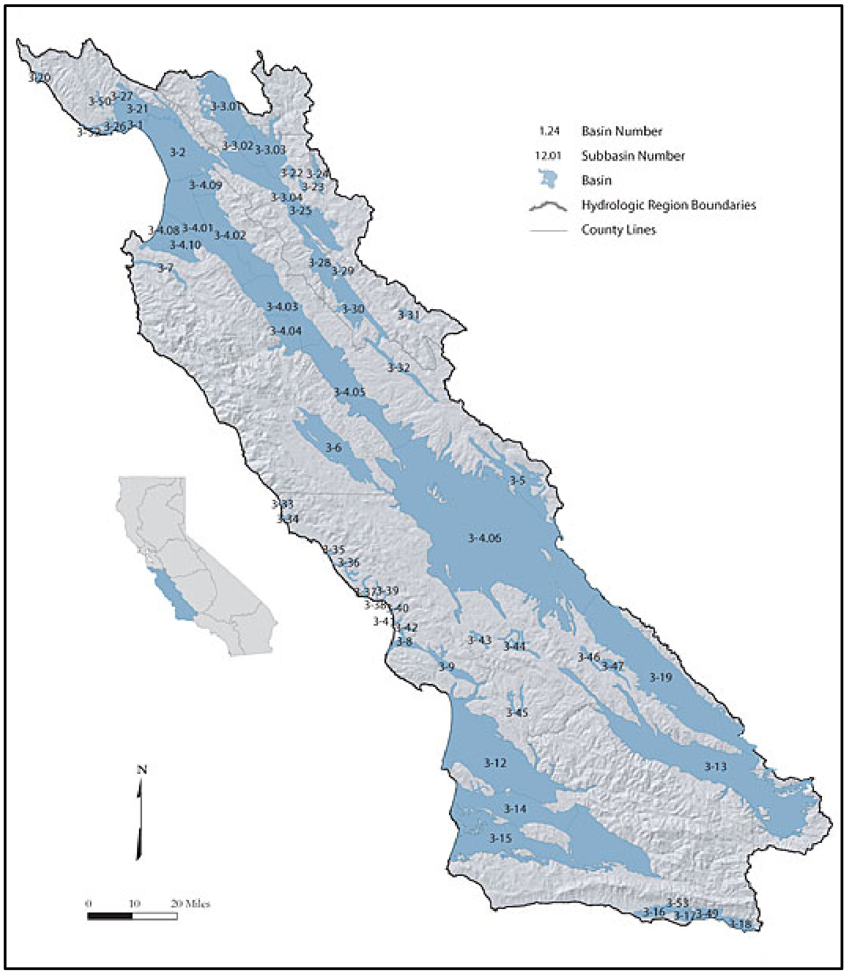

FIGURE 3: Groundwater Basins of the Central Coast Hydrologic Region

History of District's Groundwater Monitoring in San Luis Obispo County

The District, as well as other local water agencies, have a long history of measuring groundwater levels throughout the County. Water level records for these wells go back to the early 1930's. Most District records begin in the mid 1950's. Presently, several hundred wells are being measured two times per year in April and October.

Generally, wells are added to the Districts network on a voluntary basis and with the well owner's permission. As such, the monitoring network has had many additions and deletions over the years (e.g. when new land owners opt out of the program, when old wells are destroyed or become otherwise inaccessible, etc.).

Proposed Groundwater Monitoring Plan for High & Medium Priority Basins

The remainder of this section discusses the following required topics:

- Description of the Monitoring Plan rationale
- Discussion of the well network
- Maps of the well network
- Monitoring schedule
- Description of field methods
- Discussion of the role of cooperating agencies

Groundwater Basin Characteristics & Monitoring Plan Rationale

As part of the CASGEM Program, DWR was required to prioritize California groundwater basins. The California Water Code specifies the criteria listed below for prioritizing the groundwater basins. To address the prescribed criteria, DWR used available statewide data sets which are listed after the corresponding criteria.

1. Overlying population
2. Projected growth of overlying population
3. Public Supply Wells
4. Total number of wells
5. Irrigated acreage overlying the basin
6. Reliance on groundwater as the primary source of water
7. Impacts on the groundwater; including overdraft, subsidence, saline intrusion, and other water quality degradation
8. Any other information determined to be relevant by DWR

Within the District, Basin Prioritization findings indicate that five (5) of the District's groundwater basins and subbasins are High and Medium priority. The remaining basins are Low and Very Low priority. The High and Medium priority basins are listed below. The DWR basin number is also listed in parentheses. Basins that are not fully within the District are noted as "Partial".

TABLE 1: High & Medium Priority Basins in the District

Groundwater Basin / Subbasin	DWR Basin Number	DWR Prioritization
Cuyama Valley [Partial]	3-13	Medium
Los Osos Valley	3-08	Medium
Salinas Valley Paso Robles Area [Partial]	3-04.06	High
San Luis Obispo Valley	3-09	High
Santa Maria River Valley [Partial]	3-12	High

CASGEM Well Network Development

The District relied on existing groundwater level measuring programs to develop this Plan. The key monitoring program, the District's Groundwater Level Measuring Program (Program), served as the primary source for wells and well data. This Program includes wells owned by the District, the County, private property owners, and other local agencies.

Other sources of wells were considered in developing this Plan. For example, there are a number of environmental remediation sites throughout the county with existing monitoring systems, however, due to the typical temporary nature of these sites and considering other challenges, these wells were ultimately not added to this Plan. The District acknowledges that monitoring wells at remediation sites are not ideal for CASGEM, and these wells should only be used if there are few other options and if the wells are associated with long-term monitoring (e.g. a superfund site).

The wells presented in this Plan are a subset of District Program wells, and were selected using the general process described below.

In developing the proposed CASGEM Monitoring Plan well network, where possible, wells were selected to provide for reasonable geographic coverage and, where appropriate, to represent the various well depth intervals present in each area. The selection of wells for the CASGEM program also included a systematic review of existing well locations and was based on a set of well selection criteria. The following criteria were used to screen possible CASGEM wells from the existing network of wells:

- Use Wells Located Within Groundwater Basin Boundaries: The purpose of the CASGEM program is to establish a permanent, locally managed system to monitor groundwater elevations in California's alluvial groundwater basins and sub basins identified in DWR Bulletin 118.

- Honor Existing Well Confidentiality Agreements: The District has a strict policy of limiting the release of well data collected as part of the Districts historical groundwater level monitoring program. Existing Well Confidentiality Agreements are based on specific legal language in California Water Code 13751,13752 and California Government Code 6250,6254 €, 6254.5, and section 6255. Due to these agreements that are in place which prohibit the release of location, and well construction details, the number of existing District program wells available for inclusion in the CASGEM program has been severely limited. Section 3 of this Monitoring Plan addresses the District's approach to public outreach to update the agreements to allow more District program wells into the CASGEM program.

- Reliable Access to Well Site and Into Well: A site with reliable and unlimited access is preferred to ensure consistent collection of water level measurements. A well with no down-hole obstructions is preferred to ensure fast and accurate collection of water level data measurements.

- Public Water Supply Wells: The District has historically followed a policy of limiting the release of well data collected from public water supply wells or wells that provide domestic water to a larger population. However, in cases where there are no other options to fill data gaps, public supply wells will be included provided that the water service provider explicitly grants the District permission to use their wells and display construction details thru the CASGEM program.

In general, if the well is not constrained by the criteria above, the well was included in this Plan. Detailed figures and tables, on a basin-by-basin basis are presented further on in this section.

The following subsections describe the current number of wells being monitored for each groundwater basin part of this Monitoring Plan. Maps are included to show the spatial distribution of the wells in each basin. Table A-1 in Appendix A gives a listing of all wells included in this Plan, and includes key information like groundwater basin, coordinates, local well designation, etc.

The ultimate goal of this plan is to have a sufficient network of monitored wells that provides the necessary data to assess groundwater conditions in every groundwater basin in the County. The recommended density of monitoring wells for various groundwater level monitoring programs is summarized as follows:

TABLE 2: Recommended Monitoring Well Density

Reference	**Density of Monitoring Wells** (wells per 100 square miles)
DWR Recommendation (2014)	10 – 20
Hopkins (1994)	0.7 – 4
Sophocleous (1983)	6.3
Heath (1976)	0.2 – 10

The average of the recommended densities noted above is very close to one (1) well per ten (10) square miles. As a result, the data gap analysis in this Monitoring Plan will consider a target minimum density of at least one (1) well per ten (10) square miles, and is discussed further within each basin discussion, below.

Individual Basin Discussions

Specific details regarding each High and Medium priority groundwater basin and sub basin, along with a description of the proposed monitoring network and data gaps are provided in the following sections.

Cuyama Valley (3-13)

Description

The Cuyama Valley Groundwater Basin underlies an east-trending valley bounded on the north by the Caliente Range and on the southwest by the Sierra Madre Mountains. The valley is drained by the Cuyama River. Average annual precipitation ranges from 7 inches to 15 inches per year.

Groundwater is found in Holocene age alluvium, and older terrestrial deposits. Groundwater in the basin is mainly unconfined, but confined water and perched water are found locally.

Holocene Alluvium: In the western part of the basin, the alluvium consists of thick beds of sand and gravel alternating with beds of clay. In the south central part of the basin, alluvium is predominantly sand and silt with some beds of gravel and clay. In the eastern part of the basin, alluvium consists of coarse gravel and sand. Except in the western part of the basin, the alluvium is not the principal water-bearing formation. The thickness of the alluvium is inferred to be from 150 to 250 feet (Upson and Worts 1951).

Older Terrestrial Deposits: Pleistocene age terrace deposits found in the valley are relatively thin and mainly above the zone of saturation. Underlying older terrestrial deposits, which include the Pliocene age Cuyama or Morales formation and a fanglomerate, are the main water-bearing units in the basin. These deposits consist of large and extensive bodies of poorly consolidated clay, silt, and gravel (Upson and Worts 1951).

Small faults that cut through the basin fill act as barriers to groundwater movement. Historically, flowing springs were found along the trace of faults that parallel Graveyard and Turkey Trap Ridges (SBCPDC 1994).

Basin Boundary

It is important to note that that the District and other entities representing the area delineate the groundwater basin differently than as presented in DWR's Bulletin 118. The District, the USGS, the San Luis Obispo County Public Works Department, and the Santa Barbara County Department of Public Works Flood Control & Water Agency use the delineation as defined by the USGS. Their Scientific Investigations Report 2014–5150, notes that the boundary described by Bulletin 118 includes several extraneous regions that are not part of the main regional aquifer systems within Cuyama Valley (USGS 2013). These two boundary delineations are shown on Figure 4.

CASGEM Well Network

The proposed CASGEM monitoring network for the Cuyama Valley Groundwater Basin is shown on Figure 4, and includes the proposed CASGEM wells, general data gap areas, the groundwater basin as defined by DWR, the groundwater basin as defined locally, the District's Monitoring Entity boundary, and areas within the District's jurisdiction.

Currently, two (2) CASGEM wells are proposed for inclusion in this basin as part of this monitoring plan.

The District's approach to filling the data gaps identified below is described in Section 3 of this Monitoring Plan.

Horizontal Data Gaps

The portion of the locally-defined basin within the District is 37 square miles. Based on the target minimum density of at least one (1) well per ten (10) square miles, this portion of the basin should have four (4) wells to meet the needs of the CASGEM Program.

Two (2) CASGEM wells are proposed for inclusion in this basin as part of this monitoring plan. Therefore, two (2) additional wells need to be established in order to meet the target well density.

Vertical Data Gaps

The USGS "Construction of 3-D Geologic Framework and Textural Models for Cuyama Valley Groundwater Basin Scientific Investigations Report 2013-5127" was utilized to evaluate the Cuyama Valley Groundwater Basin vertical data gaps. This report documents the geologic framework of the groundwater basin, emphasizing the continental deposits and alluvial sediments that constitute the principal groundwater aquifer of the basin. For this, the overall groundwater flow of the basin is characterized and the aquifer materials are subdivided into vertical groundwater formations: the Alluvial Channel, the Younger Alluvium, the Older Alluvium, and the Morales Formations. These four main groundwater formations were emphasized for the Cuyama Valley Groundwater Basin as illustrated in Figure 5 and Figure 6 from the USGS Scientific Investigations Report 2013-5127, with underlying consolidated bedrock.

A target density of at least one (1) well per ten (10) square miles is also appropriate for monitoring levels within the four groundwater zones, given the composition of the hydrogeology of the basin. One of the two CASGEM monitoring wells is believed to be screened in the Younger Alluvium and Older Alluvium. The other CASGEM monitoring well is believed to be screened in the Younger Alluvium, Older Alluvium and possibly the Morales Formation.

Therefore as the two (2) additional wells are established to address horizontal data gaps, it will be important to ensure discrete screen intervals for all Zones are established, which may require up to fourteen (14) additional wells.

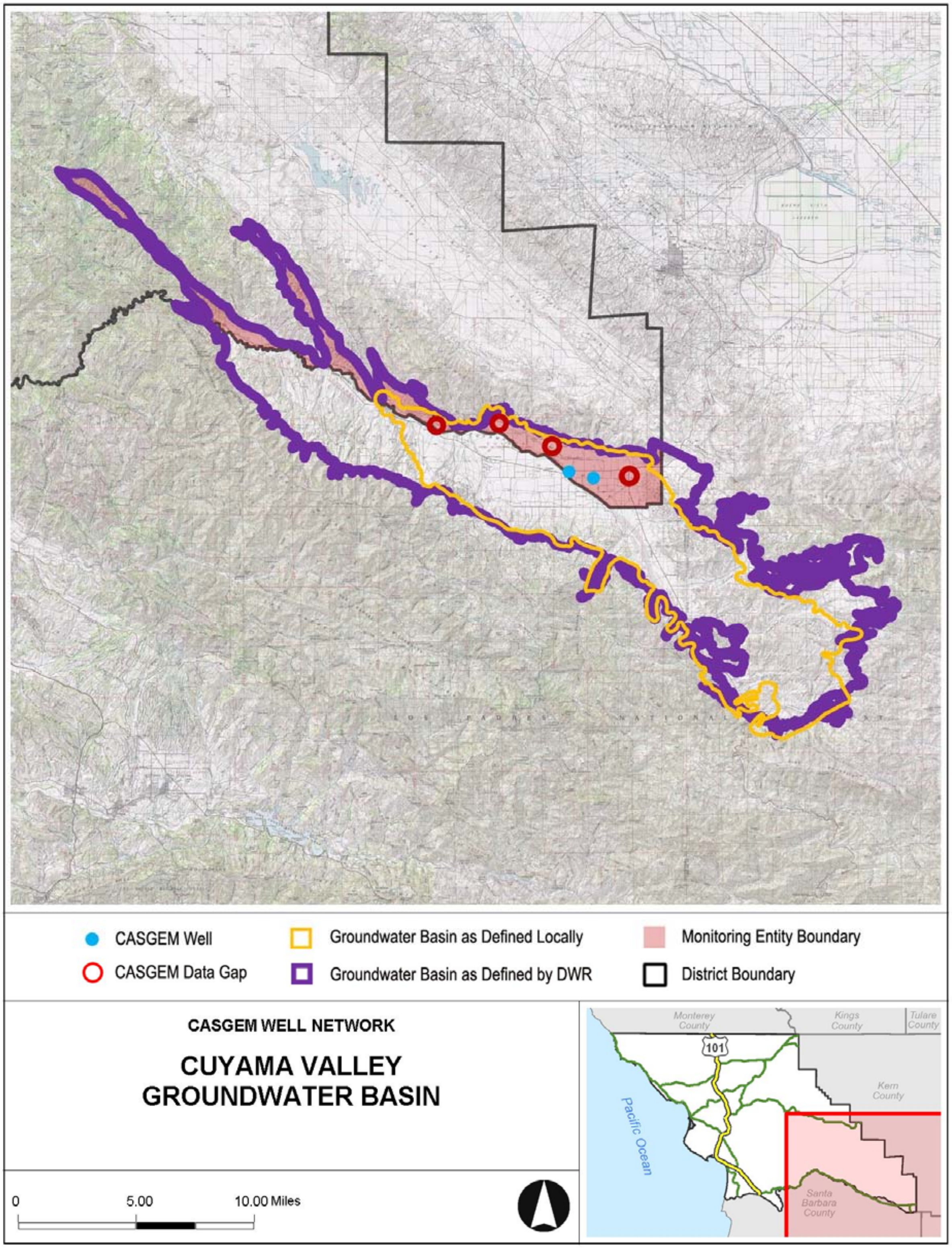

FIGURE 4: Monitoring Program for the Cuyama Valley Groundwater Basin

[This page intentionally left blank]

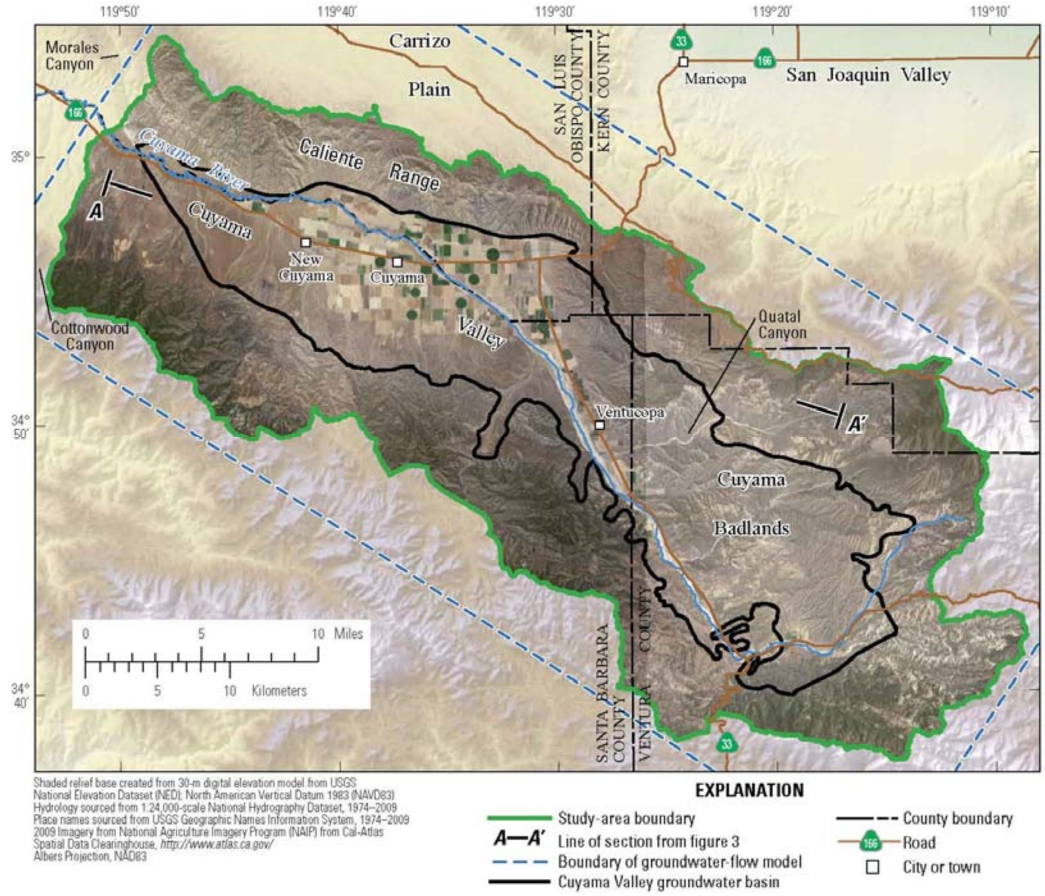

FIGURE 5: Cuyama Valley Area Aerial Geology and Location of Geologic Sections

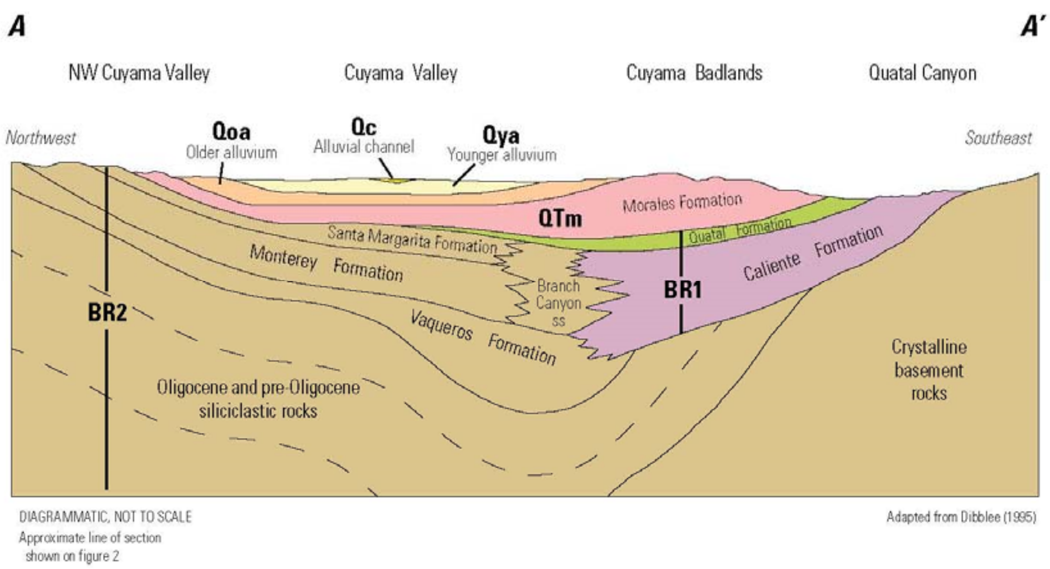

FIGURE 6: Stratigraphic Diagram of the Cuyama Valley Area

[This page intentionally left blank]

Los Osos Valley (3-8)

Description

The Los Osos Valley Groundwater Basin is bounded on the north by Park Ridge, on the south by the Irish Hills, and on the west by Morro Bay. The eastern boundary is a drainage divide separating Los Osos Valley from San Luis Valley. The valley is drained by Los Osos Creek, which flows into Morro Bay. Annual precipitation ranges from 15 to 21 inches.

Groundwater is found in alluvium of Holocene age, dune sand and the Paso Robles Formation of Pleistocene age, and the Careaga Sand of Pliocene age.

Holocene Deposits: This alluvium consists of clayey gravel and sand. The thickness of the alluvium ranges from 20 to 65 feet under the Los Osos Creek floodplain (Yates and Wiese 1988).

Pleistocene Deposits: Dune sand is composed of unconsolidated, fine to medium-grained arkosic sand with thin clay, silt, and gravel interlayers. The Paso Robles Formation, which is the main water-producing unit in the basin, typically consists of unconsolidated, interbedded clay and clayey, pebbly sand in discontinuous beds and lenses. It has a thickness of about 300 feet (DWR 1989). Clay layers found in the Paso Robles Formation impede the vertical movement of groundwater (DWR 1989).

Pliocene Deposits: The Careaga Sand is described as a massive, fine grained, micaceous quartz sandstone (Yates and Wiese 1988), and as unconsolidated deposits of white to yellowish-brown fine- to medium grained, marine sand with some silt (Worts 1951). This unit has a total thickness up to about 1,000 feet (Yates and Wiese 1988).

The east-trending Los Osos fault traverses the valley and is exposed along southeastern Los Osos Valley. The western end of the Edna fault zone terminates in two parallel, unnamed north-trending faults, which extend into the Los Osos Groundwater Basin west of the point where Los Osos Creek enters the valley. Of those two faults, the easternmost fault is a barrier to groundwater flow (Yates and Wiese 1988).

Basin Boundary

It is important to note that that the District and other entities representing the area delineate the groundwater basin differently than as presented in DWR's Bulletin 118. The District, the San Luis Obispo County Public Works Department, and the three (3) water purveyors in the basin (Los Osos Community Services District, Golden State Water Company, and S&T Mutual Water Company) all use the delineation as defined in the draft Basin Plan for the Los Osos Groundwater Basin (2013). This Basin Plan was developed within the scope for the adjudication of the basin in the case of Los Osos Community Services District v. Golden State Water Company, et al., Civil Case No., GIN 040126. The Basin Plan will be incorporated into a final stipulated judgment in the adjudication, for adoption by the parties and approval by the San Luis Obispo County Superior Court. The boundary delineations defined by DWR and in the Basin Plan referenced above are shown on Figure 7.

The basin extends westward under Morro Bay and an estimated three (3) miles beneath the Pacific Ocean, although groundwater in the western portion of the basin is brackish and not usable as a source of drinking water for the Los Osos community. The exact boundary for this portion of the basin is not well-defined, and is shown as a dashed line or not at all on Figure 7.

CASGEM Well Network

The proposed CASGEM well monitoring network for the Los Osos Valley Groundwater Basin is shown on Figure 7, and includes the proposed CASGEM wells, the groundwater basin as defined by DWR, the groundwater basin as defined locally, the District's Monitoring Entity boundary, and areas within the District's jurisdiction.

Currently, nine (9) CASGEM wells are proposed for inclusion in this basin as part of this monitoring plan.

The District's approach to filling the data gaps identified below is described in Section 3 of this Monitoring Plan.

Horizontal Data Gaps

The portion of the locally-defined basin within the District is 14 square miles. Based on the target minimum density of at least one (1) well per ten (10) square miles, this portion of the basin should have two (2) wells to meet the needs of the CASGEM Program.

Nine (9) CASGEM wells are proposed for inclusion in this basin as part of this monitoring plan. The three (3) wells shown at the western edge of the basin are well clusters with two (2) or three (3) wells per cluster. There is a well cluster and a single well in the central portion of the basin overlying the community of Los Osos. In total, zero (0) additional wells need to be established in order to meet the target well density.

Vertical Data Gaps

To evaluate the vertical data gaps, the Draft Basin Plan for the Los Osos Groundwater Basin was utilized. Figure 8 is a three-dimensional conceptual depiction of the basin, and shows the general location, aquifer layers, recharge sources and outflows of the basin. The basin is made up of six (6) sub-horizontal aquifer layers. For ease of reference, those layers are described as Zone A through E, and the Alluvial Aquifer, as shown on the north-south cross-section in Figure 9 and the west-east cross-section in Figure 10. Zone A and Zone B are also referred to as the perched aquifers, Zone C is referred to as the Upper Aquifer, and Zone D and Zone E are referred to collectively as the Lower Aquifer. First Water refers to the shallowest groundwater zones and includes the Alluvial Aquifer, the Perched Aquifer, and the top portion of the Upper Aquifer (Zone C) where not overlain by the alluvial or perched aquifer. In summary, historic studies and this Monitoring Plan divide the basin into three (3) vertically discrete zones: the Upper Aquifer, the Lower Aquifer, and First Water. A target density of at least one (1) well per ten (10) square miles is also appropriate for monitoring levels within the three zones given the composition of the hydrogeology of the basin.

Two (2) of the CASGEM monitoring wells within the basin as defined by Bulletin 118 are screened in the Upper Aquifer. Two (2) of the CASGEM monitoring wells within the basin as defined by Bulletin 118 are screened in the Lower Aquifer. Zero (0) of these CASGEM monitoring wells are screened in the First Water. Therefore, there appears to be a vertical data gap in the First Water zone and two (2) CASGEM wells should be established and screened in this zone. These wells should generally be located in the area overlying the Los Osos community, and should tap into the Alluvial Aquifer, the Perched Aquifer, or the top portion of the Upper Aquifer (where not overlain by the alluvial or perched aquifer).

[This page intentionally left blank]

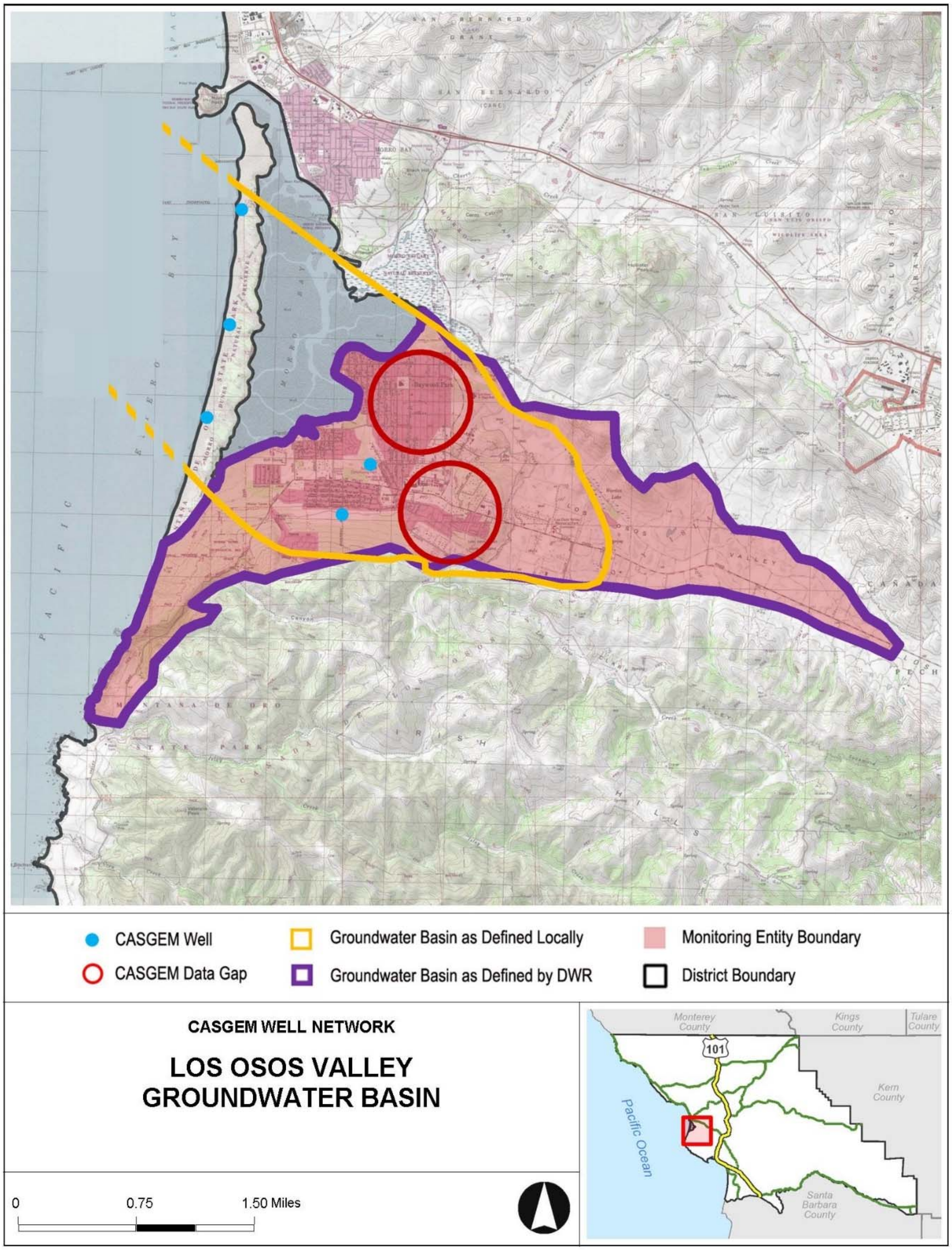

FIGURE 7: Monitoring Program for the Los Osos Groundwater Basin

[This page intentionally left blank]

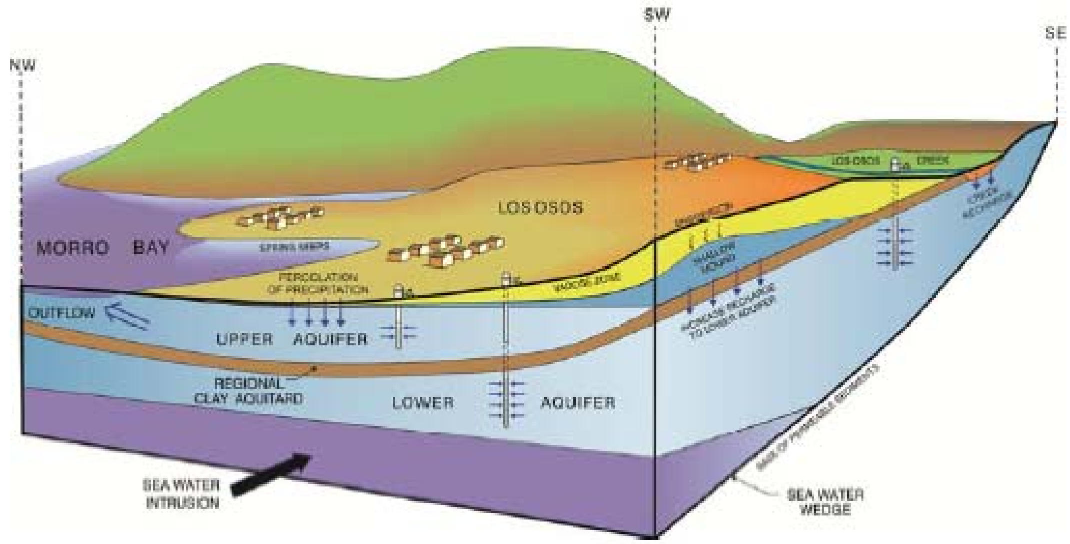

FIGURE 8: Conceptual Model of the Los Osos Groundwater Basin

[This page intentionally left blank]

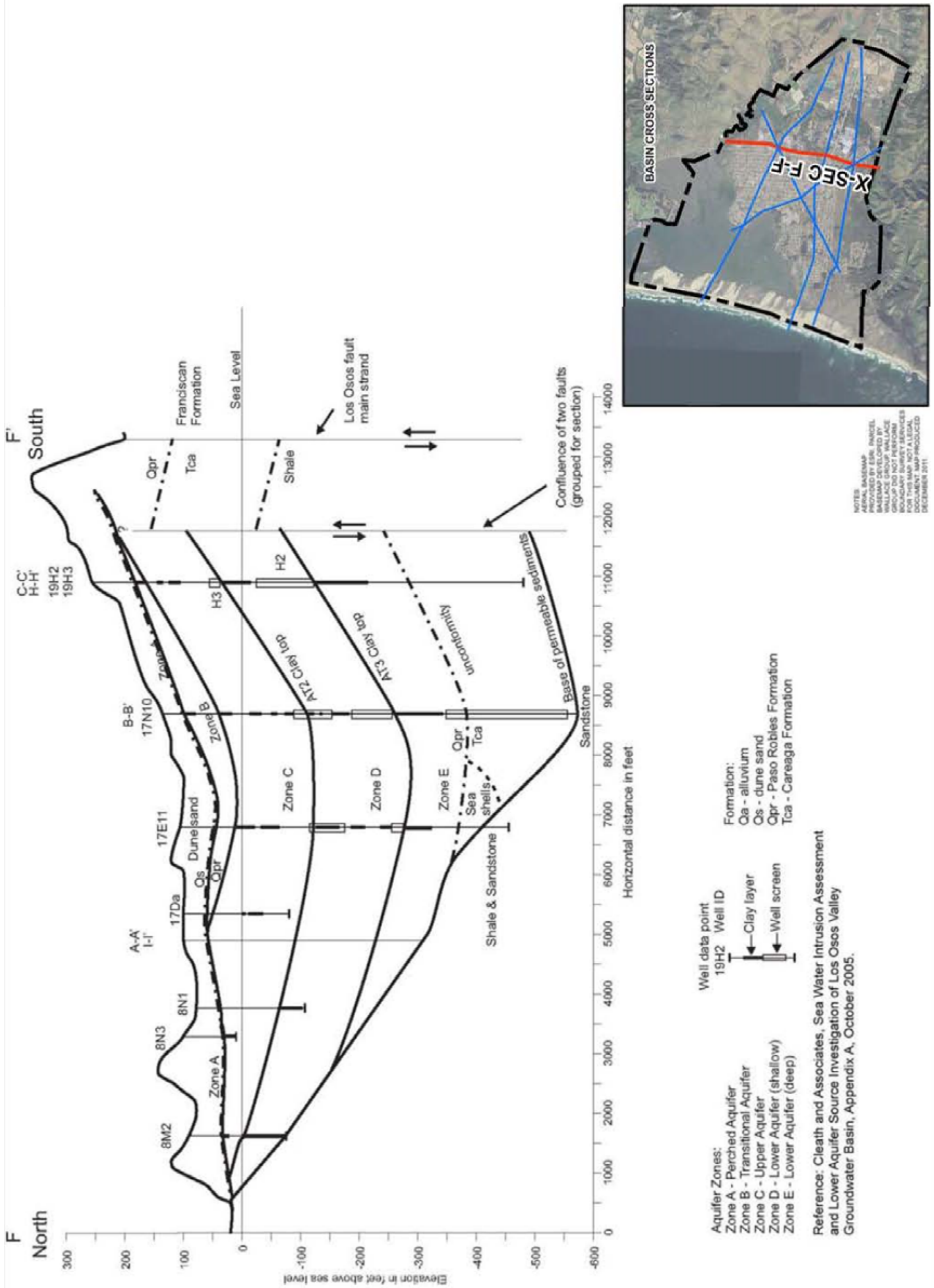

FIGURE 9: North-South Cross-Section of the Basin

[This page intentionally left blank]

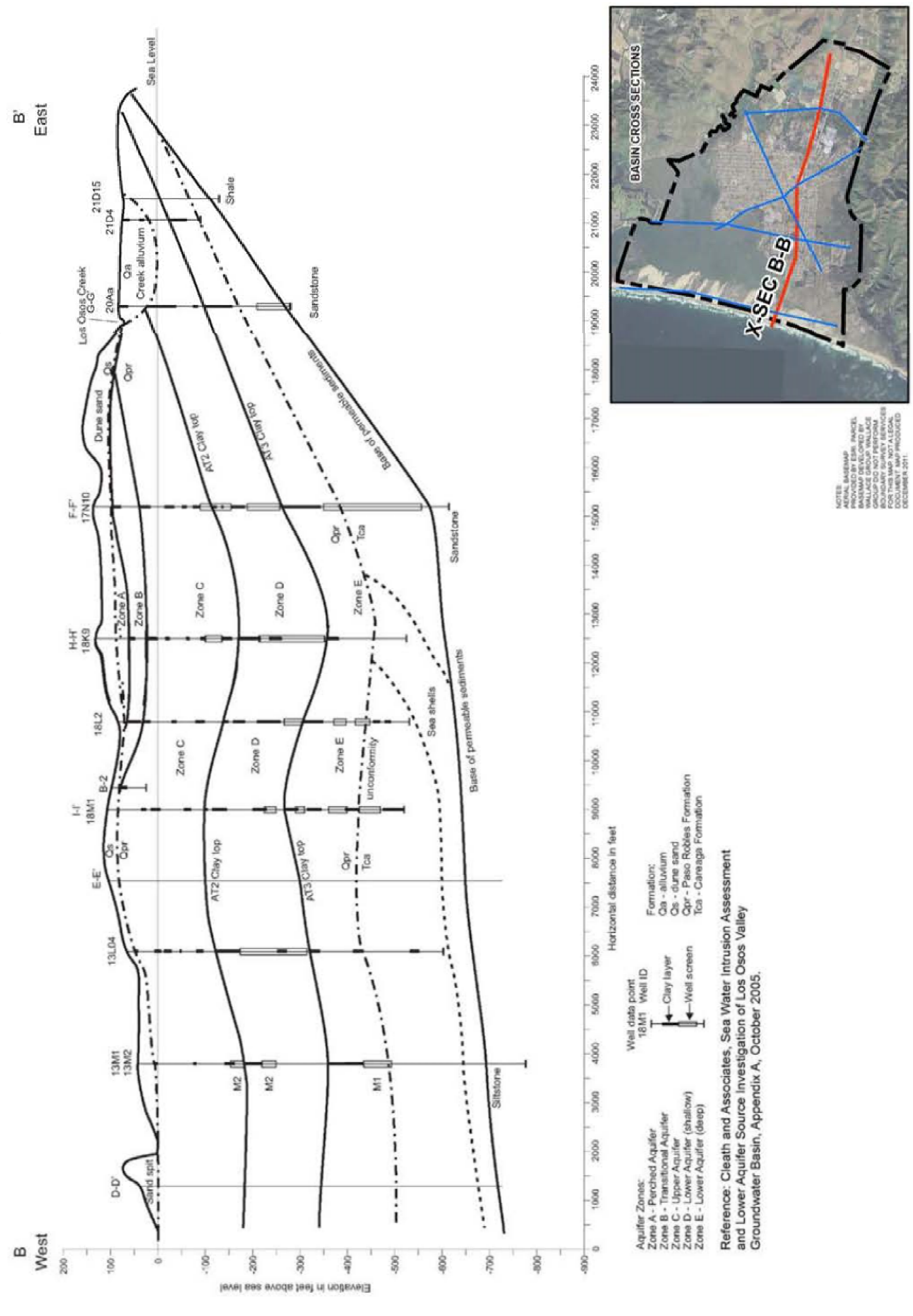

FIGURE 10: West-East Cross-Section of the Basin

[This page intentionally left blank]

Salinas Valley - Paso Robles Area (3-4.06)

Description

The Paso Robles Sub basin is bordered on the north by the Upper Valley Aquifer Sub basin, on the east by the Temblor Range, on the south by the La Panza Range, and on the west by the Santa Lucia Range. The San Andreas Fault zone bounds the basin on the northeast. The San Marcos-Rinconada fault system traverses the western part of the basin. The Red Hill, San Juan, and White Canyon faults form the eastern boundary of the sub basin. The sub basin is drained by the Salinas River and Estrella, San Juan, and Huerhuero Creeks. Rainfall averages 15 inches.

Groundwater is found in Holocene age alluvium and the Pleistocene age Paso Robles Formation.

Alluvium: Holocene age alluvium consists of unconsolidated, fine- to coarse-grained sand with pebbles and boulders. This alluvium provides limited amounts of groundwater and reaches 130 feet thick near the Salinas River, but is generally less than 30 feet thick in the minor stream valleys (DWR 1999). Groundwater in Holocene alluvium is mostly unconfined.

Paso Robles Formation: Pleistocene age Paso Robles Formation, which is the most important source of groundwater in the subbasin, is unconsolidated, poorly sorted, and consists of sand, silt, gravel, and clay (DWR 1979). This formation reaches a thickness of 2,000 feet and groundwater within it is generally confined (DWR 1958).

The Rinconada fault zone forms a leaky barrier that restricts flow from the Atascadero portion of the subbasin to the main part of the Paso Robles Subbasin (Fugro West 2001a). The San Andreas fault restricts subsurface flow.

Basin Boundary

It is important to note that that the District and other entities representing the area delineate the groundwater basin differently than as presented in DWR’s Bulletin 118. The District, the San Luis Obispo County Public Works Department, and the City of Paso Robles use the delineation as defined in the Paso Robles Groundwater Management Plan. This plan, with references to several technical reports, notes that the boundary described by Bulletin 118 includes extraneous regions that should not be a part of the subbasin. Furthermore, there is a distinct subbasin within this subbasin. These two boundary delineations and the subbasin are shown on Figure 11.

CASGEM Well Network

The proposed CASGEM well monitoring network for the Salinas Valley - Paso Robles Area Groundwater Basin is shown on Figure 11, and includes the proposed CASGEM wells, general data gap areas, the groundwater basin as defined by DWR, the groundwater basin as defined locally, the District's Monitoring Entity boundary, and areas within the District's jurisdiction.

Currently, fourteen (14) CASGEM wells are proposed for inclusion in this basin as part of this monitoring plan.

The District's approach to filling the data gaps identified below is described in Section 3 of this Monitoring Plan.

Horizontal Data Gaps

The portion of the locally-defined basin within the District is 569 square miles. Based on the target minimum density of at least one (1) well per ten (10) square miles, this portion of the basin should have fifty-seven (57) wells to meet the needs of the CASGEM Program.

Fourteen (14) CASGEM wells, in twelve (12) different locations (one well site is a cluster of three wells) are proposed for inclusion in this basin as part of this monitoring plan. Therefore, forty-five (45) additional wells need to be established in order to meet the target well density.

Vertical Data Gaps

To evaluate the vertical data gaps, the hydrogeologic conceptual model developed for the Paso Robles Groundwater Basin Computer Model was utilized. The hydrogeologic conceptual model addresses how groundwater flows through the subsurface. For this, the overall groundwater flow of the basin is characterized and the aquifer materials are subdivided into vertical groundwater zones. The Paso Robles Groundwater Basin Computer Model report defines four (4) groundwater zones in the Paso Robles Groundwater Basin. Those figures are repeated below (Figure 12 and Figure 13). One groundwater zone represents the recent alluvium deposits (Zone 1) and three zones represent vertical variations within the Paso Robles Formation (Zone 2, Zone 3, and Zone 4). A target density of at least one (1) well per ten (10) square miles is also appropriate for monitoring levels within the four groundwater zones given the composition of the hydrogeology of the basin.

The table below depicts the groundwater zones in which each CASGEM well is screened. One (1) CASGEM well is screened purely in Zone 1, zero (0) CASGEM wells are screened purely in Zone 2, five (5) wells are screened purely in Zone 3, four (4) wells are screened in Zone 4, and four (4) wells are screened in multiple Zones.

TABLE 3: Vertical Data Gap Evaluation for Paso Robles Groundwater Basin

Local Well Designation	Zone 1	Zone 2	Zone 3	Zone 4
PASO-0066				**X**
PASO-0086			**X**	**X**
PASO-0164			**X**	
PASO-0182			**X**	
PASO-0263	**X**			
PASO-0269		**X**	**X**	
PASO-0283			**X**	**X**
PASO-0313	**X**		**X**	
PASO-0317			**X**	
PASO-0328				**X**
PASO-0345			**X**	
PASO-0349				**X**
PASO-0353			**X**	
PASO-0399				**X**

Based on the review above, as the forty-five (45) additional wells are established, it will be important to ensure discrete screen intervals for all Zones are established, which may require up to one-hundred seventy two (172) additional wells.

[This page intentionally left blank]

[This page intentionally left blank]

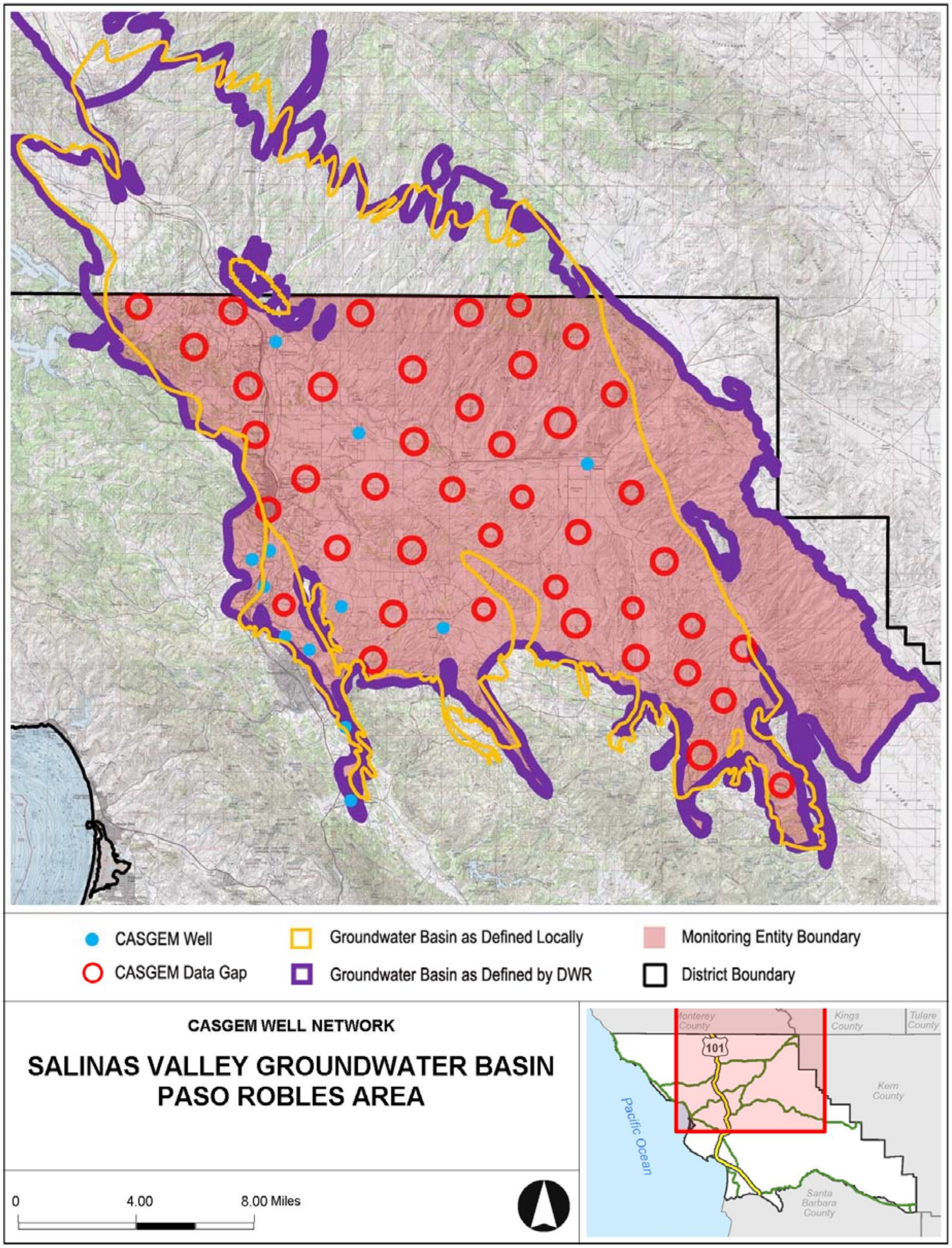

FIGURE 11: Monitoring Program for the Salinas Valley – Paso Robles Area Groundwater Basin

[This page intentionally left blank]

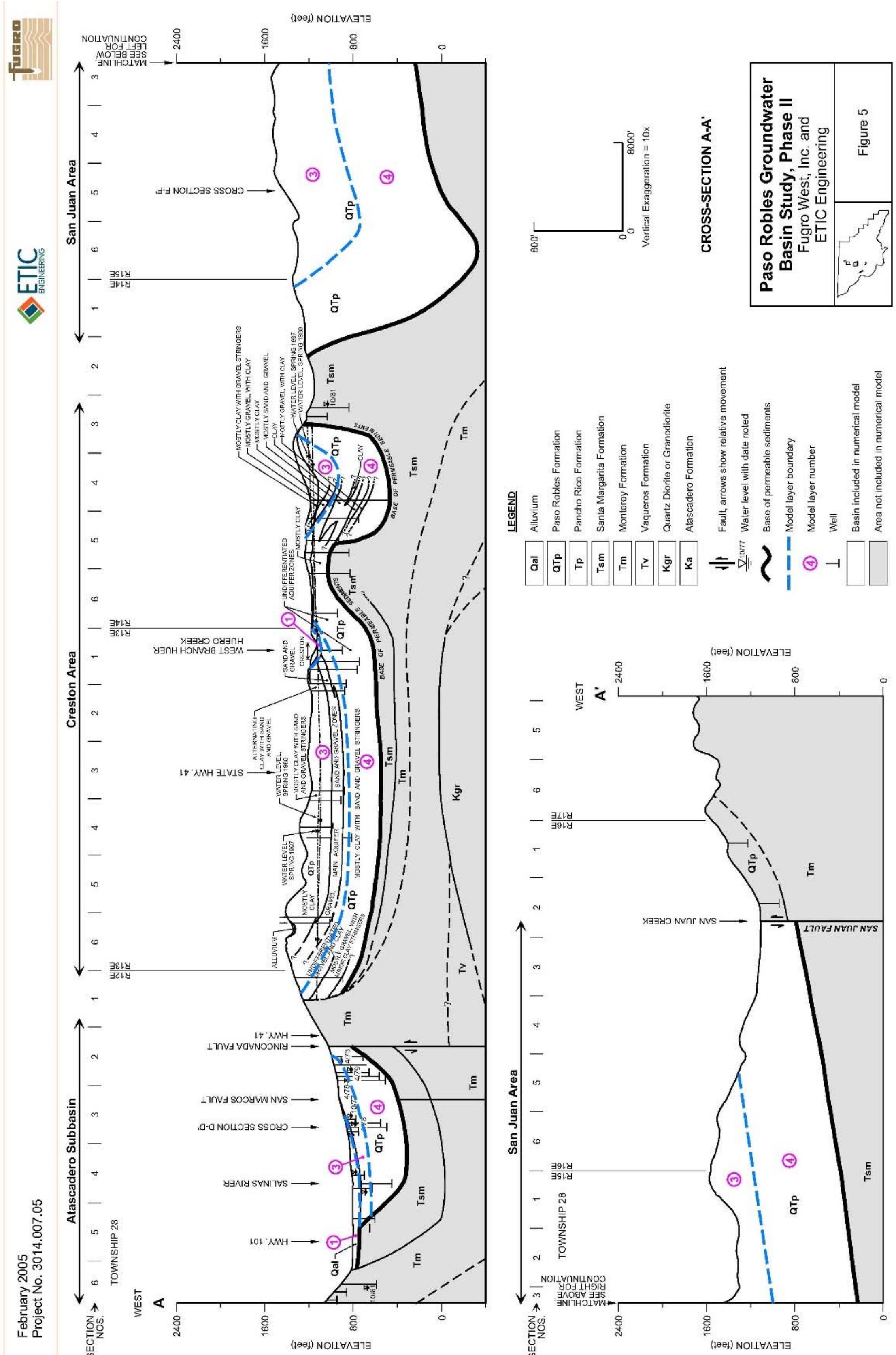

FIGURE 12: Paso Robles Groundwater Basin Cross-Section A-A’

[This page intentionally left blank]

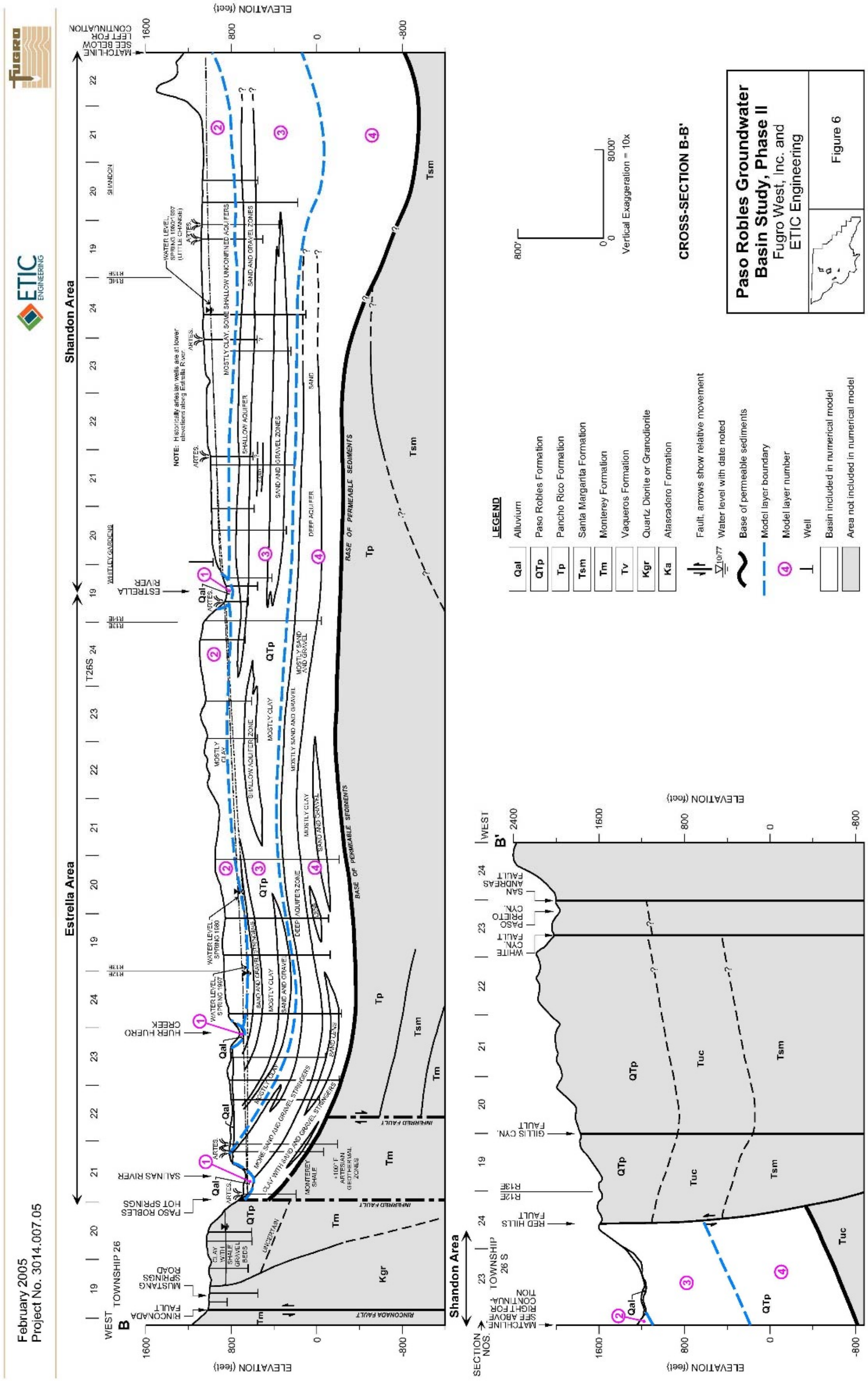

FIGURE 13: Paso Robles Groundwater Basin Cross-Section B-B’

[This page intentionally left blank]

San Luis Obispo Valley (3-9)

Description

The San Luis Obispo Valley Groundwater Basin underlies the San Luis and Edna Valleys and is bounded on the northeast by the Santa Lucia Range, on the southwest by the San Luis Range, and on all other sides by contact with impermeable Miocene and Franciscan Group rocks. The northwestern part of the valley is drained by San Luis Obispo, Prefumo, and Stenner Creeks. The southeastern part of the valley is drained by tributaries of Pismo and Davenport Creeks. Laguna Lake lies in the northwestern part of the valley. Average annual precipitation ranges across the valley from 19 to 23 inches with the mean of 21 inches.

Groundwater in the San Luis Obispo Valley Groundwater Basin is found in Pleistocene to Holocene age terrestrial deposits. The average specific yield in the San Luis and Edna portions of the basin is 6 percent (DWR 1997).

Holocene Deposits: Holocene age alluvium consists of unconsolidated gravel, sand, silt, and clay of fluvial origin that reaches a maximum thickness of about 50 feet (Boyle 1991). In the portion of the basin that underlies the San Luis Obispo Creek watershed, this alluvium covers the valley floor and is the main source of groundwater. Wells yield from 20 to 300 gpm (Boyle 1991).

Pleistocene Deposits: Pleistocene age alluvial terrace deposits as thick as 50 feet and wells completed in these deposits have yields of about 20 gpm (Boyle 1991). The Paso Robles Formation is composed of poorly sorted, unconsolidated to consolidated conglomerate, sand, silt, gravel, and clay (DWR 1979).

The Edna fault is the main geological structure in this basin; however, the fault does not appear to affect the movement or quality of groundwater (Boyle 1991).

Basin Boundary

It is important to note that that the District recognizes two subbasins within the basin as delineated by DWR. A rise in bedrock south of the San Luis Obispo Airport has created two separate subsurface drainage systems, which were designated as the San Luis Valley and Edna Valley Subbasins in a draft study conducted by the DWR in 1997. These two subbasins are shown on Figure 14 (note the yellow line transecting the basin northwest of the mapped CASGEM well).

CASGEM Well Network

The proposed CASGEM well monitoring network for the San Luis Obispo Valley Groundwater Basin is shown on Figure 14, and includes the proposed CASGEM well, the general data gap area, the groundwater basin as defined by DWR, the subbasins as defined locally, the District's Monitoring Entity boundary, and areas within the District's jurisdiction.

Currently, one (1) CASGEM well is proposed for inclusion in this basin as part of this monitoring plan.

The District's approach to filling the data gaps identified above is described in Section 3 of this Monitoring Plan.

Horizontal Data Gaps

The portion of the basin within the District is 20 square miles. Based on the target minimum density of at least one (1) well per ten (10) square miles, this portion of the basin should have two (2) wells to meet the needs of the CASGEM Program.

One (1) CASGEM well is proposed for inclusion in this basin as part of this monitoring plan. Therefore, one (1) additional well needs to be established in order to meet the target well density.

Vertical Data Gaps

To evaluate the vertical data gaps, the cross-sections developed for the San Luis Obispo Valley Basin were utilized. The sediments comprising the water-bearing series are present as beds of unconsolidated to semi-consolidated clay, silt, sand, and gravel and also poorly consolidated fossiliferous sandstone. The materials comprising this series are grouped into four geologic units: 1) Squire Member of the Pismo Formation, 2) Paso Robles Formation, 3) Terrace Deposits, and 4) Valley Alluvium, as illustrated in Figure 15 through Figure 17. A target density of at least one (1) well screened discretely in each of the water-bearing series and consistent with a horizontal density of at least one (1) well per ten (10) square miles is appropriate for monitoring levels, as the formations are relatively shallow and unconfined in this basin.

The CASGEM monitoring well is screened in the Paso Robles formation. Therefore as the additional well is established to address horizontal data gaps, it will also be important to ensure wells with discrete screen interval in the formations in each area are established, which may require up to seven (7) wells.

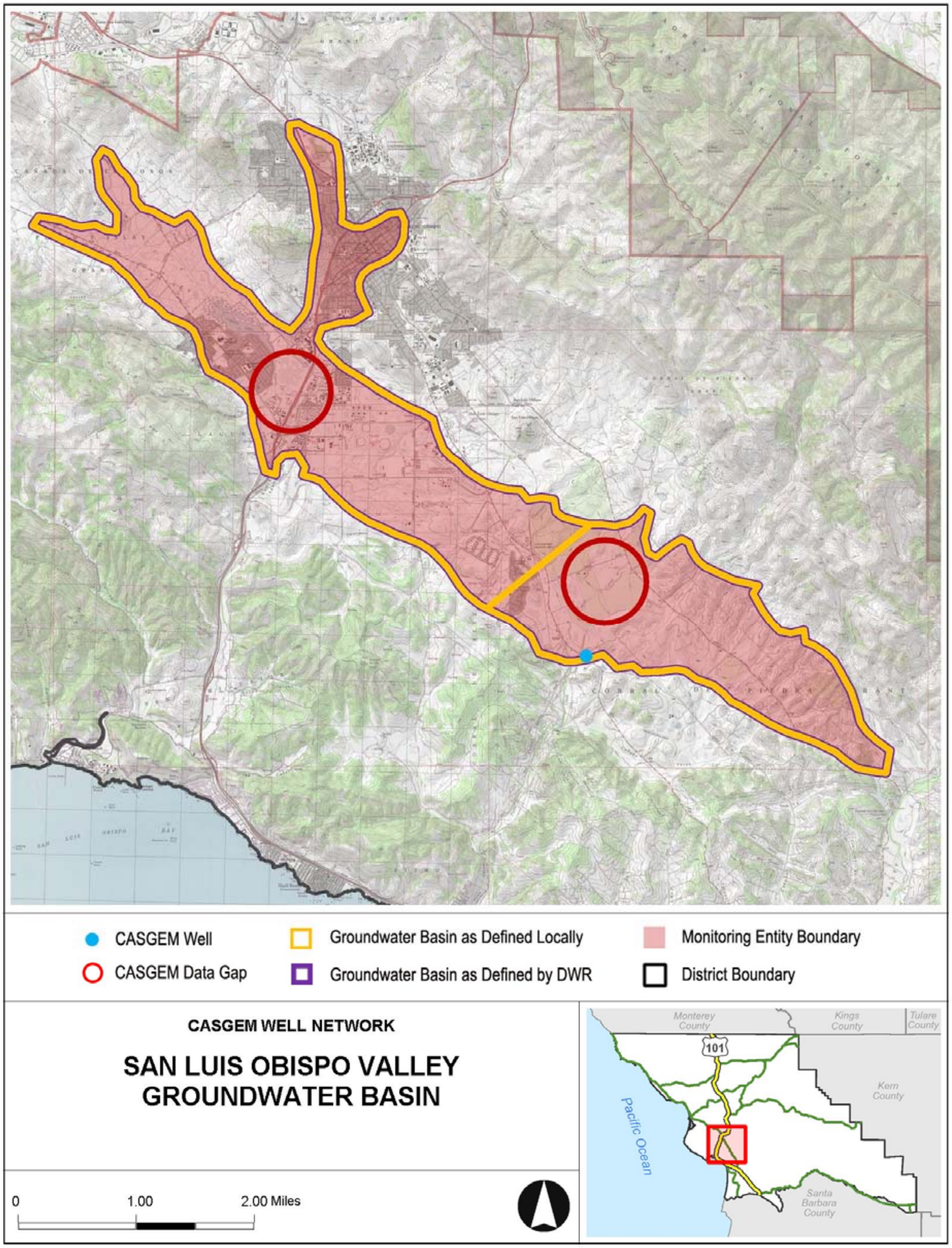

FIGURE 14: Monitoring Program for the San Luis Obispo Groundwater Basin

[This page intentionally left blank]

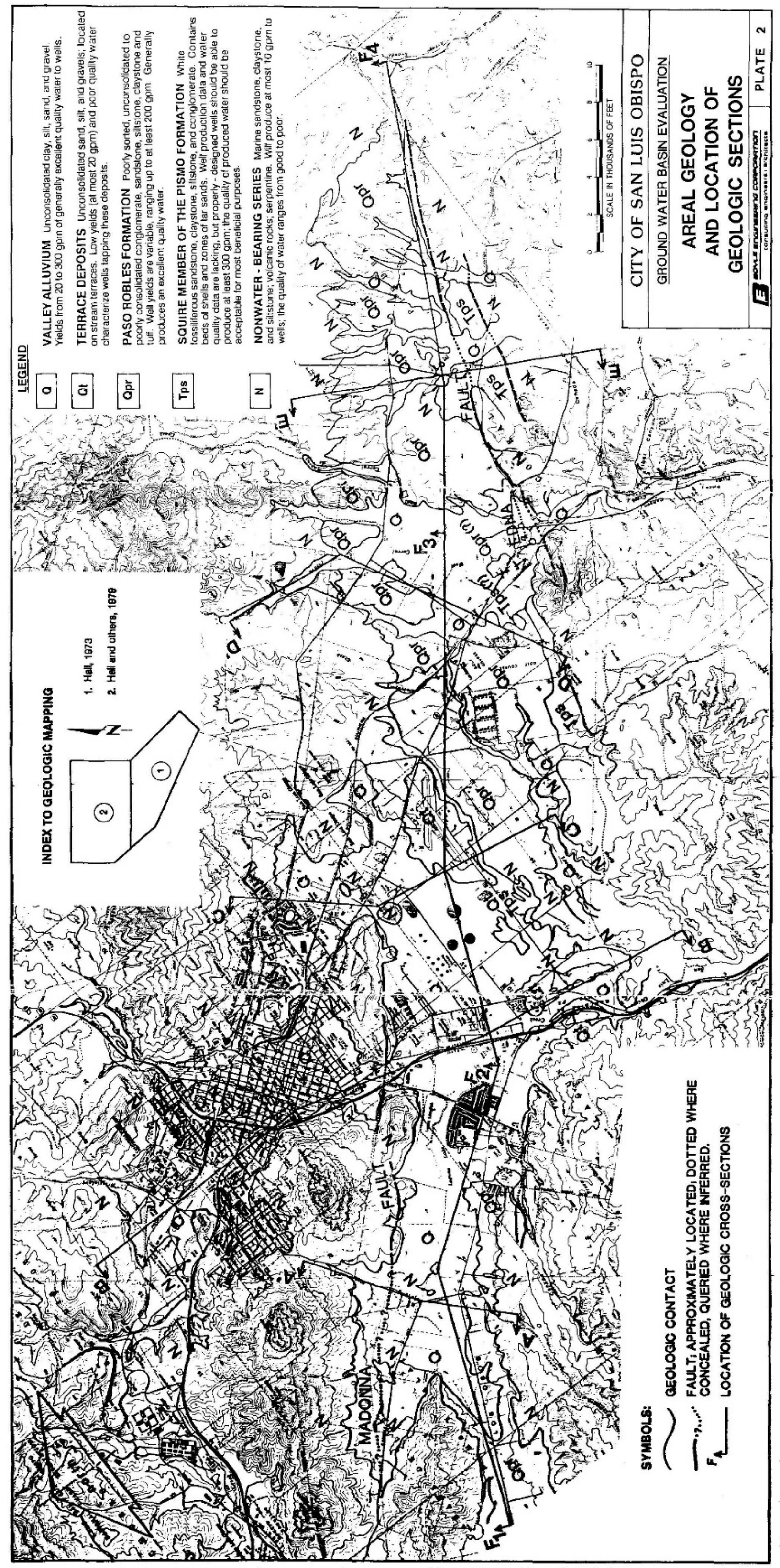

FIGURE 15: Aerial Geology and Location of Geologic Sections

[This page intentionally left blank]

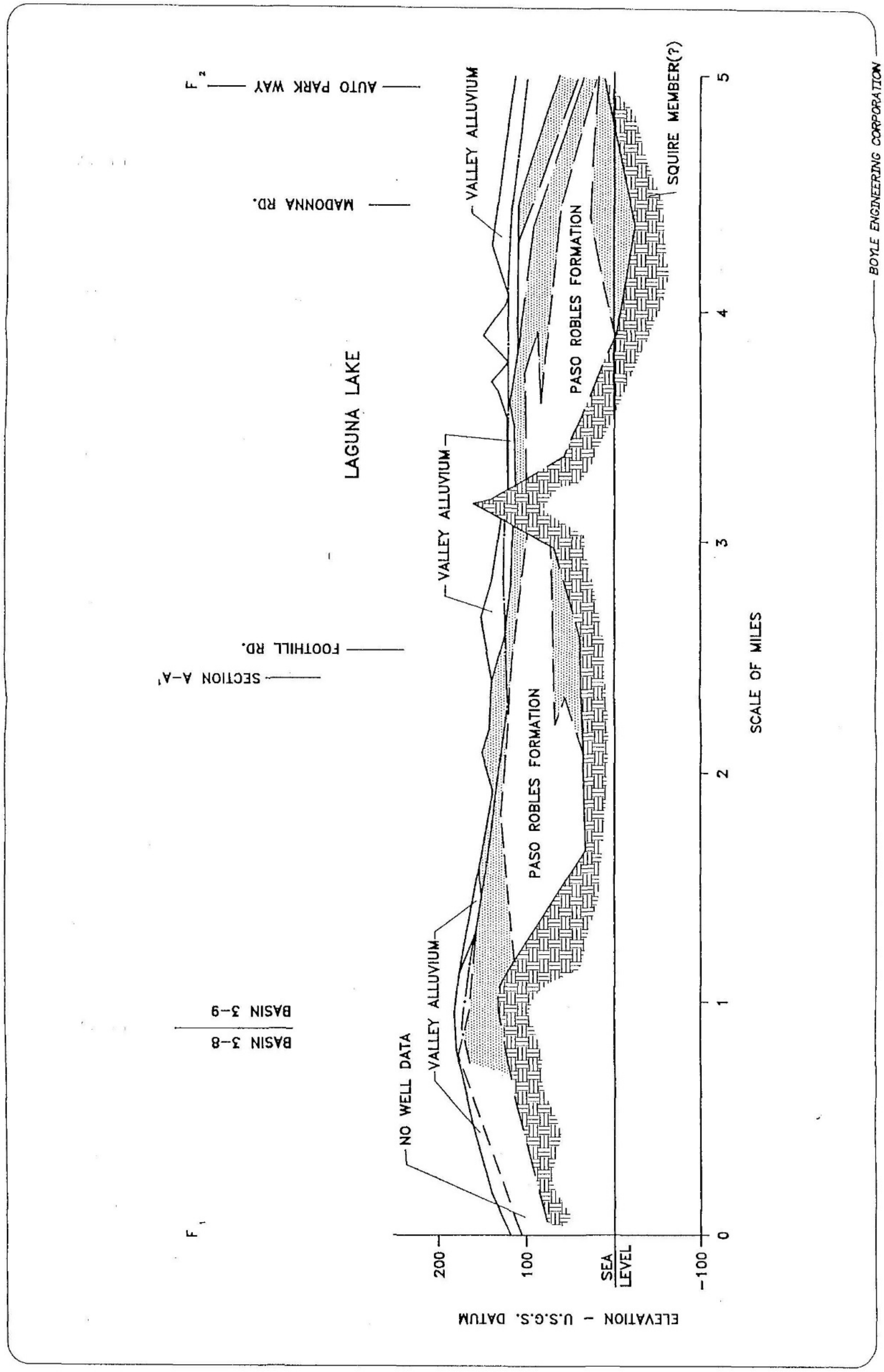

FIGURE 16: Cross-Section F_1-F_2

[This page intentionally left blank]

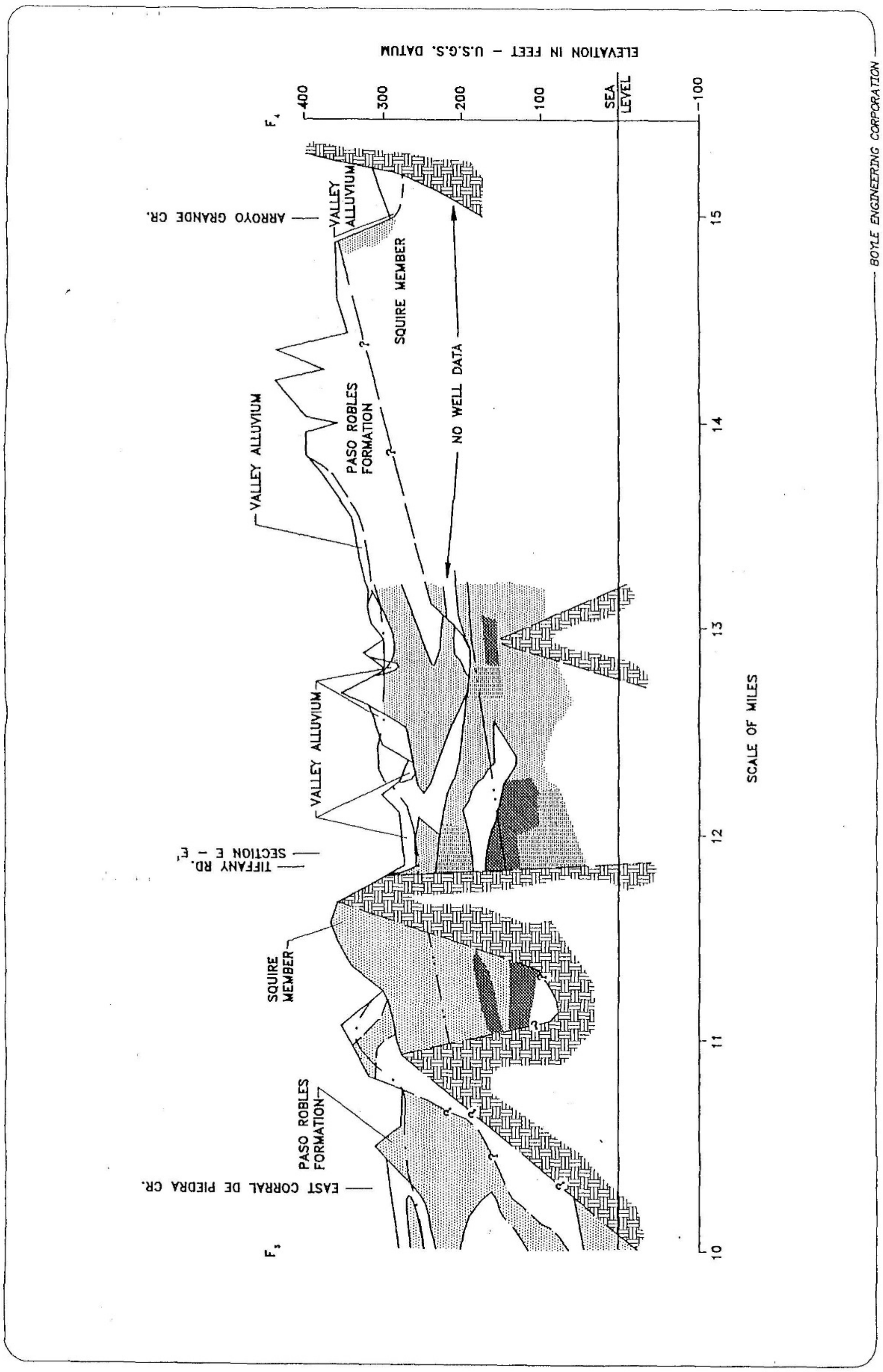

FIGURE 17: Cross-Section F3-F4

[This page intentionally left blank]

Santa Maria River Valley (3-12)

Description

This groundwater basin underlies the Santa Maria Valley in the coastal portion of northern Santa Barbara and southern San Luis Obispo Counties. The basin also underlies Nipomo and Tri-Cities Mesas, Arroyo Grande Plain, and Nipomo, Arroyo Grande and Pismo Creek Valleys (DWR 2002). The basin is bounded on the north by the San Luis and Santa Lucia Ranges, on the east by the San Rafael Mountains, on the south by the Solomon Hills and the San Antonio Creek Valley Groundwater Basin, on the southwest by the Casmalia Hills, and on the west by the Pacific Ocean. Several rivers and creeks drain westward to the Pacific Ocean. The Santa Maria Valley is drained by the Sisquoc, Cuyama, and Santa Maria Rivers and Orcutt Creek. Tri-Cities Mesa and Arroyo Grande Plain are drained by Arroyo Grande and Pismo Creeks. Nipomo Valley is drained by Nipomo Creek into the Santa Maria River. Annual precipitation ranges from 13 to 17 inches, with an average of 15 inches.

Groundwater is found in alluvium, dune sands, and the Orcutt, Paso Robles, Pismo, and Careaga Formations. Groundwater is unconfined throughout most of the basin except in the coastal portion where it is confined. The average total thickness of the waterbearing materials is about 1,000 feet with a maximum thickness of 2,800 (SBCWA 1996) to 3,000 feet (Worts 1951).

Alluvium and Dune Deposits: Holocene alluvium consists of unconsolidated lenticular bodies of gravel, sand, silt, and clay. This alluvium reaches a maximum thickness of about 250 feet (Miller and Evenson 1966). Pleistocene and Holocene dune deposits consist of wellrounded, fine- to coarse-grained sand. Holocene dune deposits are typically found along a coastal belt and attain a maximum thickness of 100 feet (Woodring and Bramlette 1950; DWR 2002). Pleistocene dune deposits found under Tri-Cities Mesa range to about 60 feet thick and those under Nipomo Mesa range to about 300 feet thick (DWR 2002).

Orcutt Formation: The Pleistocene age Orcutt Formation consists of sand and interbeds of coarse gravel, with minor amounts of silt and clay restricted to the upper parts of the unit (Woodring and Bramlette 1950). The Orcutt Formation can reach a maximum thickness of 225 feet, particularly along the axis of the Santa Maria Valley syncline (Worts 1951).

Paso Robles Formation: The Pliocene-Pleistocene age Paso Robles Formation typically consists of unconsolidated to poorly consolidated coarse to fine-grained gravel, sand, silt, and clay (DWR 2002). In this basin, the Paso Robles Formation ranges from about 40 feet near Pismo Creek (DWR 2002) to 2,000 feet (Woodring and Bramlette 1950; Worts 1951) near Orcutt (Worts 1951).

Careaga Formation: The late Pliocene age Careaga Formation is described as unconsolidated deposits of fine- to medium-grained, marine sand with some silt

(Worts 1951), and unconsolidated to well consolidated, coarse- to fine-grained sand, gravel, silty sand, silt, and clay (DWR 2002). Thickness of this unit ranges from about 150 to 700 feet in the San Luis Obispo County portion of the basin (DWR 2002) and ranges from 50 to 2,250 feet thick (Woodring and Bramlette 1950) elsewhere in the basin.

Pismo Formation: The late Pliocene age Squire Member of the Pismo Formation is an important source of groundwater in the basin north of the Santa Maria River fault. The Squire Member consists of coarse- to finegrained sand interbeded with discontinuous layers of silt and clay, and ranges from about 50 to 550 feet thick (DWR 2002).

The Santa Maria fault displaces Pliocene units vertically by about 150 feet, and a steepening of the hydraulic gradient near the trace of this fault indicates that this fault is a partial barrier to groundwater flow (SBCWA 1977). The Santa Maria River fault cuts northwestward through the basin in San Luis Obispo County (DWR 2002). Water levels at different elevations across some sections of this fault suggest that it is a barrier to groundwater movement in formations below the Pleistocene dune sand deposits (DWR 2002).

Basin Boundary

It is important to note that that the District recognizes the main portion of this groundwater basin as delineated by DWR in 2002 (and reaffirmed by the Courts in early 2008), and also recognizes that there are three (3) separate subbasins in this basin (DWR, 2002). This main basin delineation and the three subbasins are shown on Figure 18.

CASGEM Well Network

The proposed CASGEM well monitoring network for the Santa Maria River Valley Groundwater Basin is shown on Figure 18, and includes the proposed CASGEM wells, the general data gap areas, the groundwater basin as defined by DWR, the subbasins as defined locally, the District's Monitoring Entity boundary, and areas within the District's jurisdiction.

Currently, three (3) CASGEM wells are proposed for inclusion in this basin as part of this monitoring plan. However, one (1) of these wells is not located within the District's Monitoring Entity Boundary -- only the two (2) wells located within the Monitoring Entity Boundary are considered.

The District's approach to filling the data gaps identified above is described in Section 3 of this Monitoring Plan.

Horizontal Data Gaps

The portion of the basin within the District and not within the Santa Maria Valley Management Area Monitoring Entity is 62 square miles. Based on the target minimum density of at least one (1) well per ten (10) square miles, this portion of the basin should have six (6) wells to meet the needs of the CASGEM Program.

Currently, three (3) CASGEM wells are proposed for inclusion in this basin as part of this monitoring plan. However, one (1) of these wells is not located within the District's Monitoring Entity Boundary -- only the two (2) wells located within the Monitoring Entity Boundary are considered. Therefore, four (4) additional wells need to be established in order to meet the target well density.

Vertical Data Gaps

To evaluate the vertical data gaps, cross-sections developed as part of the Santa Maria Groundwater Basin Characterization project were utilized. The major geologic formations in the basin from youngest to oldest are Recent Alluvium, Young and Old Dune Sand, Paso Robles Formation, Careaga Sand(stone), Sisquoc Formation (and/or other formations older than Careaga Sandstone such as the Squire Member of the Pismo Formation), and Franciscan Bedrock, as illustrated in Figure 19 through Figure 21. The primary water-bearing formations in this portion of the basin includes Recent Alluvium, Paso Robles Formation, and Careaga Formation. A target density of at least one (1) well per ten (10) square miles is also appropriate for monitoring levels within three water-bearing formations given the composition of the hydrogeology of the basin.

All of the CASGEM monitoring wells are screened in the Paso Robles Formation. Therefore as the four (4) additional wells are established to address horizontal data gaps, it will be important to ensure discrete screen intervals for all three water-bearing formations are established, which may require up to twenty (20) additional wells.

[This page intentionally left blank]

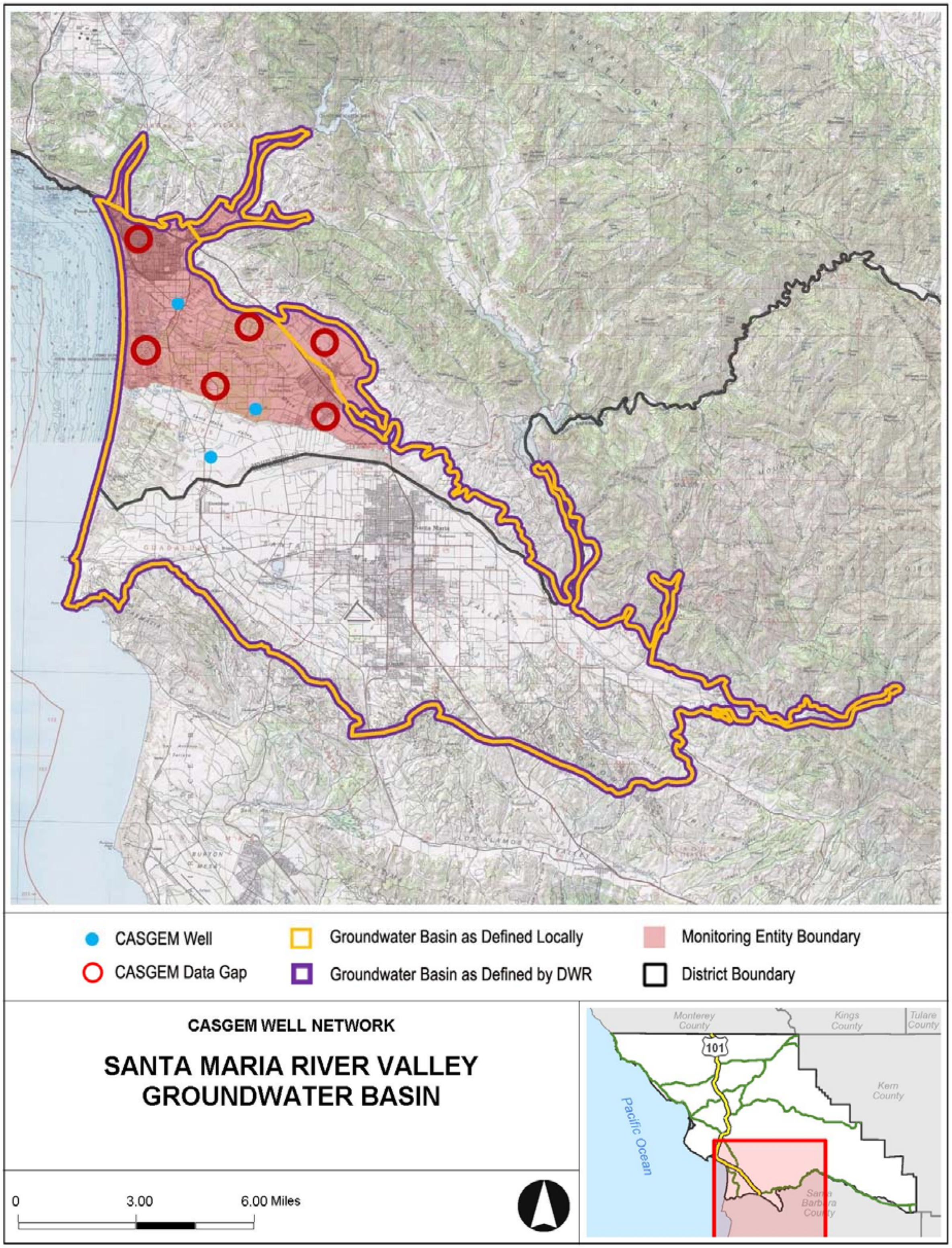

FIGURE 18: Monitoring Program for the Santa Maria River Valley Groundwater Basin

[This page intentionally left blank]

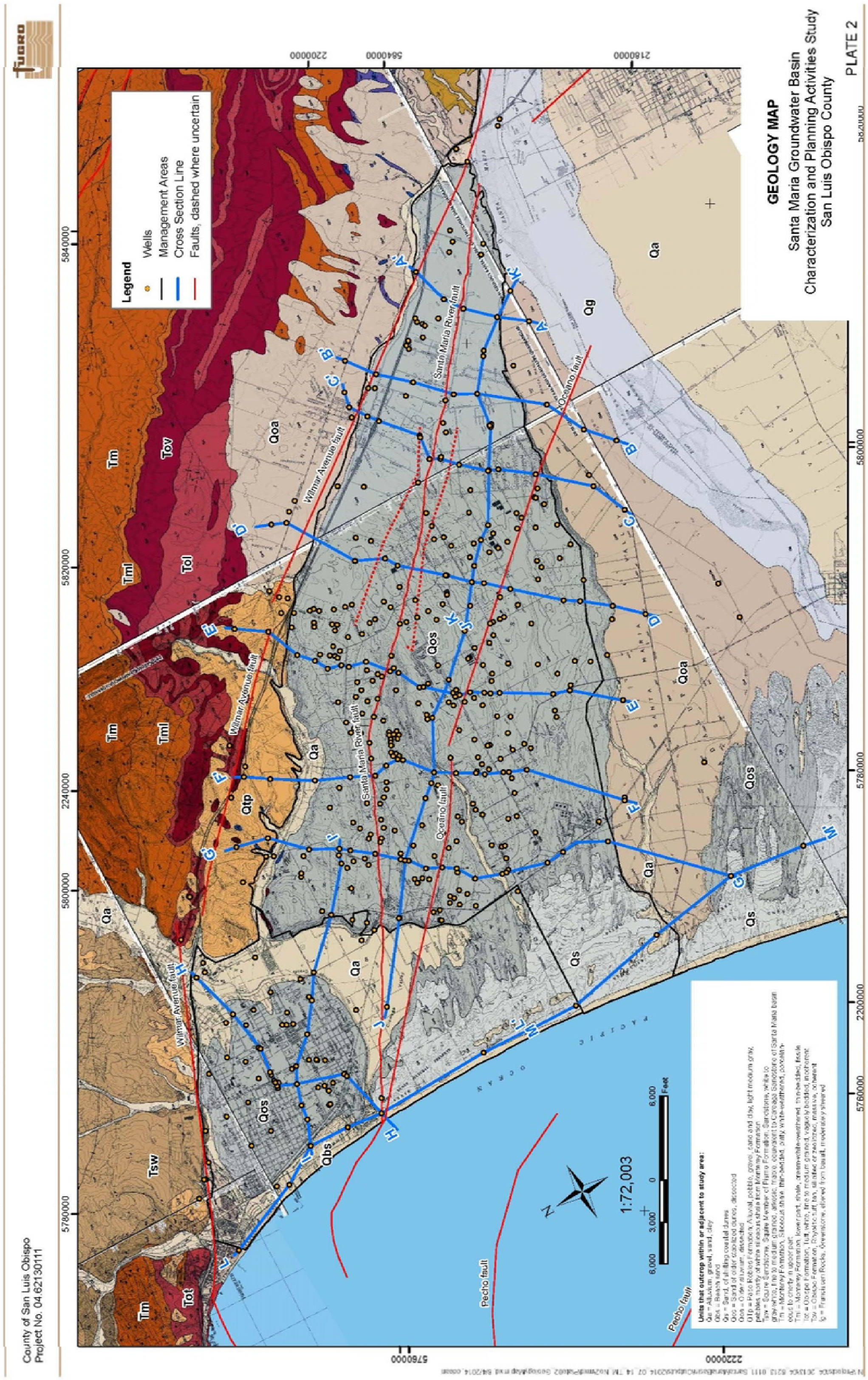

FIGURE 19: Santa Maria Valley Groundwater Basin Geology and Location of Geologic Sections

[This page intentionally left blank]

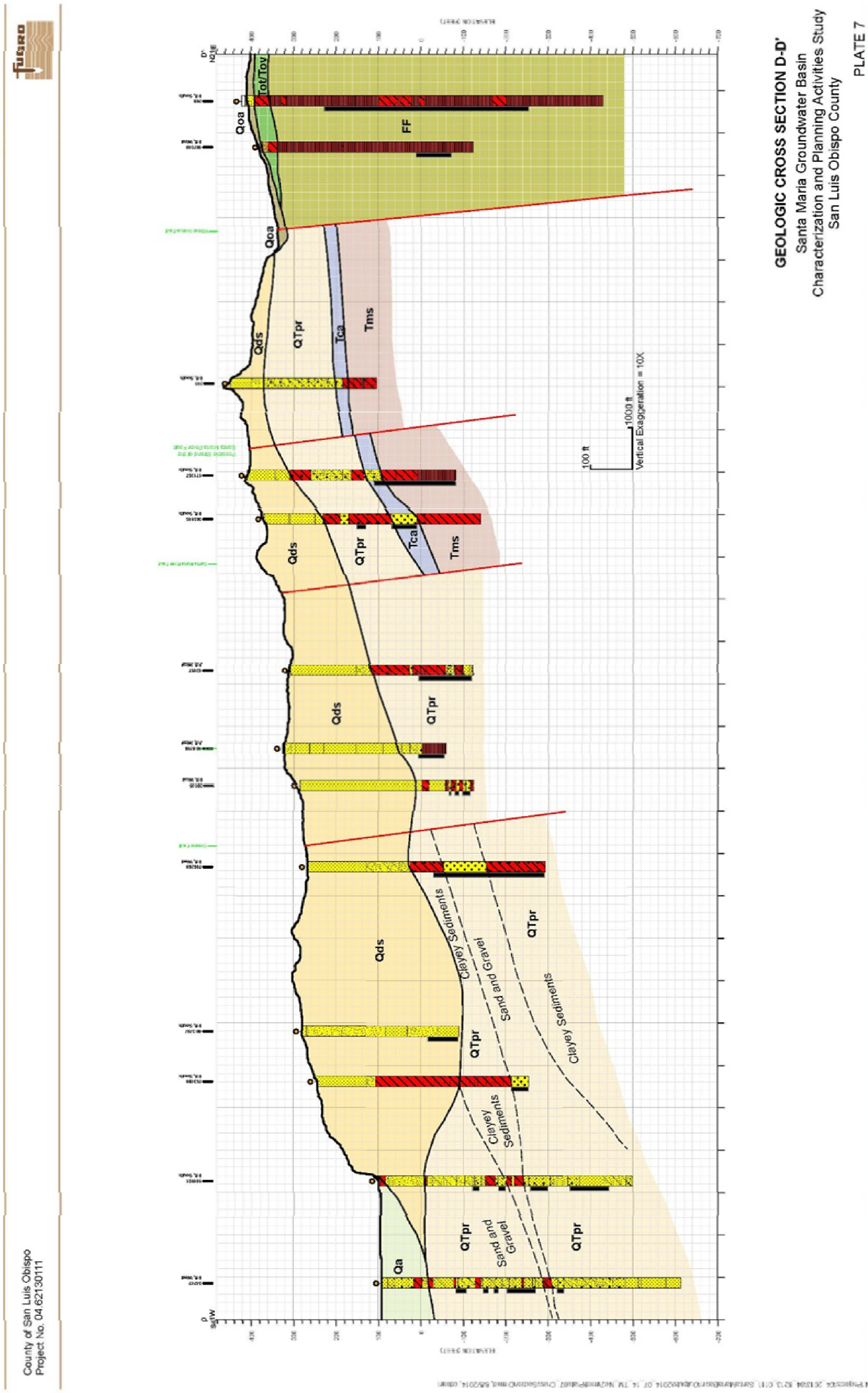

FIGURE 20: Geologic Cross-Section D-D'

[This page intentionally left blank]

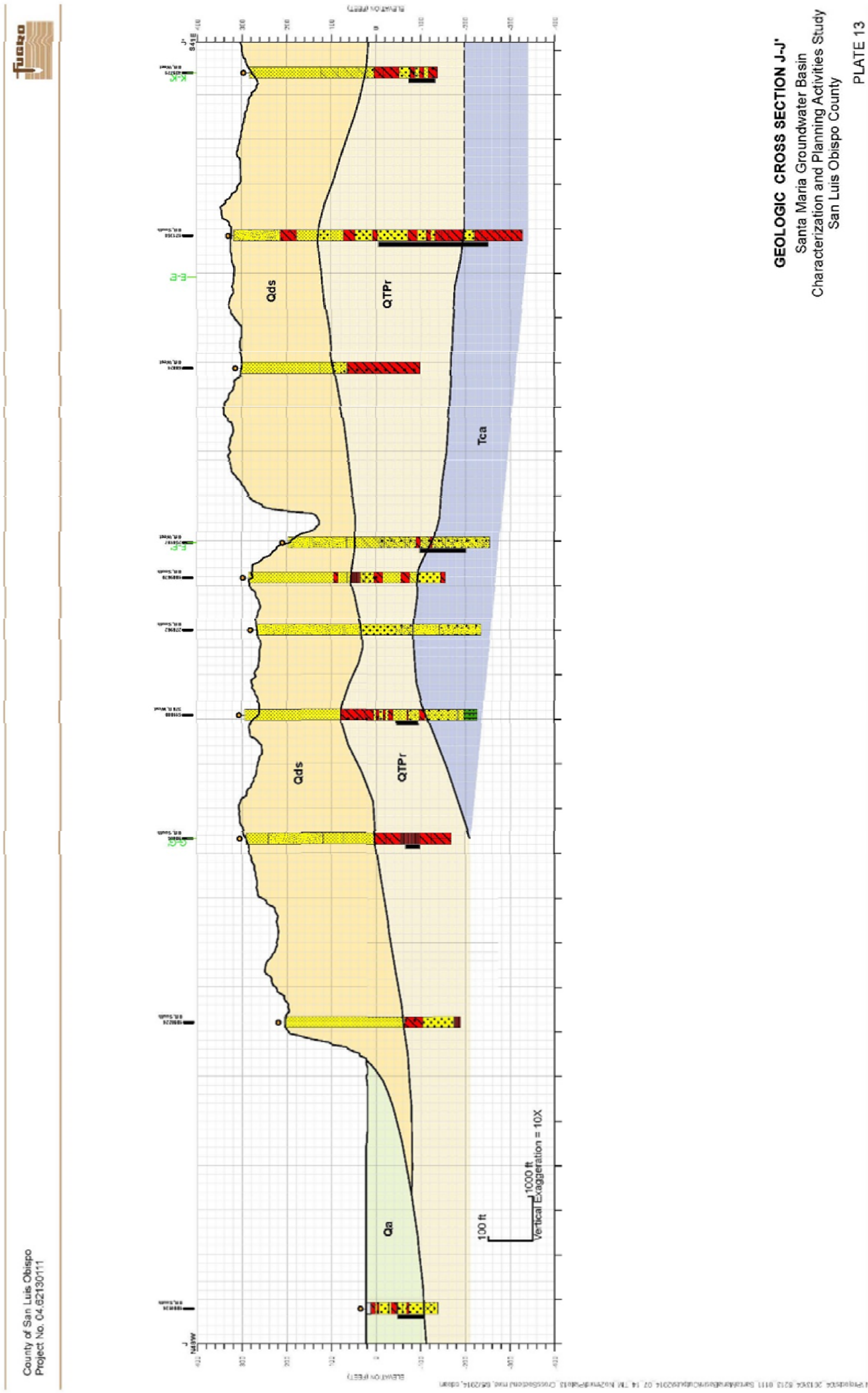

FIGURE 21: Geologic Cross-Section J-J’

[This page intentionally left blank]

3. Approach for Filling Data Gaps

Background

A data gap refers to an area with in a groundwater basin that lacks the density of monitoring wells that would allow seasonal and long-term trends in groundwater elevations to be determined for the basin, sub basin or a portion thereof. Data gaps may exist for a variety of reasons, including lack of suitable monitoring wells, lack of groundwater use, access issues, and jurisdictional issues, among others.

There have been five (5) studies conducted since 2008 which have identified data gaps throughout the District. Some of the studies overlapped in area or incorporated previous data gap studies with in the document. Each of those studies, and a brief summary is described below:

1. San Luis Obispo City Groundwater Pumping Analysis: In 2001, the City of San Luis Obispo conducted a Groundwater Pumping Analysis, which in part, reviewed the groundwater well monitoring network in this basin. The report highlighted areas where improved groundwater monitoring would be helpful.

2. San Luis Obispo County Groundwater Monitoring Evaluation: In 2008, the District evaluated their Groundwater Level Measuring Program (Program) in groundwater basins throughout San Luis Obispo County. The purpose of this evaluation was to improve the efficiency and effectiveness of the District's Program. Key tasks associated with this evaluation included a review of the distribution of monitoring wells and the determination where additional monitoring wells were needed.

3. District Data Enhancement Plan: In late 2008, the District developed a Data Enhancement Plan. The Data Enhancement Plan was an evaluation of the regional water data collection monitoring programs. One element of the Data Enhancement Plan was to identify groundwater well data gaps. The Data Enhancement Plan incorporated the results of the 2008 Groundwater Level Measuring Program Evaluation and also recommended improved monitoring in basins that were not currently monitored.

4. San Luis Obispo County Master Water Report: In 2012, the District developed a County-Wide Master Water Report. This report considered and updated the data gaps analysis contained in the 2008 Data Enhancement Plan.

5. Paso Robles Groundwater Basin Management Plan: The Paso Robles Groundwater Management Plan identified gaps in the groundwater level monitoring network for the Paso Robles Groundwater Basin. These gaps were generally located adjacent to areas currently experiencing declining groundwater levels, or are in areas where limited or no water level data is available

The table below contains results of the various data gap analyses (Table 4). The numbers within each cell represent the total number of data gaps identified, by evaluation, for each basin. Cells with a value of zero (0) indicate that no data gaps were identified in the evaluation. Cells that are blank suggest that the evaluation did not consider that groundwater basin. For example, the Cuyama Valley groundwater basin was not evaluated in the San Luis Obispo City Groundwater Pumping Update, the San Luis Obispo Groundwater Monitoring Evaluation, or the Paso Robles Groundwater Basin Management Plan. This basin was evaluated in the District Data Enhancement Plan and in the San Luis Obispo County Master Water Report, and both reports identified one (1) data gap for this basin.

TABLE 4: Recent Data Gap Analyses for High and Medium Priority Groundwater Basins within the District

Groundwater Basin / Subbasin	**San Luis Obispo City Groundwater Pumping Analysis**	**San Luis Obispo County Groundwater Monitoring Evaluation**	**District Data Enhancement Plan**	**San Luis Obispo County Master Water Report**	**Paso Robles Groundwater Basin Management Plan**	**This CASGEM Monitoring Plan** (Horizontal Gaps : Vertical Gaps)
Cuyama Valley (3-13)			**1**	**1**		**2 : 14**
Los Osos Valley (3-08)		**0**	**0**	**0**		**0 : 2**
Salinas Valley Paso Robles Area (3-04.06)		**36**	**36**	**36**	**48**	**45 : 172**
San Luis Obispo Valley (3-09)	**4**	**2**	**2**	**2**		**1 : 7**
Santa Maria River Valley (3-12)		**25**	**25**	**25**		**4 : 20**
TOTALS	**4**	**66**	**76**	**76**	**48**	**51 : 215**

Next Steps

The data gaps discussed above and in earlier sections will be addressed in the future, as funding becomes available and through continued focused outreach to landowners in these areas while exploring opportunities for partnering with other agencies in the construction of dedicated monitoring wells.

As budget and resources become available, additional wells may be added to provide better spatial and/or vertical distribution of monitored locations within the basins and to enhance the understanding of localized groundwater conditions and availability. Although the current CASGEM well network is described herein, the District would like to include additional wells over the coming years.

In general, the District's approach to filling these data gaps is as follows:

1. Outreach to District Groundwater Level Measuring Program Participants: There are over 450 water wells measured as part of the District's Groundwater Level Monitoring Program. Of these, over 250 of these wells could be used in the CASGEM program if the well owner granted the District permission to do so. It is the District's intent to update existing agreements and encourage participants to include their wells in the CASGEM program. The breakdown of potential wells in each basin with data gaps presented in this monitoring plan is as follows:

TABLE 5: Potential Wells for Filling CASGEM Data Gaps

Groundwater Basin	**CASGEM Data Gaps** (Horizontal : Vertical)	**Potential CASGEM Wells Using District Program Participants**
Cuyama Valley	2 : 14	0
Los Osos Valley	0 : 2	40
Salinas Valley - Paso Robles Area	45 : 172	190
San Luis Obispo Valley	1 : 7	15
Santa Maria River Valley	4 : 20	160

2. Outreach to Other Private Well Owners: The District will outreach to other well owners in the data gap areas if there are no District Groundwater Level Measuring Program participants, or if current participants are unwilling to participate in the CASGEM program. At present, it is unclear how many of the existing wells may be suitable candidates for the CASGEM program and how many of these well owners are interested in participating in such a program. As budget and resources become available, the District will systematically contact well owners to help fill CASGEM data gaps.

3. Outreach to Public Well Owners: The District will use this group of potential wells only if there are no other options for filling data gaps, provided that the water service provider grants the District explicit permission to use their wells and display construction details as part of the CASGEM program.

4. Drilling of New Monitoring Wells: The District will consider drilling new monitoring wells if the methods described above are unsuccessful. The District will have to consider finances and other resource limitations in advance of drilling any new well.

5. Other Options: The District is open to consider other approaches for filling these CASGEM data gaps.

District staff will update this Monitoring Plan and all associated tables or figures, as CASGEM wells are added to this Monitoring Program.

4. Standard Operating Procedures for Groundwater Monitoring

Seasonal Monitoring Schedule

For all of the basins, well level measurements are obtained semi-annually in April and October to ensure consistency and comparable data results. A review of historic data confirms that April and October generally correspond to the seasonal high and low groundwater elevations observed in their respective groundwater basins. In general the following is a schedule of monitoring for each basin.

Basin	**Scheduled Monitoring During April/October**
Salinas Valley Paso Robles Area	Weeks 1-2
Los Osos Valley	Week 2
San Luis Obispo Valley	Week 3
Santa Maria River Valley	Weeks 3-4
Cuyama Valley	Week 4

Monitoring will be performed by San Luis Obispo County Public Works acting as staff to the District and by other public water agencies within the District; however, the data will be submitted to the CASGEM online submittal system by the District.

Field Methods

Collection of water level measurements is performed consistent with groundwater technical procedural documents released by the U.S. Geological Survey (USGS). These technical procedures were written in response to the need for standardized technical procedures of many aspects of groundwater science, including site and measuring-point establishment, measurement of water levels, and measurement of well discharge. Particularly relevant groundwater technical procedural documents are included in the Appendix of this Plan (Appendix B). Others can be viewed or downloaded at the following link:

http://pubs.usgs.gov/tm/1a1/pdf/tm1-a1.pdf

Also, the District's field methodologies are consistent with the methodologies and procedures described in the Department of Water Resources' Groundwater Elevation Monitoring Guidelines (December 2010).

Several key aspects of the District's field methods are as follows:

- The District strives to only collect static groundwater levels.
- All groundwater elevations are collected using either a steel tape or using an electric sounding tape.

- Water-level measurements from a given well are always taken from the same reference point.
- Groundwater levels are reported in feet above mean sea level. The accuracy of the groundwater level measurement is 0.01 feet.

Reference Point & Land Surface Elevations

To ensure that groundwater-level measurements from a given well are referenced to the same datum (the "reference point"), the reference point is clearly marked in the field and a photograph of the reference point, with clear labeling, is included in the well binders, which are taken into the field.

The majority of reference point elevations were determined using a recreational GPS unit. Well elevations for newly added wells (circa 2010 and newer) were determined using survey grade GPS units. A few of the well elevations have been surveyed by a California licensed surveyor. In just a few cases, the well elevation was estimated from its location on a USGS topographic map. As a result, the accuracy of well elevations range from 0.01 feet, and in rare cases, up to perhaps as much as 20 feet. The District's goal has always been to collect and maintain the best elevation data possible, and continually updates elevation data as technology, funding, and / or resources become available.

Land-surface datums have been established for all monitoring network wells. Land surface datums are rough approximations of the actual land surface elevation, and have been estimated either from USGS topographic maps, determined using a GPS unit, or surveyed to a known benchmark. The method and level of accuracy used for each well will be included with information submitted to the CASGEM Online Submittal System.

Static Water Levels

The objective of the program is to collect static water levels, defined as water levels under non-pumping conditions.

The following efforts are made to facilitate the collection of static water levels from private supply wells:

- As appropriate, well owners are contacted in advance to arrange for a measurement time when the well is least likely to have been pumped in the last 24 hours.
- Multiple water level measurements are made over several minutes to determine if the water level measurements are stable and provide an indication as to whether the well may have been recently pumped.
- If a well is pumping or re-bounding or any other indicator that the well has recently been pumped, at least two more attempts within one week are made to obtain a static measurement.

Reporting

The District will input the following detailed well information into the CASGEM Online Submittal System:

- Local well ID
- Reference Point Elevation
- Reference Point description
- Ground Surface Elevation
- Method of determining elevation
- Accuracy of elevation method
- Well Use
- Well Status
- Well coordinates
- Method of determining coordinates
- Accuracy of coordinate method
- Well Completion type
- Total depth
- Top and bottom of screened intervals
- Well Completion Report number
- Groundwater basin of well (or sub basin or portion)
- Written description of well location
- Any additional comments

Groundwater data collected by the District (including data collected as part of the CASGEM program and other District programs) is input into the District's database in a systematic way through a centralized person or department to ensure data accuracy and consistency.

Per DWR's CASGEM program reporting requirements, the following information related to each of the CASGEM wells will be submitted online at the end of each measuring cycle:

- Well identification number
- Measurement dates
- Reference point elevation of the well
- Elevation of land surface datum at the well
- Depth to water below reference point (unless no measurement was taken)
- Method of measuring water depth, when known
- Measurement quality codes, as appropriate
- Measuring agency identification

[This page intentionally left blank]

APPENDIX

[This page intentionally left blank]

APPENDIX A

CASGEM Well Network Summary

Table A.01 in this appendix lists all CASGEM wells included in this Monitoring Plan, and includes other key information including groundwater basin, coordinates, local well designation, etc.

[This page intentionally left blank]

TABLE A-1: CASGEM Network Well Summary

Associated Basin	CASGEM ID	Local Well Designation	Well Use	RP Elev	GS Elevation	Perferations; depth	Latitude	Longitude
3-13 Cuyama Valley	349334N1195860W001	CUYA-0001	Unknown	2,299.00	2297	480-640; 640 deep	34.933361	-119.586000
3-13 Cuyama Valley	349272N1195561W001	CUYA-0002	Residential	2,375.50	2375	695 deep	34.927194	-119.556083
3-08 Los Osos Valley	353358N1208639W002	LOSO-0001	Observation	8.60	8.6	234-244; 323 deep	35.335833	-120.863889
3-08 Los Osos Valley	353219N1208681W002	LOSO-0026	Observation	8.00	5.14	270-280; 720 deep	35.321944	-120.868056
3-08 Los Osos Valley	353149N1208381W001	LOSO-0053	Other	76.00	76.9	355-375, 430-480, 550-600; 620 deep	35.314933	-120.838072
3-08 Los Osos Valley	353219N1208681W001	LOSO-0068	Observation	8.00	5.14	190-200; 720 deep	35.321944	-120.868056
3-08 Los Osos Valley	353531N1208617W001	LOSO-0084	Observation	8.40	8.4	220-230; 480 deep	35.353056	-120.861667
3-08 Los Osos Valley	353153N1208392W002	LOSO-0108	Observation	75.40	76.3	180-220; 220 deep	35.314933	-120.838072
3-08 Los Osos Valley	353074N1208433W001	LOSO-0113	Other	210.40	210.4	780-850; 940 deep	35.307439	-120.843253
3-08 Los Osos Valley	353358N1208639W001	LOSO-0115	Observation	8.60	8.6	150-160; 323 deep	35.335833	-120.863889
3-08 Los Osos Valley	353153N1208392W003	LOSO-0135	Observation	75.80	76.6	100-140; 140 deep	35.314933	-120.838072
3-04.06 Paso Robles Area	355262N1205215W001	PASO-0066	Residential	1,099.93	1099.73	154-254; 254 deep	35.526219	-120.521500
3-04.06 Paso Robles Area	355434N1206211W001	PASO-0086	Residential	1,086.73	1086.03	215-235, 275-355; 355 deep	35.543360	-120.621132
3-04.06 Paso Robles Area	356813N1206042W001	PASO-0164	Residential	827.93	826.529	260-400; 400 deep	35.681341	-120.604175
3-04.06 Paso Robles Area	355878N1206914W001	PASO-0182	Other	721.00	721	44-52, 80-90; 92 deep	35.587778	-120.691389
3-04.06 Paso Robles Area	353889N1206123W001	PASO-0263	Other	1,004.50	1002.5	29-49; 57 deep	35.388936	-120.612322
3-04.06 Paso Robles Area	356568N1203804W001	PASO-0269	Other	1,035.00	1032.9	300-320, 340-380, 400-440; 440 deep	35.656823	-120.380380
3-04.06 Paso Robles Area	355593N1206969W001	PASO-0283	Other	771.00	771	110-230; 230 deep	35.559331	-120.696908
3-04.06 Paso Robles Area	354470N1206173W001	PASO-0313	Observation	935.08	935.58	150-250; 250 deep	35.447036	-120.617278
3-04.06 Paso Robles Area	355192N1206764W001	PASO-0317	Observation	800.51	800.51	93-153; 153 deep	35.519167	-120.676389
3-04.06 Paso Robles Area	355808N1207086W001	PASO-0328	Other	842.40	842.4	190-300; 310 deep	35.580833	-120.708611
3-04.06 Paso Robles Area	357535N1206854W001	PASO-0345	Observation	669.80	668.2	300-310, 330-340; 350 deep	35.753528	-120.685361
3-04.06 Paso Robles Area	357536N1206854W001	PASO-0349	Observation	669.80	668.2	468-478, 508-518; 528 deep	35.753602	-120.685426
3-04.06 Paso Robles Area	357536N1206853W001	PASO-0353	Observation	669.80	668.2	194-204, 214-224, 234-244, 264-274; 284 deep	35.753639	-120.685333
3-04.06 Paso Robles Area	355086N1206525W001	PASO-0399	Other	820.00	820	300-600; 603 deep	35.508611	-120.652500
3-09 San Luis Obispo Valley	352001N1206071W001	SLOV-0024	Observation	228.85	229.35	55-150; 150 deep	35.200144	-120.607072
3-12 Santa Maria River Valley	350200N1205326W001	SMRV-0059	Observation	259.58	260.08	400-460; 460 deep	35.020036	-120.532586
3-12 Santa Maria River Valley	350834N1205896W001	SMRV-0303	Observation	45.23	45.78	90-170; 170 deep	35.083372	-120.589575
3-12 Santa Maria River Valley	349912N1205654W001	SMRV-0330	Observation	93.07	93.57	90-170; 170 deep	34.991167	-120.565444

[This page intentionally left blank]

APPENDIX B

Groundwater Technical Procedures of the U.S. Geological Survey (No. 1 & No. 4)

[This page intentionally left blank]

science for a changing world

Office of Groundwater

Groundwater Technical Procedures of the U.S. Geological Survey

Techniques and Methods 1–A1

U.S. Department of the Interior
U.S. Geological Survey

Cover photographs. Clockwise from bottom left. Photographs by W.L. Cunningham, unless otherwise noted.

- Hydrologic technician using a handheld computer to collect water-level data, Clifton Park, New York.
- Hydrologist measuring groundwater level and water temperature to determine stream-aquifer interaction, Smith River near White Sulphur Springs, Montana.
- Hydrologist obtaining calibration measurement at a continuously recording well, West Gardiner, Maine. Photograph by Nicholas Stasulis, U.S. Geological Survey.
- Water-level measurement to calibrate the transducer reading at a continuous water-level measurement site, City of Columbus South Well Field, Columbus, Ohio.
- Hydrologic technician unlocking a USGS well shelter, City of Columbus South Well Field, Columbus, Ohio.
- Hydrologist programming a data logger to record water-level change during a slug test, Charleston, South Carolina.

Groundwater Technical Procedures of the U.S. Geological Survey

Compiled by William L. Cunningham and Charles W. Schalk

Techniques and Methods 1–A1

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2011

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment, visit http://www.usgs.gov or call 1-888-ASK-USGS

For an overview of USGS information products, including maps, imagery, and publications,
visit http://www.usgs.gov/pubprod

To order this and other USGS information products, visit http://store.usgs.gov

Suggested citation:
Cunningham, W.L., and Schalk, C.W., comps., 2011, Groundwater technical procedures of the U.S. Geological Survey: U.S. Geological Survey Techniques and Methods 1–A1, 151 p.

Contents

Figures

Tables

Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
gallon (gal)	3.785	cubic decimeter (dm^3)
cubic foot (ft^3)	28.32	cubic decimeter (dm^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
cubic foot (ft^3)	28.32	liter (L)
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second (L/s)
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
	Force	
pound (lb)	4.4482	newton ($kg*m/sec^3$)
	Pressure	
pounds per square inch (psi)	0.0689	bars (bar)
pounds per square inch (psi)	703.07	kilograms per square meter (kg/m^3)

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Groundwater Technical Procedures of the U.S. Geological Survey

Compiled by William L. Cunningham and Charles W. Schalk

Abstract

A series of groundwater technical procedures documents (GWPDs) has been released by the U.S. Geological Survey, Water-Resources Discipline, for general use by the public. These technical procedures were written in response to the need for standardized technical procedures of many aspects of groundwater science, including site and measuring-point establishment, measurement of water levels, and measurement of well discharge. The techniques are described in the GWPDs in concise language and are accompanied by necessary figures and tables derived from cited manuals, reports, and other documents. Because a goal of this series of procedures is to remain current with the state of the science, and because procedures change over time, this report is released in an online format only. As new procedures are developed and released, they will be linked to this document.

Introduction

This report is a compilation of groundwater technical procedures documents (GWPDs) that describe measurement and data-handling procedures commonly used by the U.S. Geological Survey (USGS). These technical procedures, which were first compiled in 1995 as an internal tool for USGS technicians and hydrologists, have been collected from common techniques cited in USGS reports, USGS internal memoranda, and USGS training programs for many years. Because of the external demand for documentation of these procedures, and the desire to cite them outside of the USGS, they have been reviewed, edited, and compiled in this document. These techniques are a national resource for USGS Water Science Centers and, as such, may not contain sufficient detail for site-specific complexities for other than USGS users. These techniques are provided as the recommended field procedures for USGS Water Science Centers. Individual Centers are encouraged to document modifications that are made to these procedures in project-specific groundwater quality-assurance plans or the Center's groundwater quality-assurance and quality-control plan.

The GWPDs are written in concise language with step-by-step instructions of sufficient detail so that someone with limited experience with the procedure but with a basic understanding of the measurements and general field work can successfully reproduce the procedure unsupervised. The GWPDs do not provide every detail of an individual field task, as the user is expected to have at least nominal field experience. The user also must be cognizant of local regulations on working in and around groundwater wells. State and local ordinances take precedence over any guidance provided in this report. Each GWPD provides an abbreviated list of references if further detail or background information is required. Figures are included where appropriate, and some GWPDs reference other GWPDs. Hypertext links to illustrations, forms, and reports are provided in the body of each document.

Most GWPDs have the following structure:

- Title
- Version
- Purpose
- Materials and Instruments
- Data Accuracy and Limitations
- Advantages
- Disadvantages
- Assumptions
- Instructions
- Data Recording
- References

This report is designed as an online document for use by groundwater hydrologists, technicians, and data managers. The publication of the GWPDs in this format has several benefits:

- It will provide a reference for citation of techniques used during field investigations;

- It will allow hydrologists, technicians, and data managers from outside the USGS to reference techniques used by the USGS;
- It will provide a consistent set of training materials for those new to the routine aspects of groundwater-data collection and handling;
- It will provide an archive for changes in procedures over time as procedures evolve or as tools and equipment become obsolete.
- It will remain current to state-of-the-science techniques.

This report compiles techniques for groundwater-site establishment, well maintenance, water-level measurements, groundwater-discharge measurements, and single-well aquifer tests. It does not document groundwater-quality techniques. These procedures can be found in "U.S. Geological Survey, National Field Manual for the Collection of Water Quality Data." Many of the methods described in the GWPDs are based on United States Office of Water Data Coordination (1977), Garber and Koopman (1968), and Driscoll (1986).

Purpose and Scope

The purpose of this report is to provide a citable document for technical field procedures used by USGS technicians and hydrologists. These procedures have been used by the USGS as guidance for field work, standardization of measurements and other tasks, training of staff, and quality assurance. USGS Water Science Centers can use these procedures as basic guidance and modify them for their circumstances, hydrologic conditions, project objectives, and Center needs. Modifications to these procedures are documented in project-specific groundwater quality-assurance plans or the Center's groundwater quality-assurance and quality-control plan.

The scope of this report generally is restricted to common field-based procedures. Although instrument calibration in the office environment is an integral part of the quality assurance of USGS field work, office-based calibration procedures are not directly addressed in these field procedures. This report does not provide documentation of all procedures used by the Water Science Centers in the USGS, and it does not cover field techniques that are used to meet special objectives. For instance, a USGS project's objectives may require an accuracy and (or) precision not supported by these methods. In those cases, these methods are modified by the individual project and documented in the accompanying project reports.

Review and Revision

GWPDs, like any standard operating procedure, should remain current. The documents will be updated periodically as errors are detected, equipment changes, or new standard techniques evolve. Each procedure is consecutively numbered and contains a version number/date. Those wishing to cite these procedures should include the version number/date of the procedure as an integral part of the reference. These procedures will change with time, and the version number will change accordingly. New procedures will be made available as they are developed, and general electronic announcements will accompany releases of new GWPDs.

Older versions of updated procedures will be archived, as will GWPDs that no longer are used or followed. Hypertext links will be reassigned to the new versions of GWPDs so that the most up-to-date version of the document will be available online.

Technical Procedures

GWPD 1—Measuring water levels by use of a graduated steel tape

GWPD 2—Identifying a minimum set of data elements to establish a groundwater site

GWPD 3—Establishing a permanent measuring point and other reference marks

GWPD 4—Measuring water levels by use of an electric tape

GWPD 5—Documenting the location of a well

GWPD 6—Recognizing and removing debris from a well

GWPD 7—Estimating discharge from a naturally flowing well

GWPD 8—Estimating discharge from a pumped well by use of the trajectory free-fall or jet-flow method

GWPD 9—Recording minimum and maximum water levels

GWPD 10—Measuring discharge from a pumped well by use of a circular orifice weir

GWPD 11—Measuring well depth by use of a graduated steel tape

GWPD 12—Measuring water levels in a flowing well

GWPD 13—Measuring water levels by use of an air line

GWPD 14—Measuring continuous water levels by use of a float-activated recorder

GWPD 15—Obtaining permission to install, maintain, or use a well on private property

GWPD 16—Measuring water levels in wells and piezometers by use of a submersible pressure transducer

GWPD 17—Conducting an instantaneous change in head (slug) test with a mechanical slug and submersible pressure transducer

Acknowledgments

The field procedures described in this report have been compiled from existing USGS reports, various other reference documents, and the technical expertise of the compilers. In addition to the references provided, important source materials include unpublished USGS training and field manuals and technical memoranda from the Office of Groundwater. The following USGS staff (retired) contributed substantially to the contents of this document: Jilann O. Brunett, David C. Dickerman, Linda H. Geiger, and Julia A. Huff. The compilers also appreciate the important contribution by the staff of the USGS Science Publishing Network, including Kay Hedrick, Bonnie Turcott, and Jeffrey Corbett.

References Cited

Driscoll, F.G., 1986, Groundwater and wells (2d ed.): St. Paul, Minnesota, Johnson Filtration Systems, Inc., 1089 p.

Garber, M.S., and Koopman, F.C., 1968, Methods of measuring water levels in deep wells: U.S. Geological Survey Techniques of Water-Resources Investigations, book 8, chap. A1, 23 p.

U.S. Geological Survey, Office of Water Data Coordination, 1977, National handbook of recommended methods for water-data acquisition: Office of Water Data Coordination, Geological Survey, U.S. Department of the Interior, chap. 2, 149 p.

GWPD 1—Measuring water levels by use of a graduated steel tape

VERSION: 2010.1

PURPOSE: To measure the depth to the water surface below land-surface datum using the graduated steel tape (wetted-tape) method.

Materials and Instruments

1. A steel tape graduated in feet, tenths and hundredths of feet. A black tape is preferred to a chromium-plated tape. If a chromium-plated tape is used, paint the back of the tape with a flat black paint to make reading the wetted chalk mark easier. A break-away weight should be attached to a ring on the end of the tape with wire strong enough to hold the weight, but not as strong as the tape, so that if the weight becomes lodged in the well the tape can still be pulled free. The weight should be made of brass, stainless steel, or iron. Lead weights are not acceptable.
2. Blue carpenter's chalk.
3. Clean rag.
4. Pencil or pen, blue or black ink. Strikethrough, date, and initial errors; no erasures.
5. Water-level measurement field form, or handheld computer for data entry.
6. Two wrenches with adjustable jaws or other tools for removing well cap.
7. Cleaning supplies for water-level tapes as described in the National Field Manual (Wilde, 2004).
8. Key for well access.

Data Accuracy and Limitations

1. A graduated steel tape is commonly accurate to 0.01 foot.
2. Most accurate for water levels less than 200 feet below land surface.
3. The steel tape should be calibrated against another acceptable steel tape. An acceptable steel tape is one that is maintained in the office for use only for calibrating steel tapes, and this calibration tape never is used in the field.
4. Oil, ice, or debris may interfere with a water-level measurement.
5. Corrections are necessary for measurements made through angled well casings.
6. When measuring deep water levels (greater than 500 feet), tape expansion and stretch is an additional consideration (Garber and Koopman, 1968).

Advantages

1. The graduated steel tape method is considered to be the most accurate method for measuring water levels in nonflowing wells of moderate depth.
2. Easy to use.
3. Small tape diameter allows access through small ports and provides little interference with pump wiring.

Disadvantages

1. Results may be unreliable if water is dripping into the well or condensing on the well casing.
2. Not recommended for measuring water levels while wells are being pumped.
3. Initial measurement is difficult if estimated water level is not known.

4. Wetted chalk mark may dry before tape is retrieved under hot, dry conditions with large depths to water.

Assumptions

1. An established measuring point (MP) exists and the distance from the MP to land-surface datum (LSD) is known (fig. 1). See GWPD 3 for the technical procedure document on establishing a permanent MP.
2. The MP is clearly marked and described so that a person who has not measured the well will be able to recognize it.
3. For established wells, a water-level measurement taken during the last field visit is available to estimate the length of tape that should be lowered into the well.
4. The black sheen on the steel tape has been dulled so that the tape will retain the chalk.
5. The well is free of obstructions that could affect the plumbness of the steel tape and cause errors in the measurement.
6. The same field method is used for measuring depth below measuring point, or depth relative to vertical datum, but with a different datum correction.
7. The graduated steel tape has been calibrated.

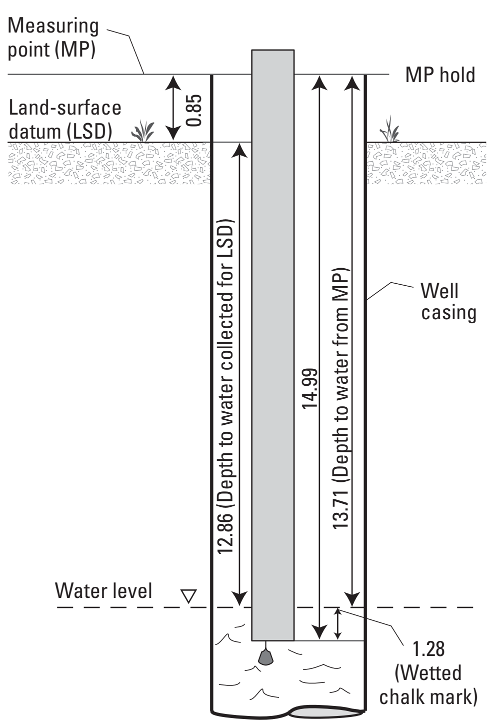

Figure 1. Water-level measurement using a graduated steel tape.

Instructions

1. Open the well.
2. Chalk the lower few feet of the tape by pulling the tape across a piece of blue carpenter's chalk. A wetted chalk mark will identify that part of the tape that was submerged.
3. Review recent measurements from the well, if available, to estimate the hold point on the tape.
4. Refer to figure 1 for an illustration of the elements of a steel tape measurement. Lower the weight and tape into the well until the lower end of the tape is submerged below the water. The weight and tape should be lowered into the water slowly to prevent splashing. Place the thumb and index finger on the tape graduation that is 0.01 less than the next whole foot mark (14.99 in figure 1). Continue to lower the end of the tape into the well until the thumb and index finger meet the MP. Record the graduation value (the HOLD) in the Hold column of the water-level measurement field form (fig. 2).
5. Rapidly bring the tape to the surface before the wetted chalk mark dries and becomes difficult to read. Record the length of the wetted chalk (the CUT) in the Cut row of the water-level measurement field form (fig. 2). Record the time of the measurement in the "Time" row of the form.
6. Subtract the CUT from the HOLD and record this number in the "WL below MP" column of the water-level measurement field form (fig. 2). The difference between the HOLD and the CUT is the depth to water below the MP.
7. If the tape-calibration procedure indicates that a correction is needed at a given water-level depth or for a given water-level range, apply that correction to the "WL below MP" value by adding or subtracting the appropriate correction.
8. Record the MP correction length on the "MP correction" row of the field form (fig. 2); the MP correction is positive if the MP is above land surface and is negative if the MP is below land surface (GWPD 3). Subtract the MP correction from the "WL below MP" value to get the depth to water below or above land-surface datum. Record the water level in the "WL below LSD" column of the water-level measurement field form (fig. 2). If the water level is above LSD, record the depth to water in feet below land surface as a negative number.
9. Make a check measurement by repeating steps 1 through 5. The check measurement should be made using a different HOLD value than that used for the original measurement. If the check measurement does not agree

WATER-LEVEL MEASUREMENT FIELD FORM

Steel Tape Measurement

SITE INFORMATION

SITE ID (C1) ____________________

Equipment ID ____________ Date of Field Visit ____________

Station name (C12) ____________

WATER-LEVEL DATA

	1	2	3	4	5
Time					
Hold					
Cut					
Tape correction					
WL below MP					
MP correction					
WL below LSD					

Measured by ____________ COMMENTS* ____________

*Comments should include quality concerns and changes in: M.P., ownership, access, locks, dogs, measuring problems, et al.

MEASURING POINT DATA (for MP Changes)

M.P. REMARKS (C324)	BEGINNING DATE (C321)	ENDING DATE (C322)	M.P. HEIGHT (C323) NOTE: (-) for MP below land surface
____________	__ – __ – ____ (month, day, year)	__ – __ – ____	___ . __
____________	__ – __ – ____	__ – __ – ____	___ . __

Final Measurement for GWSI

WATER LEVEL TYPE CODE (C243): L (below land surface), M (below meas. pt.), S (sea level)

DATE WATER LEVEL MEASURED (C235)	TIME (C709)	STATUS (C238)	METHOD (C239)	TYPE (C243)	WATER LEVEL (C237)
__ – __ – ____ (month, day, year)	____	_	_	_	____ . __

METHOD OF WATER-LEVEL MEASUREMENT(C239)

A	B	C	E	G	H	L	M	N	R	S (GWPD1)	T	V (GWPD4)	Z
airline,	analog,	calibrated airline,	estimated,	pressure gage,	calibrated press. gage,	geophysical logs,	manometer,	non-rec. gage,	reported,	steel tape,	electric tape,	calibrated elec. tape	other

SITE STATUS FOR WATER LEVEL (C238)

D	E	F	G	H	I	J	M	N	O	P	R	S	T	V	W	X	Z	BLANK
dry,	recently flowing,	flowing,	nearby flowing	nearby recently flowing,	injector site,	injector site monitor,	plugged,	measurement discon.,	obstruction,	pumping,	recently pumped,	nearby pumping,	nearby recently pumped,	foreign substance,	well destroyed,	surface water effects,	other	static

Figure 2. Water-level measurement field form for steel tape measurements. This form, or an equivalent custom-designed form, should be used to record field measurements.

with the original measurement within 0.02 foot, continue to make measurements until the reason for lack of agreement is determined or the results are shown to be reliable. If more than two measurements are made, use best judgment to select the measurement most representative of field conditions.

10. Complete the "Final Measurement for GWSI" portion of the field form (fig. 2).
11. After completing the water-level measurement, disinfect and rinse that part of the tape that was submerged below the water surface, as described in the National Field Manual (Wilde, 2004). This will reduce the possibility of contamination of other wells from the tape.
12. Close the well.
13. Maintain the tape in good working condition by periodically checking the tape for rust, breaks, kinks, and possible stretch due to the suspended weight of the tape and the tape weight. The tape should be recalibrated annually and recorded in the calibration logbook.
14. In some pumped wells, a layer of oil may float on the water surface. If the oil layer is a foot or less thick, read the tape at the top of the oil mark and use this value for the water-level measurement instead of the wetted chalk mark. The measurement will differ slightly from the water level that would be measured were the oil not present. However, if several feet of oil are present in the well, or if it is necessary to know the thickness of the oil layer, an electronic "interface probe," or a commercially available water-detector paste can be used that will detect the presence of water in the oil. The paste is applied to the lower end of the tape and will show the top of the oil as a wet line, and the top of the water will show as a distinct color change. Because oil density is about three-quarters that of water, the water level can be estimated by adding the thickness of the oil layer times its density to the oil-water interface altitude.

Data Recording

All calibration and maintenance data associated with steel tape use are recorded in the calibration and maintenance equipment logbook.

All water-level data are recorded on the water-level measurement field form (fig. 2) or by using a handheld computer program such as MONKES. Field measurements are recorded to the nearest 0.01 foot or to the appropriate precision based on the judgment of the hydrographer. When using a handheld computer to record field measurements, the measurement procedure is the same as described in the "Instructions" section.

References

Cunningham, W.L., and Schalk, C.W., comps., 2011, Groundwater technical procedures of the U.S. Geological Survey, GWPD 3—Establishing a permanent measuring point and other reference marks: U.S. Geological Survey Techniques and Methods 1–A1, 13 p.

Garber, M.S., and Koopman, F.C., 1968, Methods of measuring water levels in deep wells: U.S. Geological Survey Techniques of Water-Resources Investigations, book 8, chap. A1, 23 p.

Hoopes, B.C., ed., 2004, User's manual for the National Water Information System of the U.S. Geological Survey, Ground-Water Site-Inventory System (version 4.4): U.S. Geological Survey Open-File Report 2005–1251, 274 p.

Katz, B.G., and Jelinski, J.C., 1999, Replacement materials for lead weights used in measuring ground-water levels: U.S. Geological Survey Open-File Report 99–52, 13 p.

U.S. Geological Survey, Office of Water Data Coordination, 1977, National handbook of recommended methods for water-data acquisition: Office of Water Data Coordination, Geological Survey, U.S. Department of the Interior, chap. 2, 149 p.

Wilde, F.D., ed., 2004, Cleaning of equipment for water sampling (version 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A3, accessed July 17, 2006, at *http://pubs.water.usgs.gov/twri9A3/*.

GWPD 4—Measuring water levels by use of an electric tape

VERSION: 2010.1

PURPOSE: To measure the depth to the water surface below land-surface datum using the electric tape method.

Materials and Instruments

1. An electric tape, double-wired and graduated in feet, tenths and hundredths of feet. Electric tapes commonly are mounted on a hand-cranked and powered supply reel that contains space for the batteries and some device ("indicator") for signaling when the circuit is closed (fig. 1).
2. An older model electric tape, also known as an "M-scope," marked at 5-foot intervals with clamped-on metal bands (fig. 2) has been replaced by newer, more accurate models. Technical procedures for this device are available from the procedures document archives.
3. A steel reference tape for calibration, graduated in feet, tenths and hundredths of feet
4. Electric tape calibration and maintenance equipment logbook
5. Pencil or pen, blue or black ink. Strikethrough, date, and initial errors; no erasures
6. Water-level measurement field form, or handheld computer for data entry
7. Two wrenches with adjustable jaws or other tools for removing well cap
8. Key for well access
9. Clean rag
10. Cleaning supplies for water-level tapes as described in the National Field Manual (Wilde, 2004)
11. Replacement batteries

Data Accuracy and Limitations

1. A modern graduated electric tape commonly is accurate to +/– 0.01 foot.
2. Most accurate for water levels less than 200 feet below land surface.
3. The electric tape should be calibrated against an acceptable steel tape. An acceptable steel tape is one that is maintained in the office for use only for calibrating tapes, and this calibration tape never is used in the field.
4. If the water in the well has very low specific conductance, an electric tape may not give an accurate reading.
5. Material on the water surface, such as oil, ice, or debris, may interfere with obtaining consistent readings.
6. Corrections are necessary for measurements made from angled well casings.
7. When measuring deep water levels, tape expansion and stretch is an additional consideration (Garber and Koopman, 1968).

Advantages

1. Superior to a steel tape when water is dripping into the well or condensing on the inside casing walls.
2. Superior to a steel tape in wells that are being pumped, particularly with large-discharge pumps, where the splashing of the water surface makes consistent results by the wetted-tape method impossible. Also safer to use in pumped wells because the water is sensed as soon as

Figure 1. An electric tape or cable, double wired and marked the entire length in feet, tenths and hundredths of feet, that can be considered accurate to 0.01 foot at depths of less than 200 feet. Electric tapes commonly are mounted on a hand-cranked and powered supply real that contains space for the batteries and some device (“indicator”) for signaling when the circuit is closed. Brand names are for illustration purposes only and do not imply endorsement by the U.S. Geological Survey. (Photographs used with permission of vendors.)

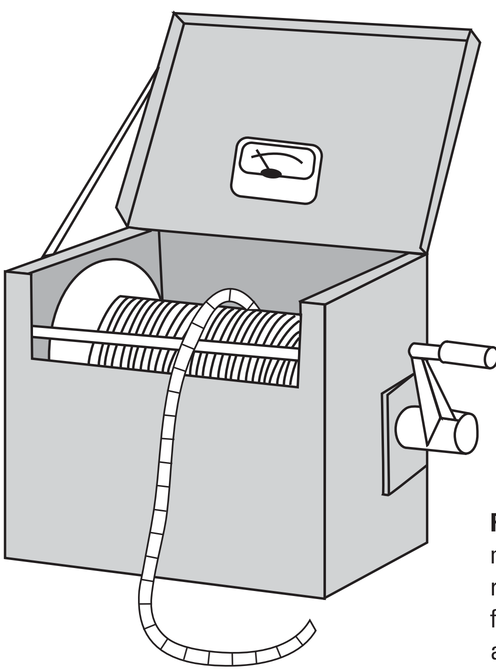

Figure 2. Older model electric tape, also known as “M-scope” marked at 5-foot intervals with clamped-on metal bands, has been replaced by newer, more accurate models. Technical procedures for this device are available from the procedures document archives.

the probe reaches the water surface and there is less danger of lowering the tape into the pump impellers.

3. Superior to a steel tape when a series of measurements are needed in quick succession, such as in aquifer tests, because the electric tape does not have to be removed from the well for each reading.

Disadvantages

1. Harder to keep calibrated than a steel tape.
2. Electric connections require maintenance.
3. Requires battery power.
4. Cable jacket is subject to wear and tear. Continuity of the electrical circuit must be maintained.

Assumptions

1. An established measuring point (MP) exists and the distance from the MP to the land-surface datum (LSD) is known. See GWPD 3 for the technical procedures on establishing a permanent MP.
2. The MP is clearly marked and described so that a person who has not measured the well will be able to recognize it.
3. The well is free of obstructions that could affect the plumbness of the steel tape and cause errors in the measurement.
4. The same field method is used for measuring depth below the MP, or depth relative to vertical datum, but with a different datum correction.
5. The tape is calibrated against a steel reference tape.
6. Field measurements will be recorded on paper forms. When using a handheld computer to record field measurements, the measurement procedure is the same, but the instructions below refer to a specific paper field form.

Tape Calibration And Maintenance

Before using an electric tape in the field, calibrate it against a steel reference tape. A reference tape is one that is maintained in the office only to calibrate other tapes.

1. Calibration of electric tape:
    - Check the distance from the probe's sensor to the nearest foot marker on the tape to ensure that this distance puts the sensor at the zero-foot point for the tape. If it does not, a correction must be applied to all depth-to-water measurements.
    - Compare length marks on the electric tape with those on the steel reference tape while the tapes are laid out straight on level ground, or compare the electric tape with a known distance between fixed points on level ground.
    - Compare water-level measurements made with the electric tape with those made with a calibrated steel tape in several wells that span the range of depths to water that is anticipated. Measurements should agree to within +/– 0.02 foot. If measurements are not repeatable to this standard, then a correction factor based on a regression analysis should be developed and applied to measurements made with the electric tape.
2. Using a repaired/spliced tape: If the tape has been repaired by cutting off a section of tape that was defective and splicing the sensor to the remaining section of the tape, then the depth to water reading at the MP will not be correct. To obtain the correct depth to water, apply the following steps, which is similar to the procedure for using a steel tape and chalk. Using the water-level measurement field form (fig. 3) to record these modifications:
    - Ensure that the splice is completely insulated from any moisture and that the electrical connection is complete.
    - Measure the distance from the sensing point on the probe to the nearest foot marker above the spliced section of tape. Subtract that distance from the nearest foot marker above the spliced section of tape. That value then becomes the "tape correction." For example, if the nearest foot marker above the splice is 20 feet, and the distance from that foot marker to the probe sensor is 0.85 foot, then the tape correction will be 19.15 feet. Write down the tape correction on the water-level measurement field form (fig. 3). Periodically recheck this value by measuring with the steel reference tape.
3. Maintain the tape in good working condition by periodically checking the tape for breaks, kinks, and possible stretch.
4. Carry extra batteries, and check battery strength regularly.
5. The electric tape should be recalibrated annually or more frequently if it is used often or if the tape has been subjected to abnormal stress that may have caused it to stretch.

USGS science for a changing world

WATER-LEVEL MEASUREMENT FIELD FORM

Calibrated Electric Tape Measurement

USGS science for a changing world

SITE INFORMATION

SITE ID (C1) ______________

Equipment ID ______________

Date of Field Visit ______________

Station name (C12) ______________

WATER-LEVEL DATA

	1	2	3	4	5
Time					
Hold					
Tape correction					
WL below MP					
MP correction					
WL below LSD					

Measured by ______________ COMMENTS* ______________

*Comments should include quality concerns and changes in: M.P., ownership, access, locks, dogs, measuring problems, et al.

MEASURING POINT DATA (for MP Changes)

M.P. REMARKS (C324)	BEGINNING DATE (C321)	ENDING DATE (C322)	M.P. HEIGHT (C323) NOTE: (-) for MP below land surface
______________	__ – __ – ____ (month, day, year)	__ – __ – ____	___ . __
______________	__ – __ – ____	__ – __ – ____	___ . __

Final Measurement for GWSI

WATER LEVEL TYPE CODE (C243): L (below land surface), M (below meas. pt.), S (sea level)

DATE WATER LEVEL MEASURED (C235)	TIME (C709)	STATUS (C238)	METHOD (C239)	TYPE (C243)	WATER LEVEL (C237)
__ – __ – ____ (month, day, year)	____	_	_	_	____ . __

METHOD OF WATER-LEVEL MEASUREMENT(C239)

A	B	C	E	G	H	L	M	N	R	S (GWPD1)	T	V (GWPD4)	Z
airline,	analog,	calibrated airline,	estimated,	pressure gage,	calibrated press. gage,	geophysi-cal logs,	manometer,	non-rec. gage,	reported,	steel tape,	electric tape,	calibrated elec. tape	other

SITE STATUS FOR WATER LEVEL (C238)

D	E	F	G	H	I	J	M	N	O	P	R	S	T	V	W	X	Z	BLANK
dry,	recently flowing,	flowing,	nearby flowing	nearby recently flowing,	injector site,	injector site monitor,	plugged,	measure-ment discon.,	obstruc-tion,	pumping,	recently pumped,	nearby pumping,	nearby recently pumped,	foreign sub-stance,	well des-troyed,	surface water effects,	other	static

Figure 3. Water-level measurement field form for calibrated electric tape measurements. This form, or an equivalent custom-designed form, should be used to record field measurements.

Instructions

1. Check the circuitry of the electric tape before lowering the probe into the well by dipping the probe into tap water and observing whether the indicator needle, light, and (or) beeper (collectively termed the "indicator" in this document) are functioning properly to indicate a closed circuit. If the tape has multiple indicators (sound and light, for instance), confirm that they are operating simultaneously. If they are not, determine the most accurate indicator.

2. Make all readings using the same deflection point on the indicator scale, light intensity, or sound so that water levels will be consistent among measurements.

3. Lower the electrode probe slowly into the well until the indicator shows that the circuit is closed and contact with the water surface is made (fig. 4). Place the nail of the index finger on the insulated wire at the MP and read the depth to water.

4. Record the date and time of the measurement. Record the depth to water measurement in the row "Hold" (fig. 3). If the tape has been repaired and spliced or has a calibration correction (see the section above on using a repaired/spliced tape), subtract the "Tape Correction" value from the "Hold" value, and record this difference in the row "WL below MP" (fig. 3).

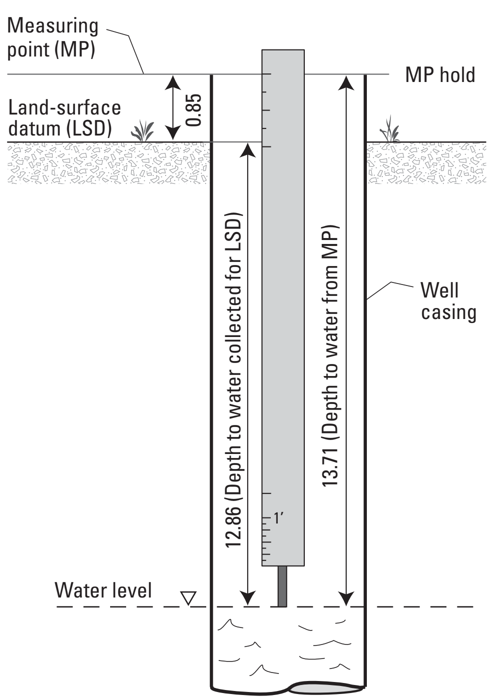

Figure 4. Water-level measurement using a graduated electric tape.

5. Record the MP correction length on the "MP correction" row of the field form (fig. 3). Subtract the MP correction length from the true "WL below MP" value to get the depth to water below or above LSD. The MP correction is positive if the MP is above land surface and is negative if the MP is below land surface (GWPD 3). Record the water level in the "WL below LSD" column of the water-level measurement field form (fig. 3). If the water level is above LSD, record the depth to water in feet above land surface as a negative number.

6. Pull the tape up and make a check measurement by repeating steps 3–5. Record the check measurement in column 2 of the field form. If the check measurement does not agree with the original measurement within 0.02 foot, continue to make measurements until the reason for lack of agreement is determined or the results are shown to be reliable. If more than two measurements are made, use best judgment to select the measurement most representative of field conditions. Complete the "Final Measurement for GWSI" portion of the field form.

7. After completing the water-level measurement, disinfect and rinse that part of the tape that was submerged below the water surface as described in the National Field Manual (Wilde, 2004). This will reduce the possibility of contamination of other wells from the tape. Rinse the tape thoroughly with deionized or tap water to prevent tape damage. Dry the tape and rewind onto the tape reel.

Data Recording

All calibration and maintenance data associated with the electric tape being used are recorded in the calibration and maintenance equipment logbook. All data are recorded in the water-level measurement field form (fig. 3) to the appropriate accuracy for the depth being measured.

References

Cunningham, W.L., and Schalk, C.W., comps., 2011a, Groundwater technical procedures of the U.S. Geological Survey, GWPD 1—Measuring water levels by use of a graduated steel tape: U.S. Geological Survey Techniques and Methods 1–A1, 4 p.

Cunningham, W.L., and Schalk, C.W., comps., 2011b, Groundwater technical procedures of the U.S. Geological Survey, GWPD 3—Establishing a permanent measuring point and other reference marks: U.S. Geological Techniques and Methods 1–A1, 13 p.

Garber, M.S., and Koopman, F.C., 1968, Methods of measuring water levels in deep wells: U.S. Geological Survey Techniques of Water-Resources Investigations, book 8, chap. A1, p. 6–11.

Heath, R.C., 1983, Basic ground-water hydrology: U.S. Geological Survey Water-Supply Paper 2220, p. 72–73.

Hoopes, B.C., ed., 2004, User's manual for the National Water Information System of the U.S. Geological Survey, Ground-Water Site-Inventory System (version 4.4): U.S. Geological Survey Open-File Report 2005–1251, 274 p.

U.S. Geological Survey, Office of Water Data Coordination, 1977, National handbook of recommended methods for water-data acquisition: Office of Water Data Coordination, Geological Survey, U.S. Department of the Interior, chap. 2, 149 p.

Wilde, F.D., ed., 2004, Cleaning of equipment for water sampling (version 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A3, accessed July 17, 2006, at *http://pubs.water.usgs.gov/twri9A3/*.