Engineering Investigation of the Bunker Hill Basin 2013–2014

Prepared By:

SBV WATER CONSERVATION DISTRICT

OUR NAME IS OUR MISSION

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All figures, tables, and appendices are available separately on San Bernardino Valley Water Conservation District's Website: http://www.sbvwcd.org and incorporated by reference.

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All figures, tables, and appendices are available separately on San Bernardino Valley Water Conservation District's Website: http://www.sbvwcd.org and incorporated by reference.

1.0 Executive Summary

Article 1, Section 75560 of the California Water Code requires that a Water Conservation District that proposes to levy a groundwater charge *"… shall annually cause to be made an engineering investigation and report upon groundwater conditions of the District*". In accordance with these requirements, the San Bernardino Valley Water Conservation District (District) must make the following findings and determinations as they relate to the ground and surface water conditions of the Bunker Hill Basin and those areas within the District boundary. Refer to **Figure 1 and 3** for locations.

Task 1. Annual change in storage for the Bunker Hill Basin for the preceding water year (Fall 2012 to Fall 2013);

Task 2. Accumulated change in storage of the Bunker Hill Basin as of the last day of the preceding water year (June 30, 2013);

Task 3. Total groundwater production from the Bunker Hill Basin for the preceding water year (July 1, 2012 - June 30, 2013);

Task 4. Estimate of the annual change in the Bunker Hill Basin storage for the current water year (July 1, 2013 - June 30, 2014);

Task 5. Estimate of the annual change in the Bunker Hill Basin storage for the ensuing water year (July 1, 2014 - June 30, 2015);

Task 6. Average annual change in Bunker Hill Basin storage for the immediate past ten water years (2003 - 2013);

Task 7. Estimated amount of agricultural water and other than agricultural water to be withdrawn from the groundwater supplies of the District for the ensuing water year (July 1, 2014 - June 30, 2015);

Task 8. Estimated amount of water necessary for surface distribution for the ensuing water year for the Bunker Hill Basin and the District (July 1, 2014 - June 30, 2015); and

Task 9. The amount of water that is necessary for the replenishment of the groundwater supplies of the Bunker Hill Basin and the District for the ensuing water year (July 1, 2014 - June 30, 2015).

To make the findings and determinations listed above, District staff researched available hydro-geologic and engineering data for the Bunker Hill Basin. These data were compiled and analyzed and a predictive relationship between precipitation, production, and change in basin storage. This relationship was based on empirical data since 1993 and enables the prediction of change in storage, given certain annual production and precipitation levels. In addition, annual and accumulated change in storage values were calculated based on current and historic water level changes throughout the Bunker Hill Basin.

Based on 20 measuring stations, precipitation throughout the contributing watershed was 53% of normal for the period October 1, 2012 to September 31, 2013. The report uses production and water level data from more than 200 wells in the basin.

The required findings for the 2014 Engineering Investigation are provided below. Each of the tasks is further explained in the main body of the report. Throughout this document a positive sign (+) denotes an increase in groundwater storage or groundwater level elevation while a negative sign (-) denotes a decrease in groundwater storage or groundwater level elevation.

Section 75574 of the California Water Code requires that the District Board indicate the amount of water the District is obligated by contract to purchase. The San Bernardino Valley Water Conservation District is not required by contract to purchase any water.

Summary of Findings for the 2014 Engineering Investigation

Task 1. Annual change in storage for the Bunker Hill Basin for the preceding water year (July 1, 2012 to June 30, 2013 groundwater levels)

Change in storage between Fall 2012 and Fall 2013

-129,945 acre-ft (decrease)

The amount of water stored in the Basin decreased by 129,945 acre-feet between 2012 and 2013.

Task 2. Accumulated change in storage of the Bunker Hill Basin as of the last day of the preceding water year (2013)

Accumulated change in storage between July 1993 and June 2013.[1]

-444,322 acre-ft (decrease)

The amount in storage in the Summer of 2013 is 444,322 acre-ft less than in the Summer of 1993.

Task 3. Total groundwater production from the Bunker Hill Basin for the preceding water year (July 1, 2012 - June 30, 2013)

182,393 acre-ft

[1] In the District's Engineering Investigation (EI) prior to 1993-94, the accumulated change in storage was based on the basin storage in 1984 as considered full. A concern arose regarding high groundwater levels in the Pressure Zone of the Bunker Hill Basin. Therefore, in response to the City of San Bernardino's comments on accumulated change in storage, all EI's since that time are based on 1993 basin storage levels considered as full. The BTAC makes annual recharge recommendations to optimize recharge.

Task 4. Estimate of the annual change in the Bunker Hill Basin storage for the current water year (July 1, 2013 - June 30, 2014)

-65,285 acre-ft (decrease)

The amount of water in the Basin is estimated to decrease by 65,285 acre- ft during the current water year.

Task 5. Estimate of the annual change in the Bunker Hill Basin storage for the ensuing water year (July 1, 2014 - June 30, 2015)

2,253 acre-ft (increase)

The amount of water in the Basin is estimated to increase by 2,253 acre-ft during the ensuing water year presuming average precipitation.

Task 6. Average annual change in Bunker Hill Basin storage for the immediate past 10 water years (2003-2013) shows a decrease.

-8,065 acre-ft (decrease)

Task 7. Estimated amount of agricultural water and other than agricultural water to be withdrawn from the groundwater supplies of the District for the ensuing water year (July 1, 2014 - June 30, 2015)

Estimated amount of agricultural water withdrawn from the groundwater supplies within the District boundary for the ensuing water year (July 1, 2014 - June 30, 2015)

18,864 acre-ft

Estimated amount of other than agricultural water withdrawn from the groundwater supplies of the District for the ensuing water year (July 1, 2014 - June 30, 2015)

87,309 acre-ft

Task 8. Estimated amount of water necessary for surface distribution for the ensuing water year for the Bunker Hill Basin and the District (July 1, 2014 - June 30, 2015)

Estimated amount of water necessary for surface distribution for the ensuing water year (July 1, 2014 - June 30, 2015) for the Bunker Hill Basin

71,861 acre-ft

Estimated amount of water necessary for surface distribution for the ensuing water year (July 1, 2014 - June 30, 2015) within the District boundary

58,856 acre-ft

Task 9. The amount of water which is necessary for the replenishment of the groundwater supplies of the Bunker Hill Basin and the District for the ensuing water year (July 1, 2014 - June 30, 2015)

The amount of water which is necessary for the replenishment of the groundwater supplies of the Bunker Hill Basin for the ensuing water year (July 1, 2014 - June 30, 2015)

141,087 acre-ft

The amount of water which is necessary for the replenishment of the groundwater supplies within the District boundary for the ensuing water year (July 1, 2014 - June 30, 2015)

103,920 acre-ft

In addition to the above findings, Section 75505 of the California Water Code requires that a finding be made as to the amount of water necessary to be replaced in the intake areas of the groundwater basins within the District to prevent the landward movement of salt water into the fresh groundwater body, or to prevent subsidence of the land within the District. Because of its location and the elevations of its water table, the Bunker Hill Basin is not subject to salt-water intrusion and the current groundwater levels do not indicate any significant land subsidence.

Section 75540 of the California Water Code requires that the District Board establish a zone or zones where a groundwater charge is to be implemented. The Code specifically states that a single zone may include the entire District and in May 1993 the Board established the entire District as one zone. This determination may be amended in the future, but lacking any evidence to the contrary, in the 2013-2014 year the entire District will remain as a single zone in regard to any groundwater charge.

Section 75561 of the California Water Code further requires the Engineering Investigation to include a finding related to the amount of water the District is obligated by contract to purchase. At this time the District has no contractual obligation to purchase water for the replenishment of the groundwater supplies. However, instead we recharge local surface water and cooperate with local and regional agencies to recharge the aquifer. The District works with San Bernardino Valley Municipal Water District (Valley) to spread excess allocation State Project Water in the District's spreading basins. In the past the District has also utilized reserves to offset the cost of water purchases which have spread in its basins. Due to the significant reduction in District reserves it has not purchased water this year.

Based on the results of the 2014 Engineering Investigation, the San Bernardino Valley Water Conservation District finds that:

- Due to the imbalance between groundwater recharge and production since 1993, the Bunker Hill Basin's storage is 444,322 acre-feet below the levee which is

considered full for purposes of this investigation. This value is significantly more than 2013 report due to lower local rainfall rates.

- During the ensuing water year (July 1, 2014 - June 30, 2015), the Bunker Hill Basin could be recharged, with up to 650,694 acre-feet of water. This recharge quantity would be needed to attain the 1993 storage level that is considered full. The Basin Technical Advisory Committee (BTAC) recommends a maximum of 145,000 acre-ft safely manage and recharge the basin. This amount includes 87,000 acre-ft in Mill Creek and Santa Ana River Basins.
- The District must continue to take all necessary steps to maintain and enhance its capability to conduct recharge operations. These steps may include maintenance and repair of existing, diversion facilities, canals, dikes, basins, roads, and other water recharge facilities. Additionally in December 2011 the District entered into a cooperative agreement with SBVMWD to enhance the recharge of the basin. This project will add significant new recharge facilities in the District's Santa Ana River Recharge Facilities. These facilities will be operated and maintained by the District. These improvements are required to ensure that the groundwater demands on the Basin, especially during drought periods, can be met.
- The District should continue to work cooperatively in the collaborative planning for the Enhanced Recharge Program to plan, design, build and maintain facilities to expand the capabilities for recharge of waters that are developed as a result of water conservation due to the construction of Seven Oaks Dam (SOD).
- The District has begun collaborative construction efforts with Valley to improve the capacities and delivery capabilities of the District's Upper Santa Ana River diverted water conveyance canals and spreading basins. The District should review the single zone of influence/benefit in 2014-2015 and revise if needed.

2.0 Introduction

The 2013-2014 Engineering Investigation (EI) process was very similar to the previous 2012-2013 EI Report. The report uses the same basis of calculation, however updates the document as proposed in the work plan prepared and approved in December 2013. This approach also includes close coordination with other groups particularly San Bernardino Valley Municipal Water District (SBVMWD) who do their own calculations for work similar to the EI Report. We believe this approach makes the best use of the resources of all water entities within the basin. This year's report provides additional research, source documentation, and summary illustration of surface and groundwater activities within the Bunker Hill Basin and specifically within the Water Conservation District's boundaries.

2.1 Purpose and Scope

The San Bernardino Valley Water Conservation District (District) was created by a vote of the people in 1931 for the purpose of managing the recharge activities that were previously conducted by the Water Conservation Association. The Water Conservation Association was incorporated in 1909 and had been diverting flows from the Santa Ana River for groundwater recharge since 1911. Currently the District has ownership, as well as easements and/or use of properties owned by the Bureau of Land Management (BLM), on a total of 3,735 acres within the Santa Ana River and Mill Creek Wash areas. The District boundary covers an area of approximately 50,000 acres, which represents about 60% of the Bunker Hill Basin. **Figure 1** displays the project area map for the Engineering Investigation. The figure shows the District boundary along with its location relative to the County and State boundaries. **Figure 2** shows the District Boundaries relative to the water agencies served by the District.

Article 1, Section 75560 of the California Water Code requires that a Water Conservation District that proposes to levy a groundwater charge "… shall annually cause to be made an engineering investigation and report upon groundwater conditions of the District". In accordance with these requirements, the San Bernardino Valley Water Conservation

District (District) must make the following findings and determinations as they relate to the ground and surface water conditions of the Bunker Hill Basin and those areas within the District boundary. Sub-Basins of the Bunker Hill Basin are shown in **Figure 3.**

Task 1. Annual change in storage for the Bunker Hill Basin for the preceding water year (Fall 2012 to Fall 2013);

Task 2. Accumulated change in storage of the Bunker Hill Basin as of the last day of the preceding water year (June 30, 2013);

Task 3. Total groundwater production from the Bunker Hill Basin for the preceding water year (July 1, 2012 - June 30, 2013);

Task 4. Estimate of the annual change in the Bunker Hill Basin storage for the current water year (July 1, 2013 - June 30, 2014);

Task 5. Estimate of the annual change in the Bunker Hill Basin storage for the ensuing water year (July 1, 2014 - June 30, 2015);

Task 6. Average annual change in Bunker Hill Basin storage for the immediate past 10 water years (2003-2013);

Task 7. Estimated amount of agricultural water and other than agricultural water to be withdrawn from the groundwater supplies of the District for the ensuing water year (July 1, 2014 - June 30, 2015);

Task 8. Estimated amount of water necessary for surface distribution for the ensuing water year for the Bunker Hill Basin and the District (July 1, 2014 - June 30, 2015); and

Task 9. The amount of water that is necessary for the replenishment of the groundwater supplies of the Bunker Hill Basin and the District for the ensuing water year (July 1, 2014 - June 30, 2015).

To make the findings and determinations listed above, District staff researched available hydrogeologic, precipitation, and engineering data for the Bunker Hill Basin and surrounding areas. These data were compiled and analyzed and a predictive relationship between precipitation, production, and change in basin storage was adapted from similar relationships developed by Geoscience Support Services in the preparation

of previous Engineering Investigations. This relationship was based on empirical data enables the prediction of change in storage, given certain annual production and precipitation levels. Precipitation trends and stations are shown in **Figure 4**. In addition, annual and accumulated change in storage was calculated based on historic water level changes throughout the Bunker Hill Basin.

2.2 Location, Topography and Climate

The Bunker Hill Basin is located at the top of the Santa Ana River Watershed and receives all the surface water runoff from the headwaters of the Santa Ana River, Mill Creek, and a portion of that from the Lytle Creek area as well as smaller periodic flows from Plunge, City, Devil Canyon, Cajon and Elder Creeks. It is part of the inland valley called the San Bernardino Valley located in San Bernardino County, California and encompasses approximately 89,600 acres. Once past the Bunker Hill Basin, the Santa Ana River continues to flow southwesterly for approximately 60 miles until it reaches the Pacific Ocean.

The Bunker Hill Basin is bounded on the northwest by the San Gabriel Mountains, on the northeast by the San Bernardino Mountains, on the south by the Crafton Hills and the Badlands, and on the southwest by a low east-facing escarpment produced by the San Jacinto fault. These geologic features are easily identified on **Figure 5** and **Figure 6**.

The major streams providing inflows and outflows for the Bunker Hill Basin are provided on **Figure 1**. The United States Geological Survey (USGS) administers stream flow gauging stations on all of these waterways except Mill Creek. Mill Creek flow is assumed to be 56% of the Santa Ana River flow in this location based on historic data. Total diversions for direct use and recharge on the Santa Ana River may exceed the stream flows due to measurements by different agencies.

The Bunker Hill Basin is also utilized by a large group of City and Water Agencies that are working to collaborate for improved transparency. **Figure 2** presents an overview of the Water Agency Jurisdictions with an overlay of City boundaries.

The climate in the region is a semi-arid Mediterranean-type characterized by long dry summers and relatively short mild winters. The annual average temperature in the valley is 62° F, with extremes ranging from as low as 18° F to as high as 116° F (Burnham and Dutcher, 1960). Precipitation in the region is highly variable depending on location and elevation. Historical annual averages range from 10.9 inches near Loma Linda Fire Department located at the southwest end of the basin to over 40.1 inches at the Lake Arrowhead located at the upper end of the mountain watershed contributing flow to the basin. Precipitation data provided by the Water Resources Division for 20 stations are summarized in **Table 1** and displayed on **Figure 4**.

2.3 Definition of Terms

For the purposes of this report, the following terms are defined:

- Bunker Hill Basin - The Bunker Hill Basin is the groundwater basin that underlies the San Bernardino Valley. By strict definition according to (Dutcher and Garrett, 1963), the Bunker Hill Basin is separate from the Lytle Groundwater Basin, but receives groundwater underflow from the Lytle Basin. However, for completeness, the definition of the Bunker Hill Basin is extended to include the Lytle Basin for the purposes of this report.

- Production - The term production includes extraction of water by groundwater pumping from wells and surface diversions from the Santa Ana River, Mill Creek, City Creek, Devil Canyon Creek, Cajon Creek, Plunge Creek, and Lytle Creek.

- Preceding Water Year - As per the California Water Code, the preceding water year is the period July 1, 2012 through June 30, 2013.

- Current Water Year - As per the California Water Code, the current water year is the period July 1, 2013 through June 30, 2014.

- Ensuing Water Year - As per the California Water Code, the ensuing water year is the period July 1, 2014 through June 30, 2015.

2.4 Sources of Data

Data used in the development of this engineering investigation were obtained from a variety of sources including public and private agencies. The data analysis tasks involved tabulating and summarizing information from documented and undocumented reports, public and private files, and personal communication with local, State, and Federal agencies. Some of the more important data sources are listed below.

Data for Fall 2012 and Fall 2013 groundwater elevations and preceding water year (July 2012 to June 2013) production were obtained from the primary water purveyors in the Bunker Hill Basin including:

- City of Colton
- City of Loma Linda/Loma Linda University
- City of Redlands
- City of Rialto
- City of Riverside
- City of San Bernardino
- Devore Water Company
- East Valley Water District
- Elsinore Valley Municipal Water District/Meeks and Daley Water Company
- Gage Canal Company
- Riverside – Highland Water Company
- San Bernardino County Department of Transportation and Flood Control
- Southern California Edison
- San Bernardino Valley Municipal Water District
- Watermaster Support Services, Steve E. Mains
- West Valley Water District
- United States Geological Survey, Santee, CA Office

Historic precipitation data were obtained from the San Bernardino County Department of Transportation and Flood Control:

http://www.sbcounty.gov/dpw/floodcontrol/water_resources.asp

Currently precipitation data is downloaded from USGS stations.

http://www.sbcounty.gov/trnsprtn/pwg/Online_Data/Online_Data_Intro.htm

3.0 Fall 2012 and Fall 2013 Groundwater Elevation Contours

The District, the Western Municipal Water District, and the primary water purveyors in the Bunker Hill Basin provided Fall 2012 and 2013 water level data. Static groundwater elevations for wells throughout the Bunker Hill Basin are compiled in **Appendix A**. These elevations were plotted for 186 wells using a Geographic Information System (GIS) are plotted in **Figures 5 & 6** for Fall 2012 and Fall 2013. The water elevation values were used to derive an interpolated surface for the extent of the Bunker Hill Basin. For purposes of comparison, Fall 2012 and Fall 2013 static groundwater elevation surface contours are provided in **Figures 5** & **6** respectively.

4.0 *Task 1* - Annual Change in Storage (Fall 2012 to Fall 2013)

4.1 Hydrologic Sub-areas

Using a Geographic Information System, the average groundwater elevation changes were determined for each of the nine hydrologic sub-areas shown in **Figure 3** and listed below.

- Bunker Hill I - Southwest of Interstate 215
- Bunker Hill I - Northeast of Interstate 215
- Bunker Hill II - West of Mentone Fault
- Bunker Hill II - East of Mentone Fault
- Lytle Basin - Southeast of Barrier J
- Lytle Basin - Northwest of Barrier J
- Pressure Zone - North of Santa Ana Wash
- Pressure Zone - Santa Ana Wash

Due to variations of changes in groundwater level elevation, the Bunker Hill II - East of Mentone Fault was further subdivided into Storage Units North of Redlands Fault and Southeast of Redlands Fault. These Storage Units are also shown in **Figure 3**.

4.2 Area and Storativity

Digitizing each polygon made estimates of the area extent of the sub-areas and storage. Average storativity for each sub-area was determined based on data from Hardt and Hutchinson, 1980. Both of these values are shown in **Table 3**. Storativity values ranged from 0.02 for the Pressure Zone - North of the Santa Ana Wash to 0.13 for the Lytle Basin - Northwest of Barrier J and Bunker Hill II - East of the Mentone Fault.

4.3 Groundwater Level Elevation Changes

In order to determine the annual change in storage for the Bunker Hill Basin, Fall 2013 groundwater level elevation data were compared with the same from Fall 2012.
Measurements for 181 wells were available for both periods and the differences are provided in **Appendix A**. **Figure 7** shows key wells for the Bunker Hill basins. These wells have long hydrologic histories.

Average changes in groundwater were determined by averaging the changes for all wells in each of the eight sub-areas and storage units as shown in **Table 3.**

4.4 Change in Groundwater Storage

The total annual change in storage for the Bunker Hill Basin was determined by summing the changes from each sub-area. Changes in groundwater storage for the period Fall 2012 to Fall 2013 for the Bunker Hill Basin were calculated using the following formula:

$$Q_{\text{change in storage}} = \Sigma\ A_i \times S_i \times \Delta h_i$$

where:

$Q_{\text{change in storage}}$ = Annual change in storage for the Bunker Hill Basin, (acre-feet)

A_i = Area of sub-area and storage unit *i*, (acres)

S_i = Storativity of sub-area and storage unit *i*

Δh_i = Average water level change of sub-area and storage unit *i*, (feet)

As shown in **Table 3**, the change in groundwater storage for the Bunker Hill Basin between Fall 2012 and Fall 2013 decreased a change of -129,945 acre-ft.

5.0 *Task 2* - Accumulated Change in Storage from Fall 1993 to Fall 2013

For purposes of this report, the accumulated change in storage as of the last day of the preceding water year (July 30, 2013) was based on the changes in water levels between Fall 1993, when the accumulated basin change in storage was considered "zero", and the Fall of 2013.[2] The accumulated change in storage as of June 30, 2013 was determined by subtracting the change in storage for the preceding water year (July 1, 2012 to June 30, 2013 of -129,945 determined in Section 4.4, from the accumulated change in storage as of June 30, 2012 (-314,377). The result of this calculation is an accumulated change in storage for the Bunker Hill Basin of -444,322 acre-ft.

Table 4 summarizes the accumulated change in storage of the Bunker Hill Basin for the period 1989 to 2013 based on 1993 as the "zero accumulated storage year". As would be expected, storage generally increases with above average rainfall and decreases with normal and below average rainfall.

[2] In the District's Engineering Investigation (EI) prior to 1993-94, the accumulated change in storage was based on the basin storage in 1984 as considered full. A concern arose regarding high groundwater levels in the Pressure Zone of the Bunker Hill Basin. Therefore, in response to the City of San Bernardino's comments on accumulated change in storage, all EI's since that time are based on 1993 basin storage levels considered as full. The BTAC makes annual recharge recommendations to optimize recharge.

6.0 *Task 3* - Total Groundwater Production for the Preceding Water Year (July 1, 2012 to June 30, 2013)

Production data for the preceding water year (July 1, 2012 to June 30, 2013) for the Bunker Hill Basin were obtained from the primary water purveyors as listed in Section 2.4. Production data for wells owned by some smaller water agencies were included if data was available from the Western-San Bernardino Watermaster, Western Municipal Water District and semiannual billing statements issued by the District.

Appendix C shows the production for each groundwater well in the Bunker Hill Basin for the period July 2012 through June 2013. As summarized on the last page of the Appendix, groundwater production from the Bunker Hill Basin for the preceding water year was approximately 182,393 acre-ft. **Table 5** summarizes the Bunker Hill Basin groundwater production for each of the sub-areas defined in Section 4.1.

Groundwater production within the Bunker Hill Basin during the period July 2012 through June 2013 is shown on **Figure 8**. The Pressure Zone has the greatest density of higher producing facilities with pockets of substantial production scattered throughout the rest of the basin.

7.0 *Task 4* - Estimate of the Annual Change in Storage for the Current Water Year (July 1, 2013 to June 30, 2014)

To estimate annual change in storage for the current water year, a multiple regression analysis was performed for the period between 1991-2013 three parameters.

- Annual Change in Storage
- Precipitation
- Production

This analysis is shown in **Figure 9.**

In Engineering Investigations (EI) prior to 1998, data for the period 1982 calendar year through 1991 calendar year were also utilized in the regression analysis. The only production data available for this time frame was based on a calendar year period instead of the June to July period required in the EI. Since the 1991-92 period, more accurate and more complete production data for the July to June period has become available, as the District has compiled detailed information for its EI. Since 1998, the regression analysis has not included pre-1991 data to more accurately represent June through July production.

Annual change in storage for the current water year is estimated using the following relationship between change in storage, precipitation, production, and the calculated regression coefficients. The accumulated change in storage is shown in **Figure 10**.

$$Q_{\text{Annual } \Delta \text{ storage}} = -142{,}365 + 7{,}948 * Q_{prec} - 0.171 * Q_{prod}$$

where:

$Q_{\text{Annual } \Delta \text{ storage}}$ = Annual change in storage, (acre-feet)
Q_{prec} = Annual Precipitation, inches
Q_{prod} = Annual Production, acre-feet

A nomograph, constructed using the above equation, is shown on **Figure 9**. Through the use of this chart or the equation above, annual change in storage can be estimated for a given set of annual precipitation and production values. The precipitation used in the nomograph is based on the average of the representative Bunker Hill Basin drainage area stations listed in **Table 6**. The historic annual precipitation information is show in **Table 1**.

The historic annual average annual precipitation for nine of the ten stations with recent data is shown in **Table 6** approximately 22.8 inches**.** Historic annual precipitation values are plotted in **Appendix D** for these nine stations and twelve other local stations.

Table 6 shows that for the period between July 1, 2012 and December 31, 2012, precipitation was 100.3 percent of normal for the nine stations with data. Remainder of the water year, January 1 to June 30, 2013, the rainfall averaged 45.5 percent of the long term average. Annually, precipitation for the 2012-2013 water year averaged 62.9 percent. For purposes of this report, it was assumed that precipitation for the current water year (July 1, 2013 to June 30, 2014) would be 14.69 inches, 62.9 percent of the 22.8 inch average for the 2012 to 2013 season. The precipitation for the ensuing water year (July 1, 2014 to June 30, 2015) was estimated, as 100 percent of normal, or 22.8 inches of rainfall.

Based on these assumptions, the estimated production for the current water year will be approximately 216,434 acre-ft as shown in **Figure 10**. Using this result in **Figure 9** an estimated change in storage for the current water year (July 2013 to June 2014) of -65,285 acre-ft was determined.

8.0 *Task 5* - Estimate of the Annual Change in Storage for the Ensuing Water Year (July 1, 2014 to June 30, 2015)

The annual change in storage for the ensuing water year (July 1, 2014 to June 30, 2015) was estimated using the same method as described in Section 7.0. It was assumed that precipitation for the ensuing water year would be 100% of normal or 22.83 inches.

Based on this assumption, the estimated production for the ensuing water year will be approximately 215,200 acre-ft as shown in **Figure 11**. Again, using this result in the nomograph shown in **Figure 9**, the estimated annual change in storage for the ensuing water year (July 1, 2014 to June 30, 2015) is 2,253 acre-ft.

9.0 *Task 6* - Average Annual Change in Storage for the Immediate Past 10 Water Years

Table 7 shows the average annual change in storage for the immediate past ten water years (July 2003 to June 2013) using the same method as described in Section 4.0. By summing the average annual change in storage for each sub-area, a total average annual change in storage for the Bunker Hill Basin for the immediate past ten water years was determined to be -8,065 acre-feet/year.

10.0 *Task 7* - Estimated Amount of Agricultural Water and Other Than Agricultural Water to be Withdrawn for the Ensuing Water Year (July 1, 2013 to June 30, 2014)

The estimated amount of agricultural water and other than agricultural water to be withdrawn within the District for the ensuing water year (July 1, 2014 to June 30, 2015) was based on the following equations:

$$Q_{agr(12\text{-}13)} = Q_{agr(12\text{-}13)} \times \left[\left(Q_{total(14\text{-}15)} - Q_{surf(14\text{-}15)}\right) / \left(Q_{total(12\text{-}13)} - Q_{surf(12\text{-}13)}\right)\right]$$

and

$$Q_{non\text{-}agr(12\text{-}13)} = Q_{non\text{-}agr(12\text{-}13)} \times \left[\left(Q_{total(14\text{-}15)} - Q_{surf(14\text{-}15)}\right) / \left(Q_{total(12\text{-}13)} - Q_{surf(12\text{-}13)}\right)\right]$$

where:

$Q_{agr(14\text{-}15)}$ = Agricultural use within the District for the ensuing water year, acre-ft

$Q_{agr(12\text{-}13)}$ = Agricultural use within the District for the preceding water year, acre-ft (Appendix C)

$Q_{total(14\text{-}15)}$ = Production (including surface diversion) from the Bunker Hill Basin for the ensuing water year, acre-ft (Figure 14)

$Q_{total(12\text{-}13)}$ = Production (including surface diversion) from the Bunker Hill Basin for the preceding water year, acre-ft (Appendix C)

$Q_{non\text{-}agr(14\text{-}15)}$ = All other uses within the District for the ensuing water year, acre-ft

$Q_{non\text{-}agr(12\text{-}13)}$ = All other uses within the District for the preceding water year, acre-ft (Appendix C)

$Q_{surf(14\text{-}15)}$ = Surface diversions from the Bunker Hill Basin for the ensuing water year, acre-ft (Table 8)

$Q_{surf(12\text{-}13)}$ = Surface diversions from the Bunker Hill Basin for the preceding water year, acre-ft (Appendix C)

Data on agricultural use and other uses within the District for the preceding water year (July 1, 2012 to June 30, 2013) are provided in **Appendix C**. For the period July 1, 2012 through June 30, 2013 approximately 17,872 acre-ft of groundwater was produced for agricultural applications within the District boundary. For the same period, approximately 82,717 acre-ft of groundwater was produced for all other uses within the District boundary. Using the equations presented above with the following values inserted:

$Q_{agr(12\text{-}13)}$ = 17,872 acre-ft (Appendix C)

$Q_{total(14\text{-}15)}$ = 287,061 acre-ft (Figure 13)

$Q_{total(12\text{-}13)}$ = 238,890 acre-ft (Appendix C)

$Q_{non\text{-}agr(12\text{-}13)}$ = 82,717 acre-ft (Appendix C)

$Q_{surf(14\text{-}15)}$ = 71,861 acre-ft (Task 8)

$Q_{surf(12\text{-}13)}$ =35,006 acre-ft (Table 8)

The estimated production within the District for the ensuing water year for agricultural uses and other than agricultural uses is:

$Q_{total(14\text{-}15)}$ = 215,200 + 71,861 = 287,061 acre-ft

$Q_{agr(14\text{-}15)}$ = 17,872 x [(287,061 – 71,861) / (238,890 – 35,006)]

= 18,864 acre-ft

$Q_{non\text{-}agr(14\text{-}15)}$ = 82,717 x [(287,061 – 71,861) / (238,890 – 35,006)]

= 87,309 acre-ft

$Q_{agr(14\text{-}15)}$ = 18,864 acre-ft

$Q_{non\text{-}agr(14\text{-}15)}$ = 87,309 acre-ft

$Q_{Dist(14\text{-}15)}$ = 106,173 acre-ft

By summing these two results, it is estimated that 88,166 acre-feet of groundwater will be withdrawn within the District for the ensuing water year (July 1, 2013 to June 30, 2014). **Appendix C** shows the Agriculture and Non-Agriculture trends for the District by sub-basin using approximately 207 wells within the District Boundary reporting type of use.

11.0 *Task 8* - Estimated Amount of Water for Surface Distribution for the Ensuing Water Year (July 1, 2014 to June 30, 2015)

The amount of water for surface distribution for the ensuing water year (July 1, 2014 to June 30, 2015) was estimated based on the average surface diversions for the Santa Ana River, Mill Creek, and Lytle Creek for the period 1986 to 2013.

As shown in **Table 8**, average surface diversions for the Santa Ana River, Mill Creek, Lytle Creek and smaller tributary creeks collectively called "Bunker Hill Creeks," between 1986 and 2013 were 40,259; 1,195; 21,315; and 11,950 acre-feet, respectively. Therefore, the total estimated amount of water for surface distribution from the Bunker Hill Basin for the ensuing water year (July 1, 2014 to June 30, 2015) is found by summing the diversions as follows:

Bunker Hill Surface Distribution = 38,573 + 1,178 + 20,282 + 11,827 = 71,861 acre-ft

As Lytle Creek and Bunker Hill Creeks are not within the District, the estimated amount of surface distribution from the District for the ensuing water year (July 1, 2014 to June 30, 2015) is the sum of the Santa Ana River and Mill Creek distributions.

District Surface Distribution = 38,573 + 20,282= 58,856 acre-ft

12.0 *Task 9* - Estimated Amount of Water for Replenishment of the Groundwater Supplies for the Ensuing Water Year (July 1, 2014 to June 30, 2015)

The amount of water necessary for replenishment of the groundwater supplies of the Bunker Hill Basin for the ensuing water year (July 1, 2014 to June 30, 2015) was estimated based on:

Replenishment = Total Production - Surface Diversions - Change in Storage

The estimated production and surface diversions from the Bunker Hill Basin for the ensuing water year (July 1, 2014 to June 30, 2015) were estimated at approximately 215,200 acre-feet (from **Figure 13**) and 71,861 acre-feet (from **Table 8**), respectively. The estimated change in storage determined in Section 8.0 and shown on **Figure 9** is an increase of 2,253 acre-feet. Therefore, the amount of water necessary for replenishment of the groundwater supplies of the Bunker Hill Basin is estimated as follows:

Replenishment = 215,200 -71,861 -2,253 = 141,087 acre-ft

The amount of water necessary for replenishment of the District's groundwater supplies for the ensuing water year (July 1, 2014 to June 30, 2015) was estimated using the same equation as shown above and substituting values for the District area. The estimated production within the District for the ensuing water year was estimated at approximately 106,173 acre-ft (from Section 10.0) and 58,856 acre-ft (from Section 11.0), respectively. The change in storage for the ensuing water year for the District was estimated as an increase of 2,253 acre-ft. Therefore, the amount of water necessary for replenishment of the District's groundwater supplies for the ensuing water year (July 1, 2014 to June 30, 2015) is:

Replenishment = Total Production - Surface Diversions - Change in Storage
Replenishment = (106,173 + 58,856) - 58,856 - 2,253 = 103,920 acre-ft

13.0 Quality Assurance and Quality Control

Quality Assurance and Quality Control (QA/QC) efforts for the Engineering Investigation Report are distributed. Virtually all information is provided by other programs and agencies that have their own QA/QC processes and this report relies on them for providing accurate data. Additionally, most of the data is used in other reports and would be flagged if in error; examples include Watermaster reports, other basin models, etc. This section will briefly discuss the QA/QC process and standards.

Process and Method: The EI process produces results that are obtained by inputting the data we receive from the cooperating agencies into a series of linked spreadsheets in an MS Excel workbook. Many different calculations are then performed on the data entered. The results from these calculations are reported in the EI. Like all reports, the EI can contain error. SBVWCD makes a great effort to identify and eliminate the sources of possible errors.

The EI has established standards for precision and representativeness in the development of the report since the process initiation in 1993. The report uses a set of key wells, which can change over time to represent the groundwater basins. If changes to the wells are made, they are reviewed to see they are consistent with prior years. The level of precision in the data supplied varies, because the District must rely on the data quality produced by others for their work. We do not have specific requirements for precision of well level or production data, because other programs use the data and because the report averages the levels over entire groundwater basins; the precision of the other programs is adequate for our change in storage calculations.

In order for accurate conclusions to be drawn from the EI, the following must happen:

1) High quality data must be input into the Daily Flow Report (DFR) by field staff
2) DFR and data from other agencies must be accurately transferred to EI spreadsheets;
3) Correct calculations must be made using this data

Data Accuracy: The EI uses a large amount of production, water level, and flow measurements in calculating the change in storage and related tasks. The data received for the study is reviewed for completeness so that all wells and flows are reported. SBVWCD verifies that DFR data is accurate by cross checking with other data and verifying the data is in the historical range. The District implements several methods to maintain the accuracy of the Engineering Investigation Report. These methods are discussed in the following sections.

The input data for the EI comes from many agencies, in many different formats, over a range of several months. The data is checked when entered to ensure that the correct

data is being provided in the correct units. To ensure this check occurs, all data entered into the EI spreadsheets is highlighted. Once all data entry has occurred, a second staff person checks the highlighted input data to make sure it is the correct value and in the correct units.

Generally, data is transferred (copied and pasted) into the EI spreadsheets rather than retyped to reduce entry errors. When data is provided in a format that cannot be transferred, hand entered data is double checked upon entry. Once all the data has been entered, it is checked again to make sure there is not any data out of historical range. Any data that is out of range is rechecked at the source, and if necessary confirmed by the providing agency.

A final check of the data is done by the reporting agencies. SBVWCD sends out a draft EI to all data providers. Any error reported by the data providers is addressed and corrected before the Final EI is approved.

Calculation Accuracy: To ensure the calculations used to obtain the results for the EI are correct, the District uses a copy of the prior year spreadsheets for the ensuing year. The spreadsheets are directly recreated from the copies, only the data is stripped out of the spreadsheet so that all cell references are maintained. This maintains the consistency of the calculations. As an additional check, the cell references and formulas are reconfirmed each year. In addition to rechecking of the structure of the spreadsheets, the methodology and logic is also rechecked in this process.

Comparability: After all the data and calculations are checked, the final results are obtained. The District compares the results from the EI to SBVMWD's groundwater modeling program change in storage calculation. The programs cover nearly the same area with very similar input data. However, the basin boundaries and methods of calculations are different. If District results and SBVMWD's results are significantly different, more than 10%, the District and SBVMWD both review data and calculations, identify any errors, and verify the new EI results are comparable and accurate.

Approval: Once the results are confirmed through the previous steps, the District Management reviews the report and recommends it to the SBVWCD's Board of Director for reviews and approval.

14.0 General Findings

In addition to the above findings, Section 75505 of the California Water Code requires that a finding be made as to the amount of water necessary to be replaced in the intake areas of the groundwater basins within the District to prevent the landward movement of salt water into the fresh groundwater body, or to prevent subsidence of the land within the District. Because of its location and the elevations of its water table, the Bunker Hill Basin is not subject to salt-water intrusion and the current groundwater levels will not (lowest=593 msl) result in any significant land subsidence.

Section 75540 of the California Water Code requires that the District Board establish a zone or zones where a groundwater charge is to be implemented. The Code specifically states that a single zone may include the entire District and in May 1993 the Board established the entire District as one zone. This determination may be amended in the future, but lacking any evidence to the contrary, in the 2013-2014 year the entire District will remain as a single zone in regard to any groundwater charge.

Section 75561 of the California Water Code further requires the Engineering Investigation to include a finding related to the amount of water the District is obligated by contract to purchase. At this time the District has no contractual obligation to purchase water for the replenishment of the groundwater supplies.

15.0 Conclusions

Based on the results of the 2014 Engineering Investigation, the San Bernardino Valley Water Conservation District finds that:

- Due to the imbalance between recharge and production since 1993, the Bunker Hill Basin's storage is 444,322 acre-feet below that which is considered full for purposes of this Investigation.

- During the ensuing water year (July 1, 2014 to June 30, 2015), the Bunker Hill Basin can be recharged, from all sources, with 650,694 acre-feet of water. This recharge quantity is derived by algebraically adding together the accumulated deficit as of the end of the preceding water year with the estimated quantity needed to maintain the 1993 storage level considered full. The BTAC recommends a maximum basin recharge of 190,000 acre-ft.

- The District should continue to take the necessary steps to work with its partners to enhance its capability to conduct recharge operations, which includes construction of new, or maintenance and repair of existing, diversion facilities, canals, dikes, basins, roads, and other water recharge facilities. These improvements are required to ensure that the increasing demands on the Basin, especially during drought periods, can be met.

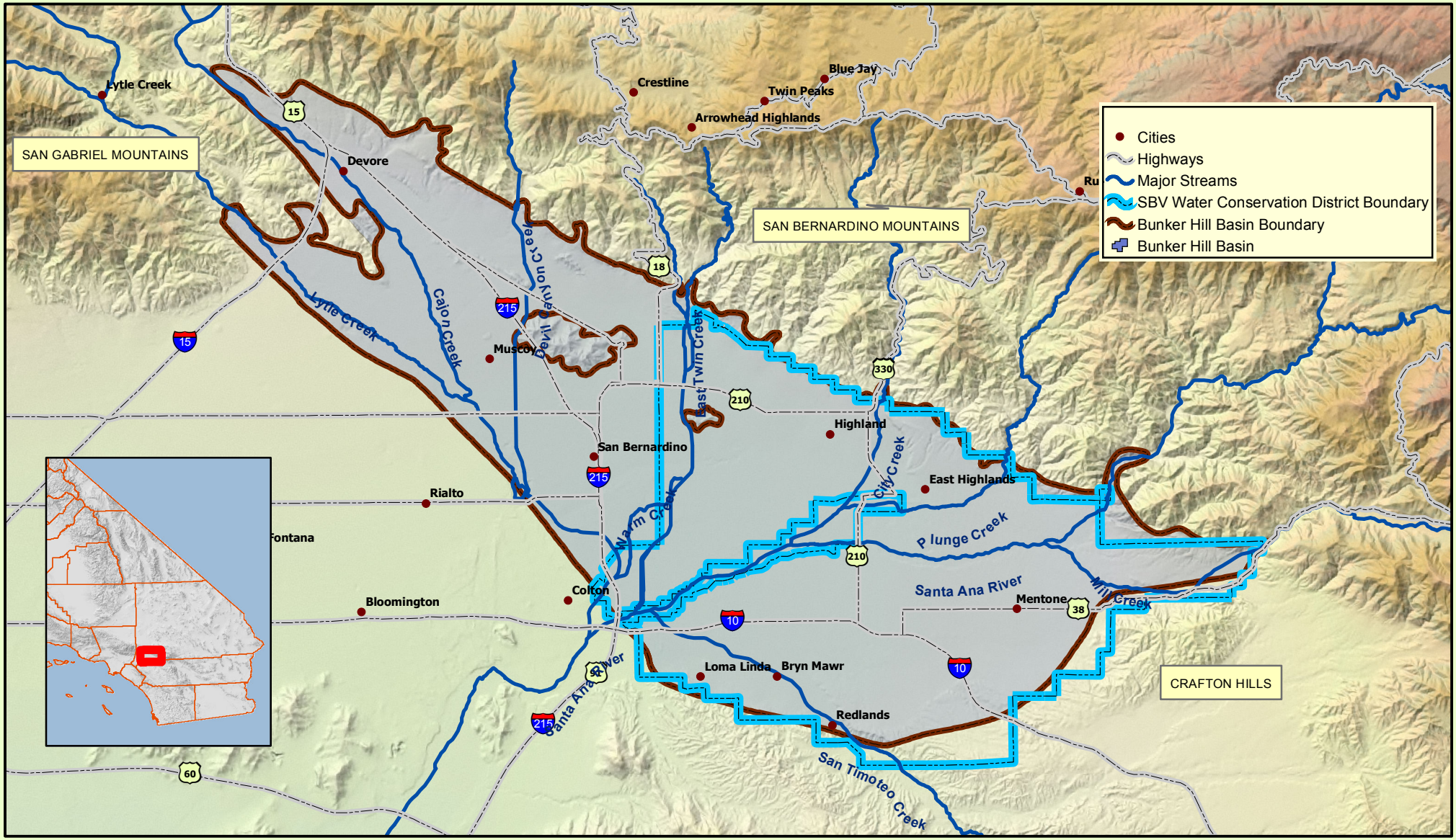
16.0 Financial Data

The San Bernardino Valley Water Conservation District, in response to questions previously provided information about the groundwater charge in this section. The District provides a complete budget and report of operations as a companion document to this report.

Any changes to the groundwater charge will not be reflected on the District's financial reports as income until the fiscal year 2014 – 2015, as the first increment of the new charge is not due until that time.

Engineering Investigation of the Bunker Hill Basin 2013–2014

Figures



Coordinate System:
NAD 1983 StatePlane California V FIPS 0405 Feet

Projection:
Lambert Conformal Conic

Data Sources:
SBVWCD, CASIL, SBVMWD

0 0.5 1 2 3 Miles

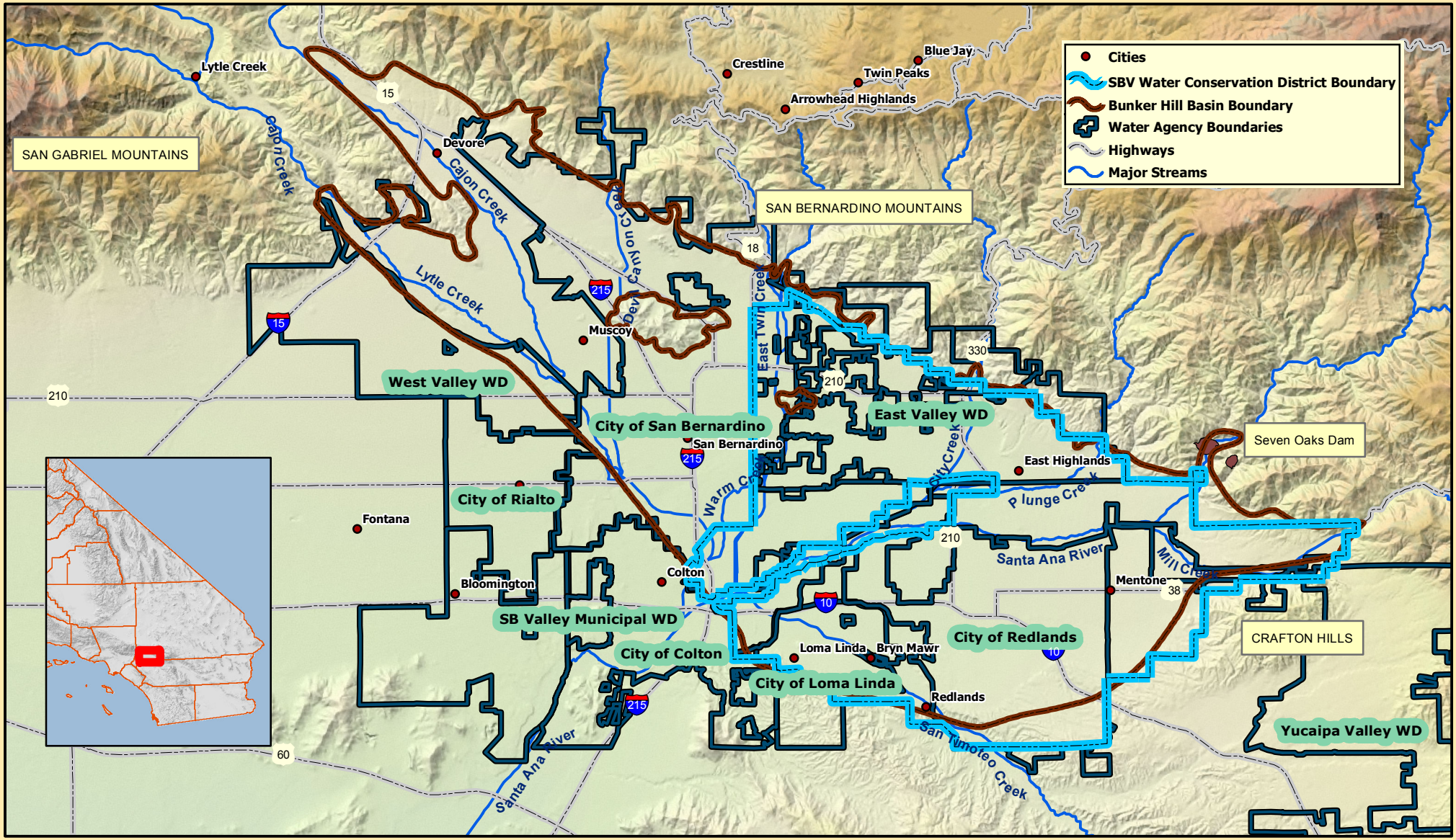
Project Area
Engineering Investigation Report 2014

Engineering Investigation
January 2014

GIS Contacts: L.Pierce, Erin Berger & Emerald Mancilla

Figure 1

X:\Engineering Investigation\2014EI\GIS\Fig01_Project_Area.mxd



Coordinate System:
NAD 1983 StatePlane California V FIPS 0405 Feet

Projection:
Lambert Conformal Conic

Data Sources:
SBVWCD, CASIL, SBVMWD

Miles
0 0.5 1 2 3

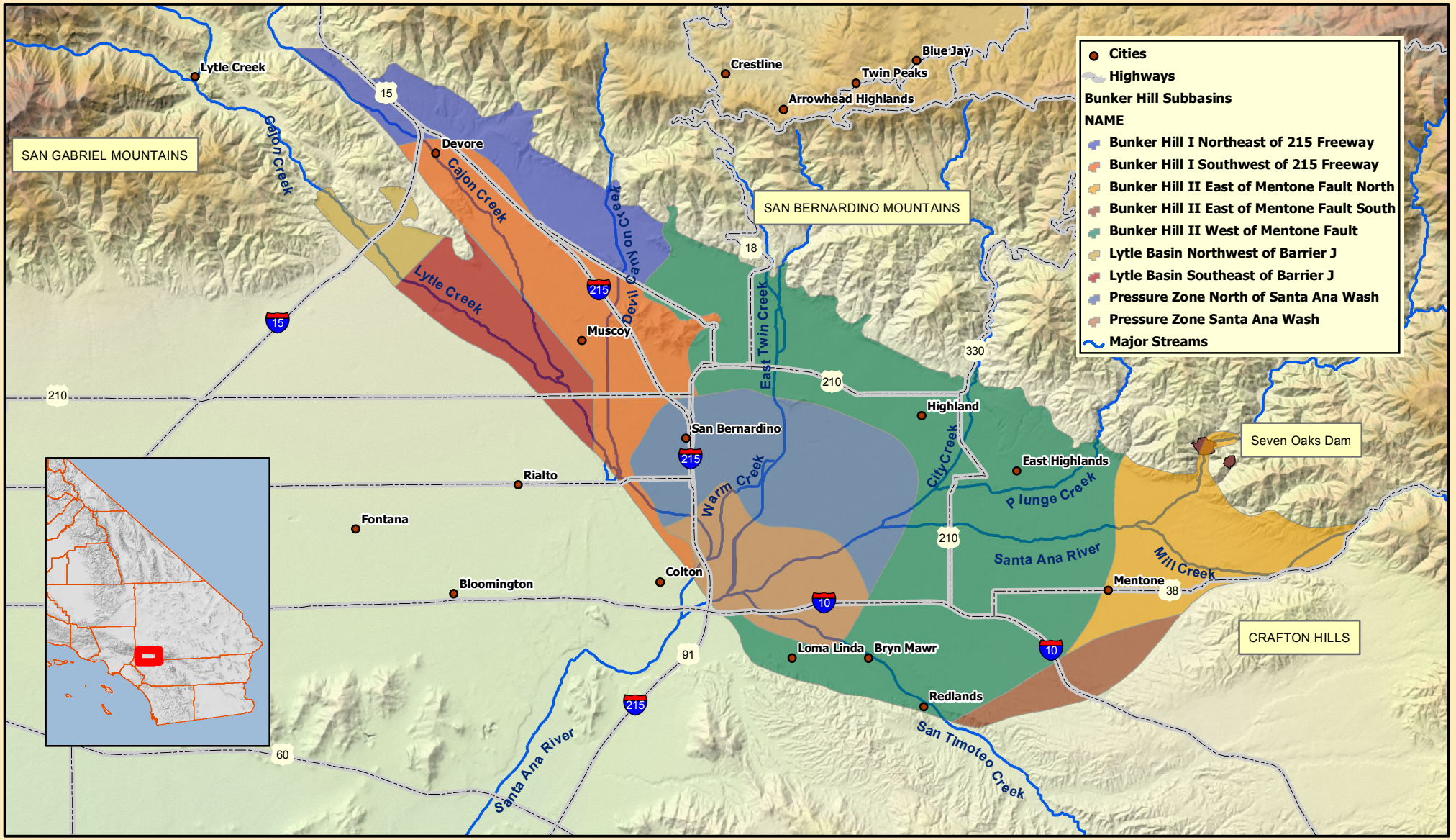
Conservation District and Water Agency Boundaries
Engineering Investigation Report 2014

Engineering Investigation
January 2014

GIS Contacts: L.Pierce, E.Berger & E.Mancilla

Figure 2

X:\Engineering Investigation\2014EI\GIS\Fig02_ConservationDistrict.mxd



Coordinate System:
NAD 1983 StatePlane California V FIPS 0405 Feet

Projection:
Lambert Conformal Conic

Data Sources:
SBVWCD, SBVMWD

0 0.5 1 2 3 Miles

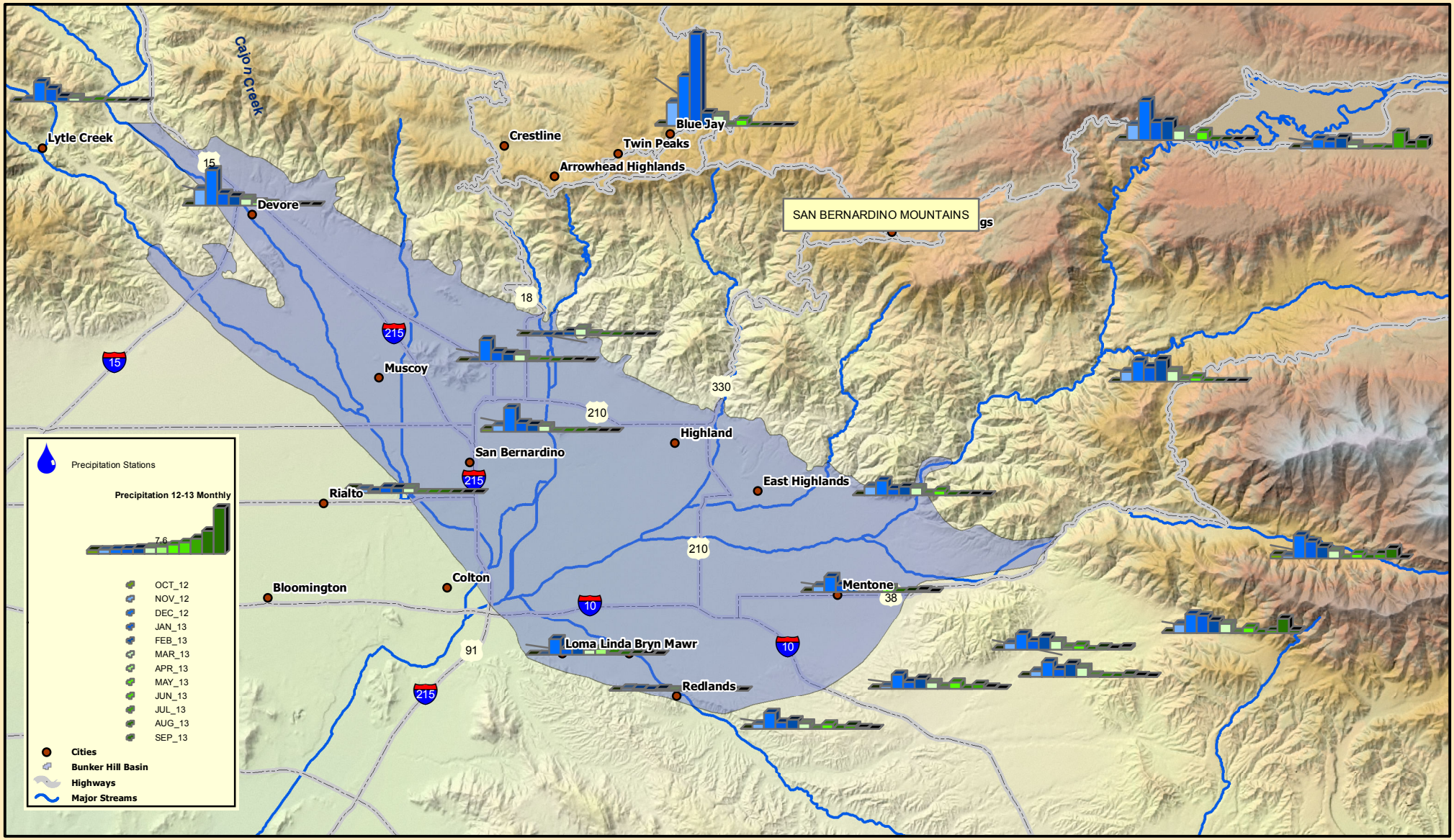
Bunker Hill SubBasins
Engineering Investigation Report 2014

Engineering Investigation
January 2014

GIS Contacts: L.Pierce, E.Berger & E.Mancilla

Figure 3

X:\Engineering Investigation\EI2014\GIS\Fig03_BunkerHillSubBasins.mxd



State Plane
NAD 83, Zone V, feet
10M DEM - DWR 2008
Data Sources:
19 Active Gauging Stations
2014

0 0.5 1 2 3 Miles

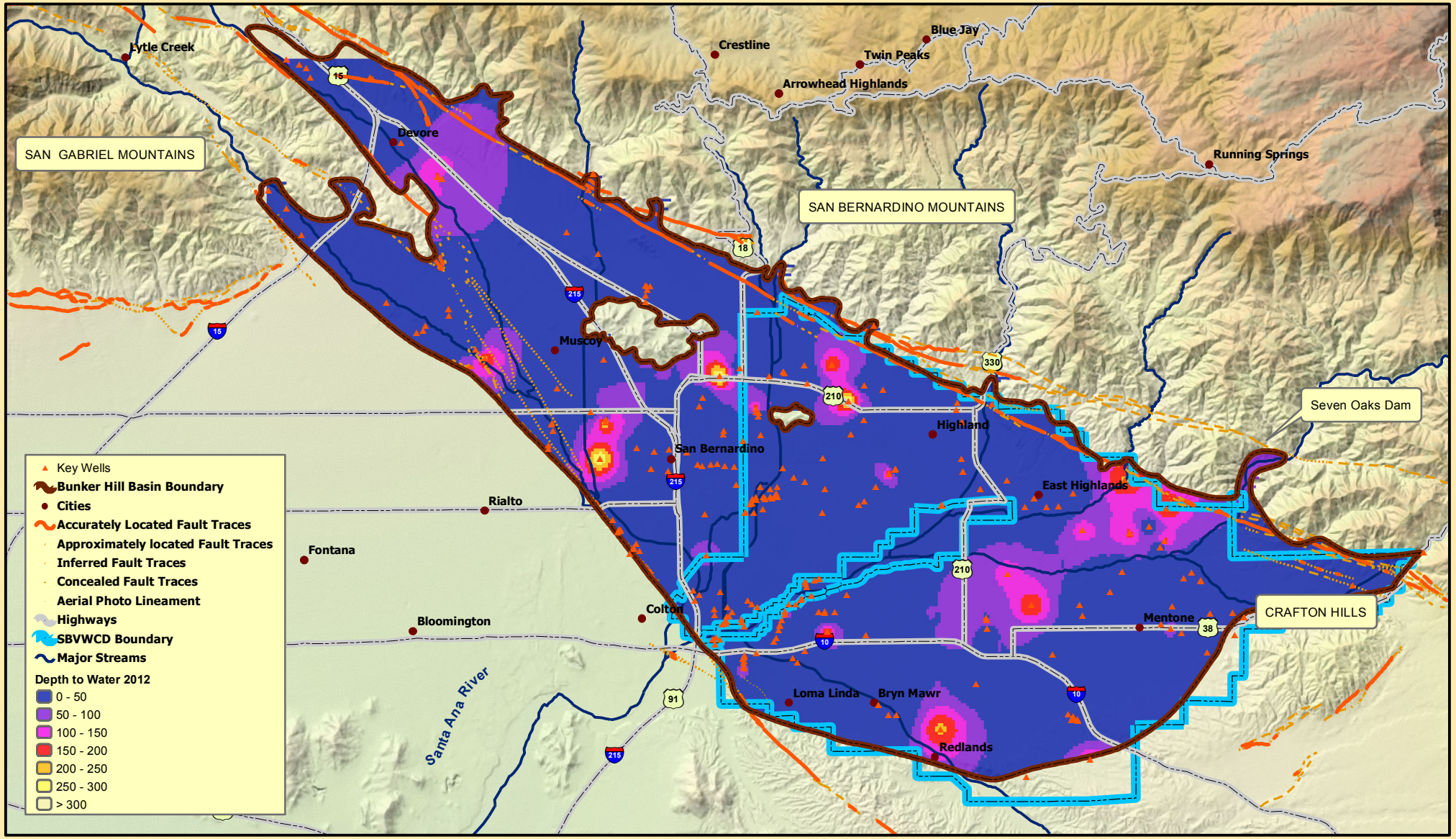
Precipitation Trends and Station Locations
October 2012 - September 2013
Engineering Investigation Report 2014

Engineering Investigation
January 2014

Map Creation: SBVWCD GIS
E.Mancilla

Figure 4

X:\Engineering Investigation\2014EI\GIS\Fig04_Precipitation Data



State Plane NAD 83, Zone V, feet
10M DEM DWR
SBVWCD Water Elevation
2011 - 340 Wells
IDW Interpolation Method
Watermaster Services,
All City Water Agencies
and SBVMWD

0 0.5 1 2 3 Miles

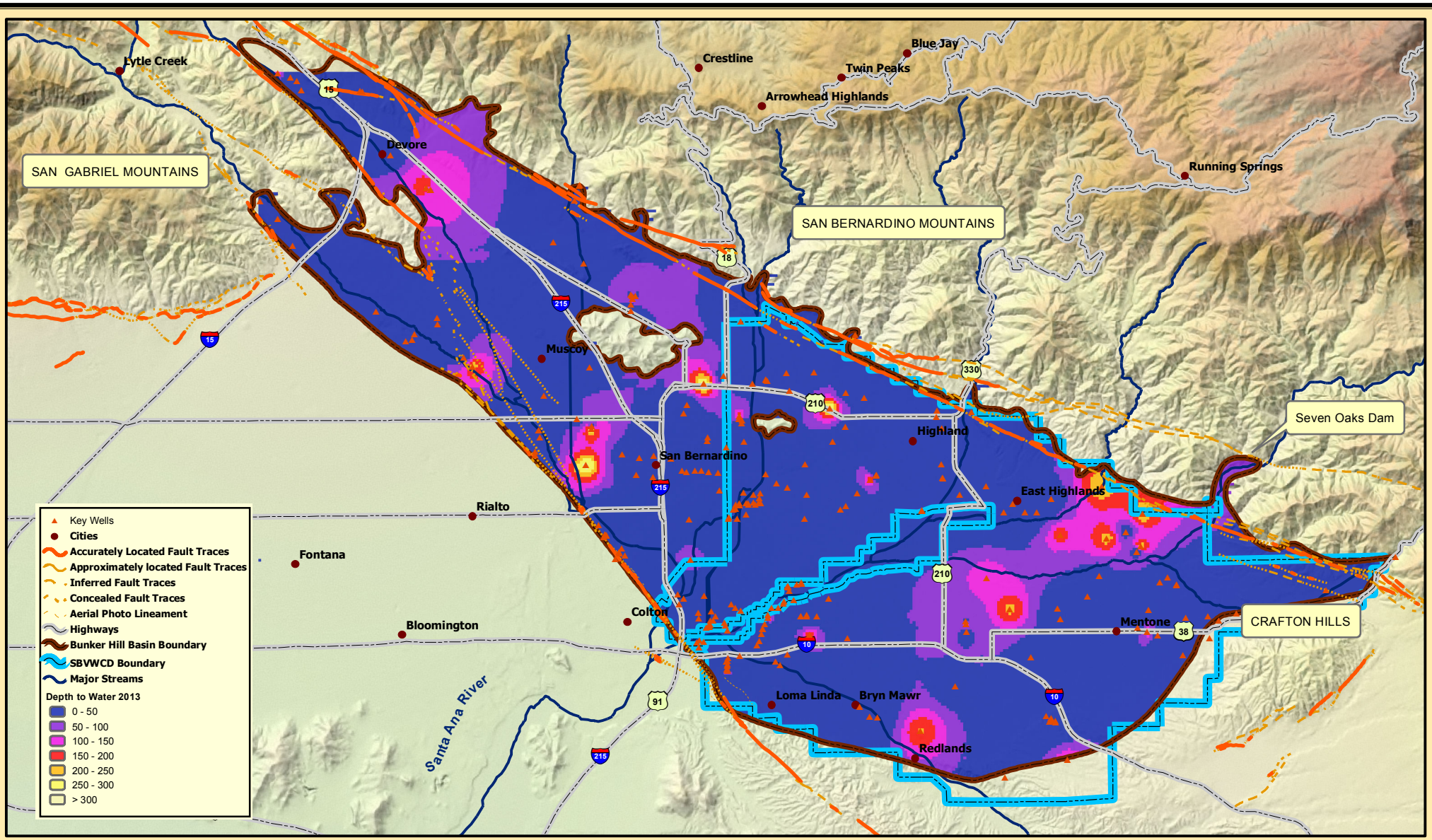
Water Elevation Contour Surface Fall 2012
Engineering Investigation Report 2014

Engineering Investigation
January 2014

Source: SBVWCD GIS
E.Mancilla & E.Berger

Figure 5

X:\Engineering Investigation\2014EI\GIS\Maps



State Plane NAD 83, Zone V, feet
10M DEM DWR
SBVWCD Water Elevation
2011 - 340 Wells
IDW Interpolation Method
Watermaster Services,
All City Water Agencies
and SBVMWD

0 0.5 1 2 3 Miles

Water Elevation Contour Surface Fall 2013
Engineering Investigation Report 2014

Engineering Investigation
January 2014

Source: SBVWCD GIS
E.Mancilla & E. Berger

Figure 6

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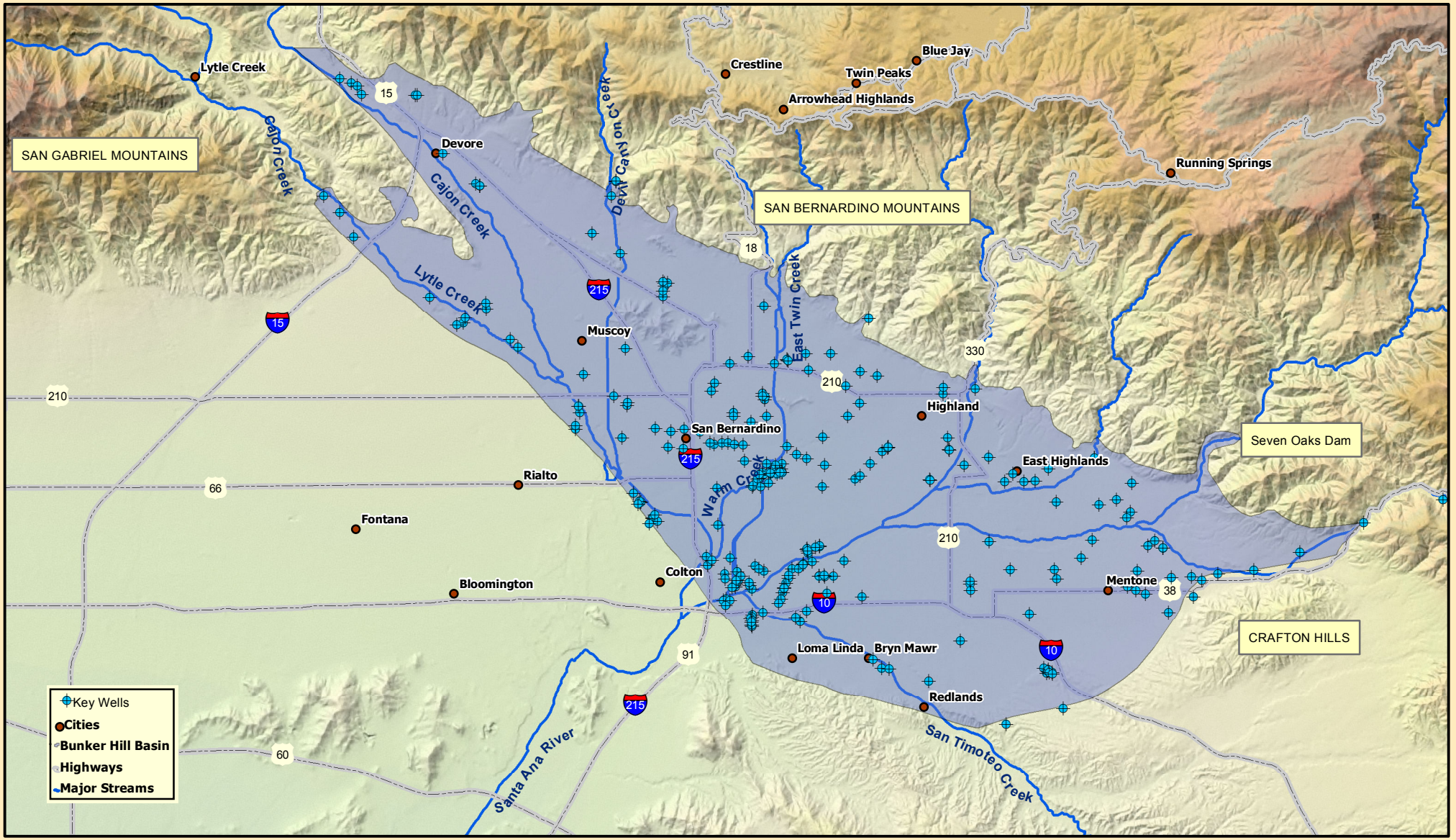

State Plane
NAD 83, Zone V, feet
10M DEM - DWR 2008
Data Sources: 2010 -11
SBVWCD, SBVMWD, WVWD

0 0.5 1 2 3 Miles

Key Wells (Appendix B Hydrographs) 2012 - 2013 Engineering Investigation Report

Engineering Investigation
January 2014

Map Creation: SBVWCD GIS
E.Mancilla

Figure 7

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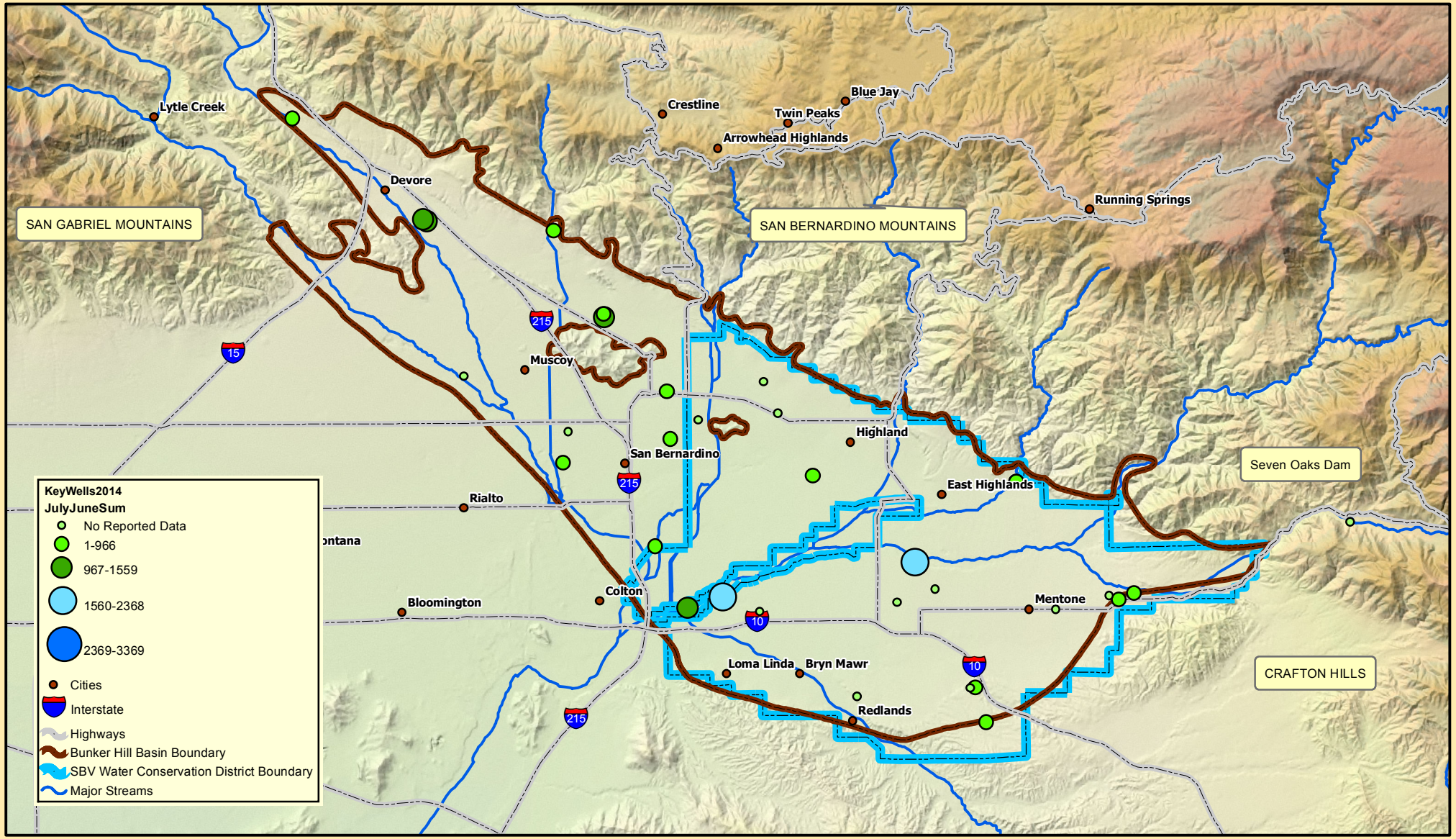


State Plane
NAD 83, Zone V, feet
10M DEM DWR
Data Sources:
SBVWCD EI Production
241 wells with 184 reporting
Watermaster Services,
All City Water Agencies
and SBVMWD

0 0.5 1 2 3 Miles

Groundwater Production -Bunker Hill Basin Subbasins
Total Well Production for July 2012 - June 2013 (Water Year)
Engineering Investigation Report 2014

Engineering Investigation
January 2014

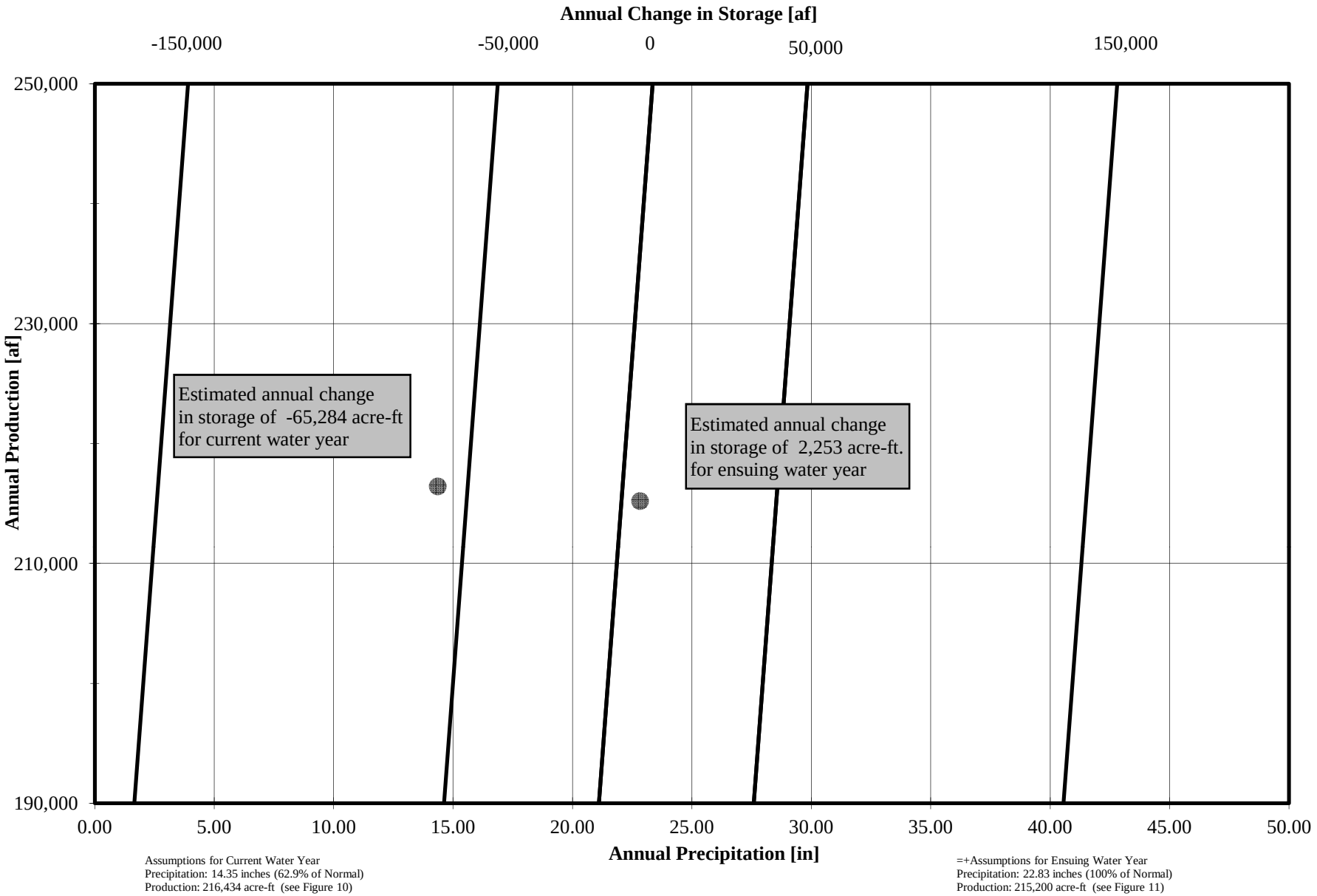
Source: SBVWCD GIS
E.Mancilla

Figure 8

X:\Engineering Investigation\2014EI\GIS\Maps

Prediction Chart for Annual Change in Storage

Current and Ensuing Water Years



Assumptions for Current Water Year
Precipitation: 14.35 inches (62.9% of Normal)
Production: 216,434 acre-ft (see Figure 10)

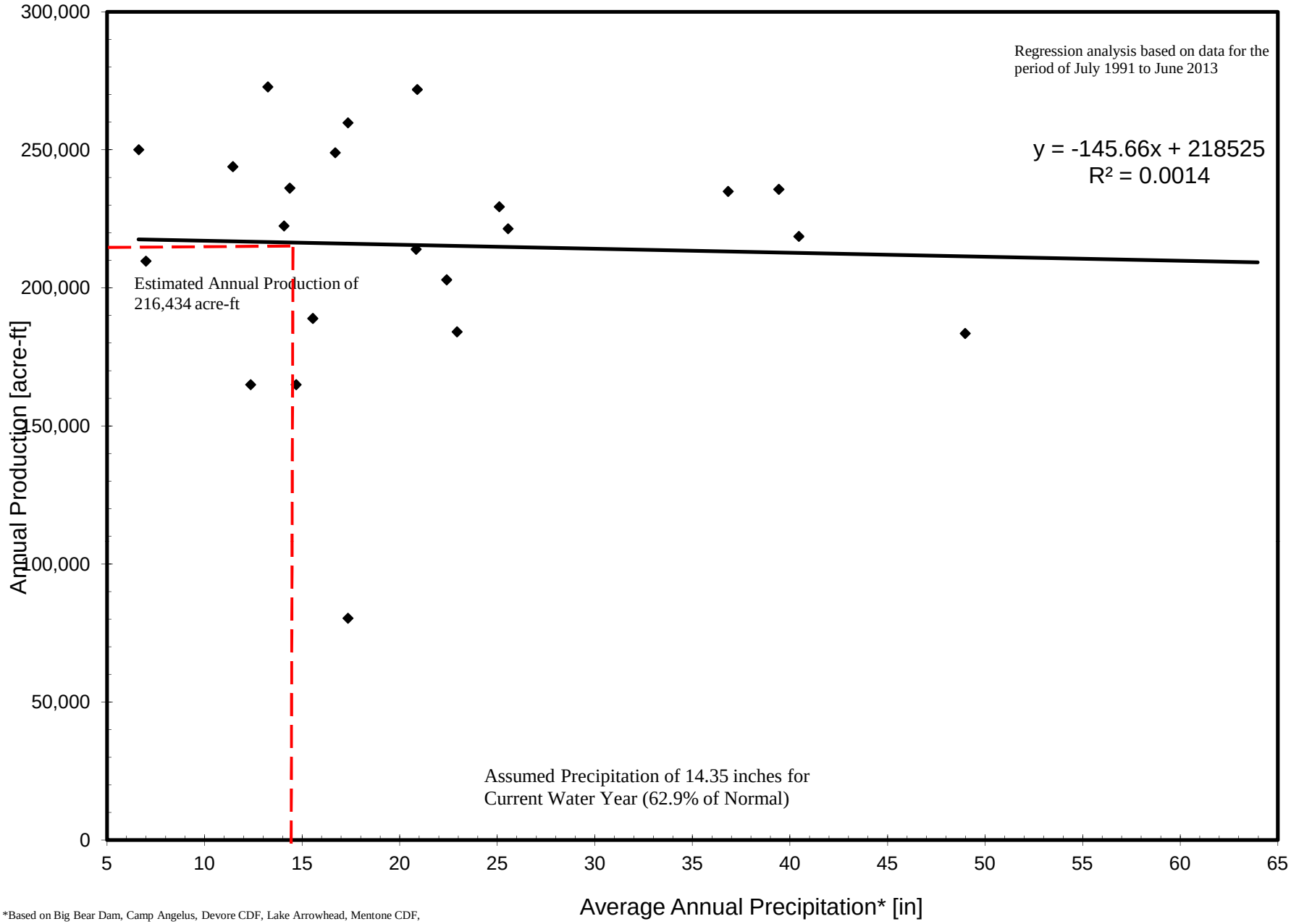
=+Assumptions for Ensuing Water Year
Precipitation: 22.83 inches (100% of Normal)
Production: 215,200 acre-ft (see Figure 11)

* Based on Big Bear Dam, Camp Angelus, Devore CDF, Lake Arrowhead, Mentone CDF, Redlands Country Club, San Bernardino County Hospital, Santa Ana Powerhouse #3, and Yucaipa CDF.

Change in Storage = -142,365+ 7,948 * Precipitation - 0.171* Production (R^2 = 0.79)

Estimate of Production for Current Water Year

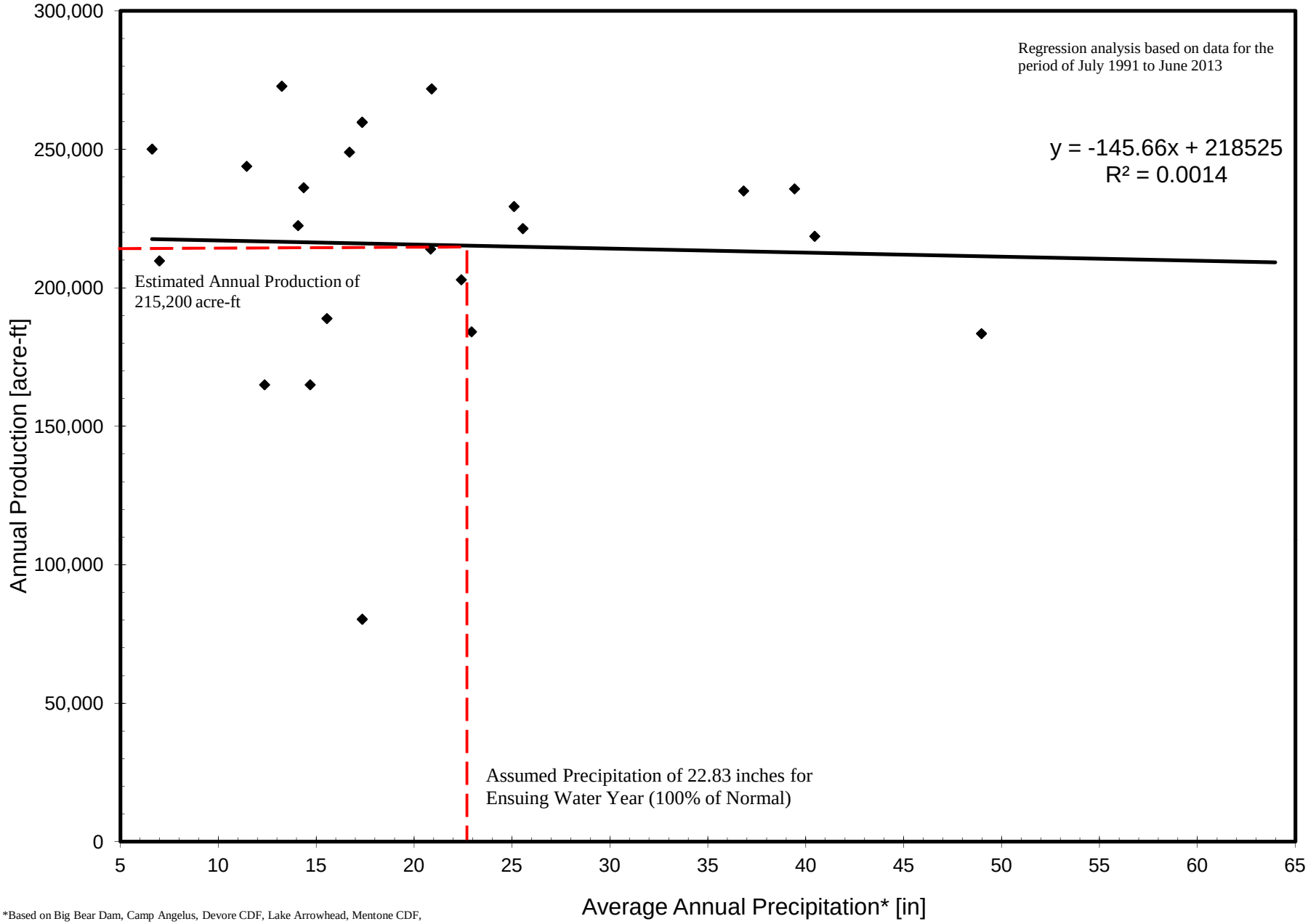
(July 2013 to June 2014)



*Based on Big Bear Dam, Camp Angelus, Devore CDF, Lake Arrowhead, Mentone CDF, Redlands Country Club, San Bernardino County Hospital, Santa Ana Powerhouse #3, and Yucaipa CDF.

Estimate of Production for Ensuing Water Year

(July 2014 to June 2015)



*Based on Big Bear Dam, Camp Angelus, Devore CDF, Lake Arrowhead, Mentone CDF, Redlands Country Club, San Bernardino County Hospital, Santa Ana Powerhouse #3, and Yucaipa CDF.

Engineering Investigation of the Bunker Hill Basin 2013–2014

Tables

SBV WATER CONSERVATION DISTRICT

OUR NAME IS OUR MISSION

Summary of Percentage of Normal Precipitation

1986 to 2013 (Water Year - Oct. to Sept.)

Station	Historic Annual Avg. [in]	1986 -1987 [in]	1987 -1988 [in]	1988 -1989 [in]	1989 -1990 [in]	1990 -1991 [in]	1991 -1992 [in]	1992 -1993 [in]	1993 -1994 [in]	1994 -1995 [in]	1995 -1996 [in]	1996 -1997 [in]	1997 -1998 [in]	1998 -1999 [in]	1999 -2000 [in]	2000 -2001 [in]	2001 -2002 [in]	2002 -2003 [in]	2003 -2004 [in]	2004 -2005 [in]	2005 -2006 [in]	2006 -2007 [in]	2007 - 2008 [in]	2008 - 2009 [in]	2009 - 2010 [in]	2010 - 2011 [in]	2011 - 2012 [in]	2012 - 2013 [in]	Each Station 28-Yr. Avg. [in.]
Big Bear City	13.75	10.18	10.59	9.37	10.23	17.81	13.96	22.92	11.53	18.59	11.17	12.06	16.83	6.53	4.75	20.14	3.33	12.62	7.55	23.25	14.36	3.67	8.53	3.51	16.24	24.55	16.27	10.46	12.63
Big Bear Dam	35.53	19.17	28.89	20.84	17.60	34.79	38.90	81.92	28.67	52.65	24.40	29.97	51.70	14.20	20.60	21.40	9.20	38.10	19.60	59.10	26.40	10.30	23.00	19.70	26.00	20.24	11.83	18.73	28.44
Camp Angelus	28.41	20.50	4.95	17.20	17.90	26.44	28.16	61.14	17.20	46.70	26.00	29.00	49.52	16.10	21.10	21.50	7.70	35.40	13.20	35.20	41.90	0.00	2.70	18.00	18.80	1.60	17.49	13.89	22.57
Crafton Hills	12.47	9.00	12.11	10.00	6.30	12.27	10.69	22.99	5.45	27.10	7.84	16.67	25.55	7.29	6.40	10.49	2.46	17.57	9.47	31.39	11.45	3.34	13.34	8.82	17.80	24.52	9.57	9.16	12.93
Del Rosa Ranger Station	18.20	9.48	18.92	13.16	12.85	8.79	24.24	41.39	12.30	27.69	14.21	17.31	37.26	8.30	12.73	16.60	6.09	19.69	13.02	38.55	17.40	8.77	17.77	13.57	22.01	30.84	13.57	2.22	17.73
Devore CDF	27.34	12.39	17.90	10.75	15.00	20.41	31.32	63.98	15.40	45.44	20.58	33.10	45.13	13.61	8.04	15.52	10.90	35.35	16.44	60.36	24.80	8.86	25.21	16.51	34.12	43.20	17.47	14.04	25.03
Fallsvale	31.67	23.00	20.30	3.50	51.00	22.50	36.00	71.90	52.00	54.90	22.10	33.80	53.00	16.30	21.20	15.30	6.50	37.50	25.20	61.40	26.90	11.10	29.30	24.70	2.85	29.52	22.9	14.1	29.21
Lake Arrowhead	40.09	23.74	40.39	28.51	26.62	23.68	45.24	85.00	28.20	74.51	30.84	36.50	72.80	18.10	25.80	28.60	10.70	36.50	22.70	69.70	46.20	18.50	41.91	30.28	26.00	37.76	25.1	32.6	36.54
Loma Linda FD	10.92	7.41	10.45	8.84	7.69	7.16	13.44	25.56	10.99	19.02	7.15	9.78	22.74	5.12	7.74	6.38	2.45	14.48	8.06	22.59	11.06	3.51	9.63	8.95	13.10	18.24	6.79	7.32	10.95
Lytle Creek at Foothill	13.40	7.00	12.96	3.90	8.50	15.51	14.91	31.61	9.16	25.51	12.23	13.83	25.84	6.25	9.81	12.12	4.00	13.60	7.16	27.23	11.22	3.84	11.89	9.03	13.03	0.23	6.9	4.51	11.92
Lytle Creek Fire Station	23.56	11.20	22.40	12.83	17.90	32.07	49.09	87.71	20.50	47.57	24.49	23.10	52.18	11.81	20.40	18.34	4.47	16.96	12.09	44.11	18.92	4.22	21.89	3.32	0.00	28.46	8.18	7.32	23.02
Mentone CDF	12.54	9.23	8.85	8.64	6.13	12.55	15.93	23.85	8.35	17.10	9.42	15.73	27.09	4.28	9.08	10.16	4.06	15.00	10.38	24.94	11.01	5.41	10.75	9.38	14.96	17.77	7.9	7.33	12.05
Oak Glen	26.80	19.29	21.46	17.82	17.71	26.92	30.78	57.96	18.76	57.92	20.04	30.39	49.46	11.32	17.12	12.28	6.72	14.28	18.39	34.14	22.58	9.71	27.60	19.92	29.72	36.82	15.13	15.65	24.44
Redlands - Roth	12.13	7.79	11.18	8.08	7.21	13.34	14.96	25.57	10.06	20.49	8.08	10.77	22.29	6.46	7.41	10.38	3.35	12.18	9.16	24.43	9.52	3.31	9.46	8.82	15.12	17.38	4.34	1.54	11.21
Redlands Country Club	13.71	8.80	14.18	10.68	8.58	14.48	16.11	29.44	12.55	19.76	8.52	9.03	17.22	6.30	5.68	9.96	3.97	16.45	11.58	29.37	10.30	4.13	11.93	11.35	17.25	22.33	7.74	8.71	12.83
San Bernardino CDF	17.34	9.27	18.26	12.85	10.55	15.49	21.89	37.35	4.46	20.29	15.77	16.17	34.32	9.30	13.62	16.61	5.29	13.14	11.52	37.28	16.39	6.33	18.91	9.85	20.45	27.94	10.63	7.69	16.36
San Bernardino Co. Hospital	15.88	8.08	13.53	12.63	8.12	15.48	16.54	30.78	11.65	24.10	11.92	17.80	32.67	8.02	11.09	2.33	3.60	17.06	10.49	29.89	13.20	4.68	12.81	10.05	17.03	21.76	9.58	9.31	14.23
Santa Ana Pumphouse #3	16.94	12.28	14.67	9.38	10.32	15.84	18.38	22.98	15.92	24.85	11.05	16.60	27.95	7.01	6.78	8.63	3.23	18.24	9.40	27.65	11.78	6.13	10.73	9.73	14.58	20.18	8.62	9.05	13.78
Yucaipa CDF	15.82	11.02	11.33	9.74	7.25	11.16	17.85	34.20	11.40	30.24	10.52	15.62	24.70	7.63	11.10	9.92	5.66	19.47	11.84	32.70	13.14	6.56	14.67	12.11	18.79	25.09	11.8	11.1	15.06
Yucaipa Valley Water District	15.85	10.55	14.36	10.55	10.84	16.98	18.68	18.08	12.51	25.20	10.88	16.93	28.60	9.87	9.63	9.65	5.27	19.50	11.10	32.73	12.52	5.53	14.79	12.11	17.68	22.74	10.8	9.37	14.72
Percent of Normal	**100%**	**62%**	**81%**	**59%**	**69%**	**90%**	**119%**	**218%**	**79%**	**169%**	**76%**	**100%**	**178%**	**48%**	**62%**	**69%**	**27%**	**105%**	**64%**	**185%**	**92%**	**32%**	**84%**	**65%**	**88%**	**117%**	**60%**	**53%**	**91%**

Total Station Average	**20.12**

Source: San Bernardino County Department of Transportation/Flood Control

Change in Groundwater Levels in Key Wells

Fall 2012 to Fall 2013

WCDCode	Recordation Number	State Well Number	Well Name	Owner Or Measuring Agency	2012 Depth To Water (ft)	2013 Depth To Water (ft)	Difference Fall 2012 to Fall 2013
1865	3601675	1N4W25A01S	27	East Valley Water District	191.6		
1984	3602113	1N3W30N01S	41	East Valley Water District	290.0	290.2	-0.2
1364	3600026	1S3W04J01S	102	East Valley Water District			
1401	3600220	1S3W01H01S	142 Mt. Harrison	East Valley Water District	205.3	250.4	-45.1
1660	3601184	1N3W33F01S	94 Corwin	East Valley Water District			
1851	3601660	1S3W06H04S	9A	East Valley Water District	207.4	213.7	-6.3
1668	3601225	1S4W02P02S	Cooley D	East Valley Water District			
1010	9900021	1S3W09E02S	Tri-City Concrete	East Valley Water District			
1727	3601308	1S2W19K01S	Agate #1	Redlands, City of	102.0	148.0	-46.0
1708	3601283	1S2W22C02S	E. Lugonia #2	Redlands, City of			
1712	3601287	1S2W21B02S	E. Lugonia #3	Redlands, City of	26.0	31.0	-5.0
1714	3601290	1S2W21D01S	E. Lugonia #6	Redlands, City of	42.0	36.0	6.0
1970	3602065	1S3W32J02S	Lee Well	Redlands, City of	209.0	206.0	3.0
1706	3601281	1S2W36F01S	Maguet #1	Redlands, City of	21.0	23.0	-2.0
1709	3601284	1S2W21E01S	Maguet #2	Redlands, City of	42.0	57.0	-15.0
1707	3601282	1S1W08H01S	Mill Creek #1	Redlands, City of			
1819	3601586	1S3W15F01S	Orange Street	Redlands, City of	118.0	139.0	-21.0
1591	3600918	2S3W01E01S	Redlands Heights	Redlands, City of	167.0	169.0	-2.0
1718	3601294	1S3W35G09S	Well #13	Redlands, City of	56.0	60.0	-4.0
1720	3601296	1S3W35H03S	Well #16	Redlands, City of	38.0	42.0	-4.0
1722	3601298	1S3W21H01S	Well #32	Redlands, City of	172.0	188.0	-16.0
1723	3601299	1S4W24K01S	Well #34	Redlands, City of	180.0	193.0	-13.0
1964	3602032	1S3W22A02S	Well #35	Redlands, City of	196.0	216.0	-20.0
1725	3601301	1S3W28H01S	Well #41	Redlands, City of			
1702	3601263	1N5W23Q01S	City 1	Rialto, City of	206.0	225.0	-19.0
1668	3601225	01S/04W-02P002S	Cooley D	Riverside, City of	138.0	176.0	-38.0
1662	3601218	1S4W14P02S	Raub 1	Riverside, City of	128.4	164.8	-36.4
1677	3601234	1S4W27A19S	Stewart 19	Riverside, City of	121.2		
1744	3601431	1S4W27H01S	Stewart 20	Riverside, City of	115.4	150.0	-34.6
1767	3601478	1S4W22B03S	Thorn 10	Riverside, City of			
1683	3601240	1S4W22H04S	Warren 1	Riverside, City of			
1554	3600787	1S4W23A02S	26-1	Riverside, City Of-Gage Canal	167.0	181.0	-14.0
2291	229101	1S2W07B01S	SBVWCD #1	San Bernardino Valley Water Cons. Dist.	205.5	247.1	-41.6
2290	229001	1S2W07K01S	SBVWCD #2	San Bernardino Valley Water Cons. Dist.	166.9	222.5	-55.6
2286	228601	1S3W12J01S	SBVWCD #3	San Bernardino Valley Water Cons. Dist.	157.5	227.2	-69.7
2288	228801	1S3W11H01S	SBVWCD #4	San Bernardino Valley Water Cons. Dist.	133.1	175.6	-42.5
1525	3600725	1N4W34G01S	17th & Sierra Way #2	San Bernardino, City of			
1517	3600717	1N4W32D03S	19th Street No. 1	San Bernardino, City of	308.3	315.0	-6.7
1520	3600720	1N4W27M02S	27th Street Well	San Bernardino, City of	270.4	273.2	-2.8
1519	3600719	1N4W27G01S	30th & Mtn. View	San Bernardino, City of	305.7	305.3	0.4
1979	3602081	1N4W27B01S	31st & Mtn. View	San Bernardino, City of	301.3	310.6	-9.3
2066	3602422	1S4W02K08S	Antil Well #6	San Bernardino, City of	161.4	169.7	-8.3
2062	3602400	1N4W32N01S	Baseline Well	San Bernardino, City of	290.0	312.0	-22.0
1510	3600710	2N5W19K02S	Cajon Canyon Well	San Bernardino, City of	69.9	111.2	-41.3
1910	3601844	1N5W03H02S	Cajon Well #2	San Bernardino, City of	167.2	212.6	-45.4
2115	3602821	1N5W03A02S	Cajon Well #3	San Bernardino, City of	170.4	218.0	-47.6
2008	3602206	1N4W06H02S	Devil Canyon #3	San Bernardino, City of	23.3	27.5	-4.2
2007	3602205	1N4W06H01S	Devil Canyon #4	San Bernardino, City of	29.7	33.4	-3.7
3139	G363790	01N/04W-32P--S	EPA EXTRAC WELL 112	San Bernardino, City of		474.9	
1537	3600737	1S4W10N06S	Mill & D	San Bernardino, City of	96.3	99.5	-3.2
1514	3600714	1N4W16E01S	Newmark #1	San Bernardino, City of	158.0	162.7	-4.7
1516	3600716	1N4W16E03S	Newmark #3	San Bernardino, City of		159.8	
1647	3601115	1N4W26P03S	Perris Hill #5	San Bernardino, City of	253.2	249.1	4.1
		01S/04W-22C	#21,Wastewater N MW #1	San Bernardino, City of / shallow wells			
2448	9900045	1S4W23H	#52 Brier/Gould/Tippecanoe	San Bernardino, City of / shallow wells			
1537	3600737	01S/04W-10N	#62, Mill & "D"	San Bernardino, City of / shallow wells			
1936	3601944	1N5W23Q01S	2/Lower 7	West Valley Water District	200.0	287.0	-87.0
1419	3600305	1N5W25E01S	5A/Lower 5	West Valley Water District	206.0	265.0	-59.0

Annual Change in Storage for Bunker Hill Basin

Fall 2012 to Fall 2013

Sub-area	[1] Annual Change in Water Level 2013 [ft]	[2] Area [acres]	[3] Storativity (*S*)	[4] Annual Change in Storage** [acre-ft]
Bunker Hill I - Northeast of 215 Freeway	-25.1	7,795	0.11	**-21,492**
Bunker Hill I - Southwest of 215 Freeway	-18.7	11,714	0.09	**-19,679**
Bunker Hill II - West of Mentone Fault	-19.7	35,206	0.06	**-41,694**
Bunker Hill II - East of Mentone Fault, North	-27.2	8,584	0.13	**-30,336**
Bunker Hill II - East of Mentone Fault, South	-2.4	2,507	0.13	**-797**
Lytle Basin - Northwest of Barrier J	0.0	1,924	0.13	**0**
Lytle Basin - Southeast of Barrier J	-30.4	5,237	0.07	**-11,144**
Pressure Zone - North of Santa Ana Wash	-15.8	11,920	0.02	**-3,755**
Pressure Zone - Santa Ana Wash	-7.8	6,686	0.02	**-1,048**
			Total =	**-129,945**

[1] Based on average changes in water level within each Sub-area

[2] Estimated using GIS

[3] Based on data from Hardt and Hutchinson (1980).

S, storativity: The amount of water stored or released per unit area of aquifer given unit head change.

[4] = [1] x [2] x [3]

*A positive sign denotes an increase in water level and a negative sign represents a decline in water level.

Accumulated Change in Storage for Bunker Hill Basin

1989 to 2013 (Based on "Zero Year" of 1993)

Year	Accumulated Storage [acre-ft]
1989	-58,000
1990	-170,700
1991	-196,000
1992	-191,000
1993	0
1994	-50,000
1995	41,100
1996	-43,100
1997	-75,500
1998	40,400
1999	-85,700
2000	-131,100
2001	-212,200
2002	-301,500
2003	-338,800
2004	-406,900
2005	-183,100
2006	-245,500
2007	-359,400
2008	-362,000
2009	-397,600
2010	-340,623
2011	-224,603
2012	-314,377
2013	**-444,322**

Note: A negative sign indicates a decline in storage and a positive sign represents an increase in storage.

Production for Sub-basins of Bunker Hill Basin

Preceding Water Year (July 2012 to June 2013)

Sub-area	Production July 2012 to June 2013 [acre-ft][2]
Bunker Hill I - Northeast of Interstate 215	7,251
Bunker Hill I - Southwest of Interstate 215	14,823
Bunker Hill II - West of Mentone Fault	44,579
Bunker Hill II - East of Mentone Fault, North	4,865
Bunker Hill II - East of Mentone Fault, South	2,176
Lytle Basin - Northwest of Barrier J	296
Lytle Basin - Southeast of Barrier J	7,598
Pressure Zone - North of Santa Ana Wash	56,131
Pressure Zone - Santa Ana Wash	44,674
Total	**182,393**

Notes: 207 Wells Used in these Calculations

1 - Refer to Appendix C for Well Values Compiled for Estimate.

2 - Estimated for Water Year July 2012-June 2013 production.

Data Sources: 25 Primary Water Purveyors (excluding Fontana Union),
as well as San Bernardino Watermaster, and SBVMWD.

Estimates of Percentage of Normal Precipitation for Previous Water Year

July 2012 to June 2013

	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]
	July to June	**July to June**	**Season - July to December**			**Season - January to June**			**Jul. 2012 to Jun. 2013**
Station	**Historic Average Annual**	**2012-2013**	**Historic Average**	**Sum Jul 2012 to Dec 2012**	**% of Normal**	**Historic Average**	**Sum Jan 2013 to Jun 2013**	**% of Normal**	**Water Year % of Normal**
	[inches]	**[inches]**	**[inches]**	**[inches]**	**[%]**	**[inches]**	**[inches]**	**[%]**	**[%]**
Big Bear Dam	35.01	20.28	11.61	10.76	93%	23.40	9.52	41%	58%
Devore CDF	27.33	13.99	8.47	8.52	101%	18.86	5.47	29%	51%
Camp Angelus	27.89	18.76	9.60	9.89	103%	18.29	8.87	49%	67%
Lake Arrowhead	40.15	33.00	13.04	12.80	98%	27.10	20.20	75%	82%
Mentone CDF	12.51	7.55	3.86	4.24	110%	8.65	3.31	38%	60%
Redlands Country Club	13.98	8.25	4.25	3.89	91%	9.73	4.36	45%	59%
San Bernardino County Hospital	15.85	9.29	4.95	5.58	113%	10.89	3.71	34%	59%
Santa Ana Pumphouse #3	16.84	9.39	5.43	4.55	84%	11.41	4.84	42%	56%
Yucaipa CDF	15.86	11.69	4.94	5.45	110%	10.93	6.24	57%	74%
Avg (in) =	**22.83**	**14.69**		**Average = 100.3%**			**Average = 45.5%**		
								2012-13 Average = 62.9%	

[1], [4]: Based on data provided by San Bernardino County Department of Transportation/Flood Control

[3] = ([2] / [1]) x 100

[5] = [0] - [2]

[6] = ([5] / [4]) x 100

[7] =(([2] + [5]) / ([1] + [4])) x 100

Average Annual Change in Storage for Bunker Hill Basin

Fall 2003 to Fall 2013

(The Immediate Past 10 Water Years)

Sub-area	[1] Average Change in 10 Years in Water Level* [ft]	[2] Area [acres]	[3] Storativity (*S*)	[4] Average Annual Change in Storage** [acre-ft]
Bunker Hill I - Southwest of 215 Freeway	-2.05	11,714	0.09	-2,109
Bunker Hill I - Northeast of 215 Freeway	-3.51	7,795	0.11	-3,009
Bunker Hill II - West of Mentone Fault	-6.00	35,206	0.06	-12,471
Bunker Hill II - East of Mentone Fault	-2.19	11,091	0.13	-3,155
Lytle Basin - Southeast of Barrier J	26.63	5,237	0.07	9,761
Lytle Basin - Northwest of Barrier J	-0.92	1,924	0.13	-229
Pressure Zone - North of Santa Ana Wash	16.61	11,920	0.02	3,959
Pressure Zone - Santa Ana Wash	-6.07	6,686	0.02	-812

Total = -8,065

[1] Based on average annual changes in water level within each Sub-area over last 10 years.

[2] Estimated using GIS.

[3] Based on data from Hardt and Hutchinson (1980).

S storativity: The amount of water stored or released per unit area of aquifer given unit head change.

[4] = [1] x [2] x [3]

*A positive sign denotes an increase in water level and a negative sign represents a decline in water level.

Summary of Surface Distribution Water for Bunker Hill Basin

1986 to 2013

Streamflow Diversions	1987 [acre-ft]	1988 [acre-ft]	1989 [acre-ft]	1990 [acre-ft]	1991 [acre-ft]	1992 [acre-ft]	1993 [acre-ft]	1994 [acre-ft]	1995 [acre-ft]	1996 [acre-ft]	1997 [acre-ft]	1998 [acre-ft]	1999 [acre-ft]	2000 [acre-ft]
Lytle Creek														
Fontana Union WC	2,725	2,991	2,245	204	1,633	12,980	7,860	12,270	10,000	10,100				
Mount Vernon WC	724	724	724	724	724	724	1,143	102	0	0	0	0	312	786
Rialto, City of	539	1,111	1,005	792	1,014	743	193	843	44	1,070	393	896	1,461	NA
San Bernardino, City of	1,448	1,448	1,448	1,448	1,448	1,448	520		2,400	2,400	0	0	0	0
West Valley Water District	3,686	3,696	3,696	2,554	3,701	3,696	3,696	3,697	3,696	3,686	4,079	3,696	3,408	3,047
Subtotal	**9,122**	**9,970**	**9,118**	**5,722**	**8,520**	**19,591**	**13,412**	**16,912**	**16,140**	**17,256**	**4,472**	**4,592**	**5,181**	**3,833**
Mill Creek														
Redlands, City of	11,178	7,731	8,285	6,794	11,109	14,559	19,086	14,505	9,786	12,250	10,250	11,224	11,951	8,852
SBVWCD Mill Creek Spreading														
SBVWCD-MC-DWR														
Subtotal	**11,178**	**7,731**	**8,285**	**6,794**	**11,109**	**14,559**	**19,086**	**14,505**	**9,786**	**12,250**	**10,250**	**11,224**	**11,951**	**8,852**
Bunker Hill Creeks														
Arrowhead Water & Power West Twin Crk														
Arrowhead Water & Power East Twin Crk														
Devore Water Company Kimbark Lower Cajon														
Subtotal	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Santa Ana River														
Bear Valley Mutual WC	16,373	14,170	14,785	11,244	20,651	26,014	42,079	23,812	30,794	38,252	31,479	36,632	30,245	29,498
Redlands Water Co	961	963	890	577							760			
SBVWCD SAR Spreading														
SBVWCD-DWR-SAR														
Subtotal	**17,334**	**15,133**	**15,675**	**11,821**	**20,651**	**26,014**	**42,079**	**23,812**	**30,794**	**38,252**	**32,239**	**36,632**	**30,245**	**29,498**

Streamflow Diversions	2001 [acre-ft]	2002 [acre-ft]	2003 [acre-ft]	2004 [acre-ft]	2005 [acre-ft]	2006 [acre-ft]	2007 [acre-ft]	2008 [acre-ft]	2009 [acre-ft]	2010 [acre-ft]	2011 [acre-ft]	2012 [acre-ft]	2013 [acre-ft]	Avg. [acre-ft]
Lytle Creek														
Fontana Union WC							8,209	7,336	5,050	*5,000*	6027	6027	5424.3	6,240
Mount Vernon WC	778	975	1,442	754	70	250	437	927	1,132	167	685	578	520	570
Rialto, City of	1,305	1,143	726	1,707	1,209	1,448	1,160	1165.00	1,135	*1,000*	1,148	1,319	1070	986
San Bernardino, City of	0	0	0	580	5	254	483	498	*450*	*450*	757	757	681.3	728
West Valley Water District	3,175	2,573	2,380	4,710	2,079	3,081	NA	3,369	*2,435*	*3,322*	3382	2954	2369	3,302
Subtotal	**5,258**	**4,691**	**4,548**	**7,751**	**3,363**	**5,033**	**10,289**	**13,295**	**10,202**	**9,939**	**11,999**	**11,635**	**10,065**	**11,827**
Mill Creek														
Redlands, City of	9,496	5,867	12,541	10,168	12,574	15,409	9,607	12,332	7,785	10,076	13,492	10,353	9317.7	10,984
SBVWCD MC					29,138	9,510	1,531	3,810	4,450	8,891	16,185	4,666	1,734	8,879
SBVWCD-MC-DWR					0	0	0	431	555	831	1,434	0	515	418
Subtotal	**9,496**	**5,867**	**12,541**	**10,168**	**41,712**	**24,919**	**11,138**	**16,573**	**12,790**	**19,798**	**31,111**	**15,019**	**11,567**	**20,282**
Bunker Hill Creeks														
Arrowhead Water & Power West Twin Crk				50	50	50	50	40	*40*	*40*	46	46	41.4	45
Arrowhead Water & Power East Twin Crk				2,500	1,750	1,700	1,725	3	*0*	*0*	1097	1097	987.3	1,086
Devore Water Company Kimbark				29	97	80	62	68	*68*	*68*	0	0	0	47
Subtotal	**0**	**0**	**0**	**2,579**	**1,897**	**1,830**	**1,837**	**111**	**108**	**108**	**1,143**	**1,143**	**1,029**	**1,178**
Santa Ana River														
Bear Valley Mutual WC	26,301	23,458	12,633	11,227	12,516	17,689	11,560	13,519	7,303	*7,000*	15,445	17,218	5,923	20,290
Redlands Water Co				588	981	1,044	884	625	654	*629*	739	816	734	790
SBVWCD SAR Spreading					27,841	14,476	4,002	17,550	8,456	21,662	36,801	9,073	5,519	16,153
SBVWCD-DWR-SAR					0	5,855	1,993	0	981	1,115	1,511	441	169	1,341
Subtotal	**26,301**	**23,458**	**12,633**	**11,815**	**41,338**	**39,064**	**18,439**	**31,694**	**17,394**	**30,406**	**54,496**	**27,548**	**12,345**	**38,573**

Assumed as average and are provisional data.

Total = **71,861**

2013 Total = 35,006

Source: Calendar year totals from Western Municipal Water District