# Engineering Investigation of the Bunker Hill Basin 2014–2015

## Prepared By:

SBV WATER CONSERVATION DISTRICT
OUR NAME IS OUR MISSION

February 4, 2016

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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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# 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 2014 to Fall 2015);

***Task 2.*** Accumulated change in storage of the Bunker Hill Basin as of the last day of the preceding water year (June 30, 2015);

***Task 3.*** Total groundwater production from the Bunker Hill Basin for the preceding water year (July 1, 2014 - June 30, 2015);

***Task 4.*** Estimate of the annual change in the Bunker Hill Basin storage for the current water year (July 1, 2015 - June 30, 2016);

***Task 5.*** Estimate of the annual change in the Bunker Hill Basin storage for the ensuing water year (July 1, 2016 - June 30, 2017);

***Task 6.*** Average annual change in Bunker Hill Basin storage for the immediate past ten water years (2005 - 2015);

***Task 7.*** Estimated amount of agricultural water and other than agricultural water to be withdrawn from the groundwater supplies of the District for the ensuing water year (July 1, 2016 - June 30, 2017);

***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, 2016 - June 30, 2017); 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, 2016 - June 30, 2017).

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 67% of normal for the period October 1, 2014 to September 31, 2015. The report uses production and water level data from more than 200 wells in the basin.

The required findings for the 2016 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 2015 Engineering Investigation

***Task 1.*** Annual change in storage for the Bunker Hill Basin for the preceding water year (July 1, 2014 to June 30, 2015 groundwater levels)

Change in storage between Fall 2014 and Fall 2015

**-45,252 acre-ft (decrease)**

**The amount of water stored in the Basin decreased by 45,252 acre-ft between 2014 and 2015.**

***Task 2.*** Accumulated change in storage of the Bunker Hill Basin as of the last day of the preceding water year (2015)

Accumulated change in storage between July 1993 and June 2015.[1]

**- 581,129 acre-ft (decrease)**

**The amount in storage in the Summer of 2015 is 581,129 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, 2014 - June 30, 2015)

**169,444 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, 2015 - June 30, 2016)

**-84,647 acre-ft (decrease)**

**The amount of water in the Basin is estimated to decrease by 84,647 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, 2016 - June 30, 2017)

**2,701 acre-ft (increase)**

**The amount of water in the Basin is estimated to increase by 2,701 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 (2005-2015) shows a decrease.

**-36,299 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, 2016 - June 30, 2017)

Estimated amount of agricultural water withdrawn from the groundwater supplies within the District boundary for the ensuing water year (July 1, 2016 - June 30, 2017)

**11,124 acre-ft**

Estimated amount of other than agricultural water withdrawn from the groundwater supplies of the District for the ensuing water year (July 1, 2016 - June 30, 2017)

**103,548 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, 2016 - June 30, 2017)

Estimated amount of water necessary for surface distribution for the ensuing water year (July 1, 2016 - June 30, 2017) for the Bunker Hill Basin

**66,338 acre-ft**

Estimated amount of water necessary for surface distribution for the ensuing water year (July 1, 2016 - June 30, 2017) within the District boundary

**53,704 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, 2016 - June 30, 2017)

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, 2016 - June 30, 2017)

**144,425 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, 2016 - June 30, 2017)

**111,847 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 2015-2016 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 limited availability of imported water the District has not purchased water this year.

**Based on the results of the 2016 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 581,129 acre-feet below the level which is considered full for purposes of this investigation. This value is significantly more than the 2015 report due to lower local rainfall and recharge rates.

- During the ensuing water year (July 1, 2016 - June 30, 2017), the Bunker Hill Basin could be recharged, with up to 810,200 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 196,800 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 2016-2017 and revise if needed.
- In 2015 the District Board of Directors approved an Engineering design to improve the sediment handling capabilities of the Mill Creek Diversion Structure. Operating and capital funds will be used to improve the structure.
- In 2015 the District approved an MOU which would develop a groundwater sustainability council for the basins.

# 2.0 Introduction

The 2015-2016 Engineering Investigation (EI) process was very similar to the previous 2014-2015 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 2015. 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 2014 to Fall 2015);

***Task 2.*** Accumulated change in storage of the Bunker Hill Basin as of the last day of the preceding water year (June 30, 2015);

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***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, 2016 - June 30, 2017).

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, 2014 through June 30, 2015.

- Current Water Year - As per the California Water Code, the current water year is the period July 1, 2015 through June 30, 2016.

♦ Ensuing Water Year - As per the California Water Code, the ensuing water year is the period July 1, 2016 through June 30, 2017.

### *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 2014 and Fall 2015 groundwater elevations and preceding water year (July 2014 to June 2015) production were obtained from the primary water purveyors in the Bunker Hill Basin including:

- City of Colton
- City of Loma Linda
- City of Redlands
- City of Riverside
- City of San Bernardino
- East Valley Water District
- Elsinore Valley Municipal Water District/Meeks and Daley Water Company
- Gage Canal Company
- Riverside – Highland Water Company
- Southern California Edison
- San Bernardino Valley Municipal Water District
- 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 2014 and Fall 2015 Groundwater Elevation Contours*

The District, the Western Municipal Water District, and the primary water purveyors in the Bunker Hill Basin provided Fall 2014 and 2015 water level data. Static groundwater elevations for wells throughout the Bunker Hill Basin are compiled in **Appendix A**. These elevations were plotted for 299 wells using a Geographic Information System (GIS) are plotted in **Figures 5 & 6** for Fall 2014 and Fall 2015. The water elevation values were used to derive an interpolated surface for the extent of the Bunker Hill Basin. For purposes of comparison, Fall 2014 and Fall 2015 static groundwater elevation surface contours are provided in **Figures 5** & **6** respectively.

# 4.0 *Task 1* - Annual Change in Storage (Fall 2014 to Fall 2015)

### *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 2015 groundwater level elevation data were compared with the same from Fall 2014.

Measurements for 299 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 2014 to Fall 2015 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*

$\Delta h_i$ = 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 2014 and Fall 2015 decreased a change of -45,252 acre-ft.

# 5.0 ***Task 2*** - Accumulated Change in Storage from Fall 1993 to Fall 2015

For purposes of this report, the accumulated change in storage as of the last day of the preceding water year (July 30, 2015) 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 2015.[2] The accumulated change in storage as of June 30, 2015 was determined by subtracting the change in storage for the preceding water year (July 1, 2014 to June 30, 2015 of -45,252 determined in Section 4.4, from the accumulated change in storage as of June 30, 2014 (-314,377). The result of this calculation is an accumulated change in storage for the Bunker Hill Basin of -581,129 acre-ft.

**Table 4** summarizes the accumulated change in storage of the Bunker Hill Basin for the period 1989 to 2015 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, 2014 to June 30, 2015)

Production data for the preceding water year (July 1, 2014 to June 30, 2015) 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 2014 through June 2015. As summarized on the last page of the Appendix, groundwater production from the Bunker Hill Basin for the preceding water year was approximately 169,444 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 2014 through June 2015 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, 2015 to June 30, 2016)

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**.

$$Q_{\text{Annual } \Delta \text{ storage}} = -116{,}786.64 + 7{,}850 * Q_{prec} - 0.274 * Q_{prod}$$

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, 2014 and December 31, 2014, precipitation was 90.7 percent of normal for the eight stations with data. Remainder of the water year, January 1 to June 30, 2015, the rainfall averaged 32.5 percent of the long term average. Annually, precipitation for the 2014-2015 water year averaged 50.8 percent. For purposes of this report, it was assumed that precipitation for the current water year (July 1, 2015 to June 30, 2016) would be 11.41 inches, 50.8 percent of the 22.68 inch average for the 2014 to 2015 season. The precipitation for the ensuing water year (July 1, 2016 to June 30, 2017) was estimated, as 100 percent of normal, or 22.68 inches of rainfall.

Based on these assumptions, the estimated production for the current water year will be approximately 212,546 acre-ft as shown in **Figure 10**. Using this result in **Figure 9** an estimated change in storage for the current water year (July 2015 to June 2016) of -84,647 acre-ft was determined.

## 8.0 *Task 5* - Estimate of the Annual Change in Storage for the Ensuing Water Year (July 1, 2016 to June 30, 2017)

The annual change in storage for the ensuing water year (July 1, 2016 to June 30, 2017) 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 22.68 inches. Based on this assumption, the estimated production for the ensuing water year will be approximately 213,465 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, 2016 to June 30, 2017) is 2,701 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 2005 to June 2015) 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 -36,229 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, 2016 to June 30, 2017)

The estimated amount of agricultural water and other than agricultural water to be withdrawn within the District for the ensuing water year (July 1, 2016 to June 30, 2017) was based on the following equations:

$$Q_{agr(14-15)} = Q_{agr(14-15)} \times \left[\left(Q_{total(16-17)} - Q_{surf(16-17)}\right) / \left(Q_{total(14-15)} - Q_{surf(14-15)}\right)\right]$$

and

$$Q_{non-agr(14-15)} = Q_{non-agr(14-15)} \times \left[\left(Q_{total(16-17)} - Q_{surf(16-17)}\right) / \left(Q_{total(14-15)} - Q_{surf(14-15)}\right)\right]$$

where:

$Q_{agr(16-17)}$ = Agricultural use within the District for the ensuing water year, acre-ft

$Q_{agr(14-15)}$ = Agricultural use within the District for the preceding water year, acre-ft (Appendix C)

$Q_{total(16-17)}$ = Production (including surface diversion) from the Bunker Hill Basin for the ensuing water year, acre-ft (Figure 14)

$Q_{total(14-15)}$ = Production (including surface diversion) from the Bunker Hill Basin for the preceding water year, acre-ft (Appendix C)

$Q_{non-agr(16-17)}$ = All other uses within the District for the ensuing water year, acre-ft

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

$Q_{surf(16-17)}$ = Surface diversions from the Bunker Hill Basin for the ensuing water year, acre-ft (Table 8)

$Q_{surf(14-15)}$ = 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, 2014 to June 30, 2015) are provided in **Appendix C**. For the period July 1, 2014 through June 30, 2015 approximately 9,036 acre-ft of groundwater was produced for agricultural applications within the District boundary. For the same period, approximately 84,013 acre-ft of groundwater was produced for all other uses within the District boundary. Using the equations presented above with the following values inserted:

$Q_{agr(14-15)}$ = 9,036 acre-ft (Appendix C)

$Q_{total(16-17)}$ = 279,803 acre-ft (Figure 13)

$Q_{total(14-15)}$ = 201,863 acre-ft (Appendix C)

$Q_{non-agr(14-15)}$ = 84,013 acre-ft (Appendix C)

$Q_{surf(16-17)}$ = 66,337 acre-ft (Task 8)

$Q_{surf(14-15)}$ =28,463 acre-ft (Table 8)

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

$Q_{total(16-17)}$ = 213,465 + 66,338 = 279,803 acre-ft

$Q_{agr(16-17)}$ = 9,036 x [(279,803 – 66,337) / (201,863 – 28,463)]

= 11,124 acre-ft

$Q_{non-agr(16-17)}$ = 84,013 x [(279,803 – 66,337) / (201,863 – 28,463)]

= 103,424 acre-ft

$Q_{agr(16-17)}$ = 11,124 acre-ft

$Q_{non-agr(16-17)}$ = 103,424 acre-ft

$Q_{Dist(16-17)}$ = 114,548 acre-ft

By summing these two results, it is estimated that 114,548 acre-feet of groundwater will be withdrawn within the District for the ensuing water year (July 1, 2016 to June 30, 2017). **Appendix C** shows the Agriculture and Non-Agriculture trends for the District by sub-basin using approximately 135 wells within the District Boundary reporting type of use. The long term average for agricultural usage within the Distiricт is between 14,000 ac-ft and 15,000 ac-ft. The long term average for non-agricultural uses within the District is between 65,000 ac-ft and 75,000 ac-ft.

## 11.0 *Task 8* - Estimated Amount of Water for Surface Distribution for the Ensuing Water Year (July 1, 2016 to June 30, 2017)

The amount of water for surface distribution for the ensuing water year (July 1, 2016 to June 30, 2017) was estimated based on the average surface diversions for the Santa Ana River, Mill Creek, and Lytle Creek for the period 1987 to 2015.

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 2014 were 35,621; 1,130; 18,083; and 11,503 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, 2016 to June 30, 2017) is found by summing the diversions as follows:

Bunker Hill Surface Distribution = 11,503 + 18,083 + 1,130 + 35,621 = 66,338 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, 2016 to June 30, 2017) is the sum of the Santa Ana River and Mill Creek distributions.

District Surface Distribution = 35,621 + 18,083= 53,704 acre-ft

## 12.0 *Task 9* - Estimated Amount of Water for Replenishment of the Groundwater Supplies for the Ensuing Water Year (July 1, 2016 to June 30, 2017)

The amount of water necessary for replenishment of the groundwater supplies of the Bunker Hill Basin for the ensuing water year (July 1, 2016 to June 30, 2017) 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, 2016 to June 30, 2017) were estimated at approximately 213,465 acre-feet (from **Figure 13**) and 66,338 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 2,701 acre-feet. Therefore, the amount of water necessary for replenishment of the groundwater supplies of the Bunker Hill Basin is estimated as follows:

Replenishment = 213,465 -66,338 -2,701 = 144,425 acre-ft

The amount of water necessary for replenishment of the District's groundwater supplies for the ensuing water year (July 1, 2016 to June 30, 2017) 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 114,548 acre-ft (from Section 10.0) and 53,704 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 2,701 acre-ft. Therefore, the amount of water necessary for replenishment of the District's groundwater supplies for the ensuing water year (July 1, 2016 to June 30, 2017) is:

Replenishment = Total Production - Surface Diversions - Change in Storage
Replenishment = (114,548 + 53,704) - 53,704 - 2,701 = 111,847 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.

**Improvements and Changes to the Report:** There were no significant changes made to the Engineering Investigation report or calculation method. However, well locations were verified with the agencies that provide data and were cross checked with other reporting systems. This allowed for greater accuracy in calculations and allowed more wells to be included in the appropriate sub-basin to which they belong. It also improved the mapping accuracy as they maps had previously been based on the location of the key wells rather than all of the available data.

## *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 2015-2016 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 2015 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 581,129 acre-feet below that which is considered full for purposes of this Investigation.

- During the ensuing water year (July 1, 2016 to June 30, 2017), the Bunker Hill Basin can be recharged, from all sources, with 810,200 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 2016 – 2017, as the first increment of the new charge is not due until that time.