TECHNICAL MEMORANDUM

BUILDING A BETTER WORLD

To:	Coachella Valley Salt and Nutrient Management Plan Technical Group	**Date:**	October 8, 2014
From:	MWH	**Reference:**	10505158
Subject:	DRAFT - Technical Memorandum No. 2 Ambient Water Quality		

1 Introduction

The Coachella Valley Water District (CVWD), Coachella Water Authority (CWA), Desert Water Authority (DWA), and Indio Water Authority (IWA) have initiated the preparation of a Salt and Nutrient Management Plan (SNMP) for the Whitewater (Indio), Mission Creek, Garnet Hill, and Desert Hot Springs Groundwater Subbasins. The preparation of the plan is in response to the requirements of the California Recycled Water Policy (Policy). The first technical memorandum (TM-1) described the methodology to be used in the development of the SNMP. This technical memorandum, TM-2, summarizes the results of the ambient water quality (AWQ) analysis, a requirement to determine the assimilative capacity of a basin, based on the methodology described in TM-1.

TM-1 and TM-2 will be used to support the development of the SNMP. The SNMP will include summaries of TM-1 and TM-2; a salt and nutrient source identification; trend summary; assimilative capacity analysis; loading estimates; anti-degradation analysis; water recycling and stormwater recharge/use goals and objectives; and monitoring plans.

1.1 BACKGROUND

In February 2009, the State Water Resources Control Board (SWRCB) adopted Resolution No. 2009-0011 which established the Policy. It requires the SWRCB and the nine Regional Water Quality Control Boards (RWQCBs) to exercise the authority granted to them by the legislation to encourage the use of recycled water, consistent with state and federal water quality laws. To achieve this goal, the Policy provides direction to California’s nine RWQCBs on appropriate criteria to be used in regulating recycled water projects (SWRCB, 2009, 2013). One objective of the Policy is that salts and nutrients from all sources be managed on a basin-wide or watershed-wide basis that ensures meeting water quality objectives and protection of beneficial uses. The Policy states that the SWRCB finds the most appropriate way to address salt and nutrient issues through the development of regional salt and nutrient management plans, as opposed to establishing requirements solely on individual recycled water projects.

1.2 SALT AND NUTRIENT MANAGEMENT PLANNING AREA

The planning area for the SNMP includes most of the Coachella Valley subbasins and subareas as shown on **Figure 1-1**. Subbasins are subdivisions, or groundwater basins within the larger Coachella Valley Basin. Subareas are further subdivisions of subbasins based on geology, water quality, areas of confined ground water, and ground water divides (DWR, 1964). The study area is defined as the Coachella Valley floor and underlying groundwater basins, extending from the Riverside County boundary at the northern end, to the Salton Sea at the southeast end. The planning area is bounded on the west end by the jurisdictional boundary separating Desert Water Agency and Mission Springs Water District (MSWD) from the San Gorgonio Pass Water Agency. This location also corresponds to the boundary between the Whitewater River and the San Gorgonio Pass subbasins. The planning area is bounded to the northeast by the Little San Bernardino Mountains and at the southwest by the San Jacinto and Santa Rosa mountain ranges. This area is coincident with the planning area of the Coachella Valley Integrated Regional Water Management Plan. **Figure 1-2** also shows the management zones that comprise the Coachella Valley Groundwater Basin. Management zones are the areas determined to evaluate and manage groundwater quality within the Coachella Valley. The determination of these zones is discussed in further detail in TM-1.

1.3 SALT AND NUTRIENT MANAGEMENT PLAN DEVELOPMENT

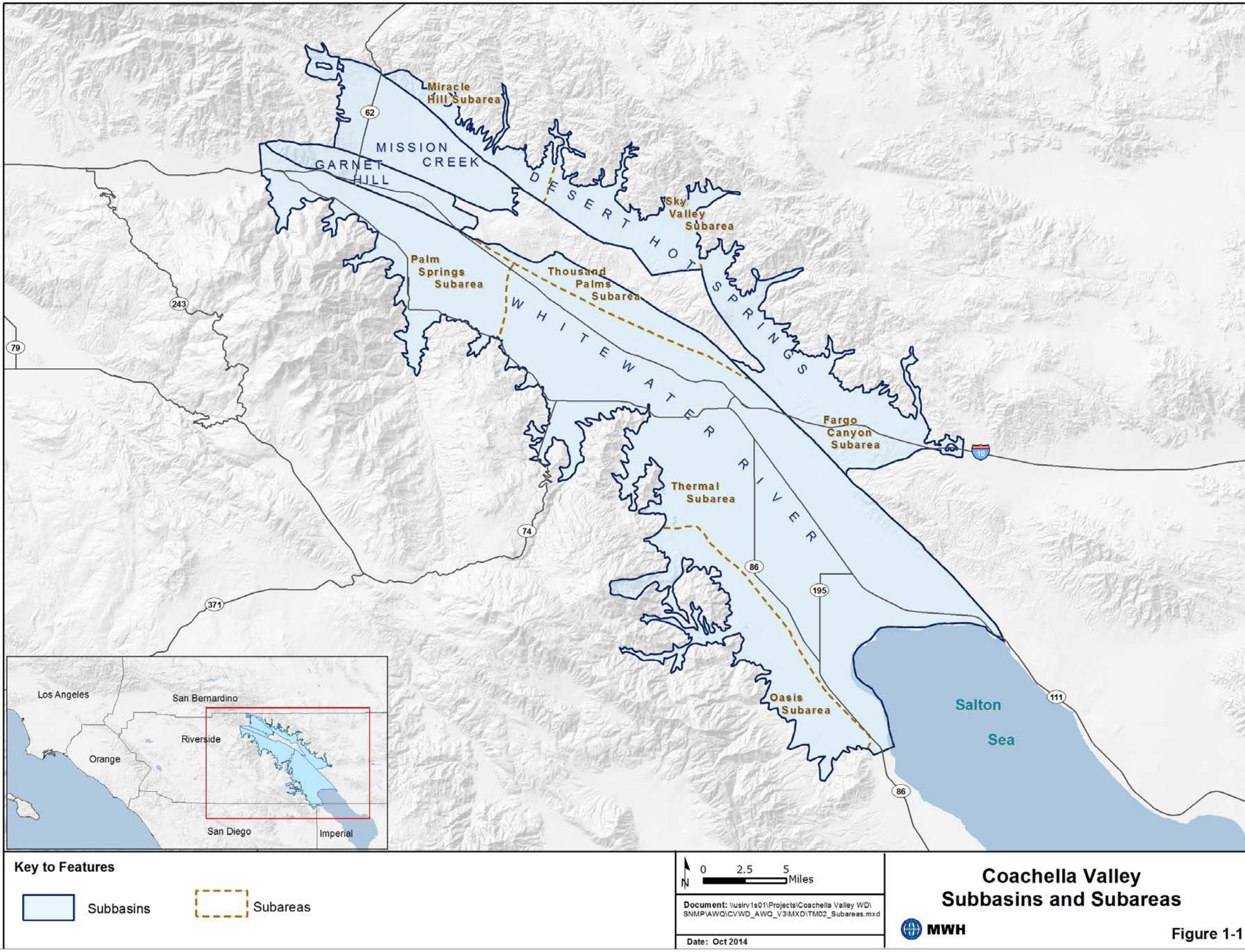
TM-2 represents the documentation of the determination of ambient water quality. The resulting analysis will be used in the preparation of the SNMP. TM-2 is organized as follows:

Section 1 – Introduction: This section provides an introduction to TM-2 and defines the role it plays in the development of the SNMP.

Section 2 – Ambient Water Quality Methods: Methods to calculate the AWQ within management zones are described.

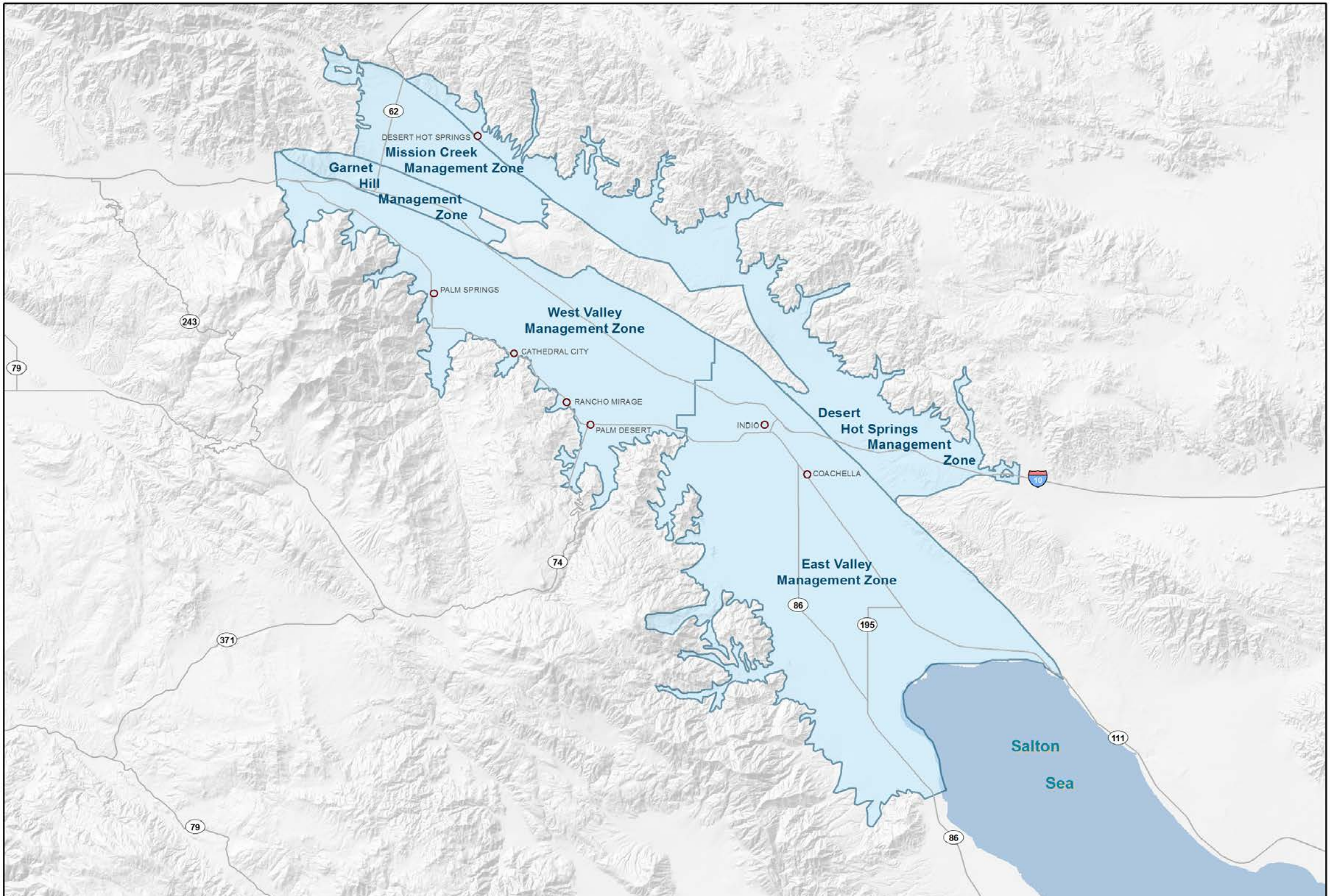
Section 3 – Ambient Water Quality Results: This section summarizes the results of AWQ determination and provides summary statistics of AWQ for each management zone.

Attachment A - Effective Porosity Approximation for the Volume Weighted Average Calculation: This section describes the method to approximate effective porosity and ranges of effective porosity for similar lithologic conditions.



Coachella Valley Subbasins and Subareas

Figure 1-1



Key to Features

City

Management Zone

Document: \\usirv1s01\Projects\Coachella Valley WD\SNMP\AWQ\CVWD_AWQ_V3\MXD\MZ_Cities.mxd

Date: Oct 2014

Coachella Valley Management Zones

MWH

Figure 1-2

2 Ambient Water Quality Methods

Ambient water quality (AWQ) is a single concentration value that is representative of the water quality within a management zone for a particular constituent and time period. If a single representative value cannot be estimated from water quality records for a management zone, a statistical range is provided. The AWQ is a prerequisite for determining basin-wide assimilative capacity. Determination of the assimilative capacity is a requirement of the Policy in order to evaluate new projects. Under the Policy, planned recycled water projects are permitted to use no more than 10 percent of the available assimilative capacity for a single project and no more than 20 percent for multiple projects; those planned projects using more assimilative capacity will require additional investigation. A 20-year baseline period from 1994 to 2013 is used for the AWQ determination. Data availability and validity may require a baseline period of 20 years in order to perform statistically meaningful calculations; even at 20-years it is difficult to perform statistically meaningful calculations in some management zones. Statistically, fewer data points results in greater uncertainty of the mean value (larger confidence interval). Most potable wells in the Coachella Valley are sampled and analyzed for TDS every three years and a larger number of wells included in the study area are not used for drinking water and are monitored even less frequently. A baseline period of 20-years is used to increase the probability of obtaining at least three sets of water quality results for most potable and non-potable wells as this is the minimum number of data points required to evaluate statistical trends.

The AWQ is determined for total dissolved solids (TDS) and nitrate for this SNMP, as these analytes are representative of salts and nutrients in the Coachella Valley. **Figure 2-1** shows the steps leading to AWQ approximation. These steps are described in greater detail in the following subsections.

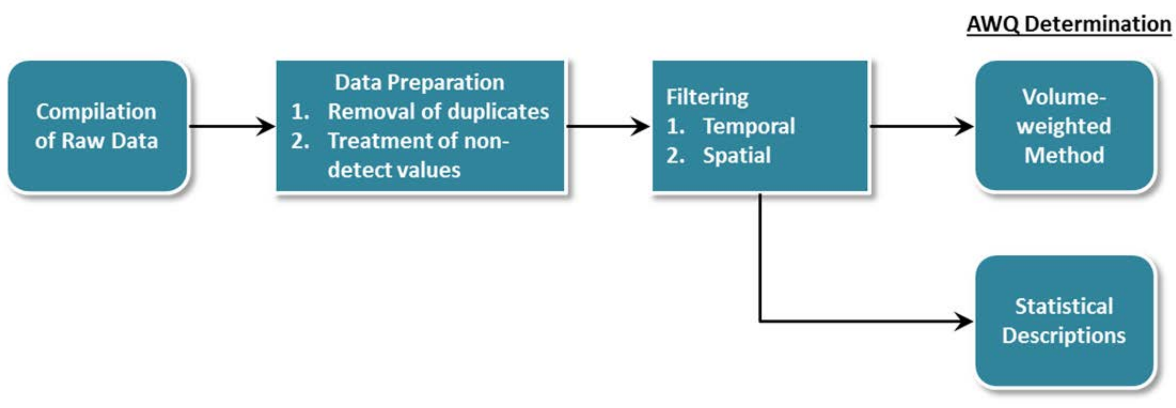


Figure 2-1
Diagram of Generalized AWQ Determination

2.1 DATA PREPARATION

Available groundwater quality data is compiled prior to the analysis of AWQ. The sources of data are presented in Section 4.2.2 – Groundwater Quality Data of TM-1. Several assumptions are made to prepare the data into a usable format for AWQ calculation.

Because groundwater quality data are obtained from a variety of sources, duplicates can occur and are removed as to not count a particular record more than once (duplicates may be the same measurement from two different databases). This is done by generating unique identifiers for each particular record that includes the well name, record date, and analyte. Those unique identifiers that occur more than once are removed such that only one record remains.

In addition, data sources may report non-detect (ND) values in several different ways. Some examples include:

- non-detect, i.e. "ND", with method detection limit;
- non-detect, i.e. "ND", with no method detection limit;
- zero value, i.e. "0"; and
- less than method detection limit, i.e. "< MDL".

For the AWQ calculation, all non-detects are represented as zero values for three reasons:

1. not all the data has the method detection limit available for each record;
2. numerical values for all results allow the calculation of summary statistics; and
3. all non-detects are treated in the same way.

This approach does have the consequence that any actual value greater than zero but less than the method detection limit are treated as a zero. If the average of an entire dataset is calculated making this substitution, the average of the censored values will be equal to or less than the true average concentration, thus introducing a bias. However, the filtering of data, as discussed in Section 2.2, will limit the effect of this bias on the AWQ calculation. This approach is consistent with the use of Aitchison's method as presented in the United States Environmental Protection Agency (EPA) guidelines – Data Quality Assessment: Statistical Methods for Practitioner (EPA, 2006) for percentages of non-detects less than 15 percent for a single well. **Table 2-1** presents all management zones percentages of non-detect values for nitrate. There are no non-detect values for TDS.

Table 2-1
Summary of Non-Detects by Management Zone

Management Zone	Percentage of Nitrate Records Listed as Non-detect
Desert Hot Springs	9
East Valley	11
Garnet Hill	1
Mission Creek	3
West Valley	2

2.2 FILTERING

Groundwater quality data is filtered temporally and spatially to generate representative groundwater quality throughout the Basin or management zone. The reason for this filtering is to eliminate biases introduced by the nature of sampling. These biases are (1) frequency bias, (2) age/type bias, and (3) location bias. Two temporal filters and one spatial filter are applied to the original dataset, hereafter referred to as the **unfiltered** dataset, to generate a **filtered** dataset on which AWQ analyses will be conducted. Note that even though a filtered dataset is used for AWQ determination, unfiltered data summaries are provided for transparency and to show the effects of filtering. Each dataset, filtered and unfiltered, has inherent uncertainties, but used together they can provide insight into the variability of groundwater quality. A review of the data and the filtering to create the filtered dataset is provided in the following sections.

2.2.1 Temporal Filter 1 – Frequency Bias

The frequency of sampling at a particular well may vary over time. For example, consider a production well that is sampled from 1994 to 2013. From 1994 to 2009, samples taken show nitrate below the maximum contaminant level (MCL) of 45 mg/L as NO_3; therefore, the well is sampled once a year. However, because the sample taken in 2010 shows a nitrate concentration above the MCL, it is decided that the well will be taken off-line and sampled weekly until the nitrate concentration drops below the MCL. The nitrate concentration continues to exceed the MCL through 2013 based on weekly samples. If all records are considered, AWQ will be skewed in the direction of poorer water quality than a time-weighted average would suggest. To address this, the median of all records for a well within a particular year is used as the yearly representative water quality, or *yearly median*; if no records exist for a particular year, no annual value is recorded. A conceptual diagram of the first temporal filter is shown on **Figure 2-2**.

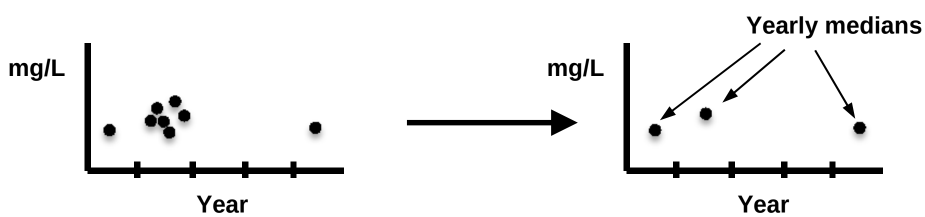


Figure 2-2
Conceptual Diagram of the First Temporal Filter

2.2.2 Temporal Filter 2 – Age/Type Bias

Over the period of record, old wells may have become inactive and new wells may have been constructed, so their particular records start and stop at different times. Additionally, datasets include multiple types of wells (e.g., production and monitoring) that are sampled at different frequencies for different purposes. For example, most water purveyors measure the TDS of their production wells every three years for compliance with drinking water regulatory requirements; whereas some monitoring wells are sampled more frequently to assess groundwater recharge operations or interactions between the Salton Sea and the groundwater basin. Without filtering, the water quality measurements from the monitoring well would overshadow those of the production well, leading to a non-representative basin water quality. To address this bias, the yearly medians for a well are aggregated and the median is computed to establish a single value to represent that well's water quality for the entire baseline period for each constituent. This value is referred to as the *baseline well concentration*. For the example above, the monitoring well and the production well would then both contribute equally to the AWQ. Because median values are used in the temporal filter, using zero values for non-detects as discussed earlier will have less consequence compared with mean values. A conceptual diagram of the first temporal filter is shown on **Figure 2-3**.

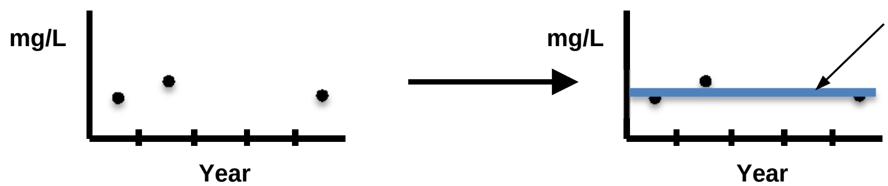


Figure 2-3
Conceptual Diagram of the Second Temporal Filter

2.2.3 Spatial Filter – Location Bias

In general, production wells are sited in areas close to the distribution system, i.e., near developed communities. Therefore, water quality data will cluster around these areas. Using all the wells in the calculation of AWQ will skew results towards the water quality around dense well zones. To address this, a 1,000 foot by 1,000 foot grid is applied to group well data within a grid cell. For continuity with previous groundwater modeling, the grid cells and layering from the Coachella Valley groundwater model (MWH, 2002) or Mission Creek groundwater model (Psomas, 2013) are used. The median baseline period concentrations for all wells in a cell are then averaged to obtain a *cell average*. If no data are available within a particular cell, no value is assigned to the cell. If screen interval data exist for wells in a particular management zone, groundwater model layers or sub-layers are used such that baseline well concentrations are averaged for a particular grid cell and layer combination to get *cell-layer averages*. A conceptual diagram of the spatial filter is shown on **Figure 2-4**.

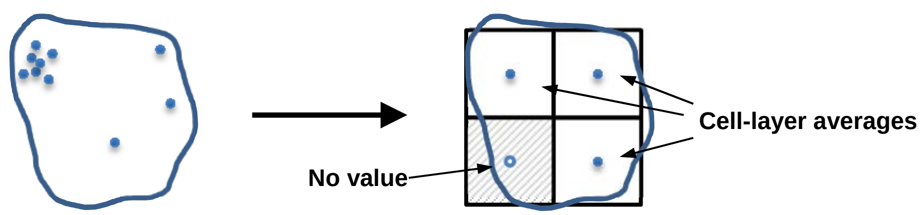


Figure 2-4
Conceptual Diagram of the Spatial Filter

2.3 METHODS TO DETERMINE AMBIENT WATER QUALITY

Two methods are used for the determination of AWQ. A statistical description of AWQ is presented for each management zone, and a volume-weighted AWQ is computed for management zones with adequate data to support the volume-weighted method. Data considered adequate for the volume-weighted method includes sufficient water quality data for wells with known depth information, aquifer thickness and effective porosity, and groundwater level.

2.3.1 Statistical Description

Statistical analyses of water quality data are performed and summarized for each management zone. The statistical descriptions are useful for management zones that lack significant well depth information or have limited water quality data, as there is not sufficient water quality and aquifer information to complete the volume-weighted method. **Table 2-2** presents definitions of the statistical analyses performed for the management zone statistical description.

Descriptive statistics are provided for both unfiltered and filtered datasets. AWQ is evaluated based on the filtered dataset; a 90 percent confidence interval on the mean filtered water quality data is used as a range for AWQ in management zones where the volume-weighted method is not appropriate.

2.3.2 Volume-weighted Method

The volume-weighted method for determination of AWQ is used when an adequate amount of data exist for a particular management zone. This method considers the volume of water in storage to assign weights to water quality within the basin.

Following data preparation and filtering, the filtered dataset is contoured, which provides inferred concentration values where no wells are present. Water quality is contoured by interpolating the filtered dataset (cell-layer averages) by the Kriging method (Matheron, 1978). The Kriging method is a widely-accepted geostatistical interpolation method that attempts to express trends suggested in the underlying data. The contours generated by this method are then refined by hand, the hand contouring considers horizontal and vertical trends, water quality from wells with no available depth information (for management zones contoured by layer) and knowledge of the underlying geology, groundwater flow direction, recharge activity, land use, and professional judgment. The final contours are the result of an iterative process with numerical interpolation and hand contouring.

Resulting cell concentrations are multiplied by the volume of water in storage in each cell, the results are totaled and then divided by the total water volume in the management zone to obtain a volume-weighted AWQ. In management zones where data availability supports layering, this process is completed at the model layer/aquifer level. A conceptual diagram of the steps involved in the volume-weighted method is shown on **Figure 2-5**.

Table 2-2
Statistical Descriptors Used to Describe Ambient Water Quality

Statistical Descriptor	Definition in this SNMP	As the Descriptor relates to: Unfiltered Data	Filtered Data
Count	The total number of data points available for a particular constituent and time period within a management zone	Number of individual lab analysis results	Number of cell-layer averages (as defined in filtering methods)
Mean	The arithmetic mean of all results, or the sum of the results divided by the count	Average of all lab results	Average of cell-layer averages
Median	The value separating the upper half of all results from the lower half	Middle value of all lab results	Middle value of cell-layer averages
Mode	The value that appears most often in a set of results	Most common lab result (if one exists)	Most common cell-layer average (if one exists)
Standard Deviation	A measure of the amount of variation or dispersion from the average; a lower standard deviation implies that the individual results are closer to the mean of the results	Variation of all lab results	Variation of cell-layer averages
Range	The lowest and highest result in the dataset	Lowest and highest lab result	Lowest and highest cell-layer average; filtered data range will always be less than or equal to the range of unfiltered data
Confidence Interval	An estimated range of values which is likely to include the mean of the population; the width of the confidence interval gives some idea about how uncertain we are about the mean; e.g., a 90 percent confidence interval has a 90 percent probability of containing the population mean	Measure of how certain the computed mean is compared to the true mean; a wider interval indicates lower certainty	Filtered confidence interval will typically be greater than the confidence interval for unfiltered data due to the reduced size of data points

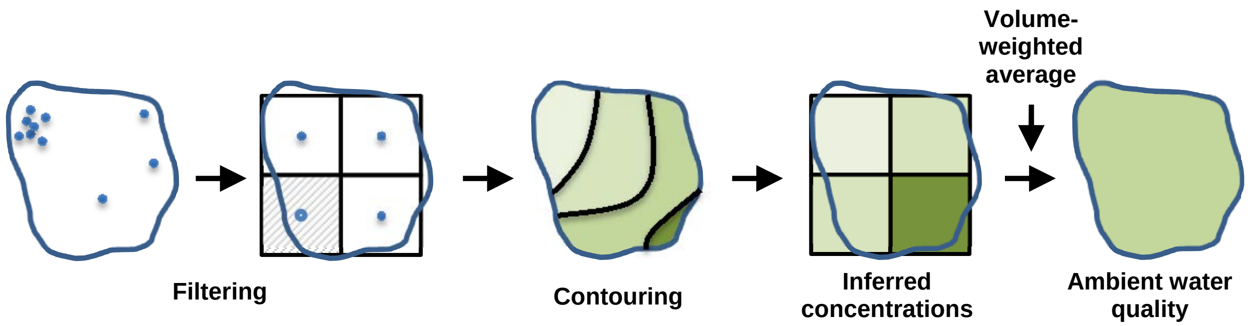


Figure 2-5
Conceptual Diagram of the Volume-weighted Method

In addition to water quality, groundwater level data is also filtered and contoured in a similar fashion. The water level contours are then used to generate a water level surface and values from the surface at the cell centers are assigned to each cell within the management zone.

To determine the volume of water in each cell volume between the water level surface and the base of the aquifer, the effective porosity for each cell-layer is needed. Total porosity is defined as the ratio of void space to the total volume of a geologic formation. The effective porosity is the portion of the void space of a porous material that is capable of transmitting (and thereby mixing) a fluid and excludes clay-bound water (water that is electrochemically attached to clay particles that does not contribute to flow). Effective porosity occurs because a fluid in a saturated porous media will not flow through all voids, but only through the voids which are interconnected. Effective porosity is typically higher than specific yield (the volume of water that can be drained by gravity). The method used to determine the effective porosity by cell-layer is summarized in **Attachment A**).

The volume of each cell combination is calculated as:

$$Vol_{i,j} = (n_e)_{i,j} \times Area_i \times (H_{sat})_{i,j} \,,$$

where i is the cell, j is the layer, n_e is the effective porosity of the cell and layer, and H_{sat} is the saturated thickness. The effective porosity is already corrected for lithostatic loading as a function of depth in the model calibration for hydraulic conductivities. **Figure 2-6** shows a conceptual representation of the cell-layers. AWQ is the total mass in all cell-layers divided by the total volume of water in storage in all cell-layers:

$$AWQ_{volume-weighted} = \frac{\sum_i \sum_j (C_{i,j} \times Vol_{i,j})}{\sum_i \sum_j Vol_{i,j}},$$

where $C_{i,j}$ is the concentration in the cell-layer. This method requires sufficient water quality data for wells with known depth information; aquifer properties such as layer thickness, effective porosity, and groundwater level; and well-distributed data in both the horizontal and vertical.

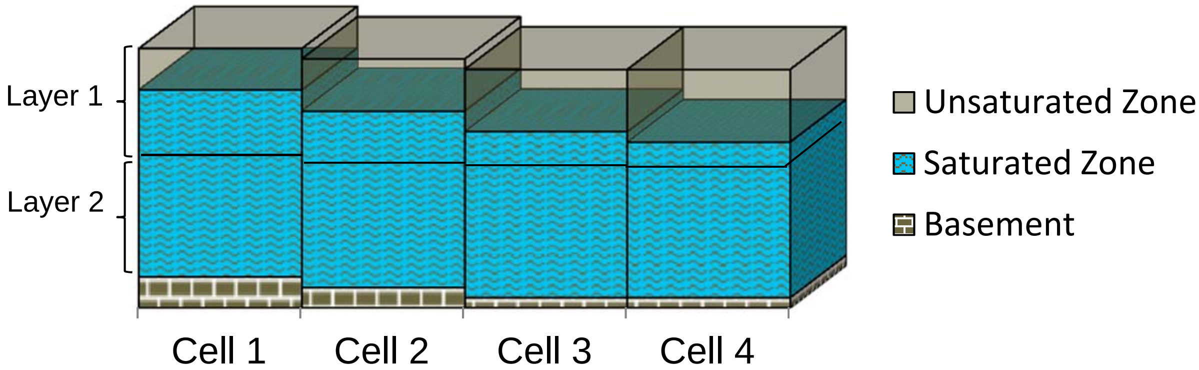


Figure 2-6
Conceptual Representation of Model Cells and Layers

3 Ambient Water Quality Results

This section summarizes the results of the AWQ determination. All analyses used water quality data for wells during the baseline period of 1994 to 2013. As discussed in TM-1, this baseline period is selected because it represents the most recent twenty-year period having water quality data. A twenty-year period is used to ensure a statistically significant sample of the historical water quality data because TDS is normally sampled once every three years.

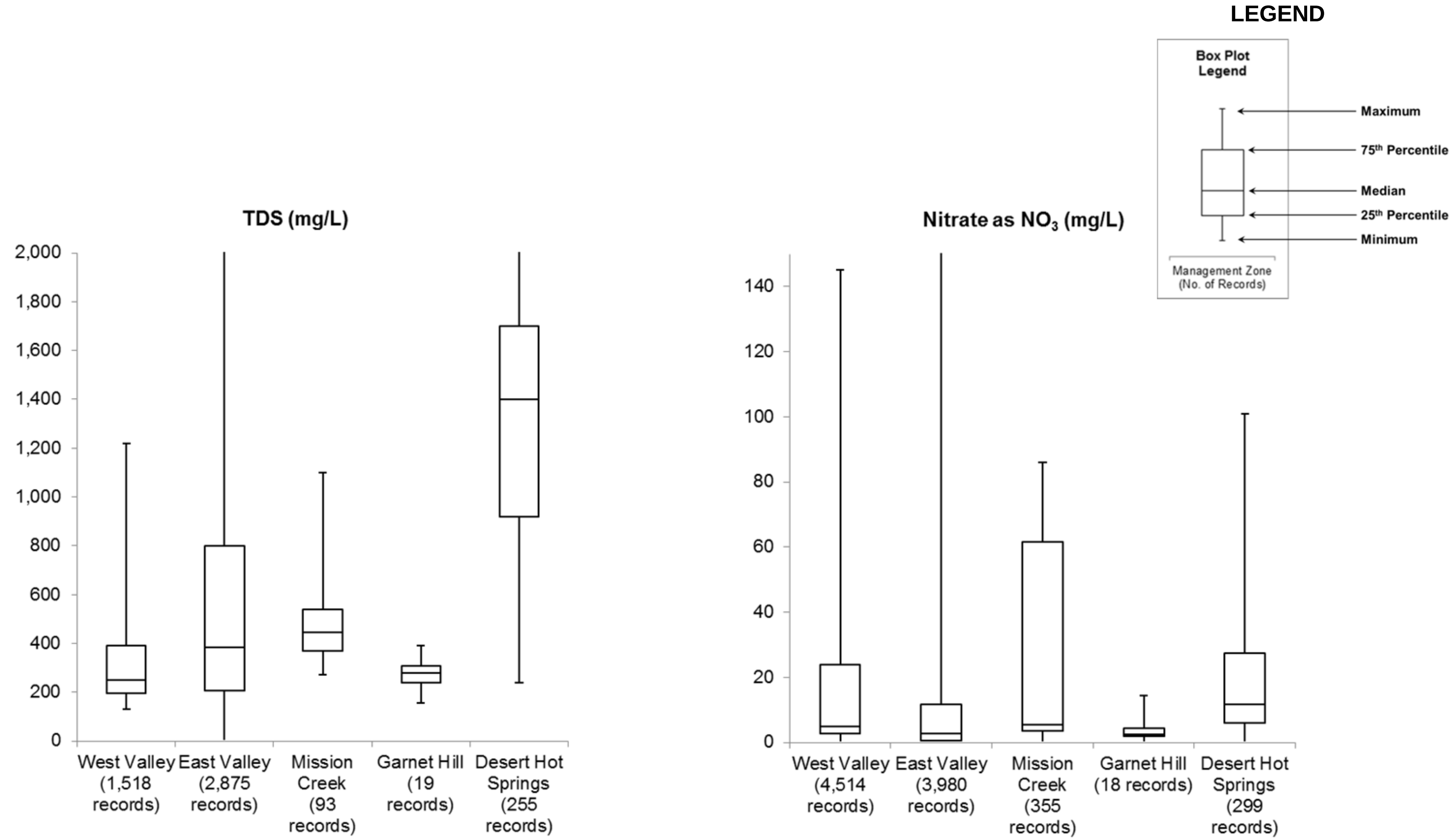
Two sets of statistical descriptions of AWQ are prepared for each management zone: the first set provides statistical descriptions of the unfiltered data within a management zone, and the second set will describe AWQ using the filtered dataset within a management zone. These two sets are presented to demonstrate the effects of the data filtering methods and to provide a deeper understanding of the AWQ. The statistical descriptors presented in this section follow from Section 2.3.1.

Box plots are shown in **Figure 3-1** to illustrate the range of water quality from the unfiltered dataset by management zone. This figure provides convenient visual summaries of the unfiltered data and shows the following:

- The median, or center, of the data (the line contained within the box)
- The range, or variation, of the data (total box height)
- The extreme values in the data (the vertical lines extending from the box)

In addition to the statistical descriptions, a volume-weighted AWQ is calculated for those management zones with adequate horizontal and vertical groundwater quality, aquifer parameter, and water level data. The AWQ for West Valley, East Valley, and Mission Creek management zones include this volume-weighted analysis.

Figure 3-1
Box Plots for of Unfiltered Data for Each Management Zone (1994-2013)



Note:
Maximum recorded TDS concentration for East Valley is 19,500 mg/L;
Maximum recorded TDS concentration for Desert Hot Springs is 2,200 mg/L.

Note:
Maximum recorded nitrate (as NO_3) concentration for East Valley is 260 mg/L;

3.1 WEST VALLEY MANAGEMENT ZONE

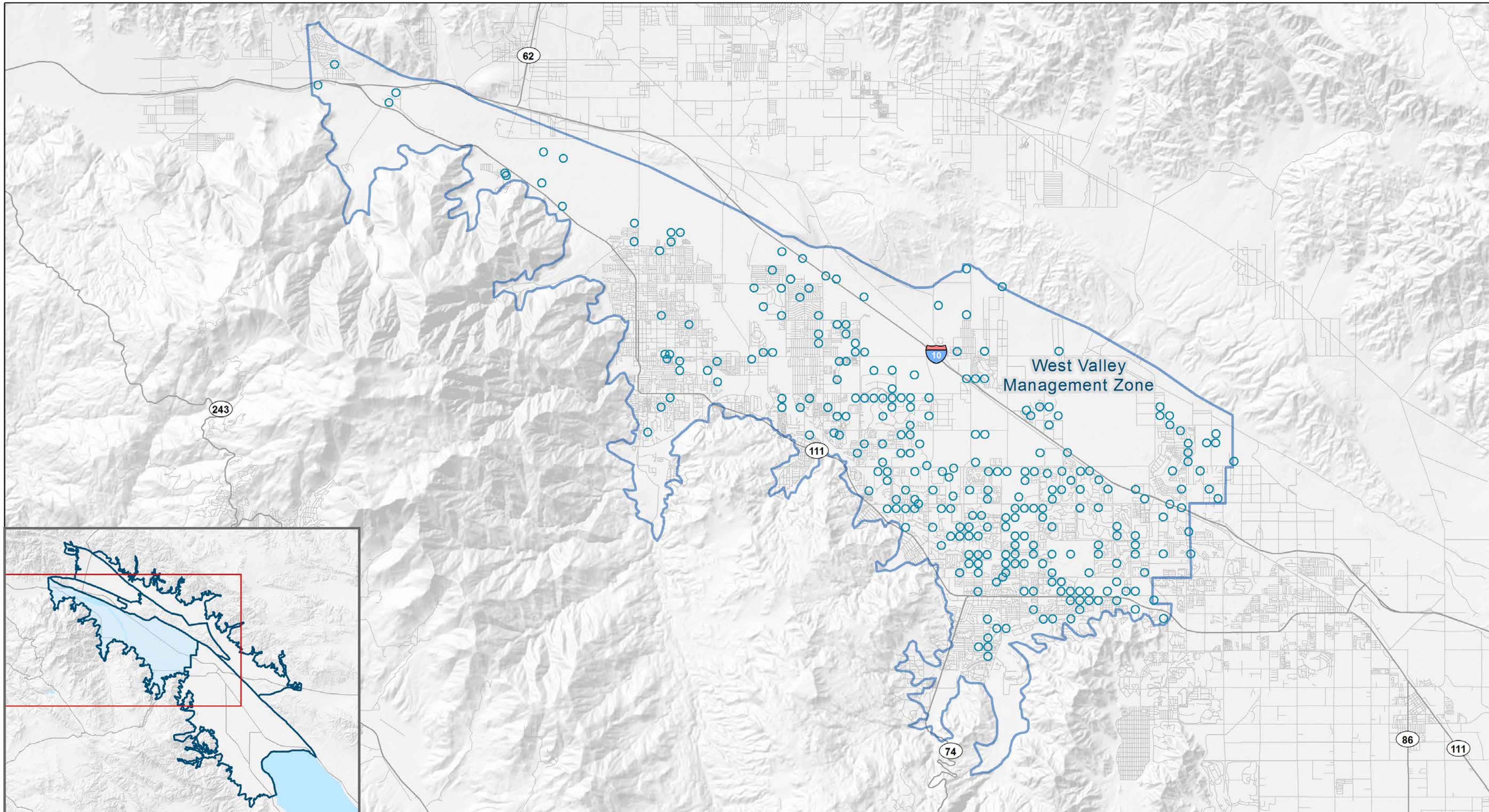
The West Valley Management Zone is comprised of the Palm Springs Subarea, the Thousand Palms Subarea, and the northern portion of the Thermal Subarea of the Whitewater River Subbasin. It lies south of the Garnet Hill Fault, west of the Indio Hills, east of the San Jacinto Mountains, and extends southeast to approximately Indian Wells. Groundwater is unconfined in this management zone. The fill materials within this area are essentially heterogeneous alluvial fan deposits with little sorting, with some finer clay layers present in the southern portion near Palm Desert and Indian Wells. The thickness of these water bearing materials is not known because no wells extend to bedrock; however, it exceeds 1,000 feet (CVWD, 2010). The Ocotillo conglomerate underlies Recent fanglomerate in the Subarea at depths ranging from 300 to 400 feet (DWR, 1964).

3.1.1 Summary of Unfiltered Data

The unfiltered dataset for the West Valley Management Zone consists of 6,032 water quality records during the baseline period of 1994 to 2013. The locations of wells with water quality records used in the AWQ determination are illustrated on **Figure 3-2**. The unfiltered dataset for West Valley Management Zone contains 1,518 TDS records and 4,514 nitrate records. Nitrate is more frequently monitored in wells than TDS because groundwater is typically more likely to see short term changes in nitrate levels. The statistical summary of unfiltered data for the West Valley Management Zone is presented on **Table 3-1**.

Table 3-1
Descriptive Statistics of Unfiltered Data for West Valley (1994-2013)

Descriptive Statistic	Total Dissolved Solids (mg/L)	Nitrate as NO_3 (mg/L)
Count	1,518	4,514
Mean	311	13.8
Median	251	5
Mode	200	2
Standard Deviation	155	15.2
Range	130 to 1,218	ND to 145
90% Confidence Interval for the Mean	304 to 319	13.3 to 14.2



Key to Features

Management Zone

Highway

Local Roads

Groundwater Wells

0 2 4 Miles

N

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Date: October 7, 2014

West Valley
Wells with Water Quality Records in 1994-2013

MWH

Figure 3-2

This map has been designed to print size 11'' by 17''.

3.1.2 Statistical Description of Ambient Water Quality

The average of unfiltered TDS data in West Valley Management Zone is 311 mg/L and the median is 251 mg/L. In general, TDS decreases significantly with depth. Higher TDS appears in the shallower part of the aquifer down gradient of the Whitewater Recharge Facility and in wells from Rancho Mirage to Palm Desert. Some higher TDS also occurs within the Thousand Palms Subarea at the very east of the management zone.

Nitrate concentrations within West Valley Management Zone are generally less than the MCL except for high nitrates observed in wells of varying depths between Rancho Mirage and Palm Desert. The average nitrate (as NO_3) of unfiltered data in West Valley is 13.8 mg/L and the median is 5 mg/L. Typically, nitrate concentrations decrease with depth.

The filtered dataset (temporal and spatial filter) for West Valley Management Zone consists of 265 TDS values and 271 nitrate values. The statistical summary of filtered data for the West Valley Management Zone is presented on **Table 3-2**.

Table 3-2
Descriptive Statistics of Filtered Data for West Valley (1994-2013)

Descriptive Statistic	Total Dissolved Solids (mg/L)	Nitrate as NO_3 (mg/L)
Count	265	271
Mean	329	17.8
Median	252	4.5
Mode	210	3
Standard Deviation	196	25.9
Range	150 to 1,218	0.1 to 145
90% Confidence Interval for the Mean	305 to 352	14.7 to 20.9

The mean TDS of the filtered dataset falls within the interval of 305 to 352 mg/L with a probability of 90 percent; for nitrate (as NO_3), this interval is between 14.7 and 20.9 mg/L. The higher nitrates that appear from Rancho Mirage to Palm Desert have a large effect on the summary statistics of West Valley.

3.1.3 Volume-weighted Ambient Water Quality

For the determination of volume-weighted ambient water quality, West Valley is separated into three layers. The upper portion of the aquifer, approximately less than 450 feet below ground surface, is grouped into one layer; the middle of the aquifer, approximately 450 to 750 feet below ground surface, into the next layer; and the bottom of the aquifer, depths greater than approximately 750 feet below ground surface, is the final layer. Water quality is estimated for each layer based on water quality information specific to that layer. Adjacent layer data and wells perforated in multiple aquifers are also used as a reference to approximate water quality concentrations. Note that these depths vary with location according to the model grid described in earlier TM-1 to take advantage of known aquifer geometry.

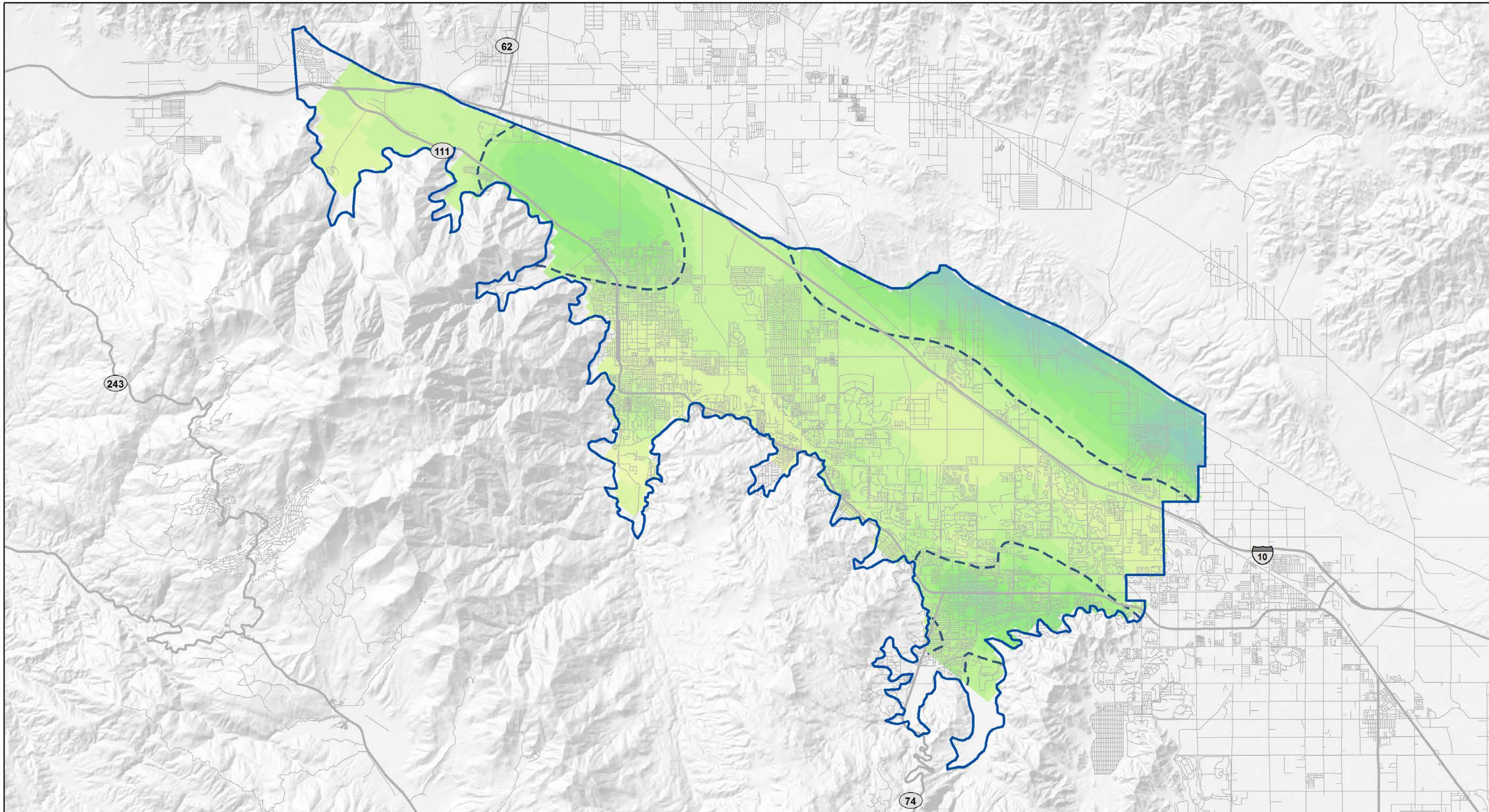
Table 3-3 summarizes the results of the volume-weighted AWQ determination for West Valley Management Zone. Water quality is contoured by layer and TDS/nitrate concentrations are assigned to each cell by layer. Layers are then aggregated using the volume-weighted method to generate the volume-weighted AWQ. **Figure 3-3** and **Figure 3-4** illustrate the relative TDS and nitrate concentrations, respectively, in the West Valley Management Zone.

Table 3-3
Volume-weighted Ambient Water Quality for West Valley Management Zone

Total Dissolved Solids (mg/L)	Nitrate as NO_3 (mg/L)
291	9.1

The volume-weighted AWQ for TDS in West Valley Management Zone is 291 mg/L. TDS concentrations are generally low throughout West Valley. The TDS exceeds the volume-weighted AWQ in three areas: (1) north of Palm Springs to the southeast of the Whitewater Recharge Facility, (2) areas in Thousand Palms Subarea, and (3) in the vicinity of Palm Desert and Indian Wells.

The volume-weighted AWQ for nitrate (as NO_3) in West Valley Management Zone is 9.1 mg/L. Nitrate concentrations are generally below the volume-weighted AWQ from the north end of West Valley to Cathedral City. Thousand Palms Subarea and surrounding areas are also relatively low in nitrate. The region above the nitrate AWQ is on the southern boundary of West Valley Management Zone just southeast of Palm Springs extending to Palm Desert and the East Valley Management Zone.



Key to Features

Estimated Ambient Water Quality Contour (291 mg/L)

Management Zone

TDS

50 mg/L

1500 mg/L

Portions of the management zone that do not have an estimated concentration lie outside the extent of known aquifer properties required for the volume-weighted AWQ method; additionally, these areas lack substantial water quality data. They have been identified as data gaps and will be further described as a data need in the final SNMP.

Ambient Water Quality = 291 mg/L

N

0 2 4 Miles

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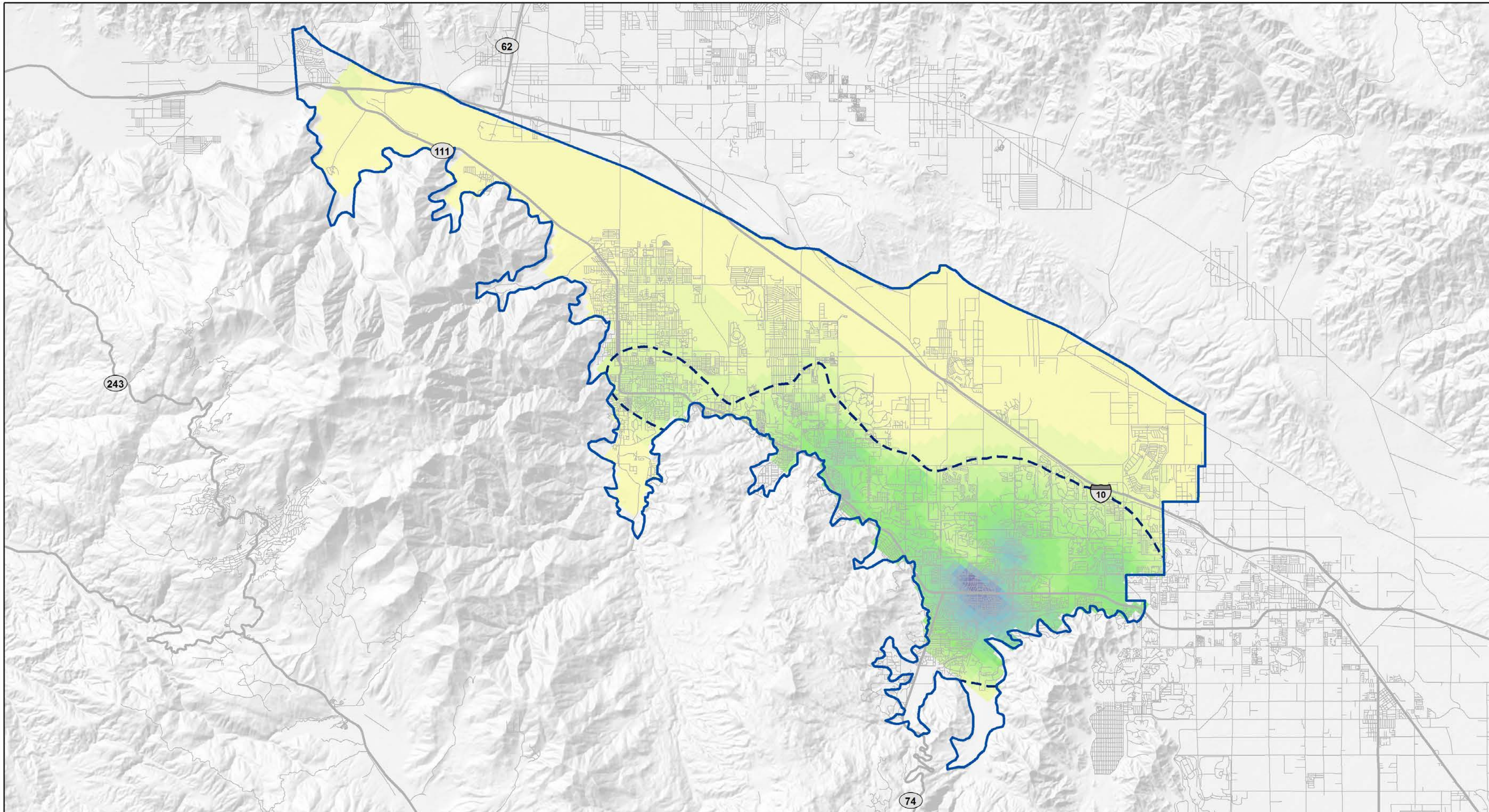
Date: October 8, 2014

West Valley TDS Ambient Water Quality

MWH

Figure 3-3

This map has been designed to print size 11'' by 17''.



Key to Features

Estimated Ambient Water Quality Contour (9.1 mg/L)

Management Zone

Nitrate (as NO_3)

0 mg/L

71 mg/L

Portions of the management zone that do not have an estimated concentration lie outside the extent of known aquifer properties required for the volume-weighted AWQ method; additionally, these areas lack substantial water quality data. They have been identified as data gaps and will be further described as a data need in the final SNMP.

Ambient Water Quality = 9.1 mg/L

N 0 2.5 5 Miles

Document: \\Usirv1s01\Projects\Coachella Valley WD\SNMP\AWQ\CVWD_AWQ_V3\MXD\NO3HeatMaps.mxd

Date: October 7, 2014

West Valley Nitrate (as NO_3) Ambient Water Quality

MWH

Figure 3-4

This map has been designed to print size 11'' by 17''.

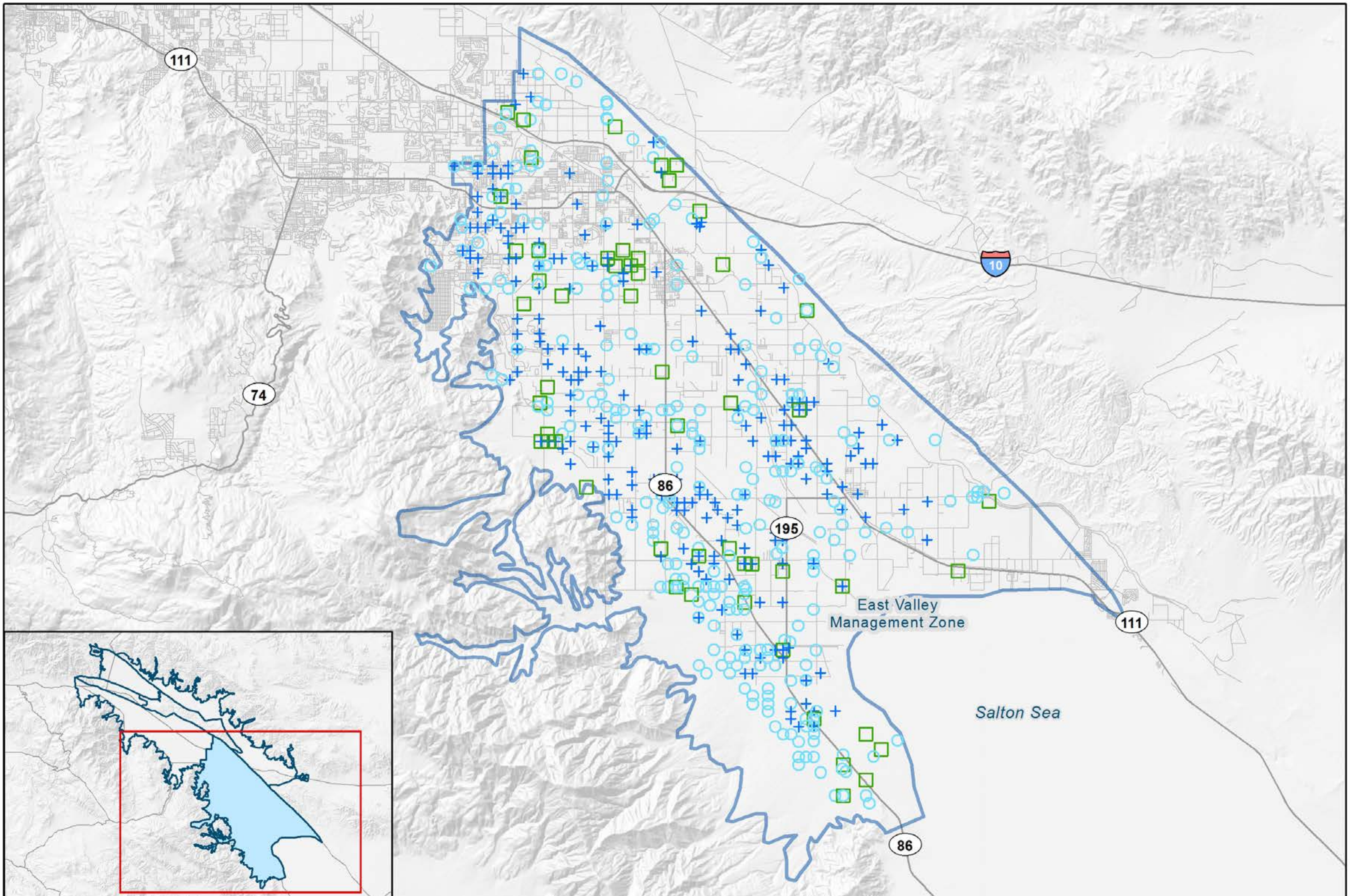
3.2 EAST VALLEY MANAGEMENT ZONE

The East Valley Management Zone is comprised primarily of the southern portion of the Thermal Subarea, the Oasis Subarea, and a small portion of the Thousand Palms Subarea of the Whitewater River Subbasin. This management zone is west of the San Andreas Fault zone, east of the San Jacinto Mountains and southeast of the West Valley Management Zone. Groundwater travels southeastward through the interbedded sands, silts, and clays underlying the central portion of the East Valley. The division between the West Valley Management Zone and East Valley Management Zone extends from Point Happy near the Indian Wells-La Quinta boundary and Highway 111 northeasterly to the Indio Hills at the northern extension of Jefferson Street.

Two aquifers separated by a zone of fine-grained materials were identified from well logs (DWR, 1964). An aquitard separates upper and lower aquifer zones in the management zone. In much of the management zone, the upper aquifer is capped at the ground surface with clays and silts with minor amounts of sand. Semi-perched groundwater occurs in this capping zone, which is up to 100 feet thick. No recent water quality data exists for the semi-perched aquifer as it is not used beneficially. Subsurface tile drainage systems were installed in the 1950s to control the high water table conditions, to allow reclamation of saline soils, and to intercept poor quality return flows. All agricultural drains empty into the Salton Sea, or into the Coachella Valley Stormwater Channel, which also flows into the Salton Sea. Each of the four water-bearing zones, from shallowest to deepest, is described earlier in TM-1.

3.2.1 Summary of Unfiltered Data

The unfiltered dataset for the East Valley Management Zone consists of 6,855 water quality records during the baseline period of 1994 to 2013. The locations of wells with water quality records used in the AWQ determination are illustrated on **Figure 3-5**. It should be noted that there are few wells in the semi perched aquifer. This is a known data gap and will be identified in the monitoring portion of the final SNMP. The unfiltered dataset for East Valley Management Zone contains 2,875 TDS records and 3,980 nitrate records. Nitrate is more frequently monitored in wells than TDS because groundwater is typically more likely to see short term changes in nitrate levels. The statistical summary of unfiltered data for the East Valley Management Zone is presented on **Table 3-4**.



Key to Features

Management Zone — Highway — Local Roads

Groundwater Well Location
Type of Aquifer Penetrated

Upper Aquifer — Unknown — Confined

Note: Includes wells with no known depth information and wells with screens across multiple aquifers.

0 3 6 Miles

Document: \\Usirv1s01\Projects\Coachella Valley WD\SNMP\AWQ\CVWD_AWQ_V3\MXD\WQWells_EV_MC.mxd

Date: October 8, 2014

East Valley Wells with Water Quality Records in 1994-2013

MWH

Figure 3-5

Table 3-4
Descriptive Statistics of Unfiltered Data for East Valley (1994-2013)

		Total Dissolved Solids (mg/L)			Nitrate as NO_3 (mg/L)		
	Aquifer Zone	**All[1]**	**Upper[2]**	**Lower[3]**	**All[1]**	**Upper[2]**	**Lower[3]**
Descriptive Statistic	Count	2,875	743	1,218	3,980	734	1,789
	Mean	1,080	613	1,616	10	9.4	6.3
	Median	383	635	252	2.7	2	2
	Mode	180	800	150	ND	ND	ND
	Standard Deviation	2,381	309	3,538	18.1	26	12.1
	Range	1 to 19,500	1 to 2,320	19 to 19,500	ND to 260	ND to 260	ND to 221
	90% Confidence Interval for the Mean	993 to 1,167	590 to 635	1,417 to 1,815	9.4 to 10.5	7.5 to 11.2	5.7 to 6.9

ND = non-detect
[1] Includes all well records including those with no depth or perforation information.
[2] Includes only wells strictly perforated in the upper aquifer within East Valley.
[3] Includes only wells strictly perforated in the lower aquifer within East Valley.

3.2.2 Statistical Description of Ambient Water Quality

The average TDS of unfiltered data in East Valley Management Zone is 1,080 mg/L and the median is 383 mg/L. A deep nested monitoring well is included in this dataset that is located near the Salton Sea that is sampled much more frequently than other wells. High salinity is found in the lower two intervals, 1,220 to 1,260 feet and 1,430 to 1,470 below ground surface. These readings have a significant effect on the summary statistics of the unfiltered dataset. In Section 3.2.2, the filtered dataset minimizes the bias induced by the more frequent sampling at this well.

Higher TDS appears in some the lower aquifer wells between La Quinta and Coachella, as well as in Oasis Subarea, and west of the Salton Sea. High TDS also appears in the lower aquifer in areas between Thermal and Mecca, south of La Quinta, and in a deep monitoring well near the Salton Sea. Higher TDS reading are also found in the upper aquifer within the Thousand Palms Subarea, to the north of the management zone.

Nitrate is generally low within East Valley Management Zone except for high nitrates in the Oasis area and the upper aquifer west of Desert Hot Springs Management Zone. The average nitrate (as NO_3) of unfiltered data in East Valley is 10 mg/L and the median is 2.7 mg/L. In general, nitrate decreases from the upper to the lower aquifer of East Valley.

The filtered dataset for East Valley Management Zone consists of 477 TDS values and 487 nitrate values. The statistical summary of filtered data for the East Valley Management Zone is presented on **Table 3-5**.

Table 3-5
Descriptive Statistics of Filtered Data for East Valley (1994-2013)

		Total Dissolved Solids (mg/L)			Nitrate as NO_3 (mg/L)		
Aquifer Zone		All[1]	Upper[2]	Lower[3]	All[1]	Upper[2]	Lower[3]
Descriptive Statistic	Count	477	53	222	487	53	224
	Mean	494	643	350	11.8	12.3	8.3
	Median	308	523	215	3	3.1	2.3
	Mode	160	665	160	ND	ND	ND
	Standard Deviation	444	484	391	19.6	21.9	16.9
	Range	1 to 3,520	1 to 2,210	19 to 4,582	ND to 178	ND to 90	ND to 152
	90% Confidence Interval for the Mean	454 to 534	510 to 776	298 to 401	10 to 13.5	6.3 to 18.4	6.1 to 10.6

ND = non-detect
[1] Includes all well records including those with no depth or perforation information.
[2] Includes only wells strictly perforated in the upper aquifer within East Valley.
[3] Includes only wells strictly perforated in the lower aquifer within East Valley.

The mean TDS of the filtered dataset falls within the interval of 454 to 534 mg/L (510 to 776 mg/L in the upper aquifer and 298 to 401 mg/L in the lower aquifer) with a 90 percent probability; for nitrate (as NO_3), this interval is between 14.7 and 20.9 mg/L (6.3 to 18.4 in the upper aquifer and 6.1 to 10.6 in the lower aquifer). The filtered dataset provides a substantially different view of TDS in the statistical summary because the contribution of the frequently sampled nested monitoring well with high TDS is normalized to that of other wells in the East Valley. It is obvious from **Table 3-5** that TDS concentrations are generally lower in the lower aquifer compared to the upper aquifer.

3.2.3 Volume-weighted Ambient Water Quality

For the determination of volume-weighted ambient water quality, the East Valley Management Zone is separated into three layers. The upper aquifer (generally less than 400 feet below ground surface), is evaluated as one contoured layer. The top portion of the lower aquifer (extending from 400 to 600 feet below ground surface) is the next contoured layer. The bottom of the lower aquifer (generally greater than 600 feet below ground surface) is the final contoured layer. Note that these depths vary with location according to the model grid described in TM-1 to take advantage of known aquifer geometry.

Table 3-6 summarizes the results of the volume-weighted AWQ determination for East Valley Management Zone. Water quality concentration is contoured in three layers: the upper, unconfined system and two subdivisions of the lower, confined aquifer due to its thickness. Concentrations are assigned to each cell in each layer. Layers are then aggregated using the volume-weighted method to generate volume-weighted AWQ. **Figure 3-6** and **Figure 3-7** illustrate the relative TDS and nitrate concentrations, respectively, in the upper aquifer, the lower aquifer (an aggregate of the two subdivisions), and the total management zone (an aggregate of all three layers, or the two aquifer systems) of East Valley Management Zone.

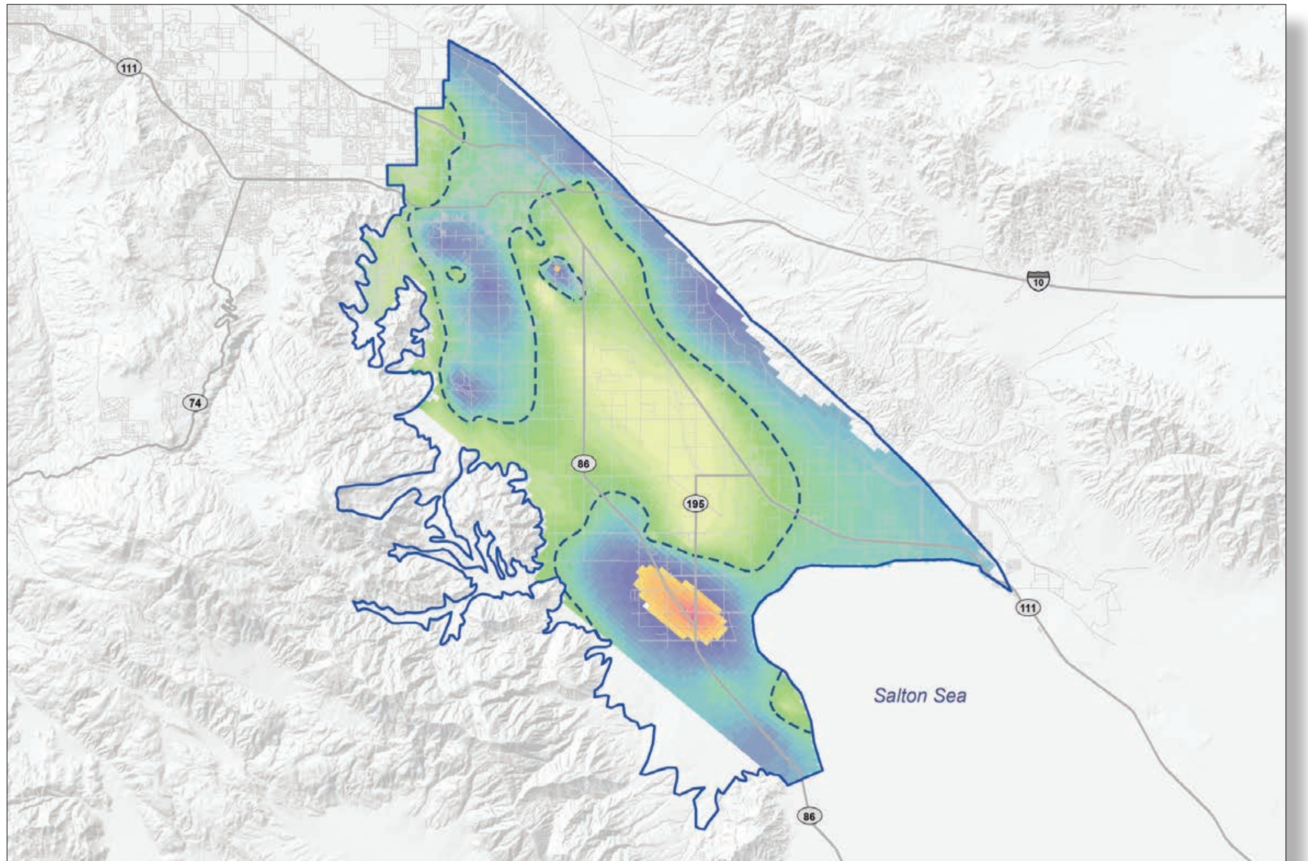
Table 3-6
Volume-weighted Ambient Water Quality for East Valley Management Zone

Total Dissolved Solids (mg/L)	Nitrate as NO_3 (mg/L)
460	8.1

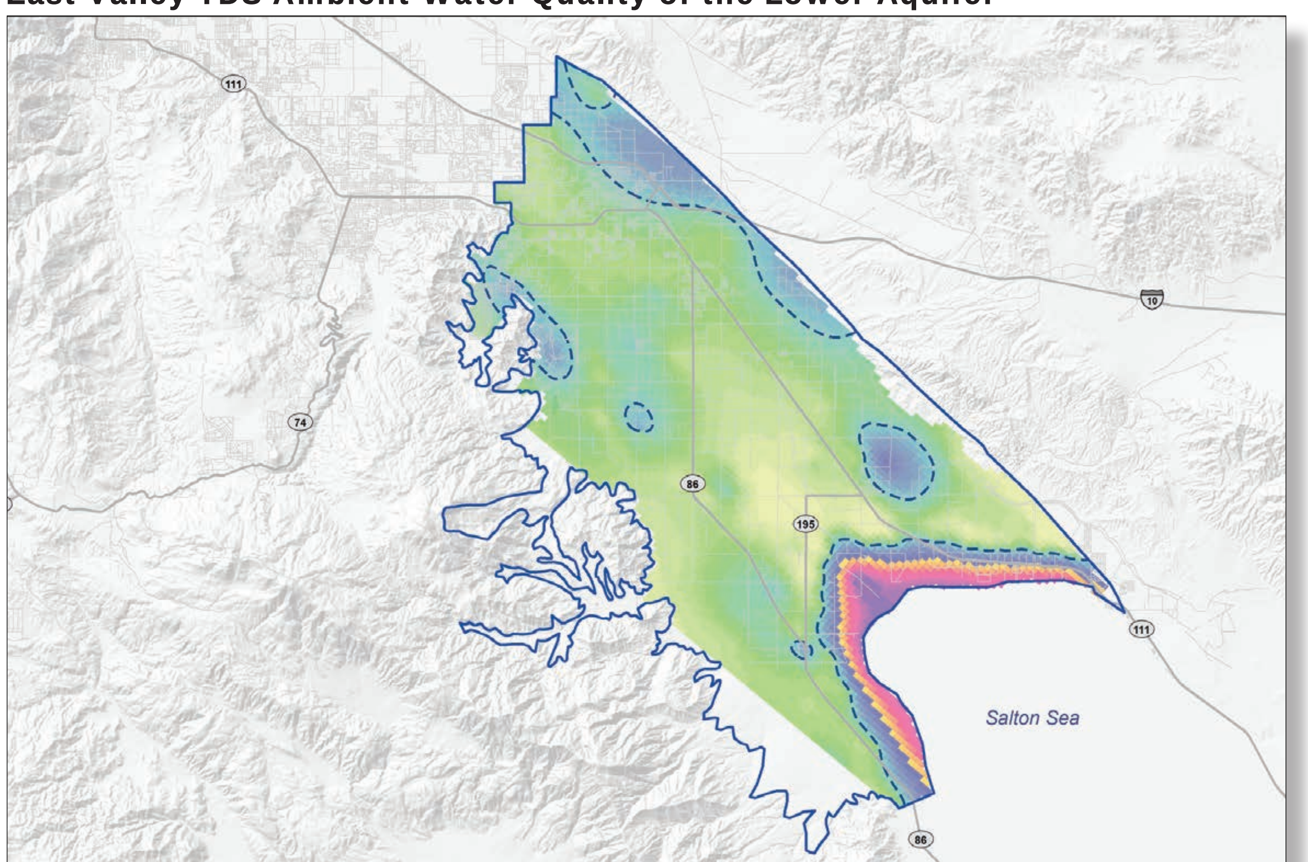
The volume-weighted AWQ for TDS in East Valley Management Zone is 460 mg/L. The lower aquifer has generally lower TDS than the upper aquifer, there are some locations in the lower aquifer near Salton Sea where high TDS concentrations have been observed with nested wells. It is not known if TDS concentration increases in very deep sediments further from the Sea as there are no monitoring wells installed in this zone away from the Sea. Areas with TDS concentrations higher than the volume-weighted AWQ include: (1) areas near the Thousand Palms Subarea, (2) isolated zones southwest of Indio, (3) areas near Desert Hot Springs Management Zone, and (4) the east end of Oasis Subarea.

The volume-weighted AWQ for nitrate (as NO_3) in East Valley Management Zone is 8.1 mg/L. The lower aquifer has marginally less nitrate content than the upper aquifer, in general. Along the center of East Valley, nitrate is generally below the volume-weighted AWQ with a large amount of undetected concentrations. Nitrate concentrations higher than the volume-weighted AWQ occur in: (1) the southern boundary of East Valley at the border of West Valley Management Zone extending to the southeast, (2) the southern parts of Thousand Palms Subarea, (3) the southern boundary with Desert Hot Springs Management Zone extending southeast to the Salton Sea, and (4) much of Oasis Subarea.

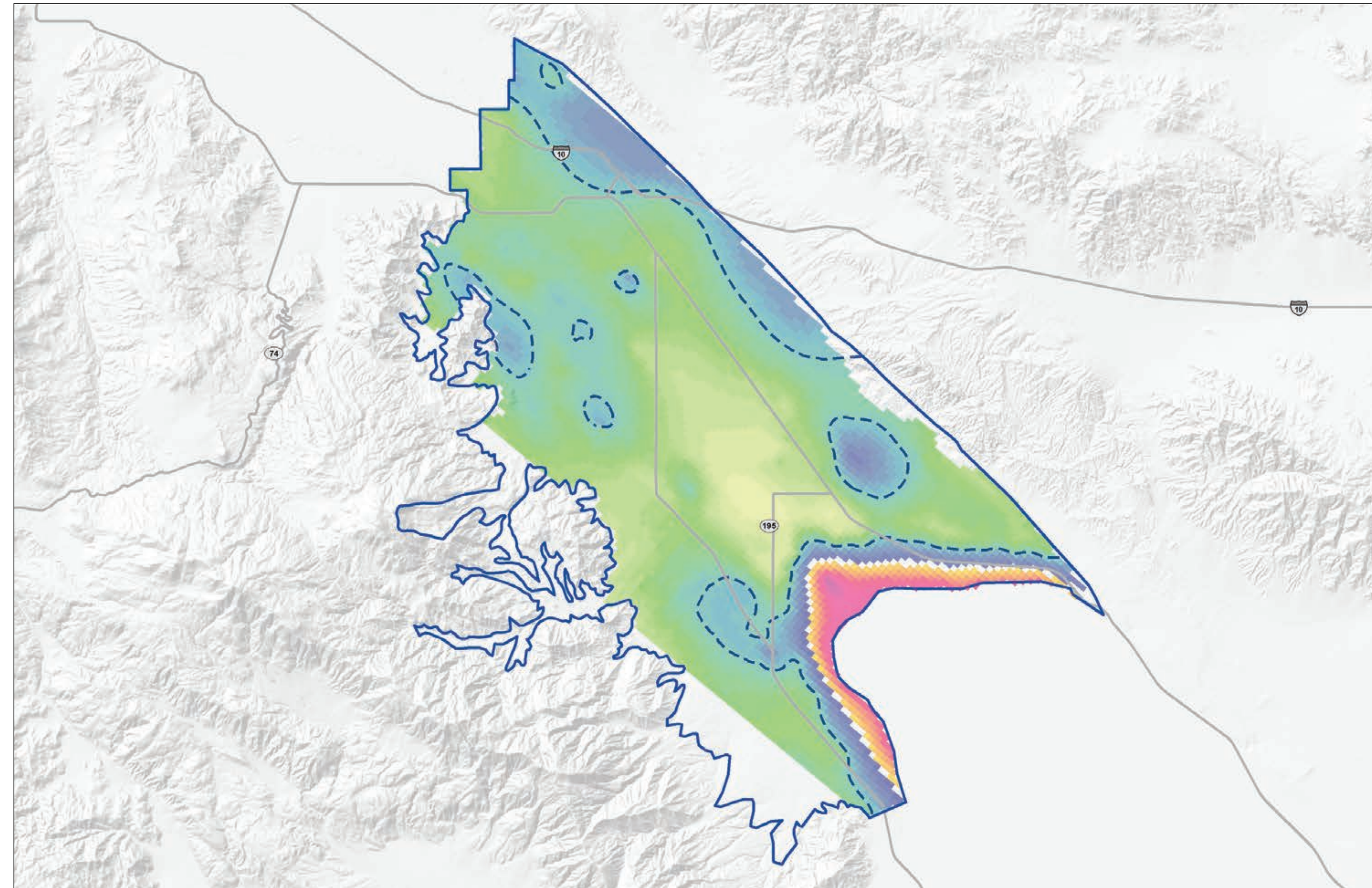
East Valley TDS Ambient Water Quality of the Upper Aquifer



East Valley TDS Ambient Water Quality of the Lower Aquifer



East Valley TDS Ambient Water Quality



Key to Features

Estimated Ambient Water Quality Contour (460 mg/L)

Management Zone

TDS

50 mg/L

1500 mg/L

1501 mg/L

3545 mg/L

Portions of the management zone that do not have an estimated concentration lie outside the extent of known aquifer properties required for the volume-weighted AWQ method; additionally, these areas lack substantial water quality data. They have been identified as data gaps and will be further described as a data need in the final SNMP.

Ambient Water Quality = 460 mg/L

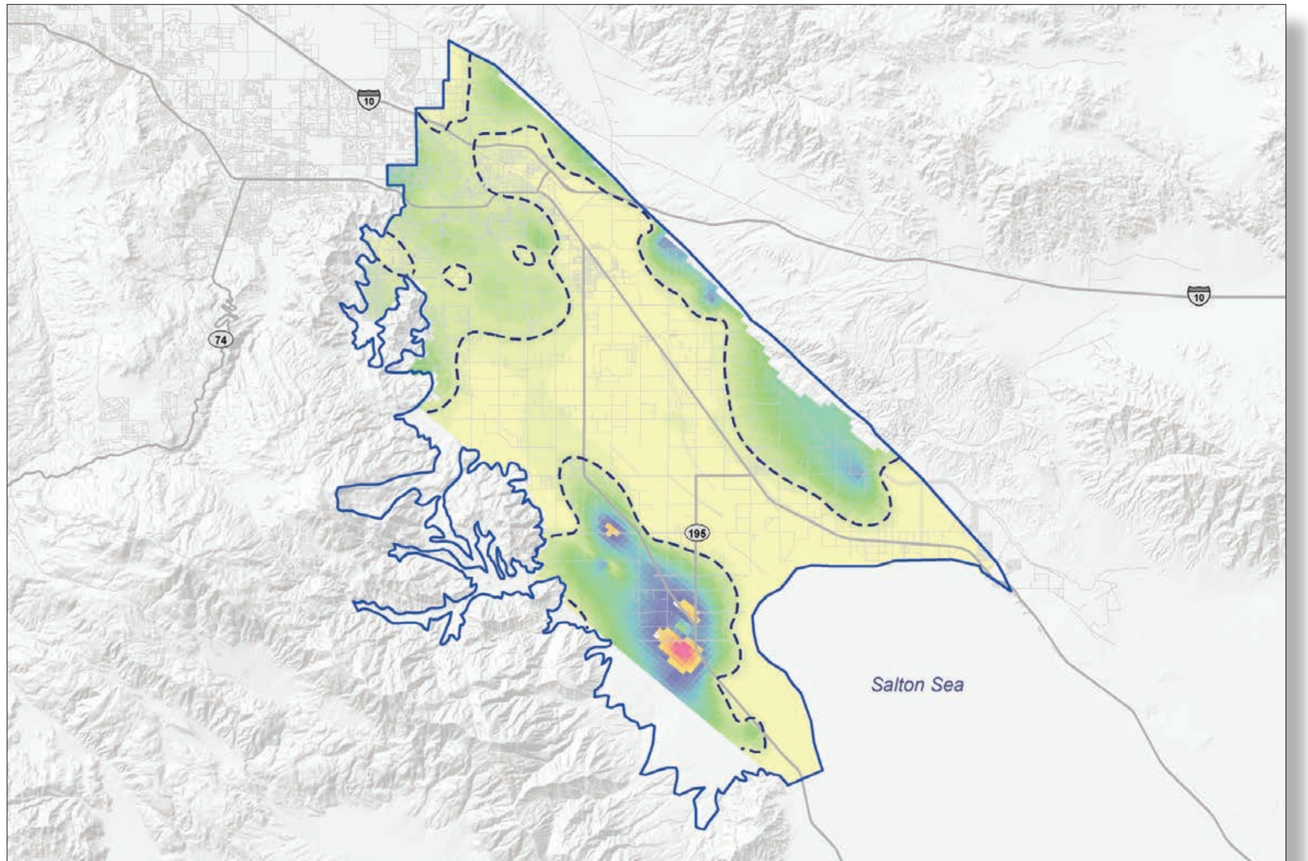
N

Water quality concentration was contoured in three layers: the upper, unconfined system and two subdivisions of the lower, confined aquifer due to its thickness. TDS concentrations were assigned to each cell in each layer. Layers were then aggregated using the volume-weighted method to generate volume-weighted AWQ. Maps on this figure illustrate the TDS concentrations in the upper aquifer, the lower aquifer (an aggregate of the two subdivisions), and the total management zone (an aggregate of all three layers, or the two aquifer systems). The AWQ for TDS in the East Valley Management Zone is 460 mg/L.

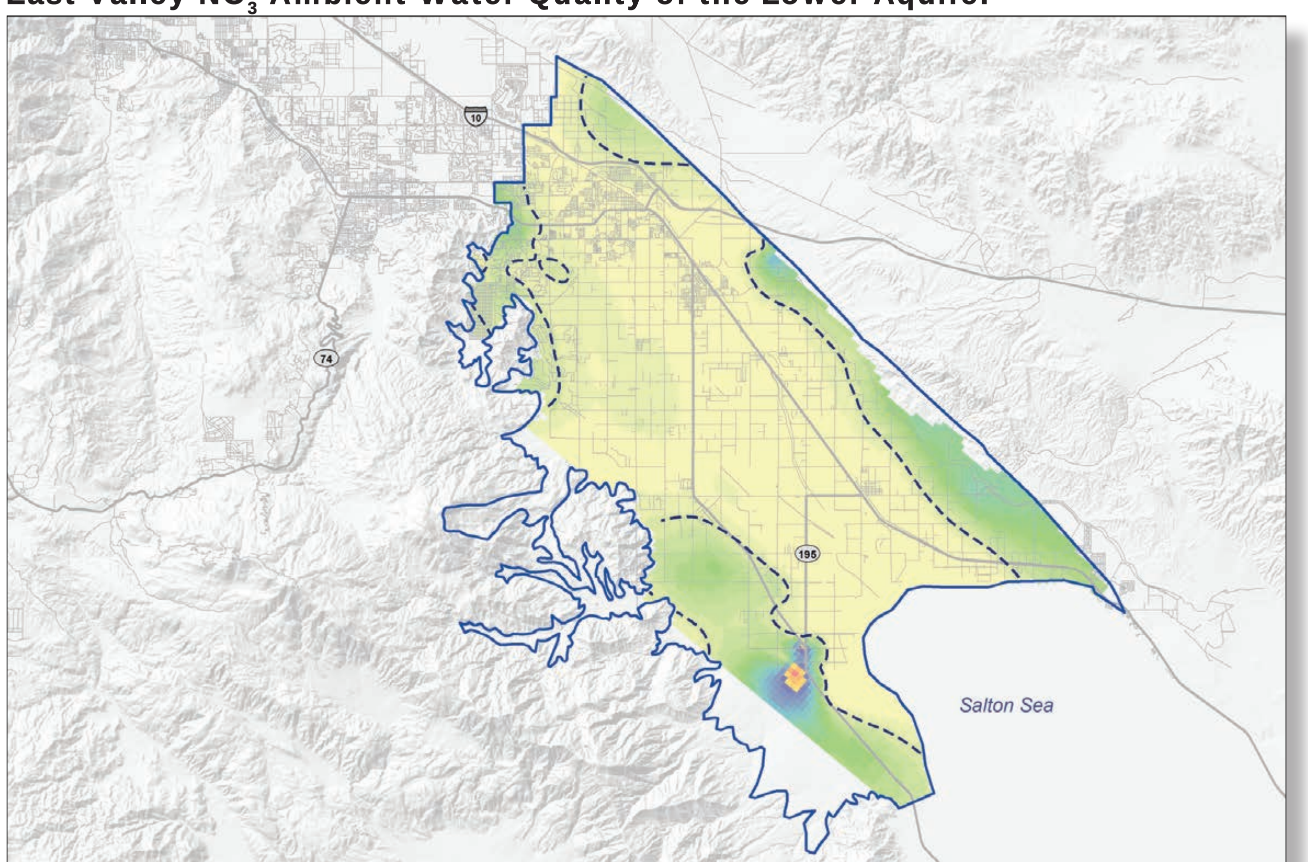
MWH

Figure 3-6
East Valley TDS Ambient Water Quality

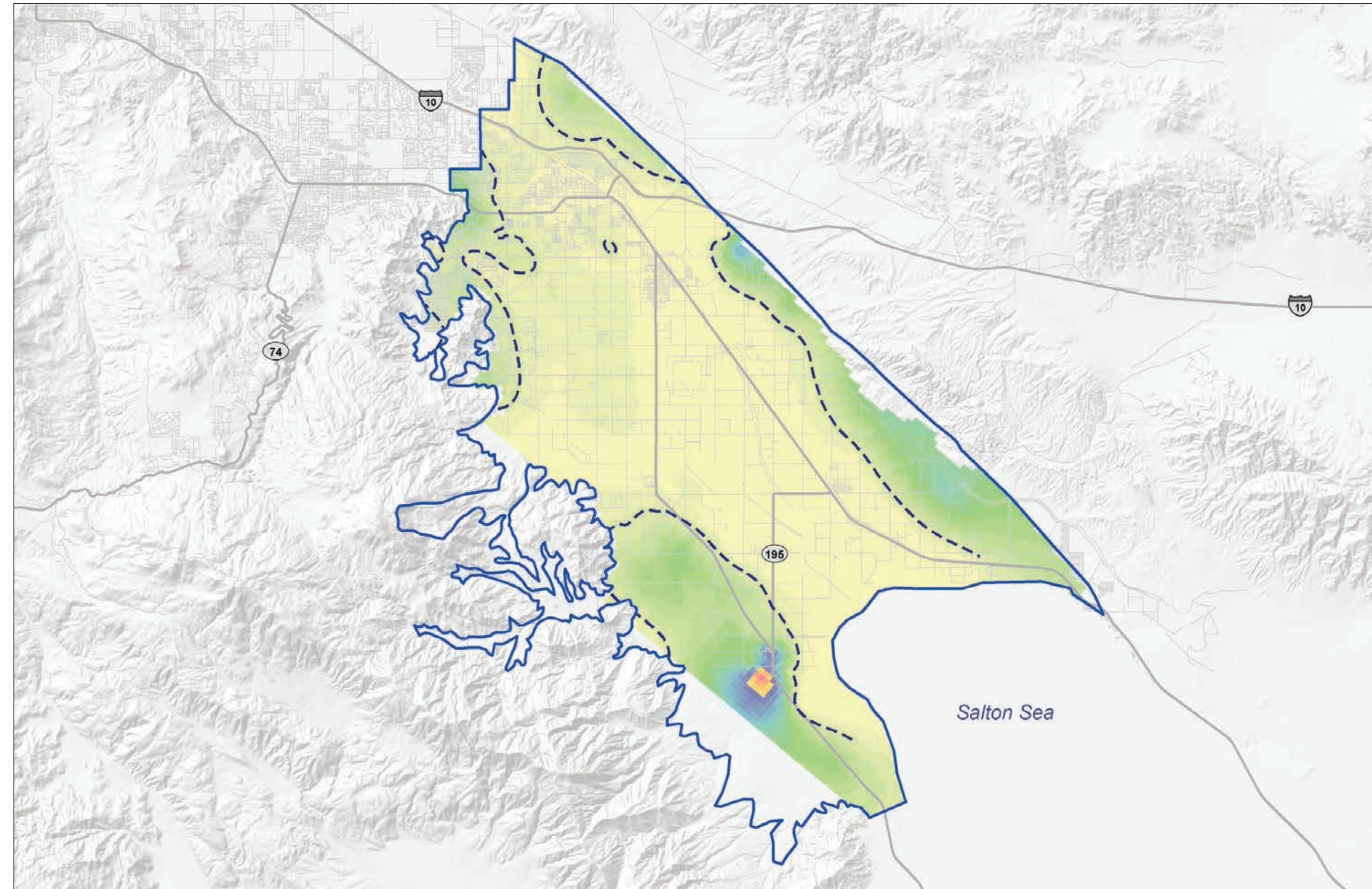
East Valley NO_3 Ambient Water Quality of the Upper Aquifer



East Valley NO_3 Ambient Water Quality of the Lower Aquifer



East Valley NO_3 Ambient Water Quality



Key to Features

Estimated Ambient Water Quality Contour (8.1 mg/L)

Management Zone

Nitrate (as NO_3)

0 mg/L

71 mg/L

72 mg/L

171 mg/L

Portions of the management zone that do not have an estimated concentration lie outside the extent of known aquifer properties required for the volume-weighted AWQ method; additionally, these areas lack substantial water quality data. They have been identified as data gaps and will be further described as a data need in the final SNMP.

Ambient Water Quality = 8.1 mg/L

N

Water quality concentration was contoured in three layers: the upper, unconfined system and two subdivisions of the lower, confined aquifer due to its thickness. Nitrate (as NO_3) concentrations were assigned to each cell in each layer. Layers were then aggregated using the volume-weighted method to generate volume-weighted AWQ. Maps on this figure illustrate the Nitrate (as NO_3) concentrations in the upper aquifer, the lower aquifer (an aggregate of the two subdivisions), and the total management zone (an aggregate of all three layers, or the two aquifer systems). The AWQ for Nitrate (as NO_3) in the East Valley Management Zone is 8.1 mg/L.

MWH

Figure 3-7
East Valley NO_3 Ambient Water Quality

3.3 MISSION CREEK MANAGEMENT ZONE

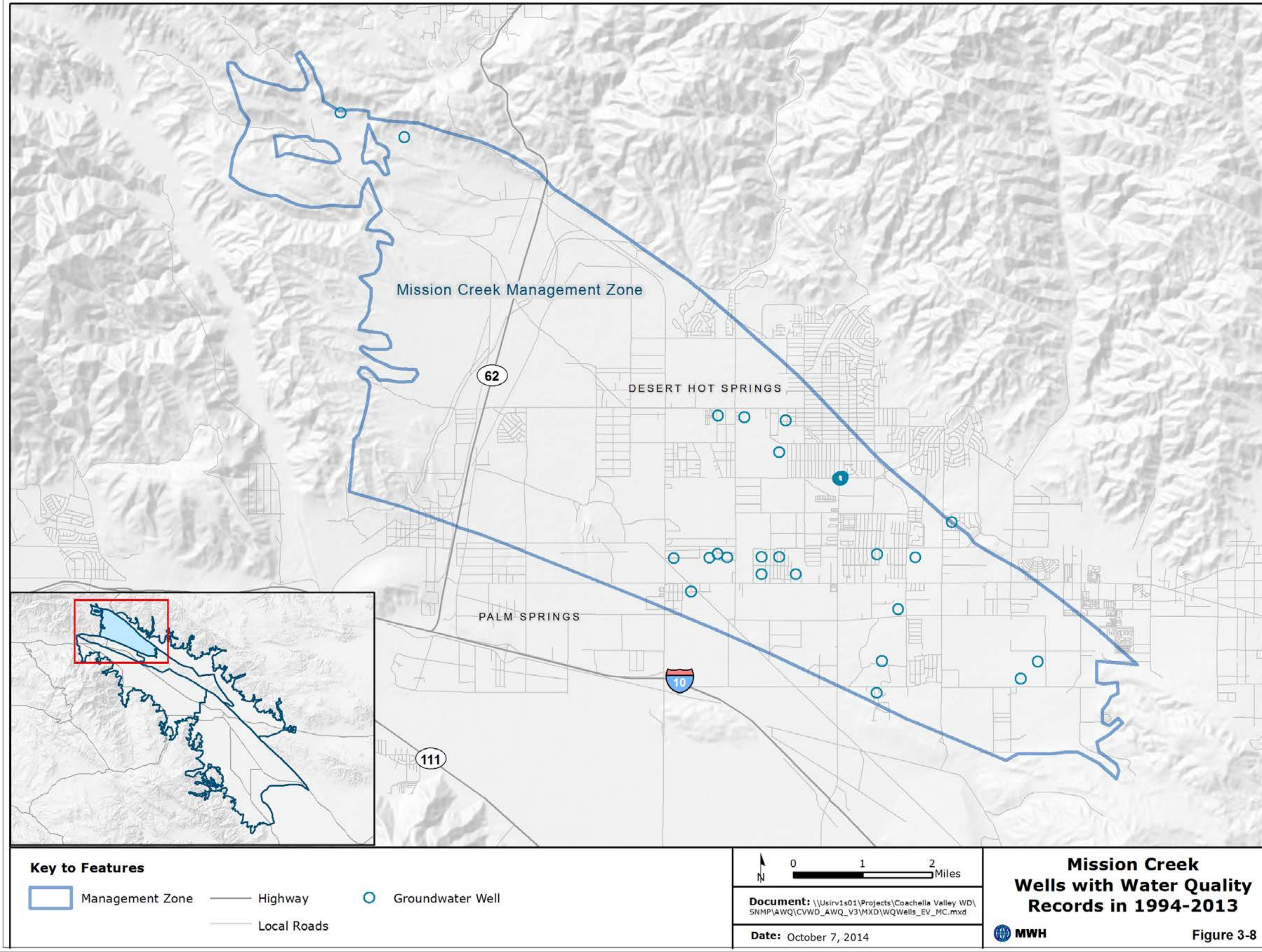
The Mission Creek Management Zone is located in the northwestern Coachella Valley, north of the Garnet Hill Management Zone and west of the Desert Hot Springs Management Zone. The Mission Creek Fault and the Banning Fault form these northern and southern boundaries, respectively. Both faults act to limit groundwater movement. The main water bearing units of the Mission Creek Management Zone are unconsolidated Holocene and late Pleistocene alluvial deposits forming a single unconfined aquifer with a saturated thickness of approximately 1,200 feet. An attempt is made to separate the aquifer into layers, but continuous perforations limited the number of data points exclusive to a single layer, and therefore separation of layers could not be completed.

3.3.1 Summary of Unfiltered Data

The unfiltered dataset for the Mission Creek Management Zone consists of 448 water quality records during the baseline period of 1994 to 2013. The locations of wells with water quality records used in the AWQ determination are illustrated on **Figure 3-8**. It should be noted that there is a lack of data on the western portion of the management zone. This is a known data gap data gap and will be identified in the monitoring portion of the final SNMP. The unfiltered dataset for Mission Creek Management Zone contains 93 TDS records and 355 nitrate records. Nitrate is more frequently monitored in wells than TDS because groundwater is typically more likely to see short term changes in nitrate levels. One shallow well with high nitrate was sampled approximately once a month over a period of nine years. The statistical summary of unfiltered data for the Mission Creek Management Zone is presented on **Table 3-7**.

Table 3-7
Descriptive Statistics of Unfiltered Data for Mission Creek (1994-2013)

Descriptive Statistic	Total Dissolved Solids (mg/L)	Nitrate as NO_3 (mg/L)
Count	93	355
Mean	506	24.9
Median	446	5.4
Mode	430	ND
Standard Deviation	198	30.1
Range	270 to 1,100	ND to 86
90% Confidence Interval for the Mean	466 to 547	21.7 to 28



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Date: October 7, 2014

Mission Creek Wells with Water Quality Records in 1994-2013

MWH

Figure 3-8

3.3.2 Statistical Description of Ambient Water Quality

The unfiltered dataset average TDS concentration in the Mission Creek Management Zone is 506 mg/L with a median of 446 mg/L. Influence from high salinity groundwater from Desert Hot Springs may contribute to the upper end of the range. TDS concentrations generally decrease from the Desert Hot Springs to the Garnet Hill management zones. Very few data exist in the northwest of the management zone.

The average nitrate (as NO_3) of the unfiltered dataset is 24.9 mg/L with a median of 5.4 mg/L. High nitrate values that appear in a shallow well sampled more frequently than others in this dataset are a cause for the large difference between the average and median nitrate.

The filtered dataset for Mission Creek Management Zone consists of 22 TDS values and 25 nitrate values. The statistical summary of filtered data for the Mission Creek Management Zone is presented on **Table 3-8**. The filtered dataset minimizes the effects of many of the biases discussed in section 2.2, such as the abundance of high nitrate values from a single shallow well.

Table 3-8
Descriptive Statistics of Filtered Data for Mission Creek (1994-2013)

Descriptive Statistic	Total Dissolved Solids (mg/L)	Nitrate as NO_3 (mg/L)
Count	22	25
Mean	599	5.1
Median	492	4
Mode	-	3.6
Standard Deviation	240	6.1
Range	300 to 1,096	0.3 to 32.3
90% Confidence Interval for the Mean	493 to 706	2.5 to 7.6

The mean TDS of the filtered dataset falls within the interval of 493 to 706 mg/L with a 90 percent probability; for nitrate (as NO_3), this interval is between 2.5 and 7.6 mg/L.

3.3.3 Volume-weighted Ambient Water Quality

For the determination of volume-weighted AWQ, Mission Creek is contoured over a single layer using the filtered dataset for TDS and nitrate. It is determined after several iterations that insufficient data are available to contour multiple layers in Mission Creek Management Zone.

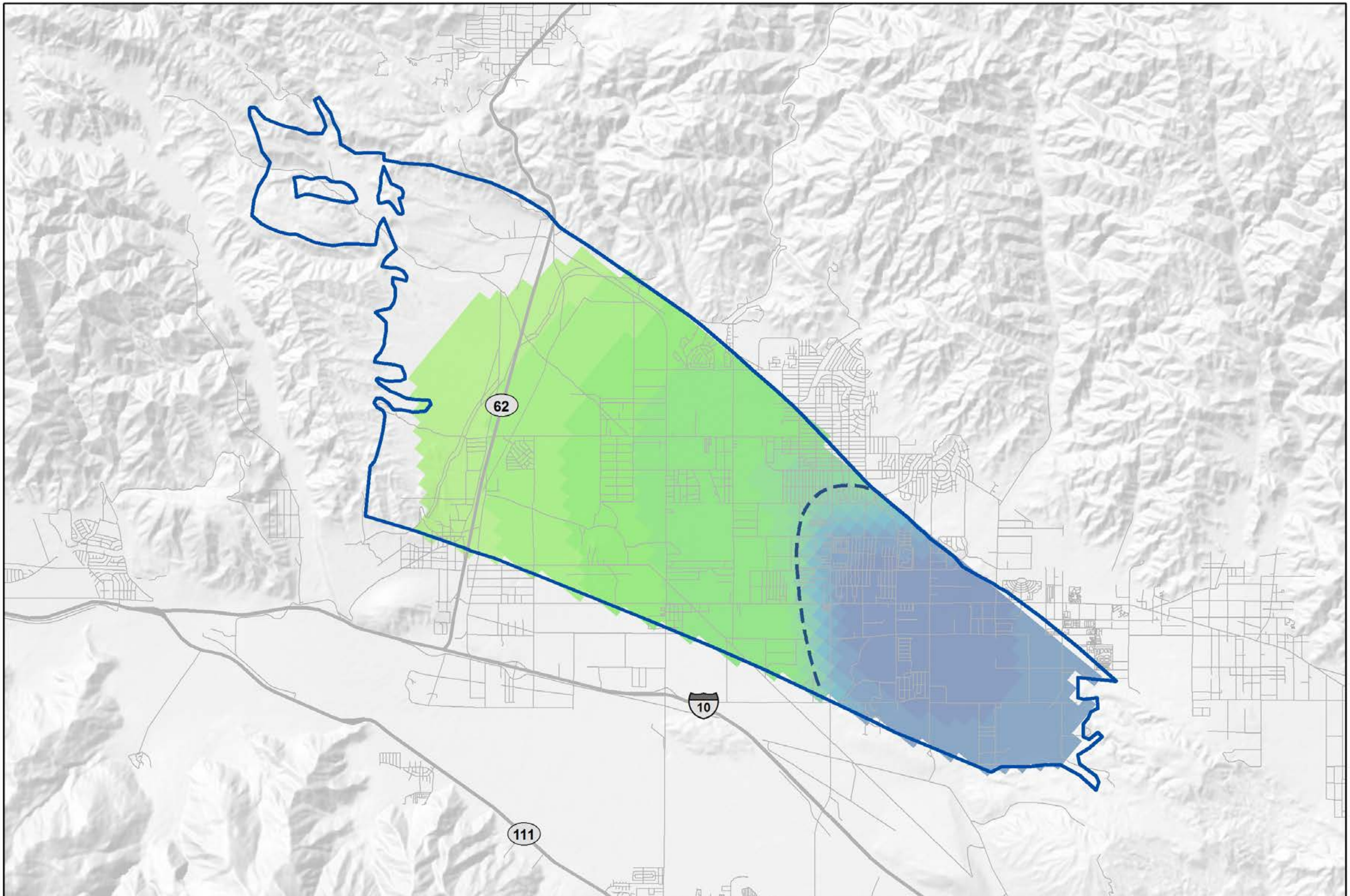
Table 3-9 summarizes the results of the volume-weighted AWQ determination for Mission Creek Management Zone. Water quality is contoured and TDS/nitrate concentrations are assigned to each cell. The layer is aggregated using the volume-weighted method to generate volume-weighted AWQ. **Figure 3-9** and **Figure 3-10** illustrate the relative TDS and nitrate concentrations, respectively, in the Mission Creek Management Zone.

Table 3-9
Volume-weighted Ambient Water Quality for Mission Creek Management Zone (1994-2013)

Total Dissolved Solids (mg/L)	Nitrate as NO_3 (mg/L)
535	3.0

The volume-weighted AWQ for TDS in the Mission Creek Management Zone is 535 mg/L. TDS is above the volume-weighted AWQ towards the southeast of Mission Creek and where it borders Desert Hot Springs Management Zone. TDS decreases to the northwest end of Mission Creek Management Zone and near the Garnet Hill Management Zone. Few data are available in the western portion of Mission Creek Management Zone.

The volume-weighted AWQ for nitrate (as NO_3) in the Mission Creek Management Zone is 3.0 mg/L. Nitrate is generally low throughout Mission Creek. The area above volume-weighted AWQ is south of the Desert Hot Springs Management Zone extending to the Garnet Hill Subbasin, with the exception of the far southeast end of the Mission Creek Management Zone.



Key to Features

Estimated Ambient Water Quality Contour (535 mg/L)

Management Zone

TDS

50 mg/L

1500 mg/L

Portions of the management zone that do not have an estimated concentration lie outside the extent of known aquifer properties required for the volume-weighted AWQ method; additionally, these areas lack substantial water quality data. They have been identified as data gaps and will be further described as a data need in the final SNMP.

Ambient Water Quality = 535 mg/L

N 0 1 2 Miles

Document: \\Uslrv1s01\Projects\Coachella Valley WD\SNMP\AWQ\CVWD_AWQ_V3\MXD\MCHeatMap.mxd

Date: October 7, 2014

Mission Creek TDS Ambient Water Quality

MWH

Figure 3-9

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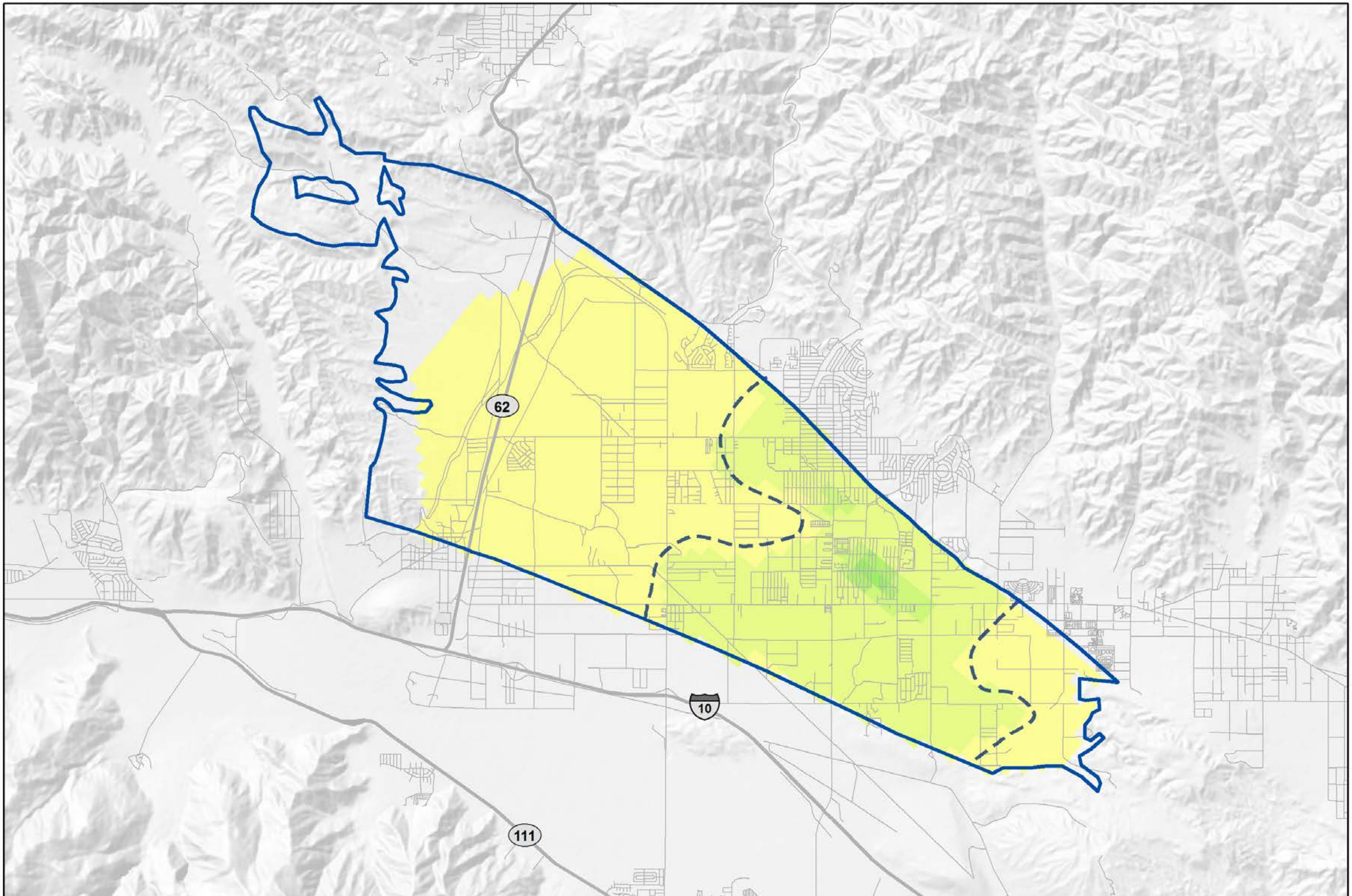

Key to Features

Estimated Ambient Water Quality Contour (3.0 mg/L)

Management Zone

Nitrate (as NO_3)

0 mg/L

71 mg/L

Portions of the management zone that do not have an estimated concentration lie outside the extent of known aquifer properties required for the volume-weighted AWQ method; additionally, these areas lack substantial water quality data. They have been identified as data gaps and will be further described as a data need in the final SNMP.

Ambient Water Quality = 3.0 mg/L

N

0 1 2 Miles

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Date: October 7, 2014

Mission Creek Ambient Water Quality of Nitrate (as NO_3)

MWH

Figure 3-10

3.4 GARNET HILL MANAGEMENT ZONE

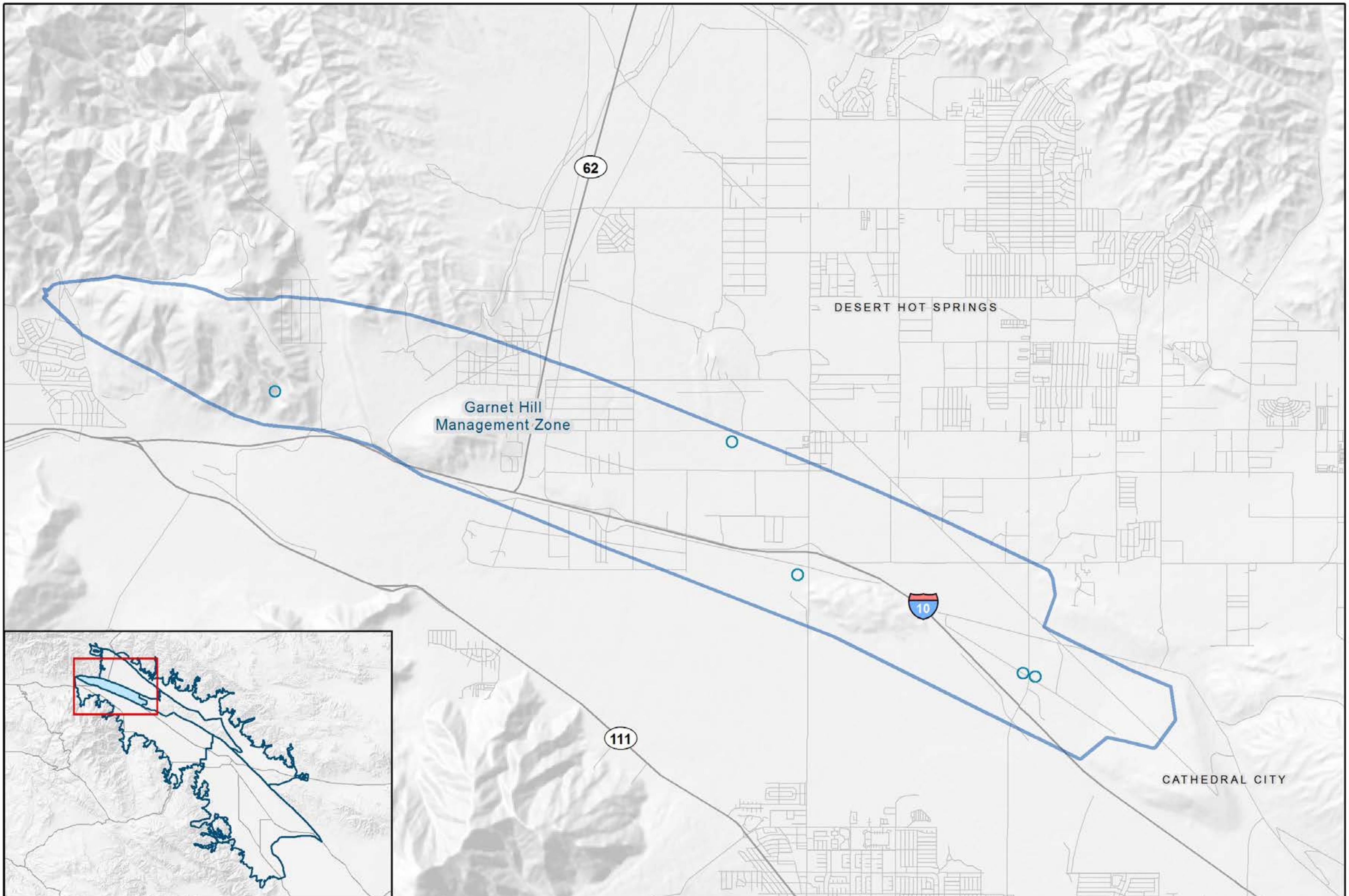
The area between the Garnet Hill Fault and the Banning Fault, named the Garnet Hill Subarea by DWR (DWR, 1964), was considered a distinct subbasin by the USGS (Tyley, 1974) because of the effectiveness of the Banning and Garnet Hill Faults as barriers to groundwater movement. This subbasin is considered part of the Whitewater River (Indio) Subbasin in DWR Bulletin 118 (2003); however, CVWD and DWA consider it a separate subbasin based on USGS findings and water level observations. In 1964 when the initial DWR evaluation was conducted, it was observed that limited data existed to characterize the hydrogeology of this subbasin (DWR, 1964). The Garnet Hill Subbasin is considered an unconfined aquifer with a saturated thickness of 1,000 feet or more based on well depths and has an estimated total storage capacity on the order of 1.0 million acre-feet.

3.4.1 Summary of Unfiltered Data

The unfiltered dataset for the Garnet Hill Management Zone consists of 37 records during the baseline period of 1994 to 2013. Too few data points are available to compute the volume-weighted AWQ for Garnet Hill. The locations of wells with water quality records used in the AWQ determination are illustrated on **Figure 3-11**.The unfiltered dataset for Garnet Hill Management Zone contains 19 TDS records and 18 nitrate records. The statistical summary of unfiltered data for the Garnet Hill Management Zone is presented on **Table 3-10**.

Table 3-10
Descriptive Statistics of Unfiltered Data for Garnet Hill (1994-2013)

Descriptive Statistic	Total Dissolved Solids (mg/L)	Nitrate as NO_3 (mg/L)
Count	19	18
Mean	274	3.5
Median	278	2.4
Mode	-	1.8
Standard Deviation	60	3.3
Range	156 to 390	ND to 14.3
90% Confidence Interval for the Mean	245 to 303	1.9 to 5.1



Key to Features

Management Zone

Highway

Local Roads

Groundwater Well

0 1 2 Miles

N

Document: \\Usirv1s01\Projects\Coachella Valley WD\SNMP\AWQ\CVWD_AWQ_V3\MXD\WQWells_EV_MC.mxd

Date: October 7, 2014

Garnet Hill
Wells with Water Quality Records in 1994-2013

MWH

Figure 3-11

3.4.2 Statistical Description of Ambient Water Quality

TDS concentrations within Garnet Hill Management Zone are very low compared to other management zones. The average TDS is 274 mg/L and the median is 278 mg/L. Nitrate (as NO_3) concentrations average 3.5 mg/L with a median of 2.4 mg/L. Very few data are available for characterizing the spatial distribution of groundwater quality within Garnet Hill Management Zone. However, available data indicate that water quality is generally excellent.

The filtered dataset for Garnet Hill Management Zone consists of 4 TDS values and 4 nitrate values. The statistical summary of filtered data for the Garnet Hill Management Zone is presented on **Table 3-11**.

Table 3-11
Descriptive Statistics of Filtered Data for Garnet Hill (1994-2013)

Descriptive Statistic	Total Dissolved Solids (mg/L)	Nitrate as NO_3 (mg/L)
Count	4	4
Mean	231	2.2
Median	236	1.8
Mode	-	-
Standard Deviation	70	1.7
Range	156 to 295	0.6 to 4.5
90% Confidence Interval for the Mean	119 to 342	ND to 4.8

There are too few data points to draw meaningful conclusions within the Garnet Hill Management Zone. This is a known data gap and will be identified in the monitoring portion of the final SNMP.

3.5 DESERT HOT SPRINGS MANAGEMENT ZONE

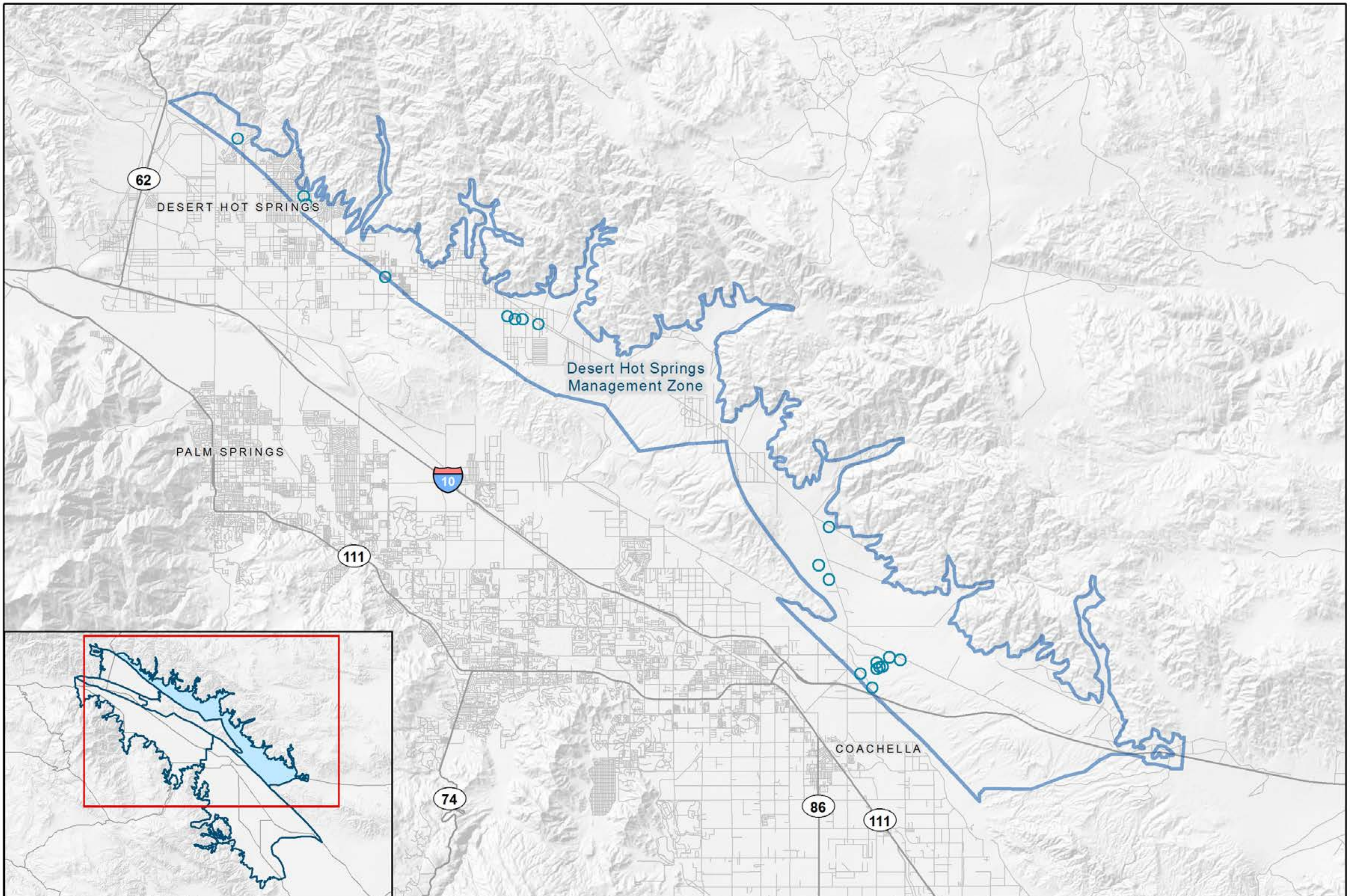
The Desert Hot Springs Subbasin is located adjacent to the Mission Creek and Whitewater River Subbasins and runs northwest to southeast along the foothills of the Little San Bernardino Mountains. The Desert Hot Springs Subbasin is bounded to the north by the Little San Bernardino Mountains and to the southwest by Mission Creek Fault, the San Andreas Fault, and the semipermeable rocks of the Indio Hills. These faults act as groundwater barriers and direct the groundwater in a southeast direction. The subbasin has been divided into three subareas: Miracle Hill, Sky Valley, and Fargo Canyon. Based on limited groundwater data for this area, flow is generally to the southeast.

3.5.1 Summary of Unfiltered Data

The unfiltered dataset for the Desert Hot Springs Management Zone consists of 554 water quality records during the baseline period of 1994 to 2013. Too few data points relative to the size of Desert Hot Springs are available to compute the volume-weighted AWQ. The locations of wells with water quality records used in the AWQ determination are illustrated on **Figure 3-12**. The unfiltered dataset for Desert Hot Springs Management Zone contains 255 TDS records and 299 nitrate records. The statistical summary of unfiltered data for the Desert Hot Springs Management Zone is presented on **Table 3-12**.

Table 3-12
Descriptive Statistics of Unfiltered Data for Desert Hot Springs (1994-2013)

Descriptive Statistic	Total Dissolved Solids (mg/L)	Nitrate as NO_3 (mg/L)
Count	255	299
Mean	1,366	18.5
Median	1,400	11.7
Mode	1,700	6.3
Standard Deviation	443	16.8
Range	240 to 2,200	ND to 101
90% Confidence Interval for the Mean	1,311 to 1,420	16.5 to 20.4



Key to Features

Management Zone
Highway
Local Roads
Groundwater Well

N
0 3 6 Miles

Document: \\Usirv1s01\Projects\Coachella Valley WD\SNMP\AWQ\CVWD_AWQ_V3\MXD\WQWells_EV_MC.mxd

Date: October 7, 2014

Desert Hot Springs Wells with Water Quality Records in 1994-2013

MWH

Figure 3-12

3.5.2 Statistical Description of Ambient Water Quality

High TDS groundwater comprises much of the Desert Hot Springs Management Zone. The average TDS concentration is 1,366 mg/L with a median of 1,400 mg/L. Areas of the Fargo Canyon Subarea near the East Valley Management Zone have the highest TDS and values over 1,000 mg/L exist in the Sky Valley Subarea. The Miracle Hill Subarea has some of the lowest TDS in Desert Hot Springs. In general, nitrate is lower in the Miracle Hill Subarea while groundwater in the Sky Valley and Fargo Canyon subareas show higher nitrate concentrations. Average nitrate (as NO_3) is 18.5 mg/L with a median of 11.7 mg/L.

The filtered dataset for Desert Hot Springs Management Zone consists of 18 TDS values and 19 nitrate values. The statistical summary of filtered data for the Desert Hot Springs Management Zone is presented on **Table 3-13**.

Table 3-13
Descriptive Statistics of Filtered Data for Desert Hot Springs (1994-2013)

Descriptive Statistic	Total Dissolved Solids (mg/L)	Nitrate as NO_3 (mg/L)
Count	18	19
Mean	1,195	18.2
Median	1,190	10.1
Mode	-	-
Standard Deviation	483	24
Range	424 to 2,020	0.1 to 101
90% Confidence Interval	954 to 1,435	6.6 to 29.7

There are too few data points to draw meaningful conclusions within the Desert Hot Springs Management Zone. This is a known data gap and will be identified in the monitoring portion of the final SNMP.

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ATTACHMENT A

Effective Porosity Approximation for the Volume Weighted Average Calculation

1 Introduction

The volume-weighted method for determination of the ambient water quality (AWQ) uses the volume of water in storage to assign weights to water quality concentration within the basin. For estimation of the volume of water in a management zone the management zone is discretized into cells. For each cell, the water level surface, aquifer thickness, and effective porosity are needed. A grid is used to delineate cells for calculations. The volume being approximated is not the total volume in storage (based on porosity) or the total volume that can be pumped (based on specific yield), but the amount available for mixing (based on effective porosity). In this case, the effective porosity is the portion of the interconnected void space of a porous material that is capable of transmitting (and mixing) a fluid.

This document summarizes the definition for effective porosity used to determine the AWQ, published effective porosity values for similar hydrogeologic conditions, and results of an approximation of effective porosity for the Coachella Valley.

2 Definition

Total porosity is defined as the ratio of void space to the total volume of a geologic formation. The effective porosity is the portion of the void space of a porous material that is capable of transmitting (and thereby mixing) a fluid and excludes clay-bound water (water that is electrochemically attached to clay particles that does not contribute to flow). Effective porosity occurs because a fluid in a saturated porous media will not flow through all voids, but only through the voids which are interconnected. Effective porosity is typically higher than specific yield (the volume of water that can be drained by gravity).

3 Representative Effective Porosity Values

A literature search has been conducted to determine effective porosity values for similar hydrogeologic conditions. This section provides a summary of the results of the literature search.

The USGS conducted a modeling study in an area of alluvial and fluvial sand and gravel aquifers to evaluate groundwater vulnerability. As part of their study, they estimated effective porosity. The three-dimensional distribution of effective porosity for the model was estimated by using an empirical relationship between hydraulic conductivity and effective porosity developed by Ahuja, et al. (1989) and modified using information from Morris and Johnson (1967). The application of these methods was completed by Hinkle (1997). A summary of the effective porosities used presented in **Table 1**.

Table 1
Effective porosities of hydrogeological units in Clark County, Washington
(Snyder et al., 1989)

Material	Minimum	Maximum	Mean
Unconsolidated sedimentary aquifer	0.19	0.31	0.31
Troutdale gravel aquifer	0.18	0.31	0.28
Confining unit 1	0.13	0.3	0.19
Troutdale sandstone aquifer	0.18	0.31	0.29
Confining unit 2	0.13	0.3	0.2
Sand and gravel aquifer upper coarse-grained subunit	0.22	0.31	0.28
Sand and gravel aquifer lower fine-grained subunit	0.2	0.24	0.24
Undifferentiated fine-grained sediments	0.13	0.31	0.23

McWorter and Sunada (1977) prepared a summary of values in their text for sedimentary materials. **Table 2** summarizes total porosity and effective porosity values for various sedimentary materials.

Table 2
Representative porosity values
(McWorter and Sunada, 1977)

Material	Total Porosity, n		Effective Porosity, n_e	
	Range	Arithmetic Mean	Range	Arithmetic Mean
Sandstone (fine)			0.02 - 0.40	0.21
Sandstone (medium)	0.14 - 0.49	0.34	0.12 - 0.41	0.27
Siltstone	0.21 - 0.41	0.35	0.01 - 0.33	0.12
Sand (fine)	0.25 - 0.53	0.43	0.01 - 0.46	0.33
Sand (medium)			0.16 - 0.46	0.32
Sand (coarse)	0.31 - 0.46	0.39	0.18 - 0.43	0.3
Gravel (fine)	0.25 - 0.38	0.34	0.13 - 0.40	0.28
Gravel (medium)			0.17 - 0.44	0.24
Gravel (coarse)	0.24 - 0.36	0.28	0.13 - 0.25	0.21
Silt	0.34 - 0.51	0.45	0.01 - 0.39	0.2
Clay	0.34 - 0.57	0.42	0.01 - 0.18	0.06

Urumovic, et al. (2014) researched effective porosity based on geometric mean grain size and measured hydraulic conductivity. This paper suggested procedures for calculating referential grain size and determining effective (flow) porosity result with parameters that reliably determine specific surface area and permeability. The work was based on data from sandy and gravely aquifers to clayey-silty deposits. Representative values for different materials are summarized in **Table 3**.

Table 3
Calculated effective porosity based on geometric mean grain size (Urumovic et al., 2014)

Material	Grain Size (mm)	Effective Porosity
Gravel	> 2	0.16 - 0.31
Sand	0.1 - 2	0.24 - 0.36
Silt	0.01 - 0.1	0.06 - 0.24
Clay	< 0.01	< 0.06

4 Method for Estimating Effective Porosity

There is little published information of the effective porosity in the Coachella Valley. Two groundwater models were obtained for quantifying the vertical and horizontal extent of the groundwater systems. These models cover the Whitewater, Garnet Hill, and Mission Springs subbasins. CVWD (Fogg *et al.*, 2002) developed a groundwater model of the Whitewater and Garnet Hill Subbasins as part the 2002 Water Management Plan (MWH, 2002). The geometry (cell size, layering, and orientation) for this model was used as the base for the recently completed Mission Creek and Garnet Hill Subbasins groundwater model. Significant effort went into characterizing hydrostratigraphy and areas of similar hydraulic properties. The layering of these groundwater models was based on a best estimate of basin lithologic characteristics. The calibrated hydraulic conductivity from these models was used to estimate the effective porosity.

Referencing the empirical method developed by Ahuja, et al. (1989), Hinkle and Snyder (1997) estimated effective porosity values for different hydrogeologic units. Ahuja, et al. (1989) analyzed 473 samples and related effective porosity to hydraulic conductivity values. Though the linear regression ranges over five orders of magnitude of the hydraulic conductivity value, the calculated effective porosity value deviates from measured data for large hydraulic conductivity values. Therefore, Hinkle and Snyder (1997) set a maximum effective porosity value of 0.31 for any hydraulic conductivity values that are greater than or equal to 15 feet per day.

The linear relation derived by Ahuja, et al (1989) is:

$$K_S = 764.5 \times n_e^{3.29} \qquad (1)$$

Where K_S is saturated hydraulic conductivity, in centimeters per hour, n_e is effective porosity. Equation (1) can be rewritten as:

$$n_e = 10^{(logK_S - 2.88)}/_{3.29} \qquad (2)$$

Using the hydraulic conductivity for each model cell, the effective porosity is estimated for the Coachella Valley lithology using equation (2).

4.1 Results

Calibrated groundwater model hydraulic conductivity values are exported from the groundwater models. These conductivity values for each individual cell are inserted into equation (2) for each cell. Similar to Snyder et al. (1998), the maximum effective porosity value is set to 0.31, when hydraulic conductivity value is greater or equal to 15 feet per day. Only calibrated hydraulic conductivity is used; therefore, any decrease in effective porosity with depth due to compaction is not necessary. Zones of like material type are aggregated for summary and comparison to published values of the same material type.

Table 4
Estimated Effective Porosity Value Range for Model Calibrated Hydraulic Conductivity Compared to Literature Data

Material	K	n_e (-)	
	(ft/day)	Estimated	Literature
Clay, Silty Clay	0.005 - 1	0.027-0.133	0.01-0.18
Silt	1 - 11	0.133 - 0.275	0.01-0.39
Sand	11-187	0.275-0.31	0.19-0.31
Gravel	107 - 602	0.31	0.21-0.31

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