Mojave
Salt and Nutrient Management Plan
Final - Volume I of II

Kennedy/Jenks Consultants and Todd Groundwater

December 2015

Mojave Water Agency

FINAL

Mojave Salt and Nutrient Management Plan

Volume I of II

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List of Acronyms

af	acre-feet
afy	acre-feet per year
bgs	below ground surface
BDVWA	Bighorn-Desert View Water Agency
BLM	US Department of the Interior Bureau of Land Management
BMP	Best Management Practice
BPO	Basin Plan Objective
CAWSC	USGS California Water Science Center
CCR	California Code Regulations
CDPH	California Department of Public Health
CEC	Constituents of Emerging Concern
CEQA	California Environmental Quality Act
CIWMC	California Integrated Watershed Mapping Committee
cfs	cubic feet per second
CIWMC	California Interagency Watershed Mapping Committee
CMD	cumulative mean departure
CSA	County Service Area
CSD	Community Services District
CUWCC	California Urban Water Conservation Council
CWA	Clean Water Act
CWC	California Water Code
CWRP	USGS Cooperative Water Resources Program
DAC	Disadvantaged Community
DBP	Disinfection By-Product
DTW	depth to water
DWR	California Department of Water Resources
ET	Evapotranspiration
GAMA	Groundwater Ambient Monitoring and Assessment
GIS	geographical information system
GPCD	Gallons per capita per day
GSWC	Golden State Water Company
HDPP	High Desert Power Project
HDWD	Hi-Desert Water District
IRWM	Integrated Regional Water Management
IWWTP	Industrial Wastewater Treatment Plant
MBAW	Mojave Basin Area Watermaster

List of Acronyms (cont'd)

MCL	maximum contaminant level
MCLB	Marine Corps Logistics Base
MDRCD	Mojave Desert Resource Conservation District
MFR	multi-family residential
MGD	million gallons per day
mg/L	milligrams per liter
mi^2	square miles
MODFLOW	USGS Modular 3-Dimensional Finite-Difference Groundwater Flow Model
MRWG	Mojave River Watershed Group
MS4	Municipal Separate Storm Sewer System
msl	above mean sea level
MUN	Municipal or Domestic Supply
MWA	Mojave Water Agency
MWC	Mutual Water Company
NO_3	nitrate
NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric Turbidity Unit
NWIS	USGS National Water Information System
O&M	Operation and Maintenance
QA/QC	Quality Assurance/Quality Control
RTP	Regional Transportation Plan
RWMG	Regional Water Management Group
RWMP	Regional Water Management Plan
RWQCB	Regional Water Quality Control Board
S/N	Salt and Nutrient
SBC	San Bernardino County
SCAG	Southern California Association of Governments
SCLA	Southern California Logistics Airport
SD	Sanitation District
SFR	single-family residential
SMCL	secondary maximum contaminant level
SNMP	Salt and Nutrient Management Plan
STELLA	Structural Thinking Experimental Learning Laboratory with Animation
SWP	State Water Project
SWRCB	State Water Resources Control Board
SWRP	Subregional Water Reclamation Plant
TAC	Technical Advisory Committee
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
USEPA	US Environmental Protection Agency
USGS	US Geological Survey
UWMP	Urban Water Management Plan
VVWRA	Victor Valley Wastewater Reclamation Authority
WC	water company
WD	water district

List of Acronyms (cont'd)

WDR	Waste Discharge Requirement
WRP	Water Reclamation Plant
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant
WY	water year

Executive Summary

Section 1: Introduction

The State Water Resources Control Board (SWRCB) Recycled Water Policy encourages the use of recycled water as a safe, local, drought-proof, and highly reliable source of water supply. The Policy also encourages recharge of stormwater as a clean local water supply. Because of the potential water quality concern associated with recycled water, the Recycled Water Policy requires completion of a Salt and Nutrient Management Plan (SNMP) for each groundwater basin in California. SNMPs are intended to help streamline the permitting of new recycled water and stormwater projects while ensuring compliance with water quality objectives.

The Mojave SNMP has been prepared for the Mojave Water Agency (MWA) service area. The MWA service area includes portions of both the South Lahontan and Colorado River California Department of Water Resources (DWR)-defined Hydrologic Regions and is governed by the Regional Water Quality Control Boards (RWQCB) Lahontan Region and Colorado River Basin Region.

The purpose of the Mojave SNMP is to (1) promote reliance on local sustainable water sources such as recycled water and stormwater, while maximizing the use of available high-quality imported State Water Project (SWP) supplies in the MWA service area, and (2) manage salts and nutrients from all sources on a sustainable basis to ensure attainment of water quality objectives and protection of beneficial uses so compliance with the Regional Water Quality Control Plans (Basin Plans) is met.

The Mojave SNMP is organized in to ten sections, as listed below:

- Introduction (Section 1)
- Stakeholder Process (Section 2)
- Conceptual Hydrogelogic Model (Section 3)
- Groundwater Quality Analysis (Section 4)
- Salt and Nutrient Loading Analysis (Section 5)
- Project Review, Prioritization, and Implementation Measures (Section 6)
- Anti-Degradation Assessment (Section 7)
- Groundwater Monitoring Program (Section 8)
- CEQA Analysis (Section 9)
- Conclusions (Section 10)

Section 2: Stakeholder Process

The Recycled Water Policy states that development of the SNMP shall be a stakeholder-driven process. The Mojave SNMP was developed in a collaborative setting with input from a wide array of stakeholders through a series of meetings and workshops. SNMP outreach efforts were directed at stakeholders from local water agencies, state and federal agencies, municipalities, regulatory agencies, and local community groups, including environmental organizations, development and real estate interests, tribal communities, disadvantaged communities and other community associations.

Eight stakeholder group meetings were held on a bi-monthly basis, from February 2013 through June 2014 in conjunction with the MWA Integrated Regional Management Plan development. The stakeholder group included 58 municipal water purveyors, several municipal and county agencies, fourteen state and federal agencies, and over 30 local community interest groups. In addition to the regular stakeholder meetings, four separate public workshops and three meetings with disadvantaged communities and tribes were held at various locations around the MWA service area to encourage participation. The Draft SNMP was presented at a MWA Technical Advisory Committee meeting held on February 5, 2015.

In addition to the stakeholder meetings, several workshops/meetings were held with Lahontan and Colorado Regional Board staff during SNMP development to discuss data collection efforts, analysis methodologies, preliminary findings, and the Regional Boards' approach to SNMP adoption and environmental review requirements.

Other outreach activities included the creation of the Mojave SNMP project website, project status updates in MWA newsletters, and invitation to stakeholders for participation and comment via email.

Section 3: Conceptual Hydrogeologic Model

The hydrogeologic conceptual model describes the Study Area characteristics necessary to account for all inflows and outflows of S/Ns as well as existing S/N mass and groundwater volume in storage. The Mojave SNMP Planning Area (Study Area) includes approximately 1,600 square miles of the Mojave River and Morongo groundwater basins. A conceptual hydrogeologic model of the Study Area was developed with emphasis on parameters that define the volume of groundwater and S/N mass in storage and control groundwater flow and S/N transport. Key elements of the conceptual hydrogeologic model include (1) mapping the depth of the production zone, aquifer hydraulic properties, and groundwater occurrence and elevations and (2) identification of major basin/subbasin inflows and outflows.

To facilitate the characterization of groundwater quality, estimation of S/N loading, the Study Area was divided into 22 analysis subregions. Subregional boundaries are based on established groundwater basin/subbasin boundaries with refinements to account for key factors influencing groundwater flow and water quality.

The volume of groundwater in operational storage represent the initial mixing volume of groundwater for the fate and transport modeling of salts and nutrients and is a critical component for understanding the effect of S/N loading on groundwater quality. A basin with a large volume of groundwater in storage has a commensurate capacity to buffer the effect of S/N loading. Conversely, a basin with a small volume of groundwater in storage is more sensitive to S/N loading and groundwater quality changes. The estimated total volume of groundwater in operational storage across the Study Area is about 35,000,000 acre-feet (af), with approximately 26,000,000 af in the Mojave River Basin and 9,000,000 af in the Morongo Basin. These storage estimates do not include potentially extractable groundwater below the base of the current production zone and are thus deemed reasonably conservative (i.e., more sensitive to S/N loading activities). By subregion, the groundwater volume in operational storage is generally near or above 1,000,000 af. Three subregions in the Mojave River Basin (Alto Transition Zone – Floodplain (Helendale), Alto Transition Zone – Floodplain, and Alto – Floodplain Narrows)) and two subregions in the Morongo Basin (Warren Valley and Joshua Tree) have relatively small volumes of groundwater in operational storage (less than 500,000 af) and are thus relatively more sensitive to S/N loading activities.

Natural inflows to the groundwater system in the Mojave River Basin are represented primarily by stream recharge from intermittent storm flows through the Mojave River bed. Subregions in the Morongo Basin are recharged naturally by runoff infiltrating through relatively small ephemeral stream channels, entering as subsurface inflow or mountain-front recharge along the margins of the basin. Due to the relatively low annual amount of precipitation on the valley floor, deep percolation of areal precipitation is considered negligible across the Study Area. The one exception is the Lucerne Valley, where deep percolation of precipitation and mountain-front recharge are natural recharge sources. In addition to recharge from rainfall and storm runoff, subsurface inflows from neighboring subregions represent a major natural recharge source for many subregions.

Anthropogenic inflows to each subregion include managed aquifer recharge, municipal outdoor and agricultural irrigation return flow, treated WWTP effluent discharge, and septic system return flow.

Natural outflows from each subregion include subsurface outflow, groundwater discharge to surface water, evapotranspiration of phreatophytes, and dry lake evaporation. The sole anthropogenic outflow from each subregion is groundwater pumping.

Section 4: Groundwater Quality Analysis

For the Mojave SNMP, TDS and nitrate were selected as appropriate indicator constituents of salts and nutrients (S/Ns) for the Study Area and used to estimate existing and future assimilative capacity for each Study Area analysis subregion.

According to the Lahontan and Colorado River Region basin plans, groundwater designated for municipal or domestic supply (MUN) shall not contain concentrations of chemical constituents exceeding their respective maximum contaminant level (MCL) or secondary maximum contaminant level (SMCL) based upon drinking water standards specified in Title 22 of the California Code of Regulations (CCR). Title 22 of the CCR designates SMCLs for TDS. The recommended SMCL for TDS is 500 mg/L with an upper limit of 1,000 mg/L and a short-term limit of 1,500 mg/L. Title 22 of the CCR designates a primary MCL for nitrate as nitrate (nitrate-NO_3) of 45 mg/L.

In accordance with the SWRCB Recycled Water Policy, the available assimilative capacity for each analysis subregion was calculated by comparing the Basin Plan Objectives (BPOs) with the average concentration of each analysis subregion over the most recent five years of available groundwater quality data. Samples collected from January 2008 through mid-2013 were used to incorporate the last five years of data for all wells. The water quality data set includes routine monitoring of a network of MWA wells and CDPH drinking water wells. Waste Discharge Requirement (WDR) site wells were also included to help establish water quality concentrations near active waste discharge facilities, where other monitoring and production well data were not available.

TDS data were available for 1,987 wells across the Study Area, of which TDS data since 2008 were available for 800 wells. Nitrate data were available for 1,379 wells in the Study Area, of which nitrate data since 2008 were available for 836 wells.

The median groundwater concentration for the recent 5-year water quality averaging period for TDS and nitrate was used to develop dots maps and concentration contour maps across the Study Area. These maps show the variability of groundwater quality within a given subregion. Older historical well concentration data were used to supplement areas lacking recent water quality data using an iterative approach. For four subregions, Baja – Regional, Centro – Regional (east), the western portion of Centro – Regional (west) and Johnson Valley, the narrow distribution of water quality data was deemed inadequate for reliable interpolation. For these subregions, the average subregional concentration was estimated by averaging available well median data.

As shown on **Figure ES-1**, TDS concentrations generally increase in downgradient portions of the Mojave River Basin and along groundwater flowpaths away from the primary recharge source in the basin, the Mojave River. Elevated TDS concentrations (greater than 1,000 mg/L) are generally associated with natural processes including mineralization and evaporation beneath dry lake beds. In the Morongo Basin, groundwater TDS concentrations generally increase along groundwater flowpaths away from the southwestern margins of the basin where mountain-front recharge occurs.

As shown on **Figure ES-2**, few areas in the Mojave River basin have nitrate concentrations near or above the BPO of 45 mg/L. Areas include the Centro – Floodplain and Centro – Regional subregions in the vicinity of Hinkley and northeast of the Helendale Fault. Elevated concentrations in each of these areas are associated with either legacy and/or existing dairy operations and agricultural operations. Elevated nitrate concentrations above 45 mg/L are also observed in the central portion of the Oeste subregion in the vicinity of an active dairy and industrial facility. Elevated nitrate concentrations (between 10 to 22.5 mg/L as NO_3) in the Alto – Mid Regional subregion are likely associated with septic tanks return flows.

In the Morongo Basin, elevated nitrate concentrations in Warren Valley are associated with the entrainment of septage residing in the vadose zone by rising groundwater following enhanced recharge of SWP water from the mid-1990s to early-2000s. Current groundwater nitrate concentrations are significantly below their historical peak in the early-2000s as a result of recent groundwater management. Elevated nitrate in the Joshua Tree subregion and southern portion of the Copper Mountain-Giant Rock subregion is associated with higher-density septic tank use.

Figure ES-1
2008-2013 TDS Concentration Contours

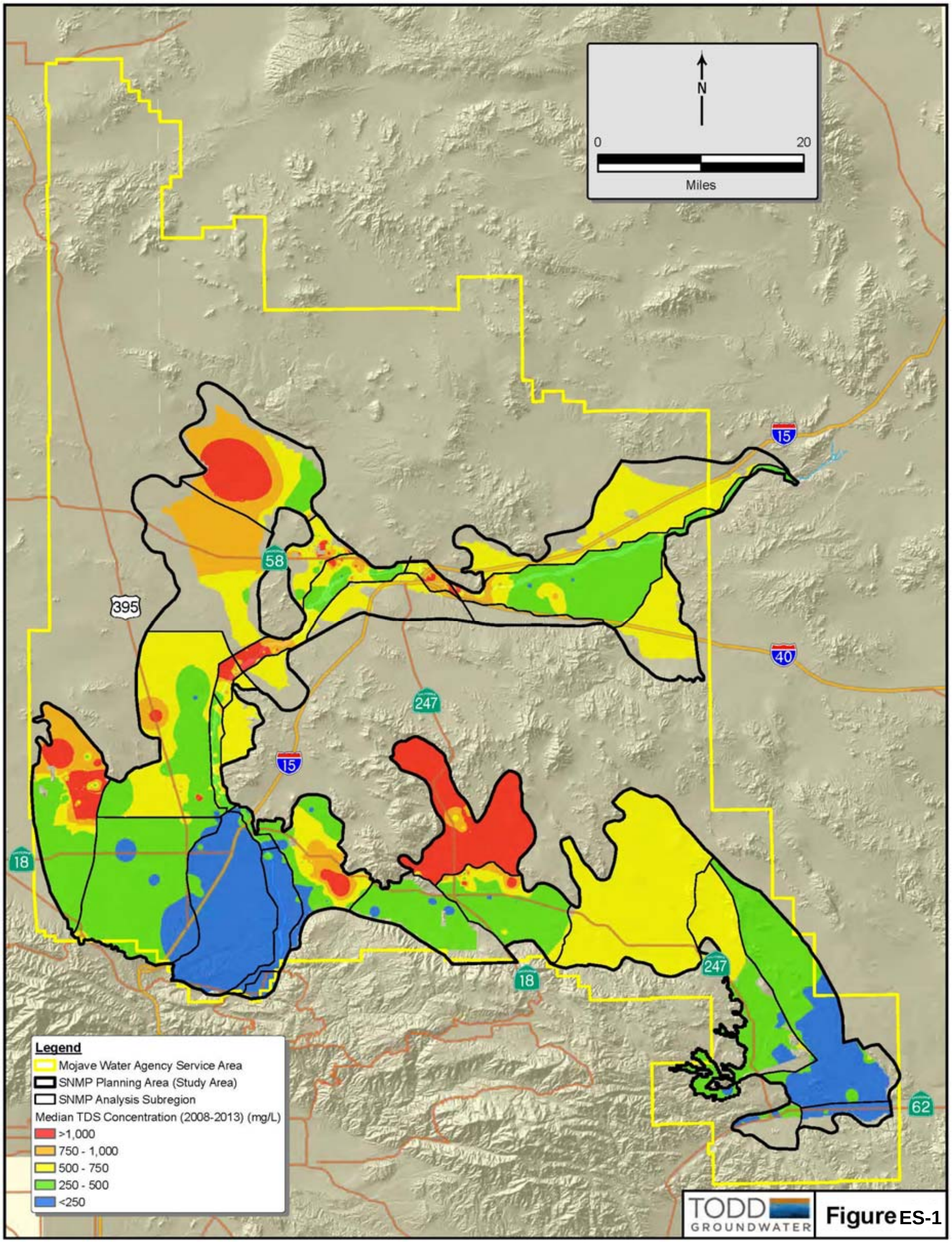
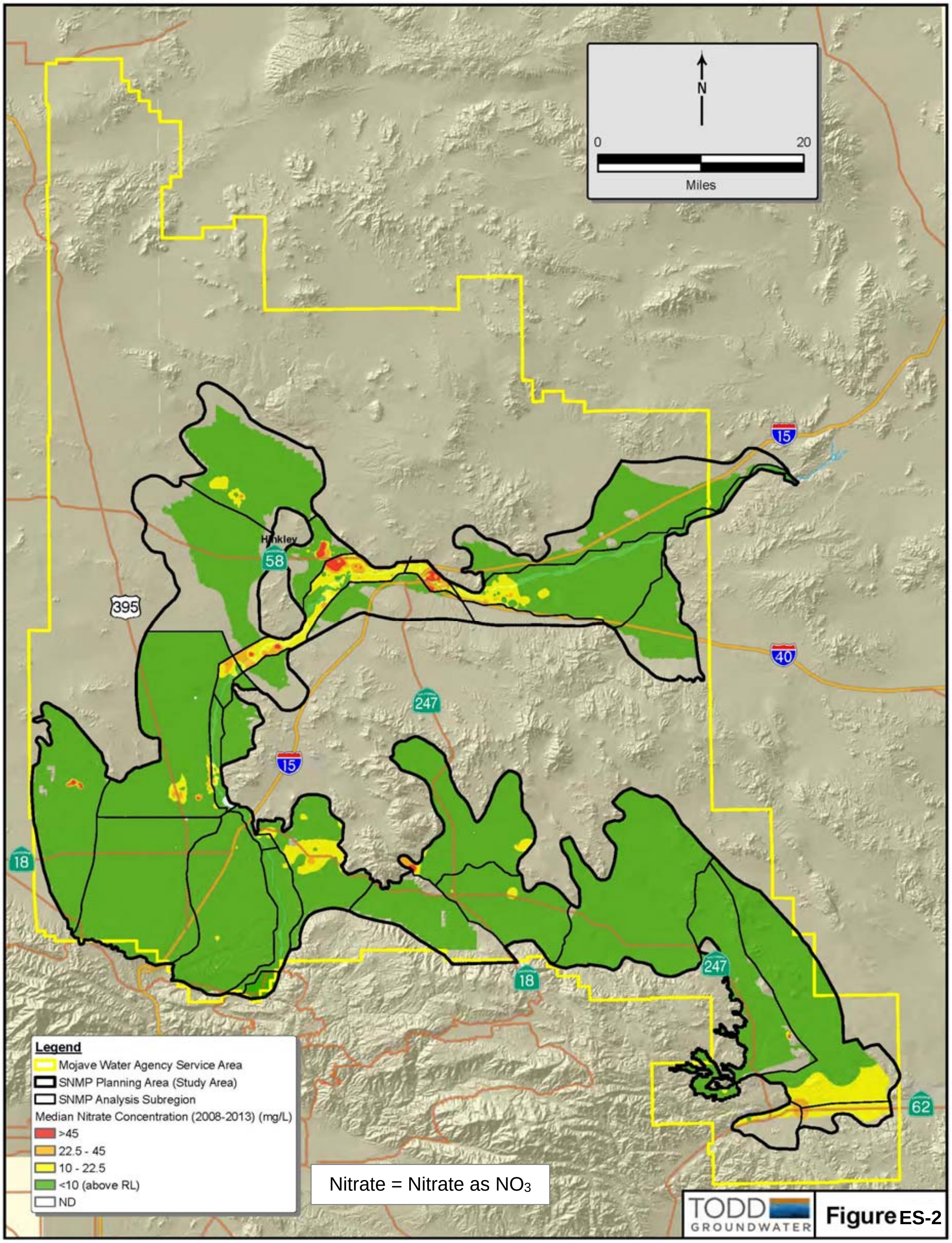


Figure ES-2
2008-2013 Nitrate Concentration Contours



The volume-weighted average TDS and nitrate-NO_3 concentrations were calculated for each subregion by weighting the variable concentration contour surface by the surface representing the volume of extractable groundwater in storage. Results are summarized in **Table ES-1** and depicted on **Figure ES-3**.

Assimilative capacity calculations for TDS and nitrate for each subregion are shown in **Table ES-2**.

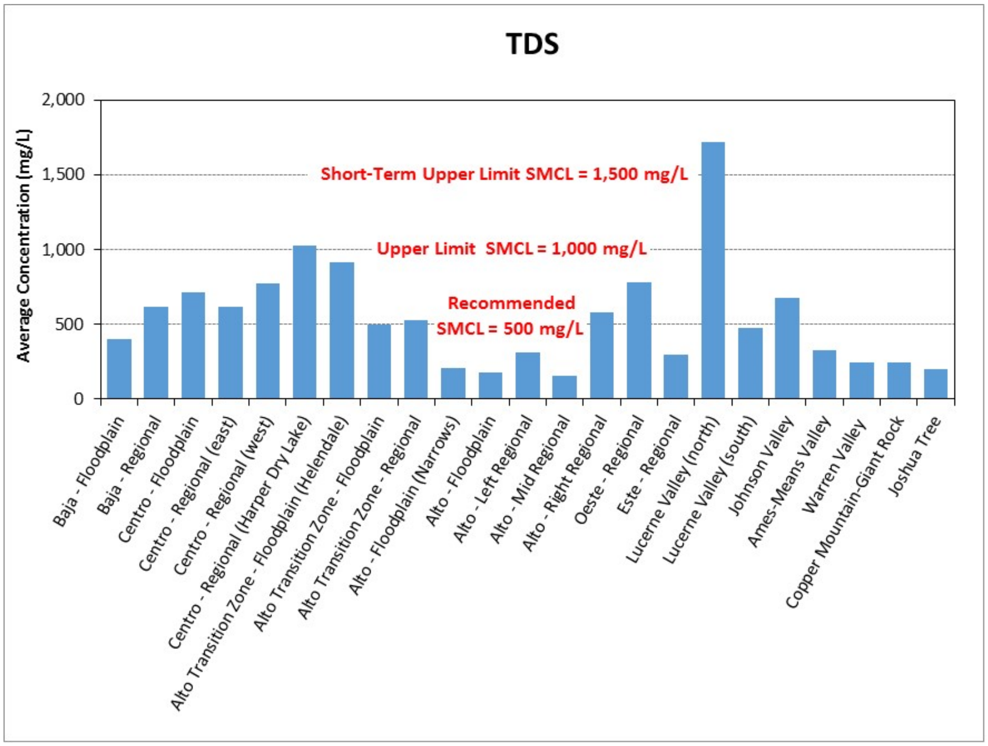
TDS and nitrate time-concentration plot maps for selected wells in each subregion were also generated for the SNMP (and are presented in Subregional Synopses in Appendix C). While the well median and groundwater concentration contour maps illustrate the distribution of existing groundwater quality, the time-concentration plots further provide a historical perspective on groundwater quality and support insights into the relationship between evolving historical land uses on groundwater quality.

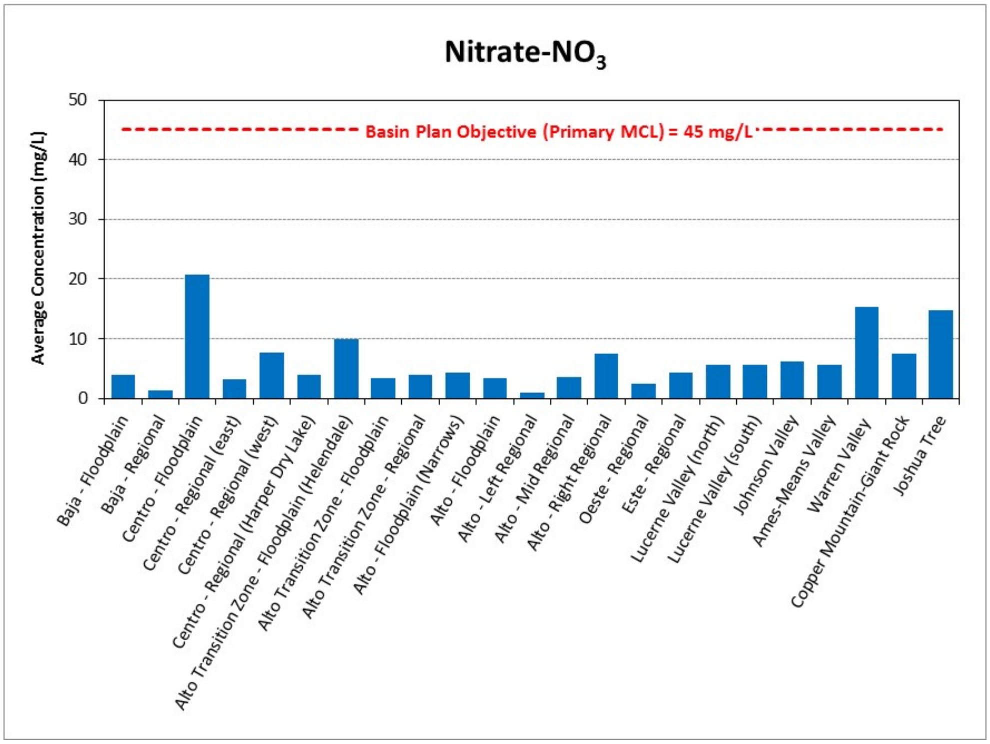
Table ES-1
Average Existing TDS and Nitrate Concentrations by Subregion

SNMP Analysis Subregion	Estimated Groundwater in Operational Storage[a] (acre-feet)	Volume-Weighted Average Existing TDS Concentration (mg/L)	Volume-Weighted Average Existing Nitrate-NO_3 Concentration (mg/L)
MOJAVE RIVER BASIN			
Baja - Floodplain	4,886,000	401	3.9
Baja - Regional	2,014,000	617	1.4
Centro - Floodplain	1,405,000	711	20.7
Centro - Regional (east)	301,000	618	3.2
Centro - Regional (west)	1,580,000	771	7.7
Centro - Regional (Harper Dry Lake)	2,128,000	1,028	4.0
Alto Transition Zone - Floodplain (Helendale)	269,000	915	10.0
Alto Transition Zone - Floodplain	431,000	500	3.4
Alto Transition Zone - Regional	5,067,000	529	3.9
Alto - Floodplain (Narrows)	264,000	205	4.3
Alto - Floodplain	801,000	177	3.3
Alto - Left Regional	1,812,000	310	0.9
Alto - Mid Regional	1,893,000	153	3.5
Alto - Right Regional	1,052,000	579	7.5
Oeste - Regional	807,000	781	2.5
Este - Regional	840,000	299	4.3
Mojave River Basin Total	**25,550,000**		
MORONGO BASIN			
Lucerne Valley (north)	869,000	1,716	5.6
Lucerne Valley (south)	996,000	472	5.7
Johnson Valley	2,273,000	678	6.2
Ames-Means Valley	692,000	330	5.7
Warren Valley	330,033	243	15.4
Copper Mountain-Giant Rock	3,827,410	247	7.5
Joshua Tree	376,748	202	14.7
Morongo Basin Total	**9,364,190**		
MOJAVE RIVER BASIN AND MORONGO BASIN TOTAL	**34,914,190**		

Notes:
mg/L = milligrams per liter
(a) Volume of groundwater above estimated base of groundwater production zone

Figure ES-3
Average TDS and Nitrate Concentrations by Subregion





Notes:
SMCL = Secondary Maximum Contaminant Level; MCL = Maximum Contaminant Level

Table ES-2
Existing TDS and Nitrate Assimilative Capacity

Subregion	TDS				Nitrate-NO_3	
	Average TDS Groundwater Concentration	Assimilative Capacity[a]			Average Nitrate-NO_3 Groundwater Concentration	Assimilative Capacity[a]
		BPO = 500 mg/L	BPO = 1,000 mg/L	BPO = 1,500 mg/L		BPO = 45 mg/L
MOJAVE RIVER BASIN						
Baja - Floodplain	401	99	599	1,099	3.9	41.1
Baja - Regional	617	-117	383	883	1.4	43.6
Centro - Floodplain	711	-211	289	789	20.7	24.3
Centro - Regional (east)	618	-118	382	882	3.2	41.8
Centro - Regional (west)	771	-271	229	729	7.7	37.3
Centro - Regional (Harper Dry Lake)	1,028	-528	-28	472	4.0	41.0
Alto Transition Zone - Floodplain (Helendale)	915	-415	85	585	10.0	35.0
Alto Transition Zone - Floodplain	500	0	500	1,000	3.4	41.6
Alto Transition Zone - Regional	529	-29	471	971	3.9	41.1
Alto - Floodplain (Narrows)	205	295	795	1,295	4.3	40.7
Alto - Floodplain	177	323	823	1,323	3.3	41.7
Alto - Left Regional	310	190	690	1,190	0.9	44.1
Alto - Mid Regional	153	347	847	1,347	3.5	41.5
Alto - Right Regional	579	-79	421	921	7.5	37.5
Oeste - Regional	781	-281	219	719	2.5	42.5
Este - Regional	299	201	701	1,201	4.3	40.7
MORONGO BASIN						
Lucerne Valley (north)	1,716	-1,216	-716	-216	5.6	39.4
Lucerne Valley (south)	472	28	528	1,028	5.7	39.3
Johnson Valley	678	-178	322	822	6.2	38.8
Ames-Means Valley	330	170	670	1,170	5.7	39.3
Warren Valley	243	257	757	1,257	15.4	29.6
Copper Mountain-Giant Rock	247	253	753	1,253	7.5	37.5
Joshua Tree	202	298	798	1,298	14.7	30.3

Notes:
Red highlighted cell indicates that average concentration exceeds respective BPO, and there is no available assimilative capacity.
(a) Assimilative capacity equals BPO minus average concentration (in mg/L); positive value indicates available assimilative capacity; a negative value indicates no available assimilative capacity.

Section 5: Salt and Nutrient Loading Analysis

A salt and nutrient (S/N) loading analysis was conducted to estimate the impact of planned future land uses and associated water use on groundwater quality in the Study Area. The S/N loading analysis considers the existing S/N mass in groundwater storage and the source water volumes of key inflows and outflows and their associated TDS and nitrate concentrations. The analysis also considers any added TDS and nitrate from use as well as other fate and transport processes that influence groundwater concentrations.

To satisfy the goals and objectives of the SNMP, a regional groundwater quality mixing model (SNMP mixing model) focusing on TDS and nitrate was developed to perform two primary functions:

1) Simulate regional groundwater quality within the Study Area over the 70-year future simulation period from water year (WY) 2012-13 through WY 2081-82 under various future S/N loading conditions (or scenarios), and

2) Quantify the effect of planned future recycled water projects and other land use/water use changes on regional groundwater quality.

The original MWA water quality mixing model developed using the Structural Thinking Experimental Learning Laboratory with Animation (STELLA) software package (MWA, 2007) served as the basis for development of the SNMP mixing model. The original STELLA model simulated storage-head-flow relationships in the calibrated USGS Mojave River Basin MODFLOW model. The SNMP model further incorporates fluxes from three separate calibrated MODFLOW models developed for areas in the Morongo Basin covering Ames Valley, Warren Valley, Copper Mountain Valley, and Joshua Tree.

The SNMP mixing model accounts for key stresses and natural volumetric flow rates within each Study Area subregion. The updated (February 26, 2014) MWA demand forecast model served as the primary basis for estimating key stresses on the groundwater system, including anthropogenic inflows (MWA 2014b). These include managed aquifer recharge with imported SWP water; return flow from municipal and agricultural irrigation, including crops and dairies; return flows (leakage) from recreational lakes; WWTP effluent discharge and septic tank discharge; and outflows represented by groundwater pumping for the various water demand sectors.

Because changes in regional groundwater quality and quasi-equilibration to changing land use (loading) conditions may take several decades, a simulation period beyond 2035 was applied to determine the long-term effect of individual and collective S/N loading factors on groundwater quality. Accordingly, water budgets for a future simulation period from 2013 to 2081 were developed for each analysis subregion and input into the SNMP water quality mixing model.

Three future scenarios were simulated to evaluate the impact of population growth and planned future recycled water projects:

- Scenario 1 – 2012 Baseline
- Scenario 2 – Growth (with no recycled water projects)

- Scenario 3 – Growth (with recycled water projects)

Recycled water projects shown in **Table ES-3** were all identified and selected during the development of the recently completed Mojave IRWM Plan (MWA, 2014c). The selected projects were required to meet certain planning requirements such as having completed permits, satisfied project-level environmental review requirements, and finalized future flows and water quality concentrations associated with each project.

Table ES-3
Recycled Water Projects Simulated in Mojave SNMP Future Scenario 3

Agency	Simulated Planned Future Recycled Water Projects	Subregion(s) directly affected	Recycled Water Use
VVWRA	SWRP (Apple Valley)	Alto - Right Regional Alto Transition Zone - Floodplain	Landscape Irrigation
	SWRP (Hesperia)	Alto - Mid Regional Alto Transition Zone - Floodplain	Landscape Irrigation
City of Victorville	IWWTP - Excess Recycled Water Recharge at VVWRA Pond 14	Alto Transition Zone - Floodplain	Excess Recycled Water Pond Discharge
Helendale CSD	Recycled Water Reclamation Plant	Alto Transition Zone - Floodplain (Helendale)	Landscape Irrigation
HDWD	Regional Water Reclamation Plant	Warren Valley	Pond Recharge

Notes:
Victor Valley Wastewater Reclamation Authority (VVWRA)
Helendale Community Services District (Helendale CSD)
Hi-Desert Water District (HDWD)
Subregional Water Reclamation Plant (SWRP)
Industrial Wastewater Treatment Plant (IWWTP)

The Adjudication of the Mojave Basin Area (Judgment) includes an injunction against diverting stormwater flow away from downstream users of the Mojave River; therefore, no major stormwater capture projects are proposed in the area. Although some stormwater related projects were identified in the Mojave River Basin in the IRWM Plan, all projects are in conceptual pre-design phase and, therefore, were not modeled. At this time, there are no immediate plans to capture the stormwater runoff in the Morongo Basin for groundwater recharge. Review of the Mojave River Watershed Group (MRWG) Phase 2 Municipal Separate Storm Sewer System (MS4) annual reports on post-construction Best Management Practices (BMPs) and development of a stormwater resources plan by the Mojave IRWM Regional Water Management Group will be considered during the next SNMP update.

TDS and nitrate concentrations were estimated from the most current, pertinent information available for the following key inflows: Mojave River stream recharge, mountain-front recharge, SWP water Recharge, municipal WWTP effluent discharges, septic tank return flows, and municipal and agricultural irrigation return flows.

The key output of the mixing model is the estimated S/N concentration in each subregion, which was calculated as a volume-weighted average concentration at the end of each annual time step, in mg/L. The concentration difference between Scenario 2 versus Scenario 1 shows the effect of projected growth and associated increased water demand and imported water with no recycled water projects. The concentration difference between Scenario 3 versus Scenario 2 shows the effect of recycled water projects alone.

Similar to existing groundwater conditions, average groundwater TDS concentrations in the Mojave River Basin are below all three BPO concentrations in 4 out of 5 Alto subregions (Floodplain, Floodplain (Narrows), Left Regional, and Mid Regional), Baja – Floodplain, and Este – Regional. Assimilative capacity exists for all subregions based on a BPO of 1,000 mg/L, with the exception of Centro – Regional (Harper Dry Lake), which has historically high TDS concentrations due to dry lake evaporation and natural mineralization processes. At a BPO of 1,500 mg/L, assimilative capacity exists for all Mojave River Basin subregions.

In the Morongo Basin, average groundwater TDS concentrations are below all three BPO concentrations (and thus there is available assimilative capacity) in 4 of the 7 subregions (Ames-Means Valley, Warren Valley, Copper Mountain-Giant Rock, and Joshua Tree). Average TDS concentrations are above 500 mg/L in Lucerne Valley (south) and Johnson Valley. Average TDS concentrations in Lucerne Valley (north) are above 1,500 mg/L due to dry lake bed evaporation and natural mineralization. Therefore, no assimilative capacity exists in Lucerne Valley (north).

Despite some projected increases in nitrate concentrations in selected subregions, groundwater nitrate-NO_3 concentrations are generally well below the BPO concentration in all subregions. The average assimilative capacity is 30.9 mg/L across the Study Area, equating to about 8 mg/L use of current assimilative capacities on average. Subregions with below-average nitrate-NO_3 assimilative capacities (less than 30.9 mg/L) include the following:

- Centro – Floodplain
- Alto Transition Zone – Floodplain (Helendale)
- Alto Transition Zone – Floodplain
- Alto - Floodplain (Narrows)
- Alto – Right Regional
- Warren Valley
- Joshua Tree

Modeling results indicate that planned future recycled water projects have minimal impact on future groundwater TDS and nitrate concentrations in their respective subregions, and in some cases incrementally improve groundwater quality.

Modeling results also demonstrate that imported SWP water recharge would benefit groundwater TDS concentrations in each of the seven subregions projected to receive imported SWP water for groundwater recharge.

Section 6: Project Review, Prioritization, and Implementation Measures

During the Mojave IRWM Plan update process, 14 objectives were developed that reflect the broad range of current challenges and opportunities related to integrated water management in the

Mojave Region (an expanded version of the MWA service area). Two of the 14 objectives are related to recycled water and stormwater. These include the following:

1. Preserve water quality as it relates to local beneficial uses of water supplied by each source, including groundwater, stormwater, surface water, imported water, and recycled water.
2. Increase the use of recycled water in the Region, while maintaining compliance with the Mojave Basin Area Judgment as applicable.

Several ongoing programs are already being implemented that include measures for the management of water quality including salts and nutrients. These include the Mojave Basin Area and Warren Valley adjudications. 2004 RWMP, MWA Groundwater Storage Program, and Mojave IRWM Plan.

Projected future groundwater quality concentrations are not expected to exceed the SNMP water quality management goals and implementation of identified recycled water and stormwater projects will not unreasonably affect the MWA service area groundwater basins' designated beneficial uses. Therefore, no new or additional implementation measures are recommended to manage salts and nutrients within the Study Area. Several programs that help manage groundwater supplies and quality are underway in the basin; these programs fall under six categories, as follows:

- Groundwater Management (including SWP Water Recharge)
- Municipal Wastewater Management
- Recycled Water Irrigation
- Onsite Wastewater Treatment System Management
- Stormwater
- Agricultural

Section 7: Anti-Degradation Assessment

Resolution 68-16, the Statement of Policy with Respect to Maintaining High Quality Waters in California, was adopted by the SWRCB in 1968. The policy is the driving force behind the analysis and planning required for SNMPs.

Based on the evaluation of salt and nutrient loading, impacts from recycled water projects to groundwater TDS and nitrate concentrations (concentration differences between Scenario 3 and Scenario 2) are small, and in some subregions, result in a small incremental benefit to groundwater quality. The one exception is in the Warren Valley, where the new HDWD Regional WRP (which will treat wastewater to recycled water quality) will significantly improve TDS and nitrate groundwater concentrations.

Mixing model results indicate the following:

- No individual recycled water project uses more than 10% of the available assimilative capacity, and combined effects of simulated recycled water projects do not use more than 20% of the assimilative capacity.

- The water quality changes will not result in groundwater quality less than prescribed in the Basin Plan(s).
- The water quality changes will not unreasonably affect existing and anticipated beneficial uses.
- The water quality changes are consistent with the maximum benefit to the people of the state of California.

Accordingly, planned future recycled water projects evaluated under this SNMP are in compliance with SWRCB Resolution No. 68-16.

Section 8: Groundwater Monitoring Program

With respect to groundwater monitoring, the Recycled Water Policy states that the SNMP should include a monitoring program that consists of a network of monitoring locations "… adequate to provide a reasonable, cost-effective means of determining whether the concentrations of salts, nutrients, and other constituents of concern as identified in the salt and nutrient plans are consistent with applicable water quality objectives." Additionally, the SNMP "… must focus on basin water quality near water supply wells and areas proximate to large water recycling projects, particularly groundwater recharge projects. Also, monitoring locations shall, where appropriate, target groundwater and surface waters where groundwater has connectivity with the adjacent surface waters." The preferred approach is to "… collect samples from existing wells if feasible as long as the existing wells are located appropriately to determine water quality throughout the most critical areas of the basin. The monitoring plan shall identify those stakeholders responsible for conducting, sampling, and reporting the monitoring data. The data shall be reported to the RWQCBs at least every three years."

Existing groundwater quality monitoring programs implemented across the Study Area are deemed adequate for determining whether the concentrations of salts, nutrients, and other constituents of concern as identified in this SNMP are consistent with applicable water quality objectives on a subregional scale. The current MWA groundwater monitoring program includes groundwater quality data collected by MWA and the USGS through their cooperative water resources program and through the Drinking Water Program directed by the SWRCB DDW. The SNMP Groundwater Quality Monitoring Program will include data collected from these programs. Available data from special/technical studies conducted in the Study Area pertinent to S/Ns will be included along with RWQCB Waste Discharge Requirement (WDR) site monitoring data and future USGS GAMA monitoring data.

Data from the DDW Title 22 Drinking Water Well Program, MWA-USGS Cooperative Water Resource Program (CWRP), and MWA-led groundwater quality monitoring programs (collectively comprising the bulk of proposed SNMP Groundwater Quality Monitoring Program wells) are uploaded to the SWRCB Division of Drinking Water (DDW) water quality portal and USGS NWIS website on a regular basis. Data are publicly available. While no additional reporting is proposed, MWA is committed in supporting the Regional Boards to protect groundwater quality objectives through its participation in both groundwater monitoring and management. MWA maintains active GIS databases that can aid in the development of future regional policies as well as address localized groundwater quality issues.

Section 9 – CEQA Analysis

In discussions with the Lahontan and Colorado River Basin Regional Board staff, it was determined that if a Regional Board is going to do a basin plan amendment to incorporate the SNMP Implementation Plan, then a Substitute Environmental Document (SED) is required and the Regional Board will be the lead agency for the SED. The SED is the SWRCB's document akin to a programmatic environmental impact report (EIR) under CEQA.

While modeling results indicate that TDS and nitrate increases are anticipated in some subregions with recycled water projects, the assimilative capacity analysis indicates that the increases are in compliance with SWRCB Resolution 68-16 and Section 9.C.(1) of the Recycled Water Policy.

Because the Mojave SNMP makes no request to amend the Water Quality Control Plan or change established water quality control objectives, beneficial use designation, or implementation programs, the Lahontan and Colorado River Basin Regional Boards have determined that no SED is required.

Section 10 – Conclusions

Based on the requirements of the SWRCB Recycled Water Policy, groundwater quality characterization, salt and nutrient loading analysis, and assessment of S/N implementation measures and groundwater monitoring programs, the following conclusions can be made with respect to the Mojave SNMP:

- The extent and scale of existing groundwater monitoring programs is sufficient to characterize existing groundwater quality and evaluate groundwater quality trends with respect to S/Ns on a subbasin/subregion scale.

- Technical information used to develop regional water management planning documents, including the MWA UWMP, MWA IRWM Plan, and MBA Watermaster consumptive use evaluations provide sufficient resolution to reliably estimate contributions from major S/N loading sources on a subbasin/subregional scale.

- Three future scenarios were simulated using the SNMP groundwater quality mixing model to evaluate the individual effects of background population growth (and associated water demand and imported water use) and recycled water projects on future groundwater quality on a subbasin/subregional scale.

- Results of the modeling indicate that while increasing TDS and nitrate concentrations are anticipated in some subregions, planned recycled water projects do not contribute significantly to assimilative capacity use and in some subregions improve groundwater quality with respect to TDS and nitrate.

- The Mojave SNMP is in compliance with SWRCB Resolution 68-16 and Section 9.C.(1) of the Recycled Water Policy with respect to anti-degradation. No individual recycled water project uses more than 10% of the available assimilative capacity, and combined effects of simulated recycled water projects do not use more than 20% of the assimilative capacity. The water quality changes will not result in groundwater quality less than prescribed in the

Basin Plans. The water quality changes will not unreasonably affect existing and anticipated beneficial uses, and the water quality changes are consistent with the maximum benefit to the people of the state of California.

- Modeling results demonstrate that imported SWP water recharge improves groundwater quality with respect to salts and nutrients. TDS and nitrate concentrations of total inflows for subregions projected to receive SWP recharge water are lower with SWP water than without SWP water, clearly demonstrating the benefit of SWP recharge water.

- Existing groundwater monitoring programs implemented across the Study Area comprise the proposed SNMP groundwater monitoring program. Existing groundwater quality monitoring programs are deemed adequate for determining whether the concentrations of salts, nutrients, and other constituents of concern as identified in this SNMP are consistent with applicable water quality objectives on a subregional scale. Water quality data are uploaded to the SWRCB DDW water quality portal and USGS NWIS website on a regular basis. Data are publicly available and can be downloaded to evaluate future basin water quality changes and for comparison with model predictions. While no additional reporting is proposed, MWA is committed in supporting the Regional Boards to protect groundwater quality objectives through its participation in both groundwater monitoring and management.

- Because the SNMP does not propose to change water quality objectives, beneficial uses, or implementation programs, preparation of a SED was not required for the Mojave SNMP.

Section 1: Introduction

In February 2009, the State Water Resources Control Board (SWRCB) adopted the Recycled Water Policy to encourage and provide guidance for the use of recycled water in California. The Recycled Water Policy requires local water and wastewater entities, together with local salt and nutrient contributing stakeholders, to develop a Salt and Nutrient Management Plan (SNMP or Plan) in a cooperative and collaborative manner for each groundwater basin in California, to manage salts, nutrients, and other significant chemical compounds on a watershed- or basin-wide basis. The SNMPs are intended to help streamline the permitting of new recycled water and stormwater projects while ensuring compliance with water quality objectives.

This SNMP was prepared for the Mojave Water Agency's (Agency, MWA) service area as shown on the vicinity map on **Figure 1-1**. The Agency was founded July 21, 1960, due to concerns over declining groundwater levels and created for the explicit purpose of doing "any and every act necessary, so that sufficient water may be available for any present or future beneficial use of the lands and inhabitants within the Agency's jurisdiction." The communities comprising the MWA service area include urban areas as well as a significant amount of rural and farmland. Groundwater is an important resource to the area. Recycled water is currently used for golf course irrigation and as coolant at a power plant and there are plans for expanded use of recycled water for non-potable use to augment or offset existing water supplies.

The MWA service area overlies portions or all of 36 local groundwater basins, which are experiencing general declines in water levels. Most of the groundwater overlain by the MWA service area is covered by two completed adjudications, relating to the major basins: the Mojave Basin Judgment and the Warren Valley Basin Adjudication, located within the Morongo Basin/Johnson Valley Area ("Morongo") as shown on **Figure 1-2.**

The MWA service area also includes portions of both the South Lahontan and Colorado River California Department of Water Resources (DWR)-defined Hydrologic Regions and is therefore governed by the two hydrologic regions of the Regional Water Quality Control Board (RWQCB, Regional Board); the Lahontan Region and the Colorado River Basin Region (see **Figure 1-3**).

The Victor Valley Wastewater Reclamation Authority (VVWRA) was originally formed by MWA to help meet the requirements of the federal Clean Water Act and provide wastewater treatment for the growing area. The original treatment plant (Regional Wastewater Treatment Plant), with supporting pipelines and infrastructure, began operating in 1981, providing tertiary level treatment for up to 4.5 million gallons per day (MGD). As the future primary local distributor of recycled water in MWA's service area, the VVWRA is a major contributor to the development of this SNMP.

This section provides an introduction to the Plan, the purpose and development, organization and adoption of the Plan, and a brief regulatory framework for the Plan.

1.1 Plan Purpose

The purpose of the Mojave SNMP is to:

- Promote reliance on local sustainable water sources such as recycled water and stormwater, while maximizing the use of available high-quality imported State Water Project (SWP) supplies in the MWA service area.

- Manage salts and nutrients from all sources on a sustainable basis to ensure attainment of water quality objectives and protection of beneficial uses so compliance with the Regional Water Quality Control Plans (Basin Plans) is met.

1.2 Plan Objectives

The main objective of the Plan is to evaluate the potential groundwater quality issues that may result from sources of salt and nutrients and to determine if they would unreasonably degrade groundwater quality and potentially worsen groundwater pollution. The specific objectives of the Plan are listed below and described in detail in this Plan:

- Gather available water quality data to evaluate the quality of surface water and groundwater at the watershed and sub-basin level;

- Identify potential sources of salt and nutrients and quantify loads for those sources;

- Determine assimilative capacity of the groundwater based on hydrologic/geologic characteristics and source water quality for individual sub-basins;

- Determine benefit (if any) of using imported SWP supply in the MWA service area;

- Develop a water quality monitoring and reporting plan that is designed to evaluate and track the long-term impacts to groundwater quality resulting from past, current, and future land uses;

- Identify and recommend most appropriate methods and best management practices for reducing and/or maintaining salt and nutrient loadings; and

- Demonstrate that implementation of the SNMP will satisfy the requirements of the State Anti-degradation Policy, State Water Board Resolution No. 68-16 and the Recycled Water Policy.

To achieve the aforementioned objectives, the SNMP includes analysis of the existing land uses and practices, water demand, as well as potential impacts from future use of recycled water.

Figure 1-1
MWA Vicinity Map

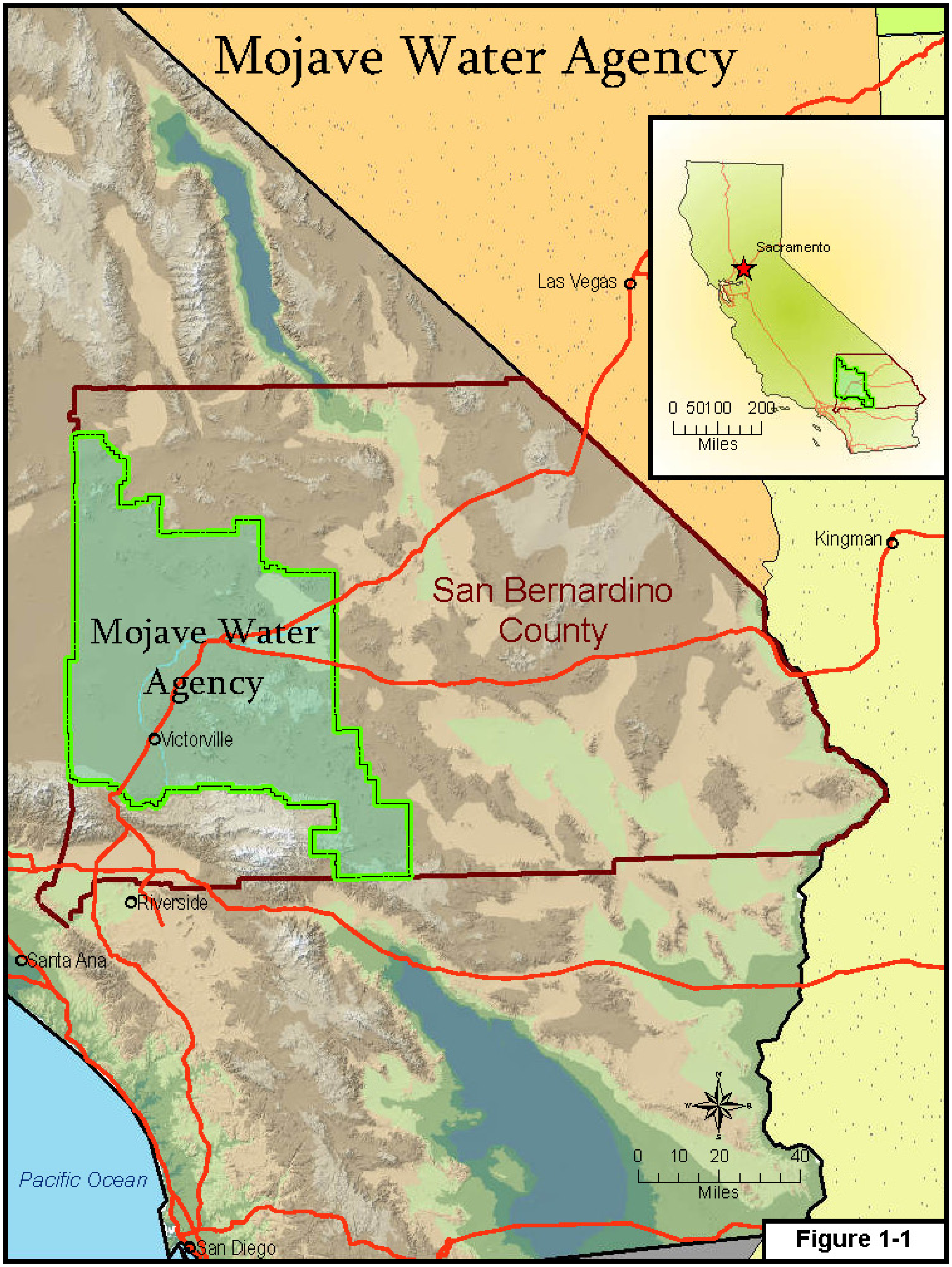


Figure 1-2
MWA Adjudicated Boundary and Subareas

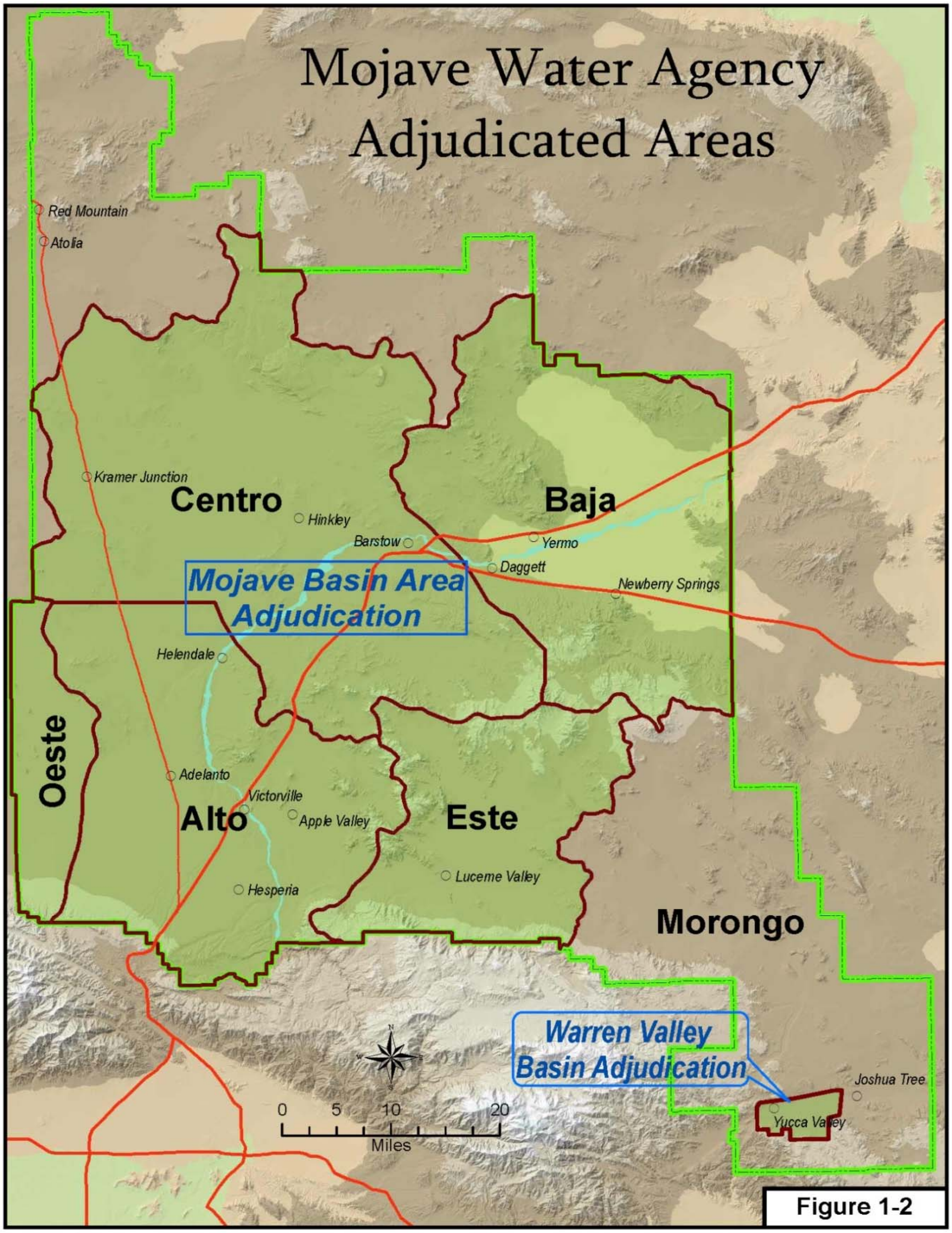
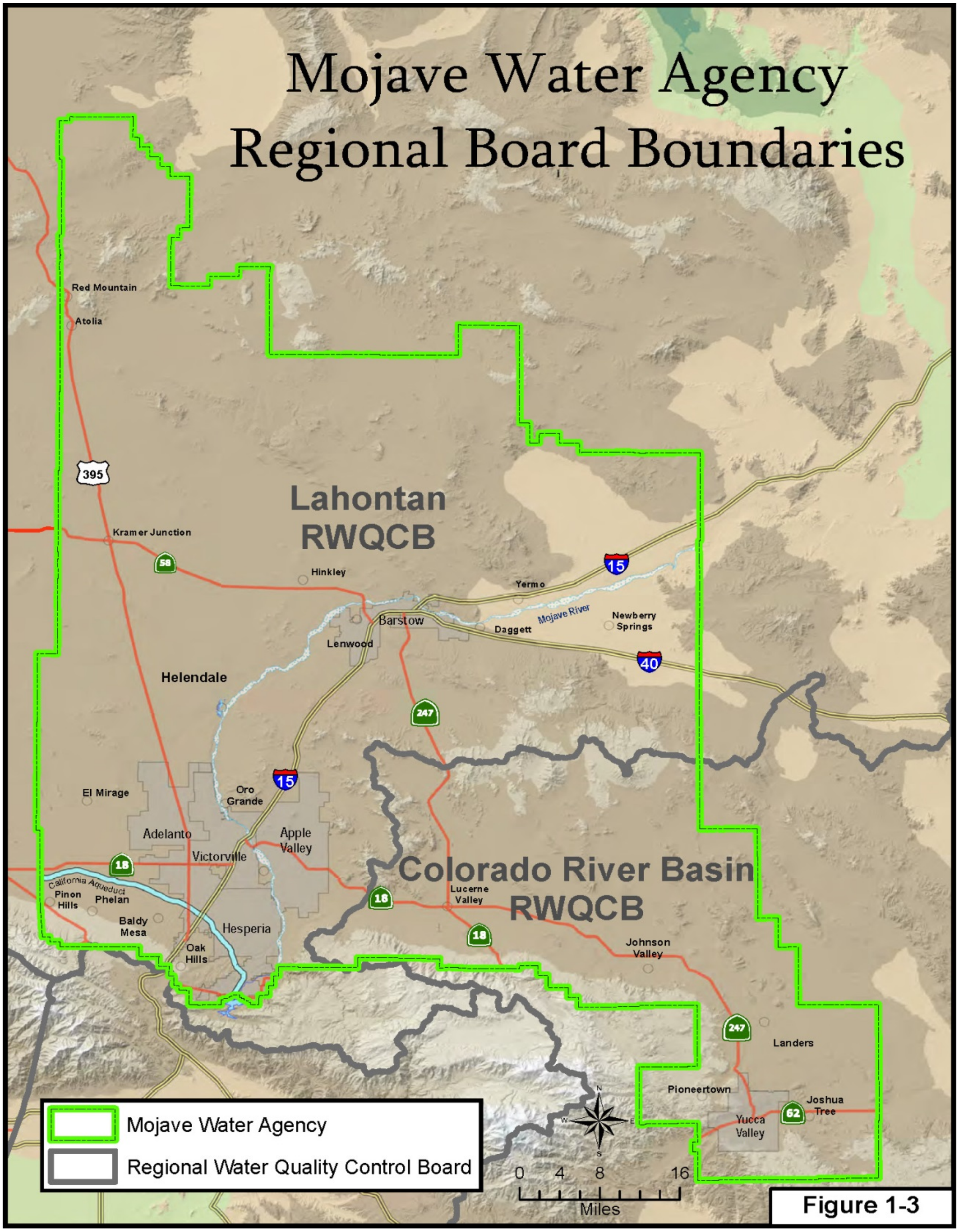


Figure 1-3
MWA Regional Board Boundaries



1.3 Plan Organization

The SNMP provides comprehensive documentation of both technical and planning work that was performed during the development of the SNMP. The SNMP is presented in ten sections, as outlined in **Table 1-1**. The SNMP describes the collaborative process undertaken to develop the Plan, the groundwater basin characteristics including groundwater quality for salt and nutrients, salt and nutrient loading analysis, and future water quality goals, implementation measures, a groundwater monitoring plan and future strategies for implementing the SNMP.

Table 1-1
Plan Organization Summary

Section No.	Section Title	Section Overview
1	Introduction	Introduction of the Plan, description of the Plan purpose, recycled water policy requirement overview, and summary of Plan organization
2	Stakeholder Process	Description of the collaborative process undertaken to inform the stakeholders during the development of the SNMP, including stakeholders meetings and regulatory coordination
3	Background and Groundwater Basin Characterization	Overview of the groundwater basin characterization, water uses, groundwater flow and levels, and water budget
4	Groundwater Basin Water Quality	Characterization of existing water quality conditions, methodology and results of the groundwater quality trend analysis for salt and nutrients, and assimilative capacity
5	Salt and Nutrient Loading Analysis	Characterization of salt and nutrient sources, methodology and results of salt and nutrient loading analyses
6	Goals, Objectives, and Implementation Measures	List of the goals for the use of recycled water and stormwater, existing and proposed implementation measures and volunteer efforts underway within the groundwater basins, and the process of implementing the Plan
7	Anti-Degradation Assessment	Description and summary of the anti-degradation assessment
8	Groundwater Monitoring Plan	Overview of the SNMP groundwater monitoring plan and reporting for ongoing and future monitoring activities, and plan for monitoring CECs in recycled water
9	CEQA	Description of the CEQA analysis in support of the SNMP development
10	Conclusions	Conclusions from the SNMP

1.4 Plan Development Process

The SNMP was developed to meet the state-mandated requirements of the SWRCB's Recycled Water Policy (SWRCB, 2009) and its amendment (SWRCB, 2013). This is a planning document to guide future actions regarding groundwater management and recycled water use in groundwater basins within the MWA service area.

The SNMP development process was organized around the stakeholder input meetings, as described in Section 2. The Mojave Integrated Regional Water Management Plan (IRWM Plan) (MWA, 2014c) was completed concurrently with the SNMP. The large stakeholder group established for the IRWM Plan was used to provide updates on SNMP development and receive stakeholder input. In addition, stakeholder meetings specific to the SNMP were held with the participation of local and regulatory agencies. The stakeholders were invited to review Draft SNMP sections and submit written comments. The Draft SNMP was revised to incorporate comments as appropriate and applicable.

1.5 Scope of Work

MWA staff wrote a Scope of Work detailing tasks to be completed in the SNMP for the Mojave area. The Scope of Work used elements described in the SWRCB's "SNMP Suggested Elements" and Recycled Water Policy.

The Lahontan Regional Board discussed the Draft Mojave SNMP Scope of Work at their meeting on January 12, 2012, for informational purposes only (see **Appendix A**). The goals and requirements for SNMPs were reviewed. MWA staff presented their Draft Scope of Work for the Mojave SNMP. The Water Board provided direction and input on the Draft Scope of Work and content of the Mojave SNMP that were then incorporated into the Final Scope of Work.

For the Colorado River Basin Regional Board, MWA had an initial meeting with the Regional Board staff to discuss data needs for the SNMP on May 22, 2013. A second meeting with the Colorado River Basin Regional Board staff and MWA took place on January 30, 2014, and an informational presentation about the SNMP was given by MWA staff to the Regional Board staff in Yucca Valley on June 26, 2014.

1.6 Plan Adoption

Upon completion of the SNMP and review of the Plan by the Lahontan and Colorado River Basin RWQCBs, MWA published a notice of intention to adopt the Plan after conducting a public hearing on April 23, 2015. The Plan was adopted by MWA on May 28, 2015.

1.7 Plan Limitations

The information in this SNMP is limited to data currently available for the groundwater basins. Information used to derive future conditions was obtained from planning documents such as Urban Water Management Plans (UWMPs); however this information is projected through a 2035 planning horizon and is subject to change. For example, recycled water expansion is planned to serve additional agricultural irrigation customers but exact sites and demands may shift as projects are implemented in the future. To address this, the SNMP Groundwater Monitoring Plan will assess changes in recycled water use on a regular basis.

1.8 Regulatory Framework

The approach for the Plan is consistent with the current regulatory guidelines for the management of salt and nutrients with respect to beneficial uses and water quality objectives.

1.8.1 Sensitive Biological Resources

In February 2009, SWRCB adopted Resolution No. 2009-0011, which established a statewide Recycled Water Policy. The purpose of the Recycled Water Policy is to increase the use of recycled water from municipal wastewater sources that meets the definition in Water Code Section 13050(n), in a manner that implements state and federal water quality laws. The Recycled Water Policy also requires local water and wastewater entities, together with local salt and nutrient contributing stakeholders to develop a SNMP for each groundwater basin or subbasin in California. SNMPs are intended to address salt and nutrient issues and identify and manage all sources of salts and nutrients on a basin-wide level in a manner that ensures attainment of water quality objectives and protection of beneficial uses. SNMPs are also intended to allow for a streamlined process for getting recycled water projects approved and permitted by the RWQCBs while ensuring they meet water quality objectives and support beneficial uses of the MWA service area's groundwater.

The Recycled Water Policy requires that salt and nutrient plans be completed and proposed to the RWQCB within five years from the date of the policy. It also discusses the basic requirements of the salt and nutrient management plans; landscape irrigation; recycled water groundwater recharge projects; anti-degradation; constituents/chemicals of emerging concern; and incentives for the use of recycled water.

1.8.2 Regional Water Quality Control Board Basin Plans

The primary responsibility for the projection of water quality in California rests with the SWRCB and the RWQCBs. As shown on **Figure 1-2**, the MWA service area lies within the jurisdictions of two Regional Boards: the Lahontan and the Colorado River Basin RWQCBs. Both of these RWQCBs implement Basin Plans that are applicable to portions of the service area.

A Basin Plan provides the regulatory guidelines and specifies beneficial uses and water quality objectives for groundwater and surface water within a jurisdiction; provides implementation plans that describe permitting options, waste discharge prohibitions, monitoring and enforcement, salt and nutrient controls, and other control measures necessary to preserve and protect water quality objectives and beneficial uses for groundwater and surface waters. Water quality objectives established by Basin Plans are intended to protect the public health and welfare, and to maintain or enhance water quality in relation to the existing and/or potential beneficial uses of the groundwater. When used in compliance with the Policy, Title 22 of the California Code of Regulations (CCR) (governing the use of recycled water in California), and all applicable state and federal water quality laws, the SWRCB finds that recycled water is safe for approved uses, and strongly supports recycled water as a safe alternative to potable water for such approved uses (SWRCB, 2009).

Basin Plans are mandated by both the Federal Clean Water Act (CWA) and the State Porter-Cologne Water Quality Act (Porter-Cologne). The purpose of the Basin Plan is to protect water quality of the local groundwater basins within the Regional Board boundaries, including the MWA service area.

1.8.3 Anti-Degradation Policy

Resolution 68-16, the Statement of Policy with Respect to Maintaining High Quality Waters in California, was adopted by the SWRCB in 1968. The policy is the driving force behind the analysis and planning required for SNMPs. This policy has two primary parts:

1) Whenever the existing quality of water is better than the quality established in policies as of the date on which such policies become effective, such existing high quality will be

maintained until it has been demonstrated to the State that any change will be consistent with maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water and will not result in water quality less than that prescribed in the policies.

2) Any activity which produces or may produce a waste or increased volume or concentration of waste and which discharges or proposes to discharge to existing high quality waters will be required to meet waste discharge requirements which will result in the best practicable treatment or control of the discharge necessary to assure that (a) a pollution or nuisance will not occur and (b) the highest water quality consistent with maximum benefit to the people of the State will be maintained (SWRCB, 1968).

Resolution 68-16 is incorporated into all Regional Board Basin Plans as it requires that existing high water quality be maintained to the maximum extent possible. It provides conditions under which a change in water quality is allowable. A change must:

- Be consistent with maximum benefit to the people of the State,
- Not unreasonably affect present and anticipated potential beneficial uses of water, and
- Not result in water quality less than that prescribed in water quality control plans or policies.

Section 2: Stakeholder Process

This section describes the stakeholder process used for the development of this SNMP. Recognizing that the success of any regional planning document depends on the degree of involvement with the stakeholder community, broad stakeholder involvement has been and continues to be an essential component of the SNMP process, as described below.

2.1 Overview of Stakeholder Involvement Process

The SNMP was completed in a collaborative setting with input from a wide array of stakeholders and interested parties through a series of meetings that took place during SNMP development. Significant efforts were made during SNMP preparation to identify and solicit input from stakeholders. The collaborative process used for developing the Plan helped to resolve issues and achieve consensus on the schedule and proposed actions for the technical approach for the SNMP. MWA coordinated with local, regional, and regulatory agencies (including representatives from the two RWQCBs) throughout the SNMP development process.

Since the SNMP and the Mojave IRWM Plan update were prepared in parallel, the same stakeholder group meetings were used for both processes. While the Mojave IRWM Plan was completed before the SNMP (adopted in June 2014), the stakeholder group was informed of SNMP status/progress at multiple regularly held meetings and had opportunities to directly participate in development of the SNMP.

SNMP outreach efforts were directed at stakeholders from local water agencies, state and federal agencies, municipalities, regulatory agencies, and local community groups, including environmental organizations, development and real estate interests, tribal communities, disadvantaged communities and other community associations.

Initially, eight stakeholder group meetings were held on a bi-monthly basis, beginning in February 2013, to engage stakeholders and other interested parties in both the IRWM Plan and SNMP development efforts within the MWA service area. **Appendix B** contains typical meeting agendas and handouts and a summary of the meeting minutes for each of the stakeholder meetings. The last of these eight meetings ended in June 2014 with the adoption of the Mojave IRWM Plan and the SNMP being well into the modeling phase of development, with all necessary stakeholder input received and considered. Therefore, no further stakeholder meetings were held until the Draft SNMP was ready for review at the February 5, 2015 Technical Advisory Committee (TAC) meeting (same venue as the IRWM Plan stakeholder meetings).

The following sections summarize the stakeholder involvement related to SNMP development. A more detailed description of IRWM Plan stakeholder activities can be found in the Final Mojave IRWM Plan (MWA, 2014c).

2.2 Stakeholders/Plan Participants

The group involved in development of the SNMP represents an inclusive group of participants, including 58 municipal water purveyors, several municipal and county agencies, fourteen state and federal agencies, and over 30 local community interest groups. Stakeholders that participated in SNMP development are listed in **Table 2-1**.

Table 2-1
SNMP Stakeholder Participants

Agency	Stakeholders
Municipal and County Governments	City of Adelanto, City of Barstow, City of Hesperia, City of Victorville, San Bernardino County Planning Department, Town of Apple Valley, and Town of Yucca Valley.
Wholesale and retail water purveyors, wastewater agencies, flood management agencies, and other special districts	58 municipal water purveyors located in the area, including water districts, cities, mutual water companies, and community services districts. Wastewater agencies including Victor Valley Wastewater Reclamation Authority. Flood management agencies and other special districts, including: Morongo Basin Pipeline Commission, Newberry Community Services District, San Bernardino County Flood Control District.
State and federal regulatory and resource agencies	US Army Corps of Engineers, California Department of Fish and Wildlife, California Department of Water Resources, Colorado River Basin RWQCB, Lahontan RWQCB, State Water Resources Control Board, US Bureau of Land Management, US Bureau of Reclamation, US Department of Agriculture, US Department of Fish and Wildlife, US Environmental Protection Agency, US Forest Service, US Geological Survey, and US Marine Corps Logistics Base (MCLB).
Environmental Community	Audubon Society, California Desert Coalition, Mojave Desert Resource Conservation District, Morongo Basin Conservation Association, Sierra Club, and the Wildlands Conservancy.
Community Organizations	San Bernardino County Farm Bureau, Various Chambers of Commerce, Joshua Basin Citizens Advisory Group, Hesperia Kiwanis Club.

2.3 Public Outreach Process

Development of this SNMP included evaluating and addressing regional issues while recognizing local interests. To do this, the planning process involved stakeholders and incorporated their input. The general approach to outreach during this planning process involved three key elements:

1. Identify stakeholders including disadvantaged communities (DAC) and tribes;

2. Hold DAC meetings at various locations within the area to encourage participation; and

Provide multiple opportunities and methods for participation and communication

2.4 Stakeholder Notification

Stakeholders were notified regarding the SNMP process by means of various outreach processes including the Mojave IRWM Plan website, emails, newsletters, letters via the US Postal Service, and personal phone calls from the MWA staff inviting stakeholders to the next meeting. SNMP development included eight stakeholder meetings, with one stakeholder meeting approximately every one to two months.

2.5 Stakeholder Meetings

The SNMP was able to utilize the existing stakeholder forum for the Mojave IRWM Plan to provide updates on SNMP developments. These meetings provided background on the planning process, identified challenges and opportunities for the SNMP, drafted and discussed Plan objectives, considered opportunities for coordination among local and regional agencies, and presented and received comments on the Draft SNMP.

Other information shared with stakeholders at the meetings included the proposed technical approach for estimating salt and nutrient loadings, plan development schedule, review of existing water quality, the proposed monitoring plan and implementation measures and the findings of the anti-degradation analysis. The meetings were also planned to obtain input and direction on assumptions and key elements of the SNMP moving forward. Stakeholder meetings are summarized in **Table 2-2.**

In addition, four public workshops/meetings and three DAC meetings were held at various locations around the MWA service area to encourage participation. The four public meetings were held in Lucerne Valley, City of Barstow, City of Victorville, and Newberry Springs. The three DAC meetings were held in Piñon Hills/Phelan, Helendale, and the Town of Yucca Valley. All of the workshops and meetings had similar formats consisting of a brief presentation on the process being used to update the IRWM Plan followed by small group discussion sessions.

Besides the regularly scheduled stakeholder meetings, it was necessary to have stakeholder meetings specific to the SNMP to coordinate between MWA and the two Regional Boards during data collection and at key milestones. Initially, the SNMP strategy and approach was presented to the Regional Boards to get their agreement on the methodology. Once the Draft SNMP was reviewed by both Regional Boards and comments incorporated, a final SNMP presentation will be provided to each Regional Board.

Table 2-2
Stakeholder Meetings during Plan Development

Stakeholder Participation	Description	Date
Kickoff Meeting	Kickoff Meeting to replace one workshop.	January 23, 2013
Stakeholder Meeting - Introduction	This meeting introduced the consultant team to the TAC, identified other potential stakeholders, presented overview of the SNMP process and identified key technical components for the Plan… Also, the Lahontan RWQCB staff attended the meeting and the Colorado River Basin RWQCB staff attended via a conference call.	April 4, 2013
Stakeholder Meeting – Status Update	A brief update on the status of the SNMP was provided.	June 6, 2013
Stakeholder Meeting – Status Update	A brief update on the status of the SNMP was provided.	November 5, 2013
Two Regional Board Workshops	Present MWA's strategy and approach for SNMP – MWA staff in person and Todd on GoToMeeting.	January 29 & 30, 2014 – both Water Boards
Informal SNMP/Regional Board Meetings	Todd completed S/N characterization and loading and provided criteria for model runs to Schlumberger. Schlumberger completed STELLA model runs; Todd developed details of Future Scenario 2 and 3; Todd developed the SNMP monitoring program. KJ developed implementation measures and conducted investigation as to what if any preliminary CEQA analysis was required; Todd/KJ completed draft SNMP.	Throughout 2014
Stakeholder Meeting	Mojave IRWM Plan adoption was completed at this meeting. SNMP in modeling phase.	June 23, 2014
Stakeholder Meeting (MWA TAC) – Draft SNMP	Todd presented the Draft SNMP and led a workshop discussion with stakeholders.	Feb 5, 2015
Present Draft Final SNMP	DELIVERABLE – Draft Final SNMP to Lahontan and Colorado RWQCBs	March 2, 2015
Lahontan RWQCB	MWA receives formal comments on Draft Final SNMP from Lahontan RWQCB	April 8, 2015
Lahontan RWQCB	MWA staff presents Powerpoint presentation on Draft SNMP to Lahontan RWQCB	June 11, 2015
Colorado RWQCB	MWA/Todd meet with Colorado RWQCB staff to discuss Draft Final SNMP	August 17, 2015
Colorado RWQCB	MWA receives comments on Draft Final SNMP from Colorado RWQCB	October 29, 2015
Present Final SNMP	DELIVERABLE - Final SNMP to VVWRA, MWA, RWQCBs	November 13, 2015
VVWRA Board of Commissioner's	VVWRA staff presents Final SNMP to Board for approval.	December 2015; exact date TBD
Public Hearing to Adopt Final SNMP	MWA staff presents Final SNMP to Board at Public Hearing.	exact date TBD
MWA Board of Directors	MWA staff presents Final SNMP to Board for approval.	exact date TBD
Colorado Regional Board Meeting	Presentation of Final SNMP at Colorado RWQCB meeting - Palm Desert.	exact date TBD
Lahontan Regional Board Meeting	Presentation of Final SNMP at Lahontan RWQCB meeting – Barstow.	February 11, 2016

In addition to the stakeholder meetings, SNMP development also included the following outreach activities:

- Project Website – The Mojave IRWM website (http://www.mywaterplan.com) serves as an important tool to solicit involvement from interested parties of the area as well as to provide information and updates pertinent to the SNMP process. Participation opportunities described on the website include regular public meetings, submittal of written comments, and online surveys. The public meeting dates, agenda and other meeting materials are provided on the website.
- Electronic and Written Communications – Email was the main tool used to maintain stakeholder communication and engagement. The email list, which contained approximately 200 entries, as well as a direct mail list of 30, was used to invite participation at the meetings as well as to notify stakeholders that materials were available for review.
- Newsletter –The newsletters contained important updates on the SNMP process as well as information on upcoming stakeholder meetings.
- Contact Information – Both email addresses and phone numbers were made available to any stakeholder or interested party to ask questions or offer comments about the SNMP.

Section 3: Conceptual Hydrogeologic Model

This section describes the conceptual hydrogeologic model of the Mojave SNMP Planning Area (Study Area), which includes key groundwater basins/subbasins within MWA's service area. Hydrogeologic conditions are presented with emphasis on the factors that define the volume of groundwater in operational storage and control groundwater flow and salt and nutrient (S/N) transport. Key factors include the basin geometry and depth of alluvial sediments, aquifer hydraulic properties, groundwater occurrence and elevations, and basin inflows and outflows. Projected water supply and demand estimates are also summarized, as they form the basis for future water budgets in the Study Area.

3.1 Groundwater Basins and Watersheds

3.1.1 USGS Groundwater Basins and Subbasins and MWA Management Subareas

The Mojave River Groundwater Basin (Mojave River Basin) and Morongo Groundwater Basin (Morongo Basin) cover over 2,400 square miles (mi^2) of western San Bernardino County (**Figure 3-1**). The basins are located in the southwestern Mojave Desert (also known as the High Desert) on the northeastern flanks of the San Gabriel and San Bernardino mountains, which separate the High Desert from coastal basins and inland valleys of Los Angeles and Riverside counties.

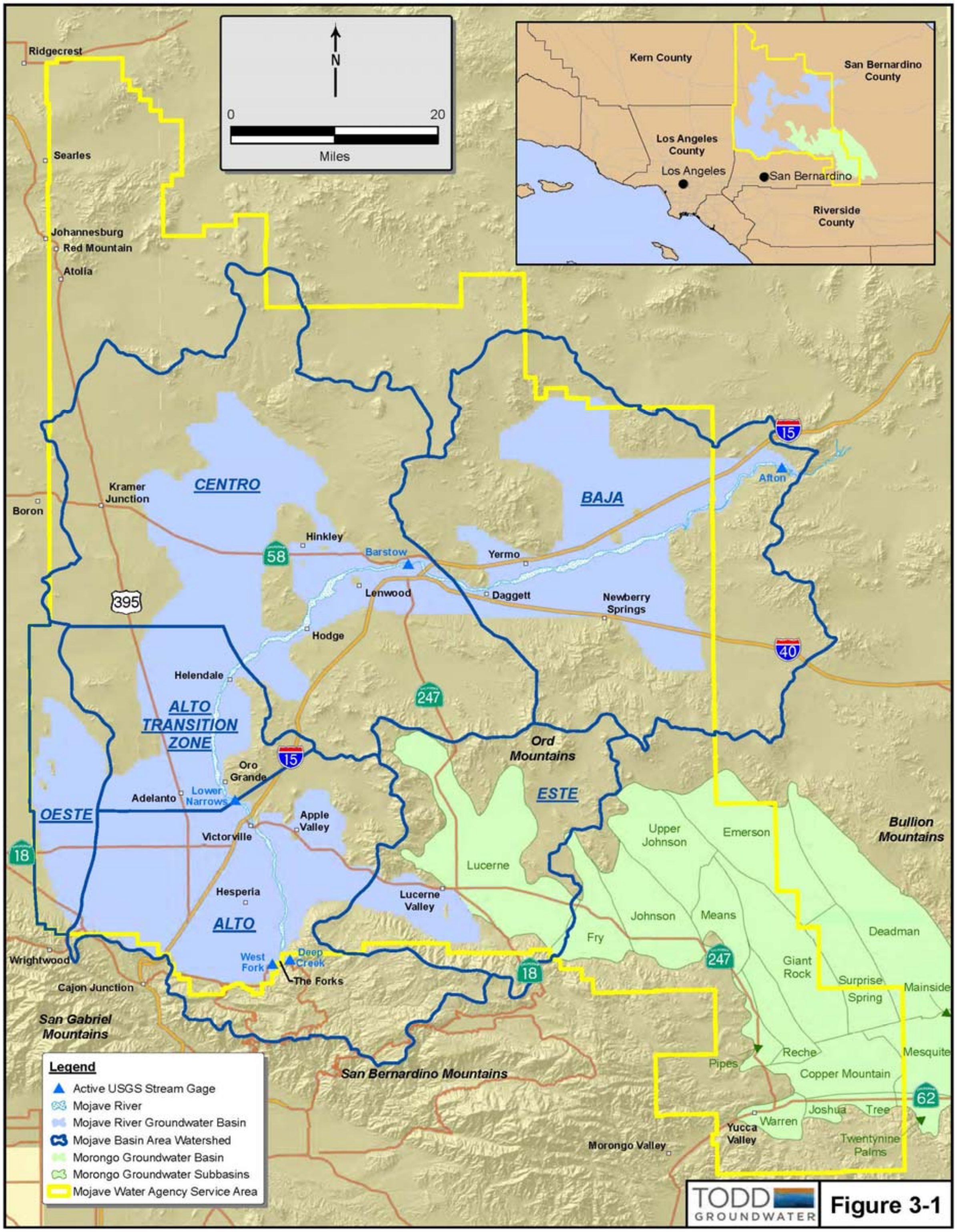
The Mojave River Basin is located within the Mojave Basin Area Watershed. The boundaries of the Mojave River Basin were defined by the US Geological Survey (USGS) initially by Hardt (1971) and subsequently refined by Stamos, et al. (2001). The Mojave River Basin covers approximately 1,400 mi^2, while the total watershed covers approximately 3,900 mi^2. The Mojave River Basin is bordered on the west by Antelope Valley and shares its southeastern boundary with the Morongo Basin.

Due to long-term overdraft of groundwater for municipal, agricultural, and industrial supplies, water production rights within the Mojave Basin Area Watershed (excluding areas outside of MWA's service area[1]) were adjudicated in 1996. As defined in the Mojave Basin Area Adjudication (Judgment), the Mojave Basin Area and associated groundwater basins were divided into five management subareas: Este, Oeste, Alto, Centro, and Baja. The Alto Subarea was subsequently further divided to create the Alto Transition Zone (Transition Zone), a sub-management unit used to better assess groundwater and surface flows from Alto to Centro. Each subarea is composed of a unique set of hydrologic and hydrogeologic conditions and land and water demand profiles. The subareas are also hydraulically inter-related to varying degrees based on their respective location to the Mojave River and the distribution of water use in the basin.

The Morongo Basin covers approximately 1,000 mi^2 and is surrounded by the Ord Mountains to the north, the Bullion Mountains to the east, the San Bernardino Mountains to the southwest, and the Little San Bernardino Mountains to the south. To characterize the variable hydrogeologic conditions across the basin, the USGS divided the Morongo Basin into 17 inter-connected subbasins: Lucerne, Fry, Johnson, Upper Johnson, Means, Pipes, Reche, Emerson, Giant Rock,

[1] The Mojave Basin Area on Figure 3-1 represents the natural watershed boundaries. The adjudicated portion of the Mojave Basin Area includes only those areas located within MWA's service area.

Figure 3-1
USGS Groundwater Basins and Subbasins and MWA Management Subareas



Copper Mountain, Surprise Spring, Deadman, Mesquite, Mainside, Warren, Joshua Tree, and Twentynine Palms. Subbasin boundaries generally are aligned with groundwater divides and geologic faults that represent partial barriers to groundwater flow. Due to historical overdraft conditions, water production rights in the Warren Subbasin were adjudicated in 1977.
As shown on **Figure 3-1**, the Este Subarea (watershed) includes the southeastern portion of the Mojave River Basin (in the vicinity of Lucerne Valley) and the western portion of the Morongo Basin (Lucerne Subbasin).

3.1.2 Mojave SNMP Planning Area

Figure 3-2 shows the Study Area in relation to the Mojave River and Morongo basins. As shown on the figure, the Study Area includes key groundwater basin/subbasin areas within MWA's service area. The Coyote Dry Lake area in the northern portion of the Baja Subarea was not included due to limited water use and water quality data in that area. The Study Area includes all portions of the Copper Mountain, Giant Rock, and Joshua Tree subbasins of the greater Morongo Basin. Excluded from the Study Area are the Emerson, Surprise Spring, Deadman, Mainside, Mesquite, and Twentynine Palms subbasins of the Morongo Basin, as these subbasins generally lie east and outside of MWA's service area and are characterized by limited water use and water quality data.

As shown on **Figure 3-2** and **Figure 3-3**, alluvial basin areas west (upgradient) of the Pipes Subbasin of the greater Morongo Basin were included in the Study Area. This area includes the unincorporated community of Pioneertown, which falls within the California Department of Water Resources (DWR) Ames Valley Basin - Basin 7-16 in Bulletin 118 (DWR, 2003; see Section 3.1.3 for discussion of DWR basin boundaries).

To facilitate the characterization of groundwater quality, estimation of S/N loading, and fate and transport modeling, the Study Area was divided into 22 analysis subregions as shown in **Table 3-1** and **Figure 3-2.**

Table 3-1
Mojave SNMP Analysis Subregions

Mojave River Basin	Morongo Basin
1. Baja – Floodplain	16. Lucerne Valley (north)
2. Baja – Regional	17. Lucerne Valley (south)
3. Centro – Floodplain	18. Johnson Valley
4. Centro – Regional	19. Ames-Means Valley
5. Centro – Regional (Harper Dry Lake)	20. Warren Valley
6. Alto Transition Zone - Floodplain (Helendale)	21. Copper Mountain-Giant Rock
7. Alto Transition Zone – Floodplain	22. Joshua Tree
8. Alto Transition Zone – Regional	
9. Alto - Floodplain (Narrows)	
10. Alto – Floodplain	
11. Alto - Left Regional	
12. Alto - Mid Regional	
13. Alto - Right Regional	
14. Oeste – Regional	
15. Este – Regional	

Figure 3-2
SNMP Planning Area (Study Area) and Analysis Subregions

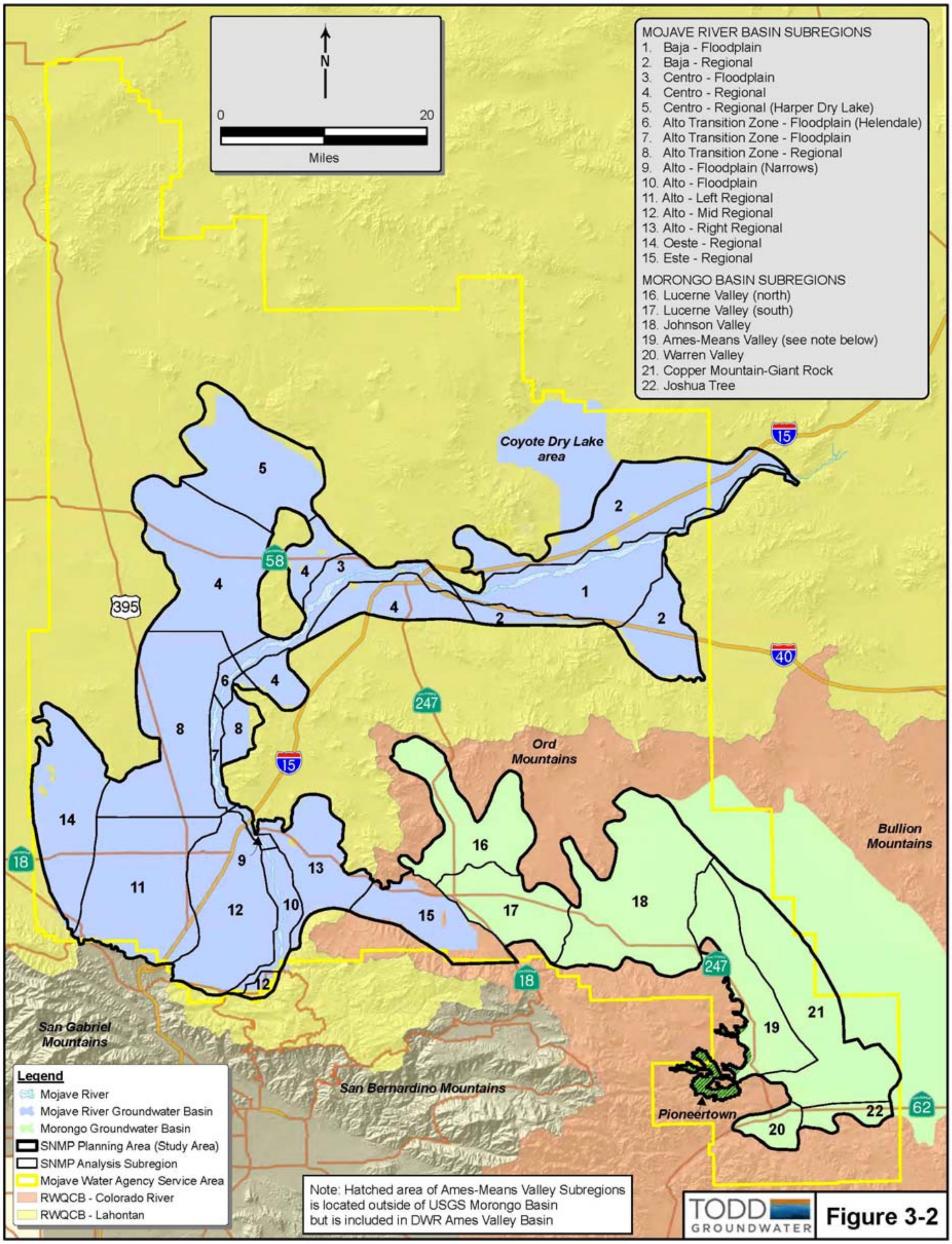
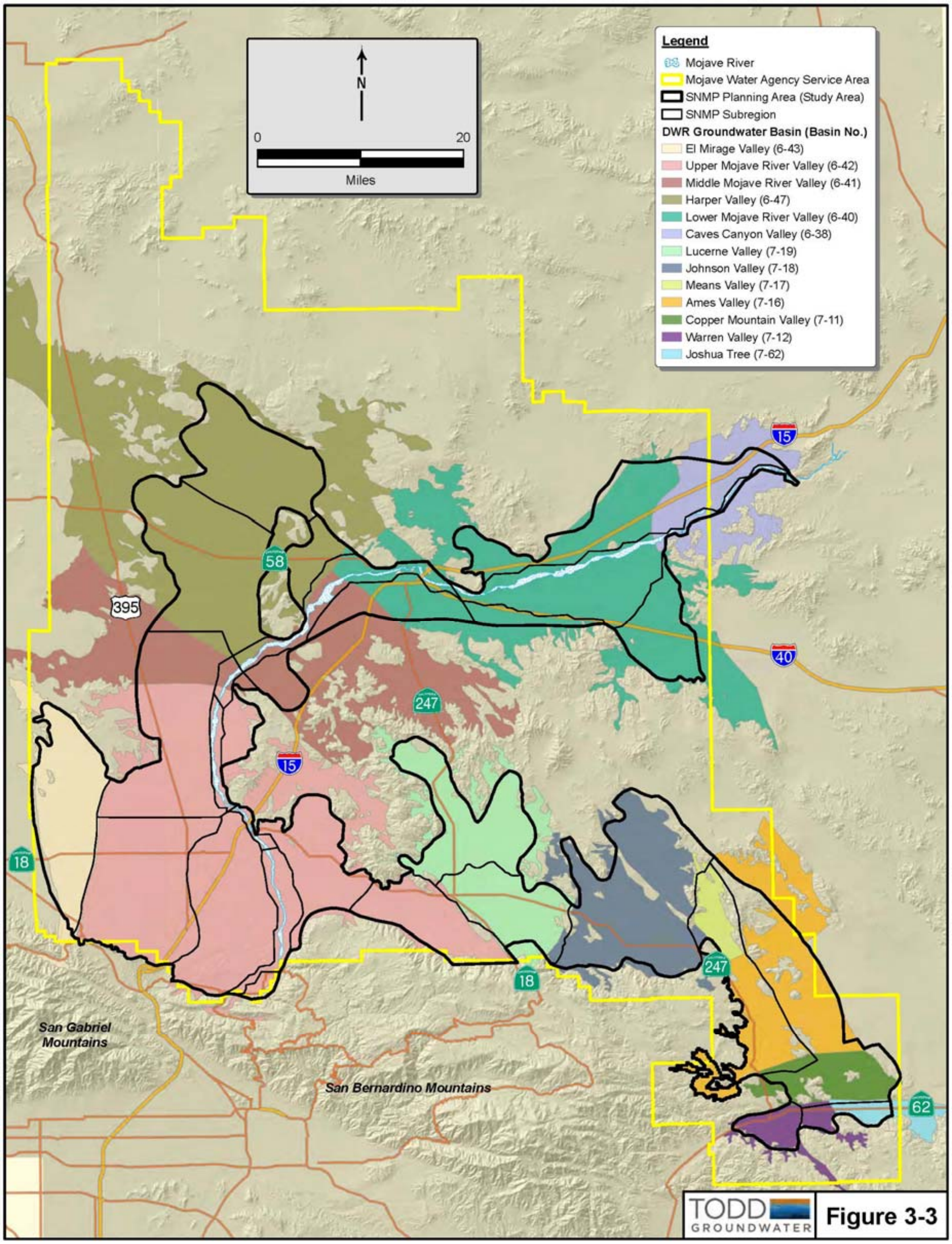


Figure 3-3
SNMP Planning Area (Study Area) and DWR Basins



Boundaries of the Study Area analysis subregions are based on established groundwater basin/subbasin boundaries and refined to account for key factors influencing groundwater flow and water quality, including geologic faults and variable hydrogeologic conditions along the Mojave River. Subregional boundaries generally coincide with those originally established for the MWA 2004 Regional Water Management Plan (also known as the 2004 IRWM Plan and Groundwater Management Plan) (2004 RWMP) (MWA, 2004) with modifications to improve alignment with USGS-defined Morongo Basin/Subbasin boundaries (e.g., Warren Valley and Copper Mountain-Giant Rock-Joshua Tree subregions).

It is noted that areas west and east of the Mojave River within the Centro - Regional subregion were characterized separately for groundwater storage and ambient groundwater quality. However, the volumetric flow and S/N loading budgets for the Centro – Regional subregion as a whole were evaluated for S/N transport modeling.

As shown on **Figure 3-2**, the Lucerne Valley area was divided into separate northern and southern subregions. The boundary separating the two subregions was chosen to evaluate areas with groundwater TDS concentrations greater than 1,000 mg/L to the north separately from areas with TDS concentrations below 1,000 mg/L to the south. It is recognized that the location of the 1,000 mg/L TDS concentration boundary is not fixed and may shift as a result of S/N loading conditions in the future. However, because groundwater flow is also parallel with the boundary (subsurface flow across the boundary is limited), the interpreted 1,000 mg/L TDS contour line provides a convenient, technically-based boundary by which to guide water quality policy.

While the technical analyses conducted for the SNMP (groundwater quality characterization, S/N loading analysis, and fate and transport modeling) were performed only for the Study Area analysis subregions, it is noted that S/N loading from contributing watershed areas outside of Study Area subregions were also considered (e.g., for estimation of storm runoff/stream recharge and mountain-front recharge).

As shown on **Figure 3-2**, analysis subregions associated with the Mojave River Basin generally fall under the jurisdiction of the Lahontan Regional Board, while subregions associated with the Morongo Basin are under the jurisdiction of the Colorado River Basin Regional Board. The one exception is the Este – Regional subregion, which is the only subregion within the Mojave River Basin that falls under the jurisdiction of the Colorado River Basin Regional Board.

3.1.3 DWR Groundwater Basins

The Study Area overlies several groundwater basins as defined in DWR Bulletin 118 (DWR, 2003). **Figure 3-3** shows the relationship between the Study Area, analysis subregions, and pertinent DWR-defined basins. With the exception of the western portion of the Ames Valley Basin, the USGS basin and MWA management subarea nomenclature is used throughout the Mojave SNMP in lieu of DWR basin nomenclature to characterize groundwater quality and apportion S/N loading for the Mojave SNMP. However, because groundwater beneficial uses are delineated by DWR basin in the Lahontan Basin Plan, the spatial relationships between DWR basins and the Mojave SNMP analysis subregions are presented for reference.

3.1.4 Hydrologic Units (Watersheds)

Beneficial uses for groundwater in the Colorado Region are delineated by watershed, or Hydrologic Unit as defined by the California Interagency Watershed Mapping Committee (CIWMC, 2004). Accordingly, the relationship between the Study Area, analysis subregions, and associated CIWMC Hydrologic Units is shown on **Figure 3-4** for reference.

3.2 Physical Setting

The Study Area is generally defined by the northwestern flanks of the San Bernardino and San Gabriel mountains. Uplifted along the San Andreas Fault, these mountains reach elevations of over 10,000 feet above mean sea level (feet msl). The Study Area is characterized overall as an alluvial plain, consisting of valleys and closed basins composed of water-bearing unconsolidated alluvial sediments. Overall, land surface elevations range from about 5,500 feet msl along the southern boundary of the Mojave River Basin to about 1,500 feet msl near Afton at the northeastern end of the Mojave River Basin. The higher elevations are associated with the upper portions of alluvial fan deposits along the mountain front. The alluvial sediments have filled the down-dropped areas within the mountainous topography; bedrock hills and ridges interrupt the coalescing alluvial fans.

Numerous alluvial washes are located along the northeastern flanks of the San Bernardino and San Gabriel mountains and other local mountains. The washes, most of which are ungaged, are fed by intermittent storm runoff from local desert mountains and represent the primary natural source of recharge for most of the Morongo Basin.

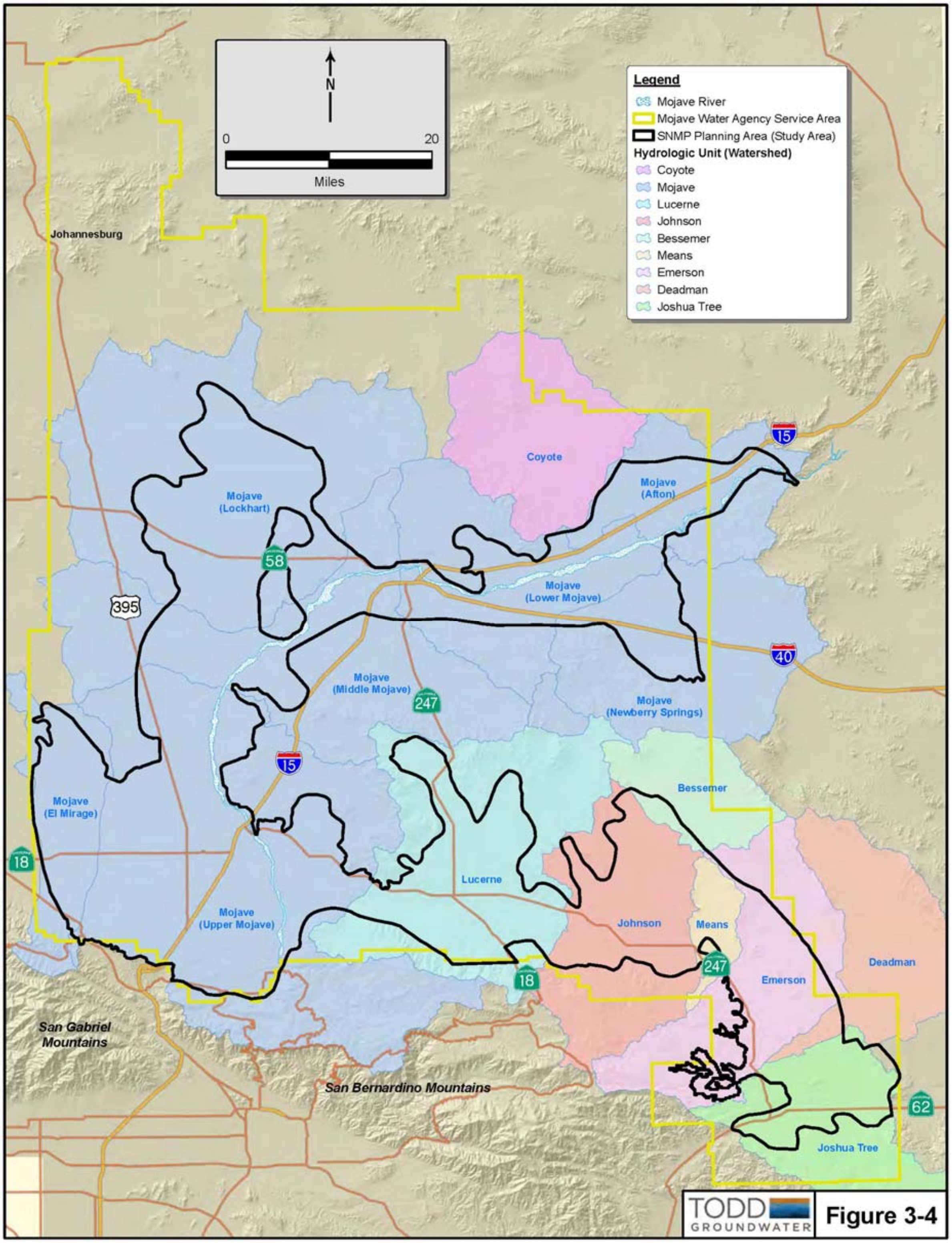
3.2.1 Climate

MWA collects climatic data from a regional network of weather stations spanning the Study Area and contributing watersheds areas. Climatic data are routinely evaluated to assess the contribution of runoff from precipitation in the San Bernardino Mountains (Mojave River headwaters) and valley floor and the evaporative potential within the Study Area. Some weather stations are maintained by MWA and others are maintained by various local and federal government agencies and citizen observers programs. The stations collect various weather data on temperature, precipitation, and evaporation. Precipitation gages are mostly located within the Mojave Basin Area Watershed and the surrounding mountains.

Runoff in the upper watershed contributes substantially more to the recharge of the Mojave River and Morongo groundwater basins than precipitation falling directly on the valley floor within each basin. Average annual precipitation in the San Bernardino Mountains is approximately 41 inches, while average annual precipitation on the valley floor averages 5 to 7 inches. Annual precipitation is variable; for the headwater stations, annual precipitation has been as high as 98 inches and in recent years, as low as 6 inches. The large variation in annual precipitation in the San Bernardino Mountains directly affects the volume of stream runoff and, in turn, the annual water supply within the Study Area.

Precipitation on the valley floor is more consistent year to year and averages approximately 5 to 7 inches per year across the Mojave River and Morongo basins. Currently, no rain gages are located in the local desert mountains. However, isohyetal (rainfall distribution) maps are available that

Figure 3-4
SNMP Planning Area (Study Area) and Hydrologic Units



account for elevation, rain shadow effects, and temperature inversions. These indicate that estimated average annual precipitation is as much as 10 inches in the local desert mountains. Temporal precipitation patterns in the local desert mountains more closely resemble those on the valley floor than those of the San Bernardino Mountains.

3.2.2 Surface Water and Watersheds

The defining surface feature in the Mojave River Basin is the Mojave River, an ephemeral stream fed primarily by storm runoff from the northern slopes of the San Bernardino Mountains. Other sources of flow in the river include localized groundwater discharge to surface water (baseflow), direct discharges of treated effluent, and ungaged local storm runoff from ephemeral desert washes. Streamflow losses from the river represent the primary source of groundwater recharge in the Mojave River Basin; these have varied in response to both physical and human factors over time.

The Mojave River is formed by the confluence of two tributary streams, West Fork of the Mojave River and Deep Creek, at a location called The Forks (**Figure 3-1**). From The Forks, the Mojave River flows north through Victorville, then north-northeast to Barstow, and finally east towards Afton Canyon, where it exits the Mojave River Basin approximately 100 miles from its origin. The Mojave River terminates at Silver Dry Lake near Baker, approximately 20 miles downstream of Afton Canyon.

The USGS has historically operated eight stream gaging stations on the Mojave River and its two main tributaries above the Mojave River Dam (at The Forks). Five of these gages (shown on **Figure 3-1)** are currently active and provide a near-continuous record of Mojave River discharge since 1930.

At present the Mojave River is perennial (continuously flowing) only along a short section downstream of The Forks, in the vicinity of Upper and Lower Narrows and Afton Canyon, and in the section immediately downstream of the VVWRA's Regional Wastewater Treatment Plant (WWTP), about 4 miles downstream of the Lower Narrows. During and immediately after large winter storm events in the San Bernardino Mountains, the Mojave River flows through several and sometimes all of its reaches.

There is no sizable river in the Morongo Basin, only small ephemeral streams that collect runoff from surrounding mountains during storms. The mountain stream runoff either percolates into the stream bed or, during infrequent large storm events, flows along dry alluvial washes to dry lake beds, where it evaporates.

3.2.3 Land Use

The Study Area includes the incorporated cities of Victorville, Adelanto, Hesperia, and Barstow, and the towns of Apple Valley and Yucca Valley, all within the County of San Bernardino. The San Bernardino County General Plan identifies the Victor Valley area as one of the fastest growing areas in San Bernardino County (San Bernardino County, 2007). This area includes the cities of Victorville, Hesperia, Adelanto, and the town of Apple Valley, which are all located in close proximity to one another. The fastest growing city in this area is currently Adelanto, which is projected to have approximately 2.4 percent annual population growth from 2010 to 2035, based on the Southern California Association of Governments (SCAG) 2012 Regional Transportation Plan

(RTP) growth forecast (baseline of 2008). Land in the vicinity of these cities has steadily been converted to more urban uses to accommodate population growth (SCAG 2012).

The Barstow area includes the City of Barstow and surrounding unincorporated communities. Most of the future growth in the Barstow area is anticipated to occur within the incorporated City of Barstow and adjacent unincorporated communities (Golden State Water Company (GSWC), 2011). Located within (and in the vicinity of) the Morongo Basin are the unincorporated communities of Johnson Valley, Pioneertown, Landers, and Joshua Tree and the incorporated Town of Yucca Valley. Development within this area is concentrated in the Town of Yucca Valley.

Besides suburban and residential development, the Study Area also supports recreational and agricultural uses and a number of energy generation plants and other large utility pipelines. Agricultural land uses occur primarily in the unincorporated areas east of Barstow, in the vicinity of Lucerne Valley and El Mirage, with additional scattered uses along the Mojave River north of Victorville. Wind and solar energy generating plants are also prevalent along with electric transmission lines, water, crude oil and natural gas pipelines (MWA 2004b).

Major existing land use categories within the MWA service area include residential, commercial, industrial, agricultural, and open space public land uses. Open space is the dominant land use within the service area, most of which is owned and managed by federal and state agencies, primarily the US Department of the Interior Bureau of Land Management (BLM). Private (non-government) land is mostly urban, containing residential and commercial development as well as undeveloped acreage. Residential, commercial and industrial land uses are, for the most part, concentrated around the main urban centers, including Victor Valley (Victorville, Hesperia, Apple Valley, and Adelanto), Barstow and the Town of Yucca Valley (SCAG 2012).

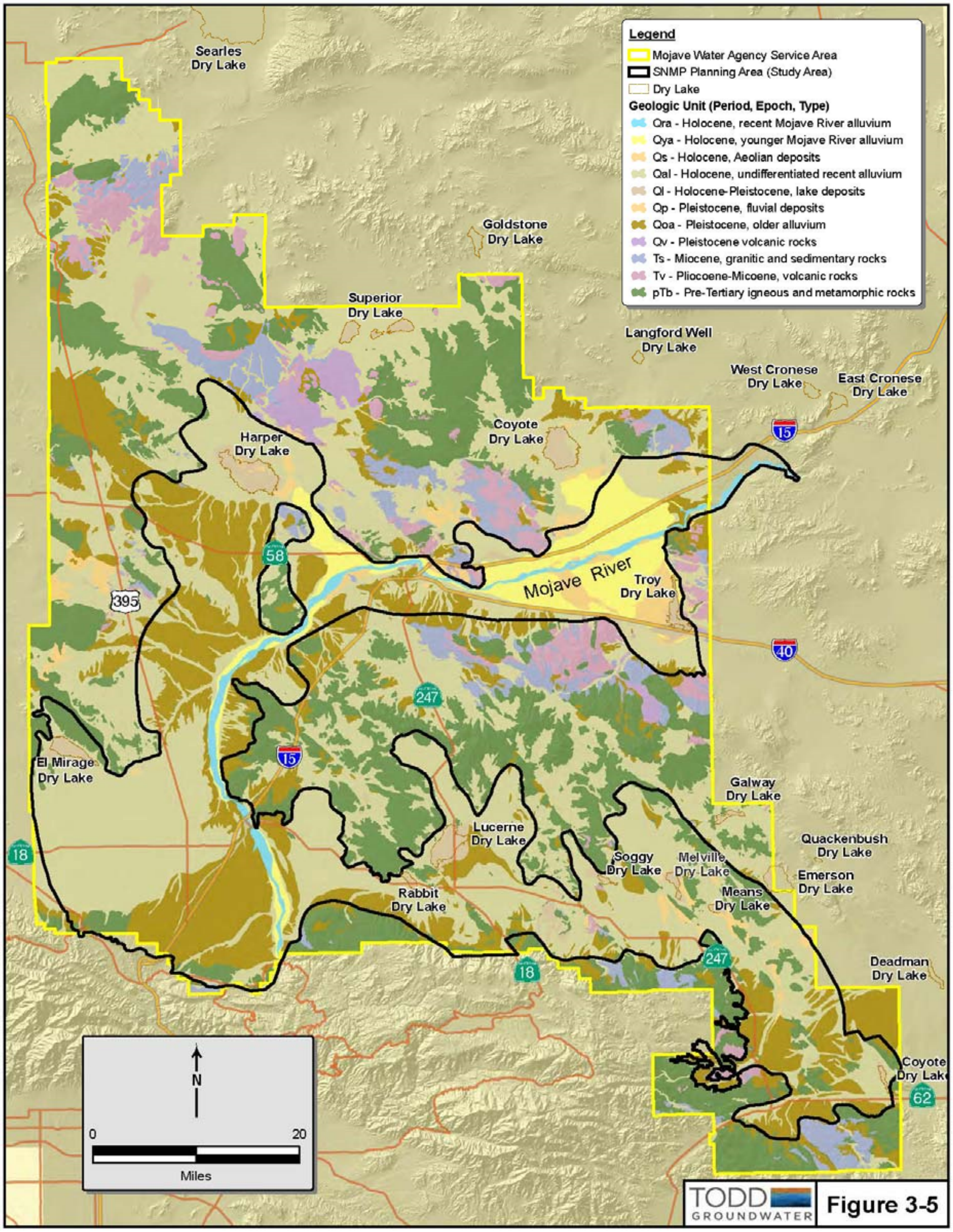
3.3 Geology, Faults, and Aquifer Systems

The Mojave Desert was formed in the Tertiary Period from movement along the San Andreas Fault to the south and the Garlock Fault to the north, creating the Mojave structural block (Norris and Webb, 1990). Tectonic activity associated with the Mojave structural block was superimposed onto the previously-formed Basin and Range province, which was characterized by normal faulting. The San Andreas and related faults created a horst-like block, uplifting the San Bernardino Mountains south of the Study Area.

The regional geology of the Study Area has been described in previous studies (DWR, 1963; DWR, 1967; Hardt, 1971; Stamos, et al., 2001). A map showing the generalized surficial geology encompassing the Study Area is provided on **Figure 3-5**. As shown on the figure, the geology is characterized by sedimentary alluvial basins bordered by igneous and metamorphic mountain ranges and uplands. The basement complex is composed of Paleozoic and Mesozoic (pre-Tertiary) crystalline igneous and metamorphic rocks (pTb) and consolidated Tertiary volcanic and sedimentary rocks (Tv and Ts, respectively). These rocks (along with Quaternary basalt [Qv]) are considered non-water bearing (DWR, 1967). The crystalline complex and Tertiary deposits exposed in the local mountains and hills also underlie the valley floor but are overlain by Quaternary deposits that generally comprise water-bearing formations (DWR, 1967).

Quaternary deposits include older alluvial fans (Qoa), which are exposed irregularly across the Study Area but generally occur near the flanks of upland areas. These deposits comprise poorly

Figure 3-5
Surficial Geology



sorted ancestral alluvial fan, braided-stream, or playa deposits and in many places are highly weathered and cemented. Accordingly, these deposits yield small quantities of water.

More recent Quaternary deposits include younger and recent fluvial/alluvial deposits associated with the modern Mojave River (Qya and Qra). These deposits represent the principal aquifer system in the Mojave River Basin and consist of boulders, gravel, sand, and silt with interbeds of clay within the river channel and associated fluvial depositional environments. Other significant recent Quaternary deposits include lake deposits (Ql) and aeolian (wind-blown) sand deposits (Qs). Undifferentiated alluvial deposits (Qal) also occur throughout the Study Area forming a thin veneer over older deposits. These undifferentiated alluvial deposits primarily occur above the water table and thus are only partially saturated.

The surficial geologic map does not show the thickness or extent of older alluvial deposits associated with the ancestral Mojave River and underlying Pliocene age alluvial deposits (identified as QToa and QTu, respectively [Stamos et al., 2001]). The ancestral Mojave River deposits are composed of interbedded alluvial sand, silt and clay and paleolake and lakeshore sediments.

The outer boundaries of the Mojave River and Morongo basins generally are defined by the contact between the water-bearing unconsolidated deposits and the surrounding and underlying non-water-bearing consolidated igneous and metamorphic rocks.

3.3.1 Geologic Faults

Numerous geologic faults cross the Mojave River and Morongo basins, reflecting the complex tectonic history of the MWA service area. As shown on **Figure 3-6**, the structural style consists of predominantly northwest-southeast trending faults, several of which are observed to impact groundwater flow and are used to define basin/subarea/subbasin boundaries. For example, the Mojave River and Morongo basins are separated by the Helendale Fault, which acts as a barrier to groundwater flow near Lucerne Valley.

The effect of faulting on groundwater flow and water quality in the Study Area has been evaluated in previous studies through groundwater level mapping (DWR, 1967; Lines, 1996; Stamos et al., 2003, Stamos et al., 2009), regional groundwater flow modeling (Hardt, 1971; Stamos et al., 2001); and geochemical analysis (Stamos, et al., 2003). Documented barriers to groundwater flow include the Helendale Fault, Lockhart Fault, Calico Fault, and Camp Rock-Harper Lake (Waterman) Fault in the Mojave River Basin and the Johnson Valley.

3.3.2 Aquifer Systems

Unconsolidated basin fill deposits in the Mojave River Basin have been delineated into two aquifer systems: the Floodplain Aquifer and Regional Aquifer (Stamos et al., 2001). The width of the Floodplain Aquifer varies considerably, from less than one mile at the Lowers Narrows in the Alto Subarea and in the eastern portion of the Centro Subarea up to several miles in the Hinkley Valley (Centro Subarea) and Baja Subarea. **Figure 3-7** presents three hydrogeologic cross sections across the Mojave River Basin developed by the USGS (Stamos, et al., 2001) that illustrate the relationship between the Regional Aquifer and Floodplain Aquifer. As shown on the cross sections, alluvial deposits of late Pliocene to Holocene age (QTu and QToa) form the Regional Aquifer, which uncomformably underlies and surrounds Pleistocene to Holocene fluvial/alluvial deposits of the

Figure 3-6
Geologic Faults

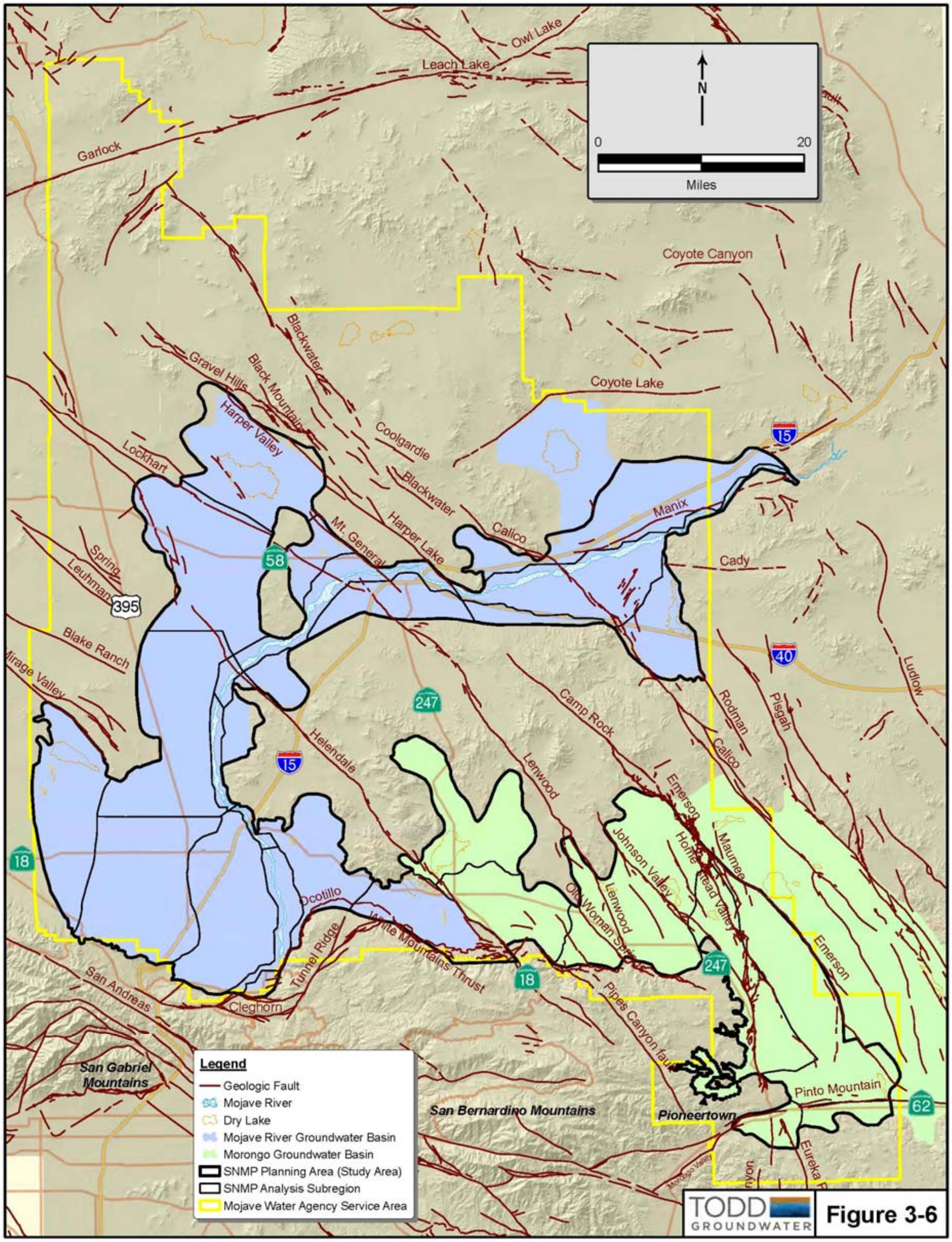
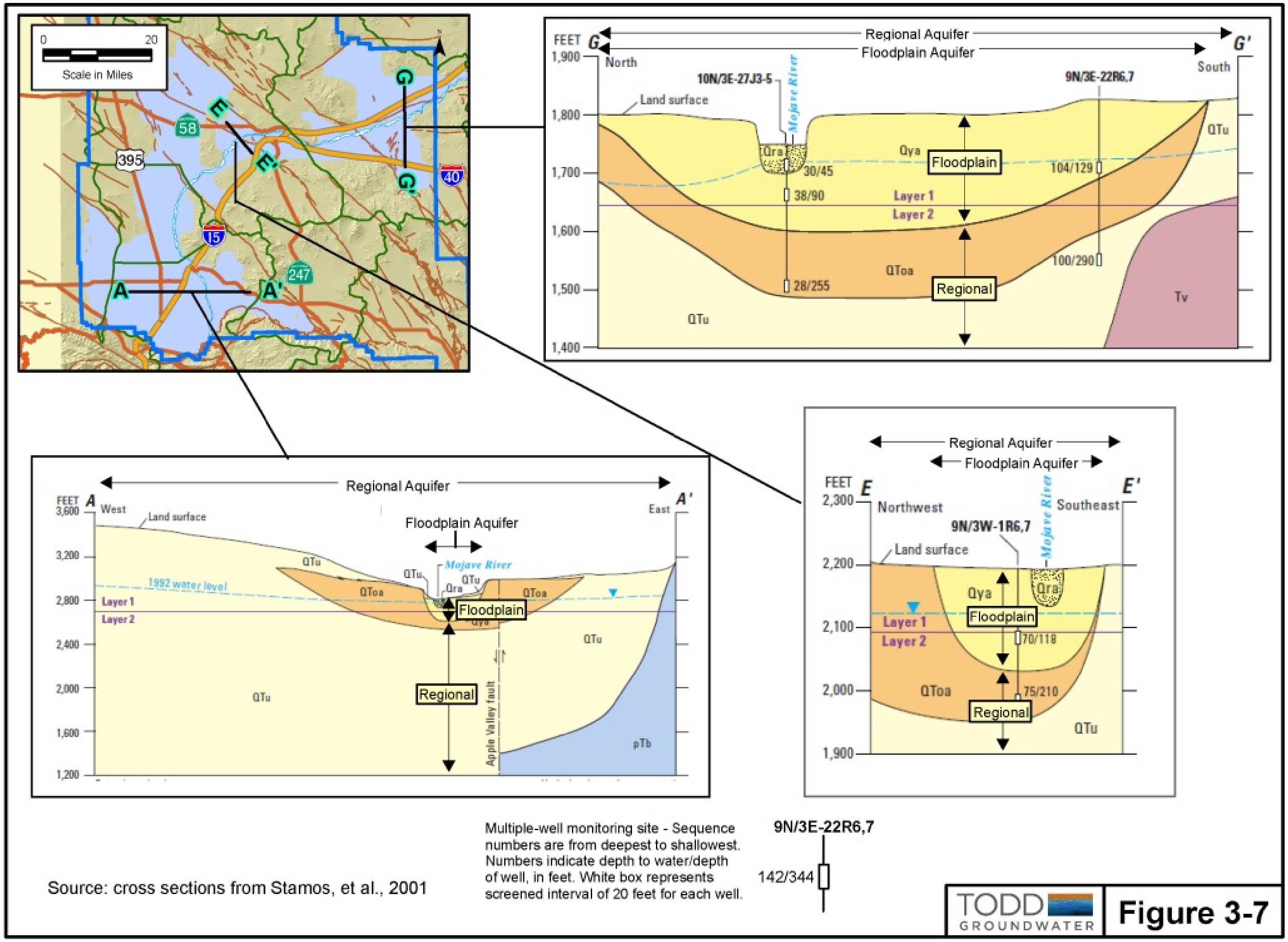


Figure 3-7
Mojave River Basin Aquifer Systems



Floodplain Aquifer throughout the Mojave River Basin. Directly beneath the river, permeable unconsolidated sand and gravel deposits of more recent Mojave River alluvium (Qra) and Younger Mojave River Alluvium (Qya) compose the Floodplain Aquifer. The thickness of the Floodplain Aquifer is generally less than 200 feet in most areas.

Aquifers in the Morongo Basin are composed of late Pliocene to Holocene age alluvial sediments, resembling the Regional Aquifer of the Mojave River Basin. The thickness of saturated alluvial sediments ranges from less than 100 feet to greater than 1,000 feet in some areas.

Groundwater production generally occurs within the upper few hundred feet of saturated alluvial sediments.

3.4 Groundwater Basin Geometry and Production Zone Depth

The impact of surface or near-surface S/N loading on groundwater quality depends on the volume of the groundwater resource into which S/Ns are mixed. Given the areas defined in Sections 3.2 and 3.3, the next step is definition of the vertical extent of the groundwater resource.

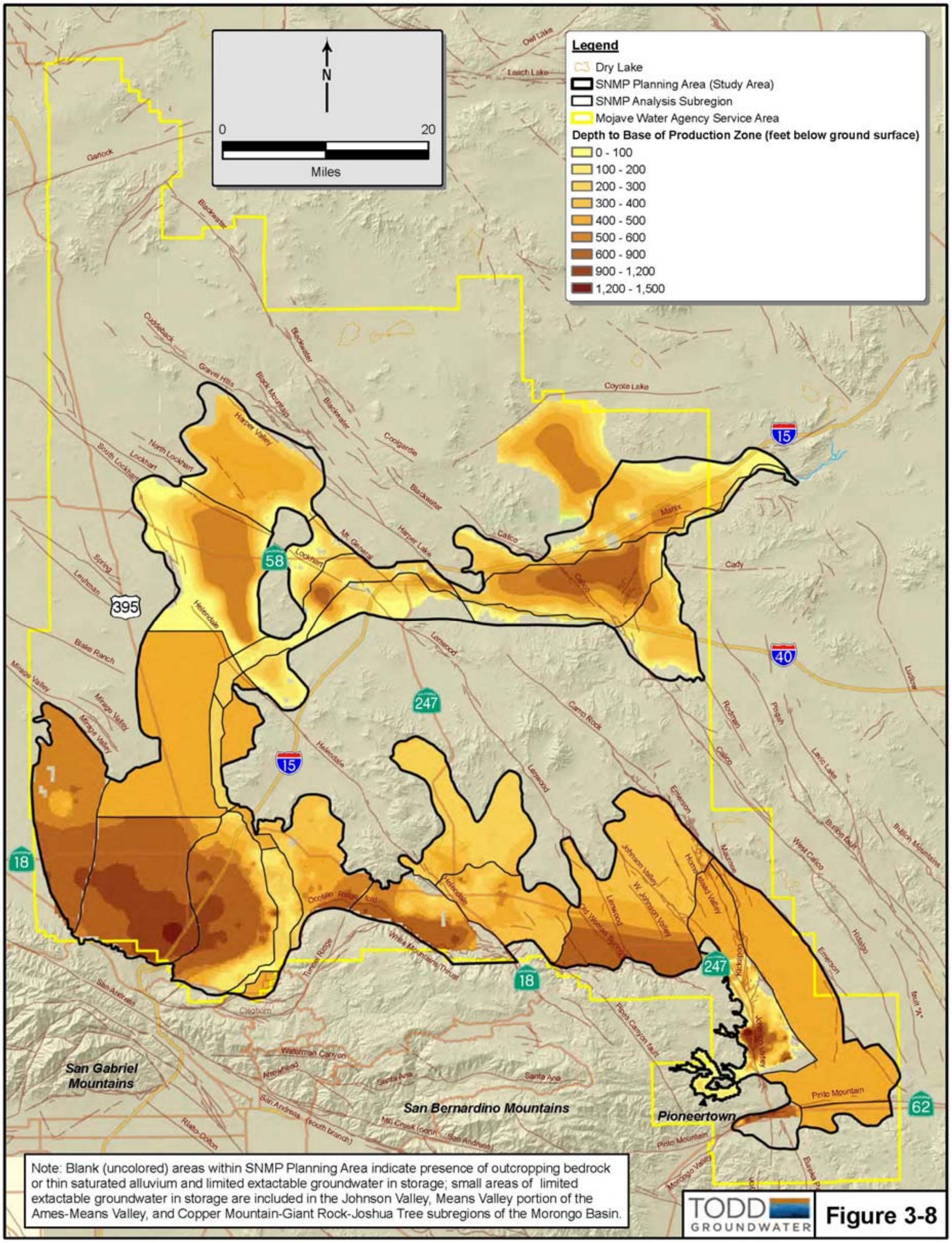
As described in Section 3.3, consolidated pre-Tertiary igneous and metamorphic rocks (pTb) and Tertiary sedimentary and volcanic rocks (Ts and Tv) compose the basement complex underlying the basin fill deposits of the Study Area. These rocks (along with Quaternary basalt [Qv]) are considered non-water bearing (DWR, 1967). The crystalline complex and Tertiary rocks cropping out in the local mountains and hills also underlie the valley floor, but are overlain by Quaternary deposits that generally compose the water-bearing aquifers in the Basin. The depth to basement complex rocks across much of the Study Area has been estimated by previous investigators using gravimetric surveying methods (URS, 2003; French, 1978; Subsurface Surveys, Inc., 1990; Geothermal Surveys, Inc., 2000). Gravimetric survey results indicate that the depth to basement complex rocks extends to more than a few thousand feet below ground surface in some areas.

The degree of cementation/consolidation of older Quaternary alluvial deposits (Qoa) also is an important consideration. Increasing cementation/consolidation of older Quaternary alluvial deposits (Qoa) can occur with depth; this has been documented through interpretation of geologic maps; well construction, lithologic, and aquifer pumping test information contained in water well driller's reports; borehole geophysical logs; and groundwater level and water quality data (Bighorn-Desert View Water Agency (BDVWA) and MWA, 2007; MWA 2014a; DWR, 1967). Because cementation/consolidation typically corresponds to lower water yields, production wells in the Study Area may be screened above the base of unconsolidated sediments.

For the purposes of the Mojave SNMP, the depth to the base of unconsolidated sediments was used to define the vertical extent of the groundwater resource developed or likely to be developed for water supply (herein referred to as the production zone). For areas where the base of unconsolidated alluvial sediments is unknown, and production well construction data are well distributed, the maximum depths of production well screens were used to estimate the base of the production zone using Geographical Information System (GIS) spatial analysis tools.

Figure 3-8 shows the estimated depth to the base of the production zone across the Study Area. As shown in the figure, the depth to the base of the production zone extends to greater than 600 feet in portions of the Centro and Baja floodplain subregions, and more than 1,000 feet in the Mid Alto and Left Alto - Regional, Ames-Means Valley, and Warren Valley subregions. As a result of faulting, the

Figure 3-8
Depth to Base of Production Zone



elevation of the base of the production zone is highly variable across the Study Area. Due to limited hydrogeologic data, a saturated alluvial thickness of 400 feet is assumed across the Transition Zone Regional and Copper Mountain-Giant Rock-Joshua Tree and (southern portion of the) Johnson Valley subregions. The corresponding depth to the base of the production zone in these areas is estimated in the figure.

The surface shown on the figure serves as the basis (along with groundwater elevations and aquifer storativity) for estimating the available extractable groundwater in operational storage across the Study Area.

3.5 Aquifer Storativity

The storativity (S) of an aquifer is the volume of water released from or taken into storage per unit surface area of aquifer per unit change in water level. For an unconfined aquifer, the S value is referred to as specific yield, representative of the effective porosity of aquifer sediments. The distribution of S values across the Study Area has been estimated in several studies using various methods, including comparison of groundwater level changes to calculated streamflow losses following flood events (Lines, 1996), estimations from geologic samples, and the calibrated results of electrical analog and numerical groundwater flow models developed by Hardt (1971) and Stamos et al. (2001), and through general lithologic interpretation (Lewis, 1972; Schaefer, 1978).

Figure 3-9 shows the S values across the Study Area. The values in the Mojave River Basin are based on the USGS groundwater flow model (Stamos et al., 2001), the most reliable source of S values on a regional scale in the basin. As shown on the figure, S values range from 0.05 to 0.39, with higher values assigned to the coarse-grained deposits along the Mojave River system and lower values assigned to deposits comprising the Regional Aquifer. In the Morongo Basin, S values generally range from 0.06 to 0.13, with the exception of the Warren Valley, where S values range from 0.1 to 0.3 in the upper two layers of USGS groundwater flow model (Nishikawa et al., 2001).

S values were used in combination with a map of saturated thickness of the groundwater production zone to estimate the extractable groundwater in operational storage across the Study Area.

3.6 Groundwater Occurrence

The depth to groundwater (or groundwater occurrence) varies considerably across the Study Area. In the Mojave River Basin, depth to groundwater is relatively shallow beneath and adjacent to the Mojave River (ranging from less than 20 feet to about 100 feet). Depth to groundwater can vary considerably in areas further downstream along the Mojave River (e.g., Centro Subarea) depending on the frequency of large storms in the San Bernardino Mountains that generate flows reaching Afton Canyon. Depth to water typically increases away from the Mojave River and along the edges of the basin, exceeding 200 to 300 feet in some areas. Groundwater levels can be relatively shallow in natural discharge areas (e.g., adjacent to and beneath the many dry lakes in the Study Area). Historically, shallow groundwater beneath dry lakes allowed for groundwater discharge to the atmosphere leaving behind once-dissolved S/Ns. **Table 3-2** shows the average depth to groundwater in production zone aquifers by analysis subregion based on 2012 groundwater monitoring well data.

Figure 3-9
Aquifer Storativity

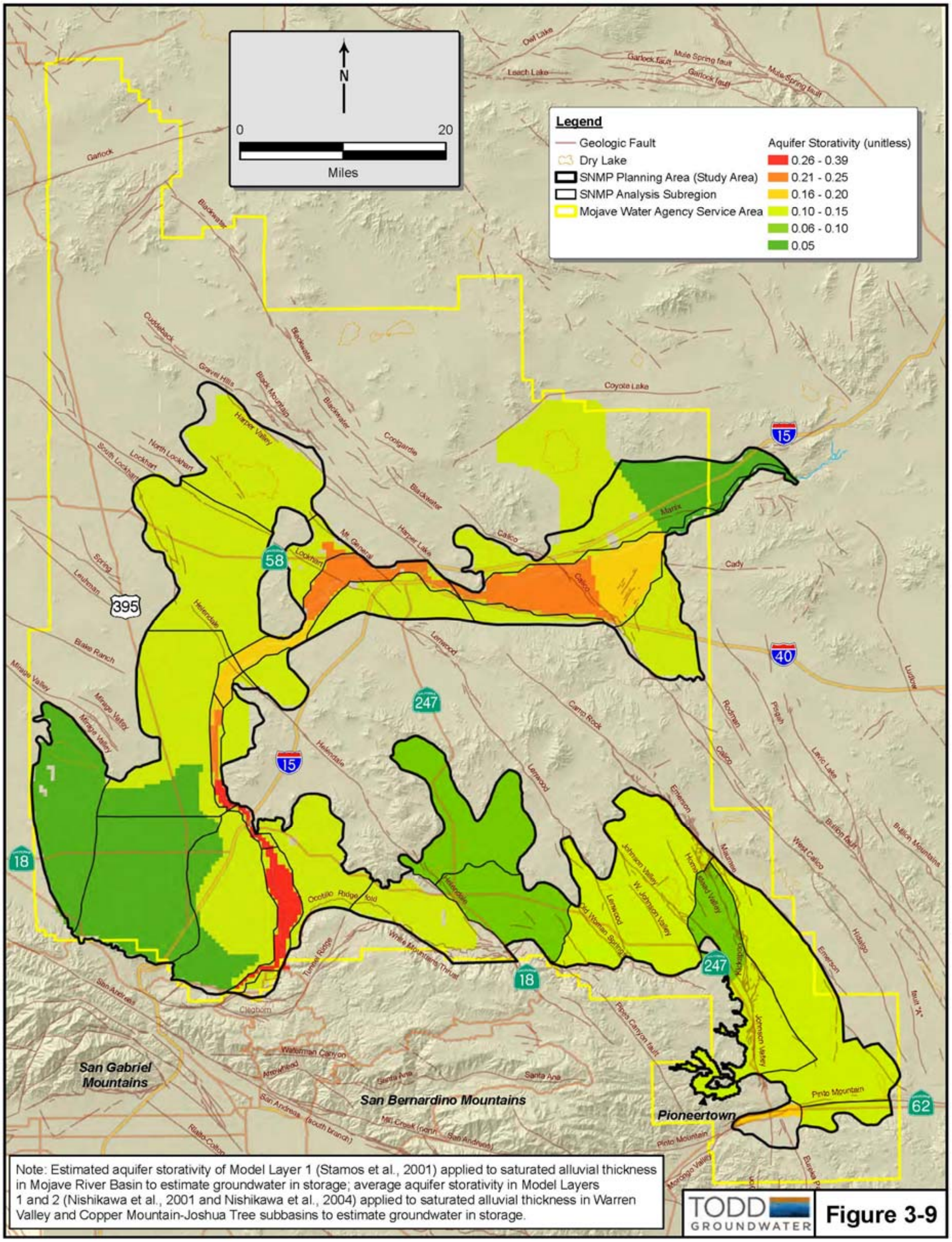


Table 3-2
Mojave SNMP Analysis Subregions

Analysis Subregion	Average Depth to Water [(a)] (feet-bgs)
Alto Transition Zone – Floodplain (Helendale)	20
Alto Transition Zone – Floodplain	20
Centro – Floodplain	30
Alto – Floodplain (Narrows)	40
Alto – Floodplain	40
Centro – Regional (Harper Dry Lake)	60
Baja – Floodplain	70
Este – Regional	70
Johnson Valley	90
Centro – Regional (east)	110
Alto Transition Zone – Regional	110
Oeste – Regional	110
Baja – Regional	120
Lucerne Valley (north)	140
Alto – Right Regional	150
Lucerne Valley (south)	160
Centro – Regional (west)	160
Warren Valley	200
Ames – Means Valley	220
Copper Mountain-Giant Rock	250
Alto – Mid Regional	280
Alto – Left Regional	290
Joshua Tree	360

Notes:
feet-bgs = feet below ground surface.
(a) Average depth to water in production zone aquifer.

Perched groundwater has been identified in four areas of the Mojave River and Morongo groundwater basins. Perched groundwater is unconfined groundwater separated from an underlying body of groundwater by an unsaturated zone (Lohman, 1972). The approximate areas of perched groundwater in the Mojave River groundwater basin have been identified near El Mirage Dry Lake and northeast of the City of Adelanto. In the Morongo groundwater basin, perched groundwater has been identified in Lucerne Valley and Mesquite Dry Lake (Mendez and Christensen, 1997).

Perched groundwater zones occur locally near and beneath dry lake beds and by definition are hydraulically disconnected from the regional groundwater resource. Accordingly, perched groundwater was not included in the estimated volume of groundwater in operational storage.

For the Mojave SNMP, average depth to water was used to estimate the degree of natural attenuation of nitrate from septic tank returns in the unsaturated (vadose) zone across the Study Area.

3.7 Groundwater Levels and Flow

The Study Area overlies portions or all of several groundwater basins, which have historically experienced general declines in water levels. Most of the area's groundwater is covered by two completed adjudications, relating to the major basins: the Mojave Basin Area Adjudication and the Warren Valley Basin Adjudication in the Morongo Basin.

Figure 3-10 shows the (2012) regional water table elevation contours across the Study Area. As shown on the figure, groundwater elevations range from greater than 3,000 feet msl in the southern portion of the Mojave River Basin along the flanks of the San Gabriel, San Bernardino, and other local mountains and to less than 1,500 feet msl at Afton. Groundwater flows perpendicular to groundwater elevation contours from higher to lower elevations.

In the Mojave River Basin, groundwater generally flows towards the Mojave River and upon reaching the river in the direction of surface water flow. Exceptions to this rule occur in the Oeste Subarea and Centro Subarea, where groundwater flows and discharges beneath El Mirage Dry Lake and Harper Dry Lake, respectively.

In the Morongo Basin, groundwater levels range from greater than 3,000 feet msl along the southern and western edges of the basin (where storm runoff from the San Bernardino Mountains and local mountains enters the basin as surface runoff within desert washes or as subsurface inflow) to less than 1,800 feet msl in the eastern portion of the basin. Groundwater flows towards the numerous dry lake beds across the basin, where it evaporates.

3.8 Groundwater in Operational Storage

The volume of groundwater in storage is a critical component for understanding the effect of S/N loading on groundwater quality. A basin with a large volume of groundwater in storage has a commensurate capacity to buffer the effect of S/N loading. Conversely, a basin with a small volume of groundwater in storage is more sensitive to S/N loading and groundwater quality changes.

To quantify the volume of groundwater in storage, 2012 groundwater elevations and elevations representing the base of the groundwater production zone were imported into the project GIS database. The thickness of saturated (unconsolidated) alluvial sediments was determined electronically by computing the difference in elevation between raster surfaces generated from each dataset (**Figure 3-11**). The thickness of saturated unconsolidated sediments was then multiplied by the estimated aquifer storativity to estimate the volume of groundwater in storage. The groundwater volumes estimated using this approach represent the amount of stored groundwater that theoretically could be pumped with existing wells (albeit without consideration of long-term sustainability, economic or environmental factors) and is herein termed the groundwater in operational storage.

It is noted that there is additional groundwater in storage below the current production zone that could be developed in the future, the volume of which is difficult to estimate reliably. Because this additional storage was not included in the storage volume discussed above, the volume of groundwater in operational storage estimates and associated capacity to buffer against the effect of S/N loading is considered somewhat conservative but is appropriate for the purposes of the S/N transport modeling.

Figure 3-10
2012 Groundwater Elevations

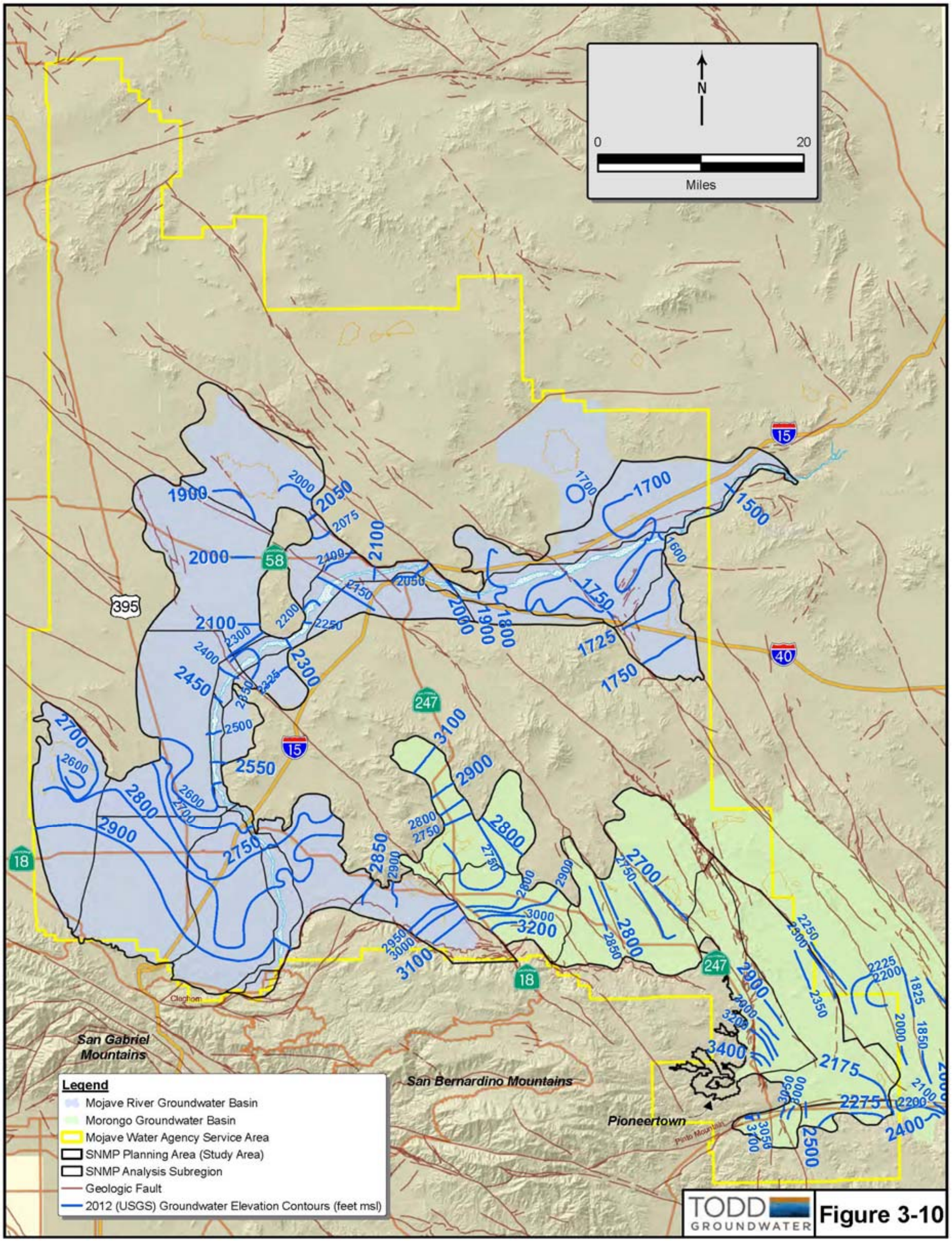


Figure 3-11
Saturated Alluvial Thickness in Operational Storage

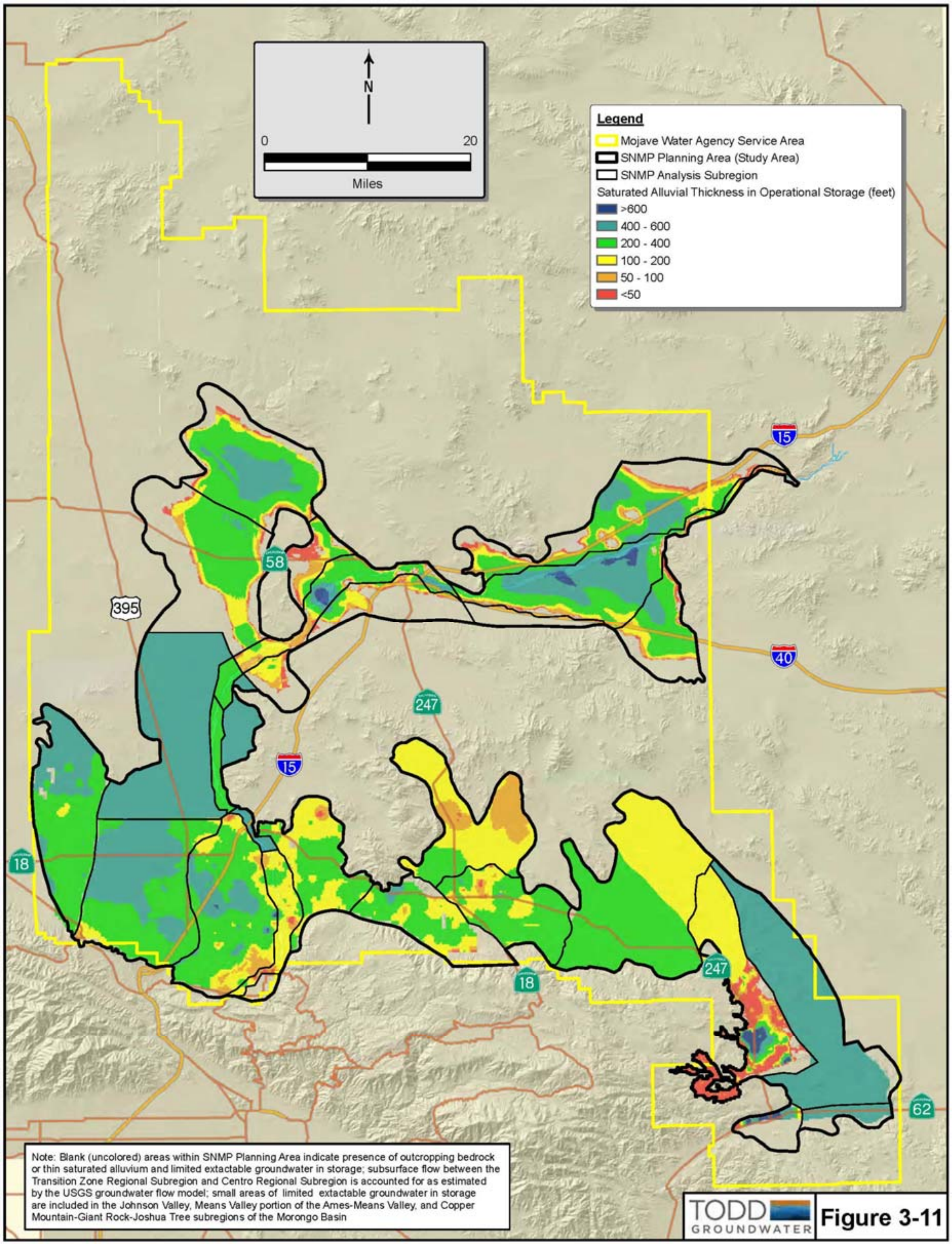


Table 3-3 shows the average saturated thickness and estimated volume of groundwater in operational storage for the 22 analysis subregions. As shown in the table, the estimated total volume of groundwater in operational storage across the Study Area is about 35,000,000 acre-feet (af), with approximately 26,000,000 af in the Mojave River Basin and 9,000,000 af in the Morongo Basin. The average saturated thickness in operational storage in each subregion of the Mojave River Basin ranges from 154 to 402 feet. The average saturated thickness in operational storage for the subregions composing the Morongo Basin ranges from 123 to 471 feet. By subregion, groundwater volume in operational storage is generally near or above 1,000,000 af. Three subregions in the Mojave River Basin and two subregions in the Morongo Basin have relatively small volumes of groundwater in operational storage (less than 500,000 af)[2]. These include:

- Alto Transition Zone – Floodplain (Helendale)
- Alto Transition Zone – Floodplain
- Alto – Floodplain (Narrows)
- Warren Valley
- Joshua Tree

The groundwater storage volumes shown in **Table 3-3** represent the initial mixing volume of groundwater for the fate and transport modeling of salts and nutrients.

3.9 Groundwater Production

Groundwater production is one of the primary mechanisms by which salts and nutrients are removed from the groundwater system. Groundwater is pumped for municipal, industrial, agricultural, aquaculture, and recreational supply. **Figure 3-12** shows the major water purveyors in MWA's service area. The figure shows that of the 45 purveyors in MWA's service area, the boundaries of all but three purveyors are located within a Study Area analysis subregion. The three purveyors that are not included are the Indian Wells Valley Water District (29 on map), Rand Communities Water District (39 on map), and Stoddard Valley Mutual Water Company (41 on map).

Figure 3-13 shows the spatial distribution of metered groundwater production by well within MWA's service area for Water Year (WY) 2011-2012 (not including unmetered private domestic pumping). The figure shows that production in the Mojave River Basin is generally concentrated along the Mojave River in the floodplain aquifer. However, production also occurs in areas away from the river in the Regional Aquifer, primarily in the Alto and Centro subareas. In the Morongo Basin, production is concentrated in the Ames-Means Valley and the Warren Valley subregions. An overview of the water production is provided in Section 3.11.

Figure 3-14 shows the location of occupied residential parcels that rely on private wells for water supply within MWA's service area (referred to as Minimal Producers). MWA recently estimated unmetered private domestic pumping by Minimal Producers by examining aerial imagery and applying unit indoor water demand rates and outdoor evaporative demand to irrigated acreages. On average, groundwater production by a single Minimal Producer is less than a few acre-feet per year (afy) and nothing over 10 afy.

[2] Centro Regional (east) and Centro - Regional (west) comprise one subregion, Centro – Regional, for S/N loading analysis

Table 3-3
Groundwater in Operational Storage

SNMP Analysis Subregion	Area of Saturated Alluvial Deposits (acres)	Average Saturated Alluvial Thickness in Operational Storage (feet)	Aquifer Storativity	Estimated Groundwater in Operational Storage[a] (acre-feet)	Data Sources Used to Estimate Groundwater in Storage (see notes)
MOJAVE RIVER BASIN					
Baja - Floodplain	62,477	384	0.05 to 0.22	4,886,000	b
Baja - Regional	74,329	264	0.05 to 0.12	2,014,000	b
Centro - Floodplain	26,148	259	0.20 to 0.22	1,405,000	b
Centro - Regional (east)	16,030	154	0.12	301,000	b
Centro - Regional (west)	56,985	225	0.12 to 0.21	1,580,000	b
Centro - Regional (Harper Dry Lake)	56,239	304	0.12	2,128,000	b
Alto Transition Zone - Floodplain (Helendale)	4,978	270	0.20	269,000	c
Alto Transition Zone - Floodplain	7,969	235	0.23	431,000	c
Alto Transition Zone - Regional	105,566	400	0.12	5,067,000	d
Alto - Floodplain (Narrows)	3,297	400	0.12 to 0.26	264,000	e
Alto - Floodplain	16,896	155	0.05 to 0.39	801,000	e
Alto - Left Regional	90,083	402	0.05	1,812,000	e
Alto - Mid Regional	57,117	316	0.05 to 0.12	1,893,000	e
Alto - Right Regional	41,322	212	0.12	1,052,000	e
Oeste - Regional	49,679	325	0.05	807,000	e
Este - Regional	29,385	238	0.12	840,000	e
Mojave River Basin Total	**698,497**	**313**		**25,550,000**	
MORONGO BASIN					
Lucerne Valley (north)	59,148	147	0.10	869,000	f
Lucerne Valley (south)	44,290	225	0.10	996,000	f
Johnson Valley	112,100	169	0.12	2,273,000	g
Ames-Means Valley	52,840	123	0.06 to 0.12	692,000	h
Warren Valley	3,507	471	0.10 to 0.30	330,033	i
Copper Mountain-Giant Rock	49,923	400	0.12 to 0.15	3,827,410	h,j
Joshua Tree	6,279	400	0.15	376,748	j
Morongo Basin Total	**328,088**	**208**		**9,364,190**	
MOJAVE RIVER BASIN AND MORONGO BASIN TOTAL	**1,026,585**	**279**		**34,914,190**	

Table 3-3 (continued)
Groundwater in Operational Storage

Notes:
(a) Volume of groundwater above estimated base of groundwater production zone.
(b) 2010 groundwater levels and depth to base of unconsolidated sediments (MWA, 2014a); Model Layer 1 storativity (Stamos et al., 2001).
(c) Estimated 700,000 af in storage in Transition Zone (TZ) Floodplain (URS, 2003) apportioned to TZ Floodplain and TZ Floodplain (Helendale) subregions based on relative acreage; low estimate of aquifer storativity for floodplain aquifer (Stamos et al., 2001) applied to estimate average saturated thickness in operational storage.
(d) Model Layer 1 storativity (Stamos et al., 2001), assumed constant production zone saturated thickness of 400 feet.
(e) Model Layer 1 storativity (Stamos et al., 2001), Stipulated Party well perforations and 2012 water levels.
(f) Average aquifer storativity (Schaefer, 1978; Malcolm Pirnie, 1990), stipulated party well perforations and 2012 water levels.
(g) 2004 groundwater levels and depth to bedrock (French, 1978; BDVWA and MWA, 2007); storativity based on USGS Ames Valley study (Lewis, 1972).
(h) 2004 groundwater Level and Depth to Bedrock (BDVWA and MWA, 2007); Specific Yield (Lewis, 1972).
(i) Active model cell storativity (Nishikawa, T., Densmore, J., Martin, P., and Matti, J., 2001), public water supply well perforations and September 2012 water levels.
(j) Active saturated model cell storativity (Nishikawa, T., J. A. Izbicki, J. A. Hevesi, C. L. Stamos, and P. Martin, 2004); assumed maximum production zone saturated thickness.

Figure 3-12
Water Purveyors

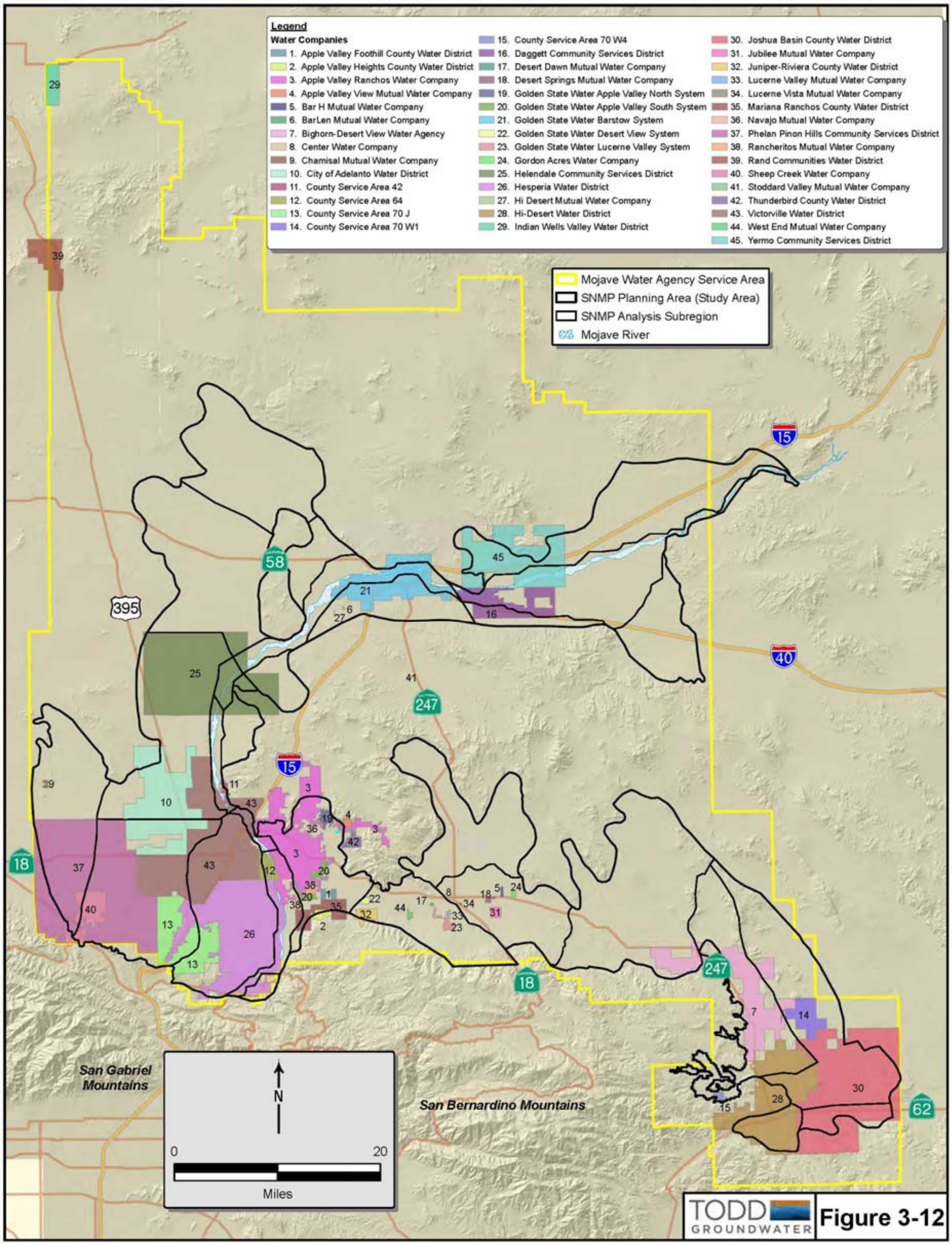


Figure 3-13
Water Year 2011-2012 Groundwater Production

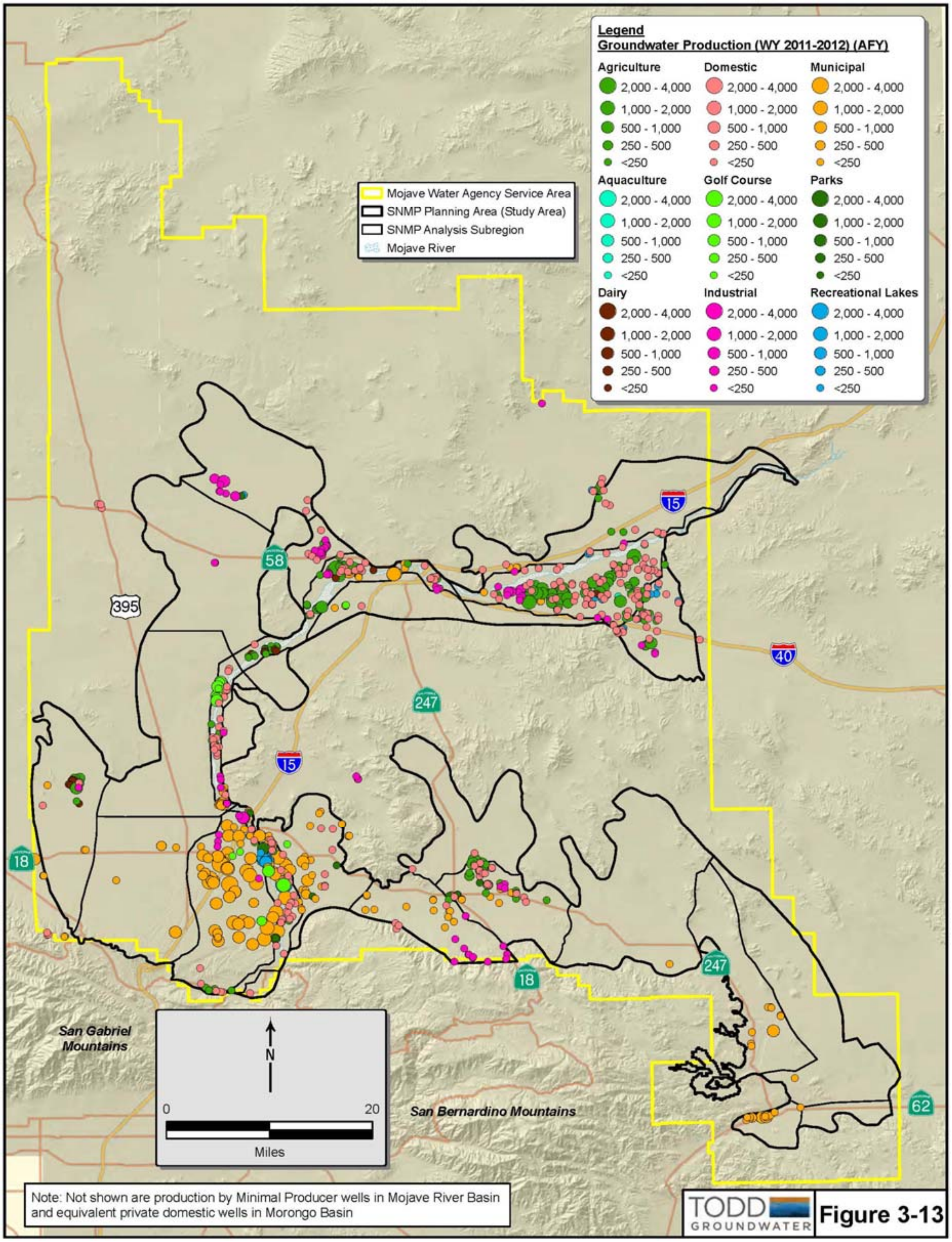
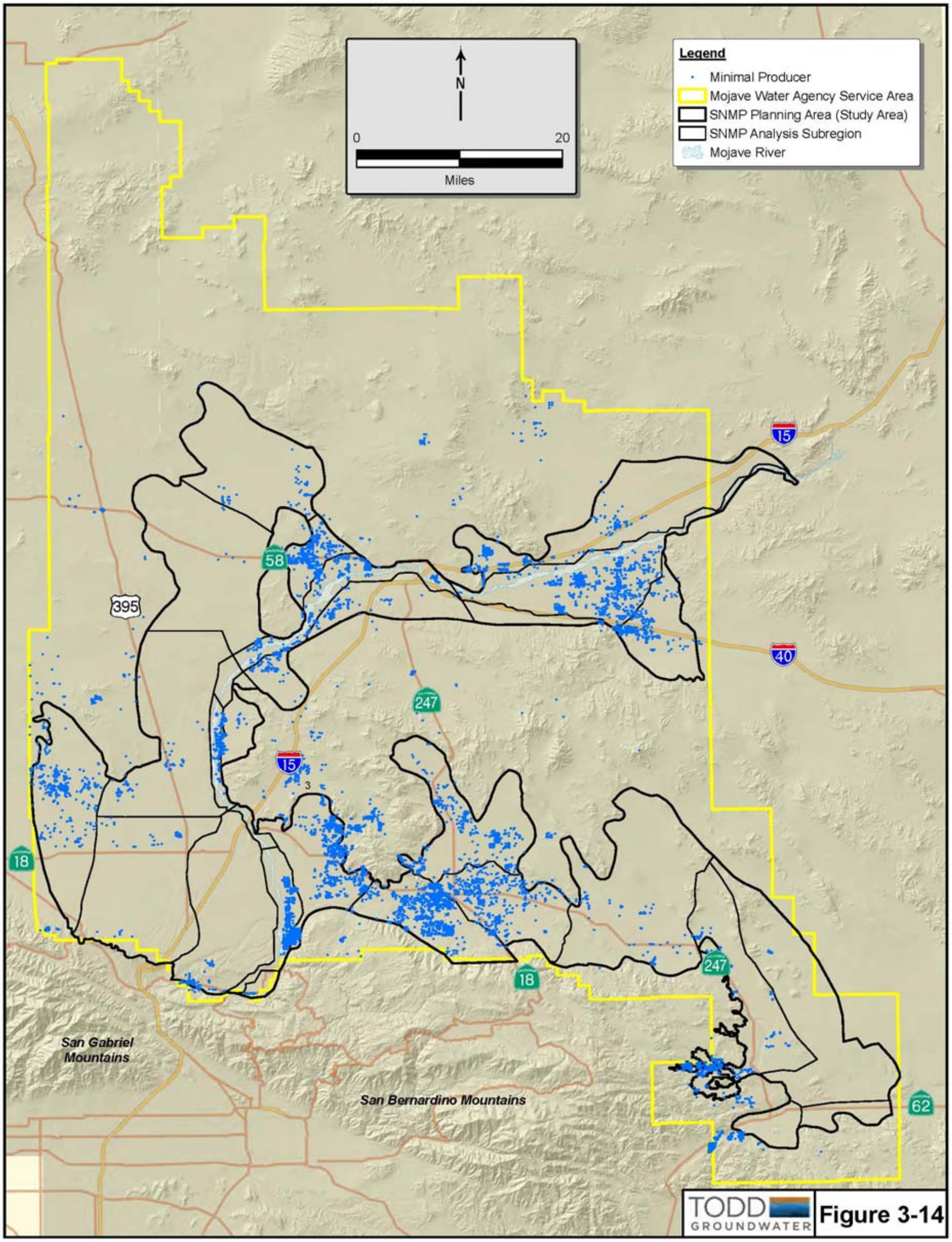


Figure 3-14
Minimal Producers



3.10 Imported Water and Related MWA Infrastructure

3.10.1 State Water Project (SWP) Water, Pipelines, and Infrastructure

MWA is one of twenty-nine State Water Contractors with access to SWP water from the California Aqueduct. MWA currently has an annual Table "A" amount of up to 82,800 afy of SWP water. Since 1991, MWA has been regularly importing water from the California Aqueduct to recharge the groundwater basins from which local water companies, municipalities, and other well owners pump for beneficial uses.

As stated in the Judgment, MWA is required to acquire or construct conveyance facilities for the importation and equitable distribution of supplemental water to the respective water management subareas. To accomplish this, MWA has actively secured several federal and state grants and loans to finance imported water-related infrastructure, including the Mojave River and Morongo Basin pipelines, storage reservoirs, and in-stream and off-stream recharge facilities across its service area.

MWA owns and operates two major pipelines (Mojave River Pipeline and Morongo Basin Pipeline) and associated infrastructure that convey imported SWP water to augment local groundwater supplies within the Mojave River Basin and MWA's service area. MWA operates multiple enhanced recharge facilities in its service area. **Figure 3-15** shows the locations of MWA's current and future conveyance and recharge features.

3.11 Wastewater and Recycled Water Quality

Table 3-4 identifies the local water, wastewater, imported wastewater, and planning agencies within the Study Area (including agencies that export wastewater to the Study Area) and could potentially have a role in any recycled water activities (MWA, 2014c). Local water agencies share many issues related to local and regional water supplies. Wastewater agencies that collect and treat wastewater share a common interest in maximizing the beneficial uses of treated wastewater. Wastewater is also imported to the Study Area from several agencies as shown in **Table 3-4**. In addition, various land use planning agencies with general land use plans are included because they will coordinate where future growth is to occur.

Figure 3-15
MWA Facilities

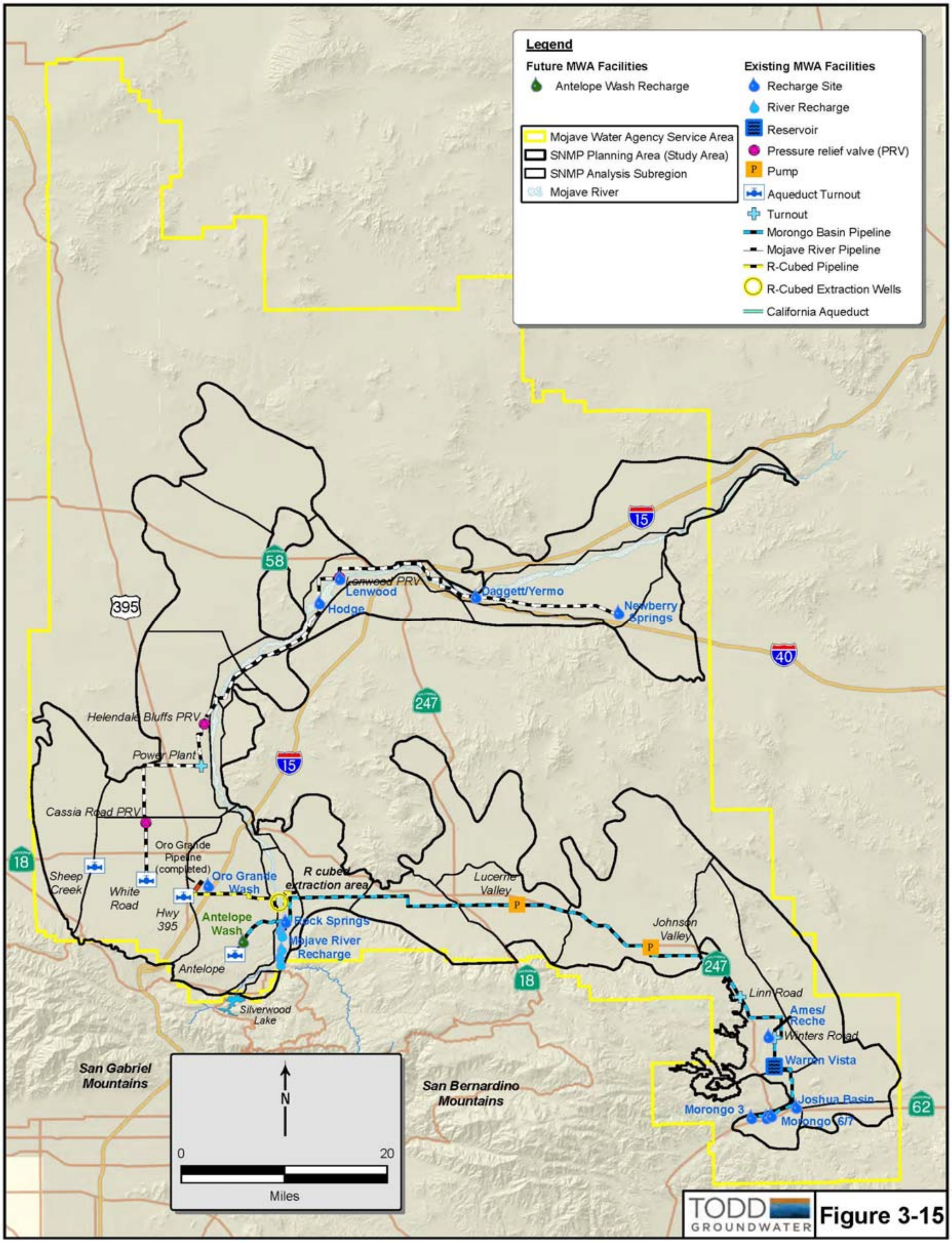


Table 3-4
Participating Agencies in Recycled Water

Water Agencies	Wastewater Agencies	Imported Wastewater Agencies	Planning Agencies
City of Adelanto	City of Adelanto	Lake Arrowhead CSD	City of Adelanto
Golden State Water Company - Barstow	City of Barstow	Big Bear Area Regional Wastewater Agency	City of Barstow
Helendale Community Services District (CSD)	Helendale CSD	Crestline Sanitation District (SD)	City of Hesperia
Hesperia Water District	Marine Corps Logistics Base (MCLB)		City of Victorville
Hi-Desert Water District	Victor Valley Wastewater Reclamation Authority (VVWRA)		San Bernardino County Department of Public Works and Flood Control
Joshua Basin Water District			San Bernardino County Planning Department
San Bernardino County Service Areas 42 and 64			Town of Apple Valley
Victorville Water District			Town of Yucca Valley

Wastewater discharges from treatment plants in the Study Area (including those in contributing watershed areas) consist of discharging the excess treated effluent to land applications such as percolation ponds/irrigation/Mojave River channel. For the location of each wastewater treatment plant, see **Figure 3-16**.

3.12 Water Budget Components

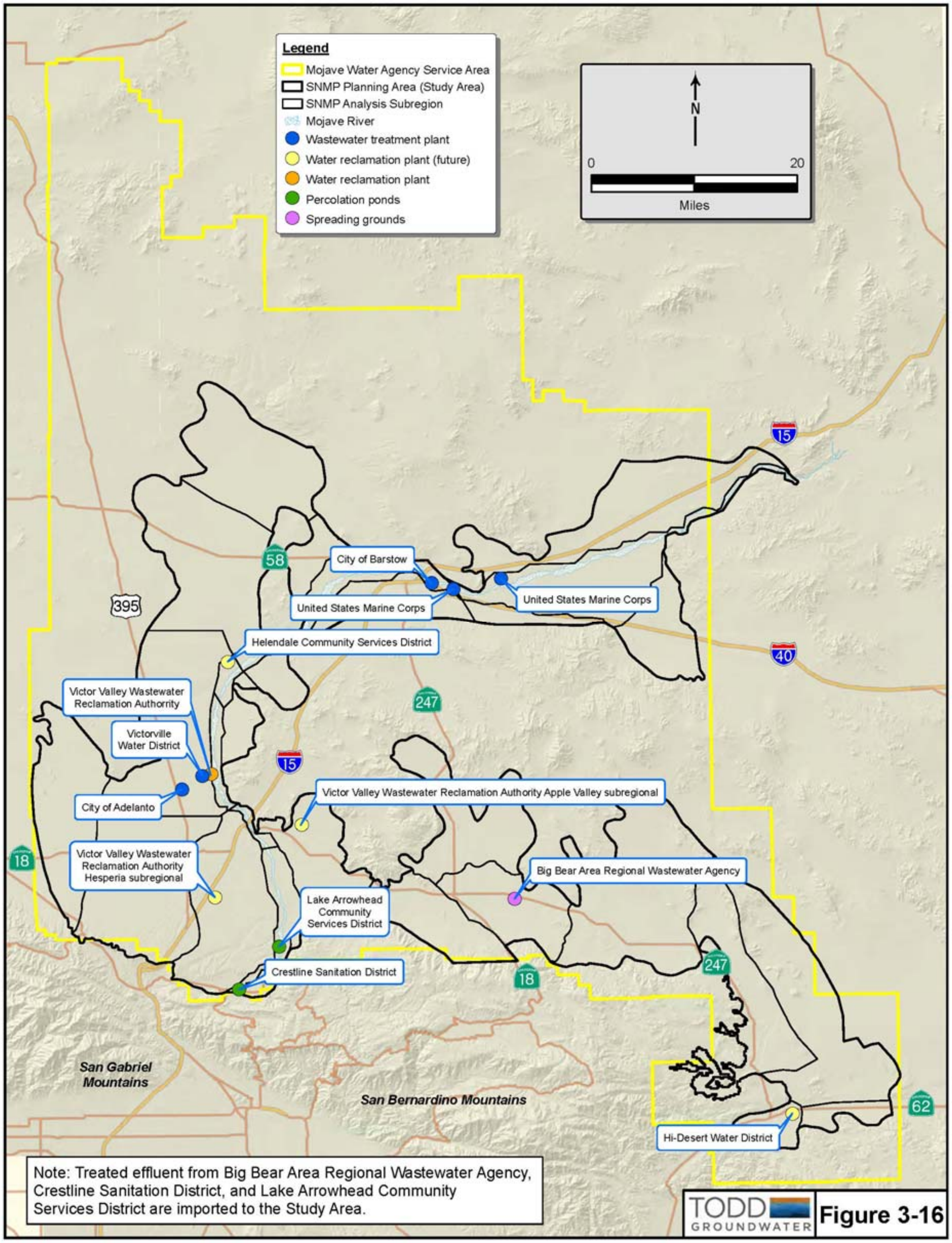
3.12.1 Inflows

Natural inflows to the groundwater system in the Mojave River Basin are represented primarily by stream recharge from intermittent storm flows through the Mojave River bed. Stream flows are fed by runoff from the San Bernardino Mountains and ungaged tributary flows from local mountains concentrated in dry alluvial washes. Additionally, some mountain-front recharge occurs along the southern edge of the basin and in the Baja Subarea (Stamos et al., 2001).

Subregions in the Morongo Basin are recharged naturally by runoff infiltrating through relatively small ephemeral stream channels, entering as subsurface inflow or mountain-front recharge along the margins of the basin.

Due to the relatively low annual amount of precipitation on the valley floor, deep percolation of areal precipitation is considered negligible across the Study Area. The one exception is the Lucerne Valley Subregion, where deep percolation of precipitation and mountain-front recharge are natural recharge sources (Brose, 1987).

Figure 3-16
Wastewater Treatment and Reclamation Plants, Ponds, and Spreading Grounds



In addition to recharge from rainfall and storm runoff, subsurface inflows from neighboring subregions represent a major natural recharge source for many subregions.

Anthropogenic inflows to each subregion include one or more of the following:

- Managed aquifer recharge (imported SWP water)
- Municipal outdoor irrigation return flow (including potable water and recycled water)
- Agricultural irrigation return flow (from crop fields and dairies)
- Treated WWTP effluent discharge
- Septic system return flow

Within the Study Area, all industrial wastewater is discharged to lined evaporation ponds; thus industrial return flows to groundwater are considered insignificant.

3.12.2 Outflows

Natural outflows from each subregion include subsurface outflow, groundwater discharge to surface water, evapotranspiration of phreatophytes, and dry lake evaporation. The sole anthropogenic outflow from each subregion is groundwater pumping.

3.13 Overview of Water Supply

The Mojave IRWM Plan (MWA, 2014c) presents water supply/demand projections for the MWA service area that are updated from MWA's 2010 Urban Water Management Plan (UWMP) (MWA 2011) projections. Both planning documents use the same demand forecast projection model to predict future inflows and outflows to the MWA service area. These inflows and outflows can also be described in terms of water supply (going into the groundwater basin or inflows) and water demand (or water going out of the basin or outflows) for MWA water purveyors. Therefore, if the terms "water supply and demand" are used, then Section 3: Water Supply and Demand of the Mojave IRWM Plan details the projections and assumptions used for the study.

The updated demand forecast projection model (dated February 26, 2014) used for the Mojave IRWM Plan is also used for modeling the inflows/outflows described later in this SNMP.
In MWA's demand forecast projection model, natural and SWP supply are expressed as an annual average, although both sources of supply vary significantly from year to year. Almost all of the water use within the MWA service area is supplied by pumped groundwater. Native surface supply, return flow, and SWP imports recharge the groundwater basins; therefore, water management practices render the annual fluctuations in these sources of supply relatively unimportant for water supply planning.

The extent to which water demand changes is also dependent on the conservation activities imposed. Residential, commercial, and industrial usage can be expected to decrease as a result of the implementation of more aggressive water conservation practices and stricter building and plumbing codes and upgraded appliance standards. The greatest opportunity for conservation in the MWA service area is in developing greater efficiency and reduction in landscape irrigation as it typically represents as much as 70 percent of water demand for residential customers, depending on lot size and amount of irrigated turf and plants.

As detailed in the previously mentioned planning documents, to account for conservation in the water demand projections, three possibilities were developed to book-end the possible range in future single family residential (SFR) gallons per capita per day (GPCD) based upon varying levels of conservation:

a. No conservation beyond the year 2012: GPCD remains flat at the 2012 level (145 GPCD in the Mojave Basin and 99 GPCD in the Morongo Area). This represents the high end of the range.

b. Extreme conservation on a regional basis: GPCD in the Mojave Basin decreases by 2020 to the 2010 Morongo Area level of 113 GPCD, and GPCD in Morongo decreases 5 percent (to 95 GPCD). This represents the low end of the range.

c. Moderate conservation. Halfway between the high end of the range and the low end of the range as defined above (129 GPCD by 2020 for Mojave and 97 GPCD by 2020 for Morongo).

Voluntary conservation programs, State-mandated GPCD reductions, tiered rate structures at the retail level, and the continuously increasing cost of water will all influence future water demands. Recognizing these factors and that substantial potential still exists for reductions in SFR per-capita use, it is assumed in the Mojave IRWM Plan that a moderate amount of additional conservation will be attained in the SFR use sector.

The moderate conservation assumption is continued in the SNMP modeling inflow and outflow projections, as described later in this report.

Section 4: Groundwater Quality Analysis

4.1 Background

Groundwater is used throughout the Study Area for drinking water and irrigation supplies. Numerous studies have characterized groundwater quality in the Study Area. Early work assessed the general suitability of groundwater as a water supply source (Stone, 1957; DWR, 1964a and 1967; Miller, 1969; DWR, 1983) and described the impact of industrial and municipal wastewater discharges on groundwater quality in the Barstow area (California Department of Public Health (CDPH) and DWR, 1960; CDPH, 1966; Miller, 1969; CDPH, 1970; Brown and Caldwell Engineering, 1973; Hughes, 1975; Eccles, 1981; Geraghty and Miller, 1990). Despite local groundwater quality degradation in Barstow and variability elsewhere, these studies generally confirmed the suitability of groundwater for beneficial uses.

More recently, groundwater quality data, including intrinsic tracers, have been used to confirm sources of groundwater recharge and travel times along interpreted flowpaths in the Floodplain and Regional aquifers (Izbicki and Michel, 2004; Izbicki et al., 2004). Investigations have also been conducted to identify the source and occurrence of key groundwater contaminants, including hexavalent chromium (Cr-6) and arsenic, in the Mojave Desert region (Ball and Izbicki, 2004; Welch et al., 2000).

The impairment of groundwater for the beneficial use of drinking water is determined by comparing concentrations of constituents of concern in the groundwater against drinking water maximum contaminant levels (MCLs) and agricultural water quality parameters needed for specific crops. MCLs consist of primary and secondary MCLs. Primary MCLs are assigned to constituents for which a health-based risk is associated with consumption of water that exceeds a particular concentration. Secondary MCLs are assigned to constituents for which there is no health risk, but for which there may be aesthetic concerns above a particular concentration.

There are numerous groundwater quality issues within the Study Area. Key contaminants include arsenic, nitrates, iron, manganese, Cr-6, and total dissolved solids (TDS). Some of these are naturally occurring in desert environments while others are associated with human activities. Measurements in excess of drinking water standards have been found for some of these constituents within the Mojave River Basin and the Morongo Basin. Groundwater in these areas may have to be treated prior to consumption.

For the Mojave SNMP, TDS and nitrate have been selected as appropriate indicator constituents of salts and nutrients (S/Ns) for the Study Area. Accordingly, groundwater quality with respect to TDS and nitrate are discussed in detail in this section.

4.2 Groundwater Quality Characterization

TDS and nitrate were selected as the most appropriate indicators of S/Ns in the Study Area. These two constituents are the focus of the characterization of existing S/N groundwater quality and assimilative capacities discussed. In addition, the S/N source water quality that recharges the basins and the S/N balances with respect to these three constituents are also discussed in Section 5 Salt and Nutrient Loading Analysis.

Total salinity is commonly expressed in terms of TDS as milligrams per liter (mg/L). TDS concentrations in the groundwater are influenced by the chemistry of the aquifer and quality of water recharging the aquifer. TDS is not a health hazard at typical groundwater concentrations, but can be an aesthetic issue and can shorten the useful life of pipes and water-based appliances in homes and businesses. Because TDS monitoring data are widely available for source waters (both inflows and outflows) in the Study Area and because TDS is a general indicator of total salinity, TDS is an appropriate indicator of salt loading. While TDS can be an indicator of anthropogenic impacts, there are also natural background TDS concentrations in groundwater. The background TDS concentrations in groundwater can vary considerably based on purity and crystal size of the minerals, rock texture and porosity, the regional structure, origin of sediments, the age of the groundwater, and other factors (Hem, 1989).

Nitrate is a widespread contaminant in California groundwater. In drinking water, high nitrate levels can have acute health problems in infants less than six months old, causing a condition known as blue baby syndrome. Long-term health impacts in adults are not well-known. High levels of nitrate in groundwater are associated with agricultural activities, septic systems, confined animal facilities, landscape fertilization, and wastewater treatment facilities. Nitrate does occur naturally in groundwater; however, natural nitrate levels in groundwater are generally very low (typically less than about 10 mg/L as nitrate (NO_3)) (Madison and Brunett, 1985).

4.3 Water Quality Objectives for Groundwater

According to the Lahontan and Colorado River Region basin plans, groundwater designated for municipal or domestic supply (MUN) shall not contain concentrations of chemical constituents exceeding their respective maximum contaminant level (MCL) or secondary maximum contaminant level (SMCL) based upon drinking water standards specified in Title 22 of the California Code of Regulations (CCR).

Title 22 of the CCR designates SMCLs for TDS to address aesthetic issues related to taste, odor, or appearance of the water and are not related to health effects. The recommended SMCL for TDS is 500 mg/L with an upper limit of 1,000 mg/L and a short-term limit of 1,500 mg/L.

Title 22 of the CCR designates a primary MCL for nitrate-nitrite as nitrogen (as N) of 10 mg/L and for nitrate as nitrate (nitrate-NO_3) of 45 mg/L. These MCLs are based on a health concern due to methemoglobinemia, or "blue baby syndrome," which affects infants, ruminant animals (such as cows and sheep) and infant monogastrics (such as baby pigs and chickens). Elevated levels may also be unhealthy for pregnant women (SWRCB, 2010).

The SMCLs for TDS and MCL for nitrate-NO_3 are used for the Mojave SNMP to assess existing and future groundwater quality concentrations across the Study Area and evaluate the potential impact of S/N loading sources on groundwater quality.

4.4 Constituents of Emerging Concern (CECs)

Constituents of Concerns (CECs) generally have no established water quality standards. These chemicals may be present in waters at very low concentrations and are now detected as the result of more sensitive analytical methods. Information regarding their health significance is evolving with the development of acceptable daily intake levels and drinking water equivalent levels;

however, information is lacking on the full spectrum of potential CECs and their health significance in mixtures. CECs include several types of chemicals such as (i) pesticides, (ii) pharmaceuticals and ingredients in personal care products, (iii) veterinary medicines, (iv) endocrine disruptors, and others. The SWRCB Recycled Water Policy states, "Each salt and nutrient management plan shall include . . . [a] provision for annual monitoring of Emerging Constituents/Constituents of Emerging Concern (e.g., endocrine disruptors, personal care products or pharmaceuticals) (CECs) consistent with recommendations by CDPH and consistent with any actions by the State Water Board taken pursuant to paragraph 10(b) of this Policy."

A Science Advisory Panel (Panel) was formed to identify a list of CECs for monitoring recycled water used for groundwater recharge and landscape irrigation. The Panel completed its report (Panel Report) on CECs in June 2010 and recommended monitoring of selected health-based and treatment performance indicator CECs and surrogates for groundwater recharge projects. No CEC monitoring was recommended for landscape irrigation due to low risk for ingestion of the water. The groundwater recharge monitoring recommendations were directed at surface spreading using tertiary recycled water (recycled water and groundwater monitoring) and injection projects using reverse osmosis and advanced oxidation (recycled water monitoring). The Panel did not address or make recommendations related to CEC monitoring for SNMPs.

Draft amendments to the Recycled Water Policy were released in May 2012, September 2012, October 2012 (SWRCB hearing change sheets), and January 2013. In the September and October 2012 drafts, language was included that provided three exceptions for RWQCBs to impose additional CEC monitoring requirements: 1) if recommended by CDPH; 2) if requested by a project sponsor; and 3) or required in an adopted SNMP. Stakeholders submitted written comments to the SWRCB asking that—until such time as a SWRCB expert panel specifically makes recommendations regarding CEC monitoring for SNMPs—that this issue should be left to stakeholders preparing SNMPs and the Basin Plan amendment process. In response, the SWRCB deleted exception No. 3. The Recycled Water Policy Amendment was adopted by the SWRCB on January 22, 2013 and became effective on April 25, 2013.

Since 1976, the SWRCB Division of Drinking Water, formerly CDPH has issued numerous draft versions of Groundwater Replenishment Reuse Regulations that served as guidance for requirements applied to permitted groundwater replenishment projects. Final regulations for groundwater replenishment using recycled water (Groundwater Replenishment Reuse Regulations or 2014 GWR Regulations) became effective on June 18, 2014.

4.5 Groundwater Quality Data Sources

Groundwater well TDS and nitrate data contained in the MWA groundwater quality database were obtained for the Mojave SNMP. The MWA database is extensive and includes data from a network of dedicated monitoring wells, scientific investigation wells, and private domestic, agricultural, and aquaculture supply wells. Water quality data for public water system wells in MWA's service area (as compiled and reported annually by the CPDH) are also included in the MWA water quality database.

The MWA water quality database was supplemented with additional groundwater quality data including data collected from wells associated with VVWRA's Regional WWTP facility and Southern California Logistics Airbase (SCLA). These data were provided by VVWRA. Additionally, groundwater quality data from active Waste Discharge Requirement (WDR) sites were obtained from the Lahontan and Colorado River Basin Regional Boards electronically (via the Geotracker website) and through onsite file review by MWA staff. The locations of active WDR sites are shown on **Figure 4-1**. An inventory of the various WDR site types is provided by subregion in **Table 4-1**. There are a total of 106 WDR sites within the MWA service area, of which 99 sites are located within a Study Area analysis subregion. Groundwater quality data from WDR sites were incorporated through onsite review of pertinent case files, geo-referencing of site and well locations, and digital formatting of TDS and nitrate groundwater quality data for compatibility with project databases.

All well location, well construction, and groundwater quality data were assimilated into a master groundwater quality database and subjected to rigorous quality assurance/quality control (QA/QC) protocols to remove duplicate entries and otherwise unreliable records.

4.6 Existing Groundwater Quality Conditions

Due to the complexity of hydrogeologic conditions and variability in water quality, the Study Area was divided into separate subregions to evaluate water quality and to facilitate understanding of the distribution of S/Ns and potential implementation measures. The boundaries of the analysis subregions are shown on **Figure 3-2** (Section 3.1.2) and include both the floodplain and regional aquifer systems of the Mojave River Basin and alluvial aquifers of the Morongo Basin. Physical characteristics of the analysis subregions, including the area and average depth of alluvial sediments and estimated volume of groundwater in operational storage, are summarized in **Table 3-3** (Section 3.8).

In accordance with the SWRCB Recycled Water Policy, the available assimilative capacity for each analysis subregion was calculated by comparing the Basin Plan Objectives (BPOs) with the average concentration of each analysis subregion over the most recent five years of available groundwater quality data. Because the last sampling event for many wells occurred in 2012 or 2013, samples collected from January 2008 through mid-2013 were used to incorporate the last five years of data for all wells. The water quality data set for the Study Area is extensive and includes routine monitoring of a network of MWA wells and other data sets such as the CDPH drinking water well database. Water quality data from WDR site wells were also used to help establish water quality concentrations near active waste discharge facilities, where other monitoring and production well data were not available.

Table 4-2 summarizes the number of wells used in the groundwater quality evaluation for the Mojave SNMP.

Figure 4-1
Active Waste Discharge Requirement (WDR) Sites

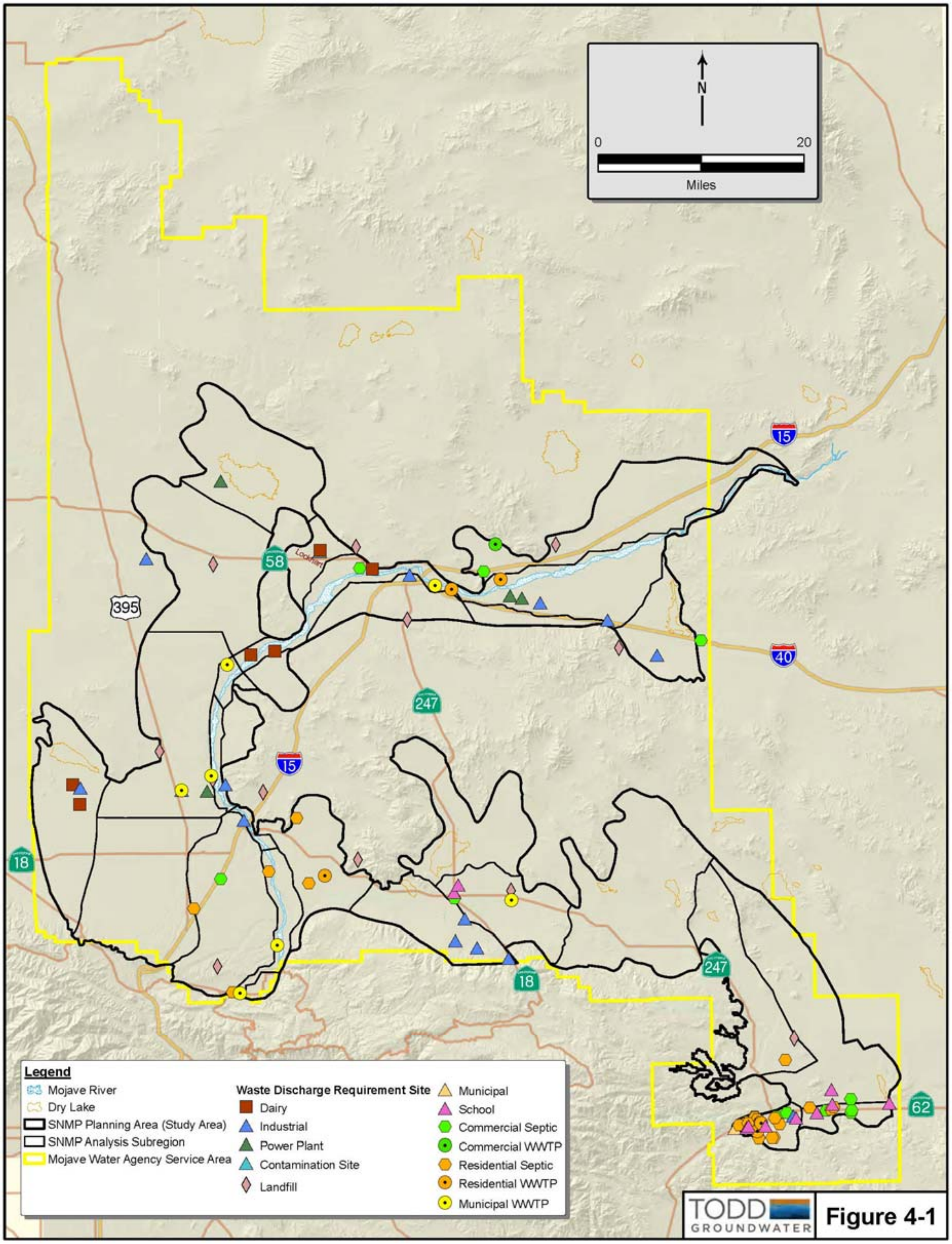


Table 4-1
Inventory of Active Waste Discharge Requirement (WDR) Sites by Subregion

Waste Discharge Reporting (WDR) Site Type	MOJAVE RIVER BASIN															MORONGO BASIN							TOTAL
	Baja - Floodplain	Baja - Regional	Centro - Floodplain	Centro - Regional	Centro - Regional (Harper Dry Lake)	Alto Transition Zone - Floodplain (Helendale)	Alto Transition Zone - Floodplain	Alto Transition Zone - Regional	Alto - Floodplain (Narrows)	Alto - Floodplain	Alto - Left Regional	Alto - Mid Regional	Altro Right Regional	Oeste - Regional	Este - Regional	Lucerne Valley (north)	Lucerne Valley (south)	Johnson Valley	Ames-Means Valley	Warren Valley	Copper Mountain-Giant Rock	Joshua Tree	
Commercial Septic		2	1									2					1			4	1	3	**14**
Commercial WWTP		1																					**1**
Contamination Site				1																			**1**
Dairy			3	1										2									**6**
Industrial	2	1		1				1	1					1	8		1			1			**17**
Landfill		1		2			1					1					1		1				**7**
Municipal																				1			**1**
Power Plant	2				1			1															**4**
Municipal WWTP	1		1			1	1	1		2							1						**8**
Community Septic										2		1	2						1	17		3	**26**
Residential WWTP			1										1							2			**4**
School Septic																	2			4	1	3	**10**
Total Sites	**5**	**5**	**6**	**5**	**1**	**1**	**2**	**3**	**1**	**4**	**0**	**4**	**3**	**3**	**8**	**0**	**6**	**0**	**2**	**29**	**2**	**9**	**99**

Table 4-2
Inventory of Wells Used in Evaluation of Existing Groundwater Quality

Subregion	No. of Wells with TDS Data All Years	No. of Wells with TDS Data 2008-2013	No. of Wells with Nitrate Data All Years	No. of Wells with Nitrate Data 2008-2013
MOJAVE RIVER BASIN				
Baja - Floodplain	201	64	110	48
Baja - Regional	135	28	63	33
Centro - Floodplain	338	117	302	177
Centro - Regional (east)	32	5	41	2
Centro - Regional (west)	102	78	85	80
Centro - Regional (Harper Lake)	35	5	16	2
Transition Zone - Floodplain (Helendale)	43	26	27	27
Transition Zone - Floodplain	142	73	95	73
Transition Zone - Regional	159	54	168	51
Alto - Floodplain (Narrows)	49	1	28	20
Alto - Floodplain	91	80	76	64
Alto - Left Regional	37	19	20	18
Alto - Mid Regional	143	88	117	86
Alto - Right Regional	72	24	48	27
Oeste - Regional	81	20	41	18
Este - Regional	37	14	27	19
MORONGO BASIN				
Lucerne Valley (north)	41	14	14	14
Lucerne Valley (south)	86	13	28	18
Johnson Valley	27	2	1	1
Ames-Means Valley	50	30	35	29
Warren Valley	51	37	27	20
Copper Mountain-Giant Rock	18	3	4	6
Joshua Tree	17	5	6	3
MOJAVE RIVER BASIN AND MORONGO BASIN TOTAL	**1,987**	**800**	**1,379**	**836**
AVERAGE NUMBER OF WELLS PER SUBREGION	**95**	**38**	**66**	**40**

As shown in the table, there is a high density of wells with water quality data that allow for reliable estimation of existing groundwater quality in each subregion. TDS data were available for 1,987 wells across the Study Area, of which TDS data since 2008 were available for 800 wells. Nitrate data were available for 1,379 wells in the Study Area, of which nitrate data since 2008 were available for 836 wells.

Generally, the degree of groundwater quality monitoring for a given subregion is commensurate with the degree of groundwater production, hydrogeologic complexity, and active management. For example, the Mojave River Basin floodplain provides a significant portion of the water supply to the area, is characterized by complex groundwater-surface water interactions, and is the location of several MWA managed aquifer recharge facilities. Thus, the six subregions comprising the Mojave River floodplain each has a high density of wells with water quality data. Conversely, more rural subregions located away from the Mojave River floodplain, such as Centro – Regional (Harper Dry Lake) and Johnson Valley, have fewer wells with water quality data.

The median groundwater concentration for the recent 5-year water quality averaging period for TDS and nitrate is plotted on maps with median concentrations symbolized by circles of varying size and color (dots maps). Older (pre-2008) well median TDS concentration data (transparent colored dots in the figure) were also relied upon for characterization of areas with limited recent data. Medians were used instead of arithmetic averages to prevent potential skewing by potential data outliers and to obtain representative estimates for wells with nitrate records potentially composed of censored (non-detect) and non-censored data.

The TDS and nitrate dots maps were used to develop concentration contour maps across the Study Area using geographical information system (GIS) spatial analysis tools. For each subregion, the density and distribution of 2008-2013 well median water quality data were evaluated closely to identify data gaps, and the following two steps were applied prior to interpolation:

1. Older historical well concentration data were used to supplement areas lacking recent water quality data. Specifically, an iterative approach was used whereby well median datasets for 2000-2007 data were prioritized, then 1990-1999 well median data, and so forth);

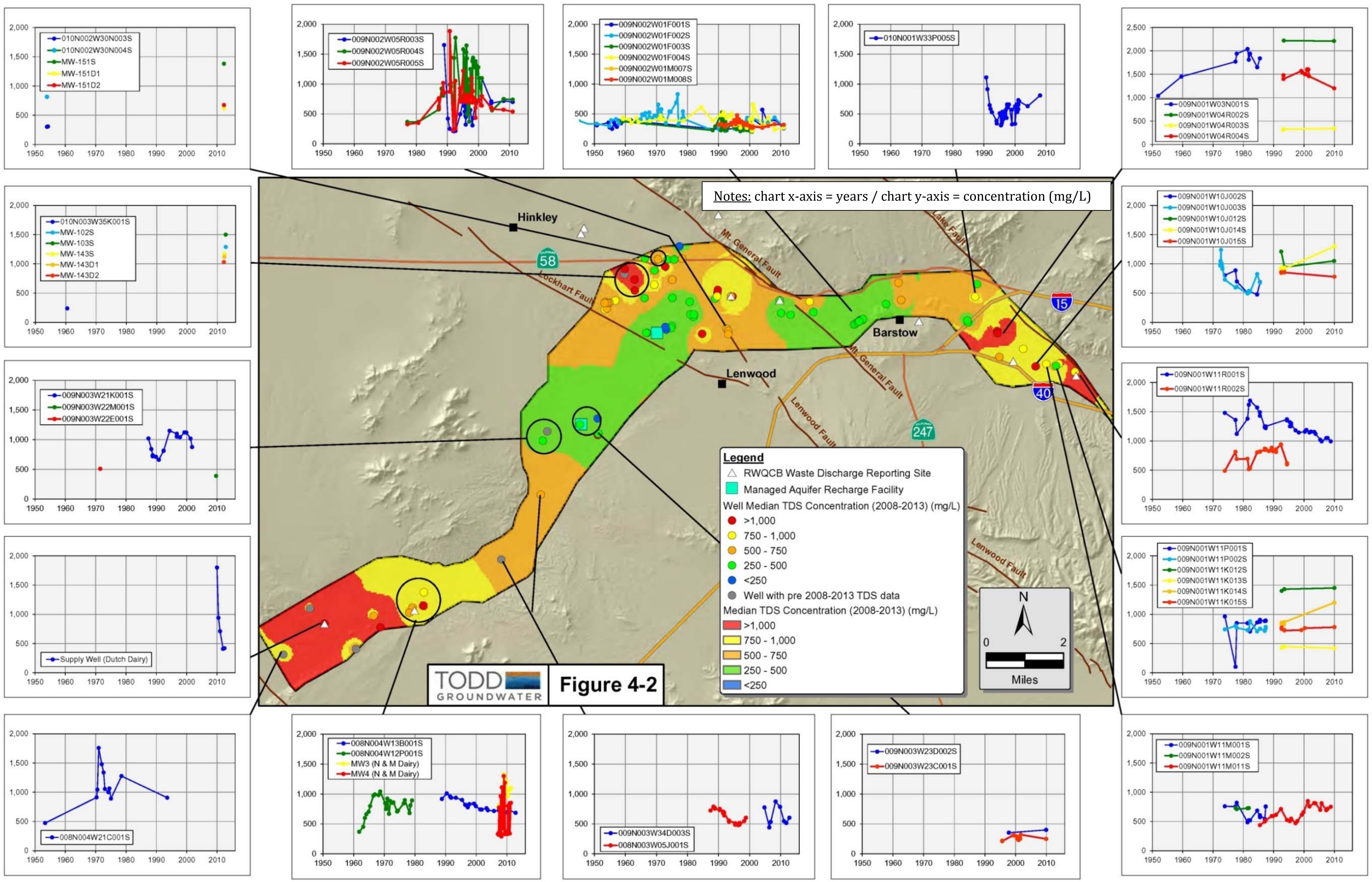
2. Control contours were used to prevent erroneous artifacts of the interpolation process. The inverse-distance weighted interpolation method was used for all subregions.

For four subregions, Baja – Regional, Centro – Regional (east), the western portion of Centro – Regional (west) and Johnson Valley), the narrow distribution of water quality data was deemed inadequate for reliable interpolation. For these subregions, the average subregional concentration was estimated by averaging available well median data.

Following interpolation, the volume-weighted average groundwater concentration for TDS and nitrate-NO_3 was calculated for each subregion by weighting the variable concentration contour surface by the similarly variable surface representing the volume of extractable groundwater in storage. This process weights the groundwater concentrations estimated in thicker portions within a given subregion over the estimated groundwater quality in thinner portions within that same subregion.

TDS and nitrate time-concentration plot maps for selected wells in each subregion were also generated for the SNMP. An example is shown on **Figure 4-2** for the Centro-Floodplain subregion. TDS and nitrate time-concentration plot maps are included in the individual subregional synopses presented in **Appendix C**. While the well median and groundwater concentration contour maps illustrate the distribution of existing groundwater quality, the time-concentration plots further provide a historical perspective on groundwater quality and support insights into the relationship between evolving historical land uses on groundwater quality. On each time-concentration plot, waste discharge sites and MWA managed aquifer recharge facilities are provided for reference. Time-concentration plots were developed to help identify any dominant historical groundwater quality trends on a subregional-scale and provide a relative calibration target for S/N loading model results (recognizing the challenge in comparing projected average concentration trends from the model to well-by-well concentration trends).

Figure 4-2
TDS Time-Concentration Plot Map for Centro – Floodplain



4.6.1 Existing TDS Concentrations

Figure 4-3 shows median TDS concentrations for monitoring and production wells for the recent 5-year water quality averaging period (dot map). **Figure 4-4** shows the TDS concentration contour map of the Study Area. As shown on the figures, groundwater quality is of very high quality (less than 250 mg/L) in the upgradient portions of the Mojave River Basin along the river (specifically the Alto - Floodplain and Alto - Mid Regional subregions) and in the Warren Valley subregion and southern portion of the Copper Mountain-Giant Rock-Joshua Tree subregion in the Morongo Basin.

TDS concentrations generally increase in downgradient portions of the Mojave River Basin and along groundwater flowpaths away from the primary recharge source in the basin, the Mojave River. Elevated TDS concentrations (greater than 1,000 mg/L) are observed in the vicinity of El Mirage Dry Lake (Oeste), Harper Dry Lake (Centro – Regional [Harper Dry Lake]) and Lucerne Dry Lake (Lucerne Valley), showing the effect of mineralization and evaporation beneath dry lake beds. There are a few areas with elevated TDS concentrations in the Mojave River Basin, particularly in the vicinity of dry lakes and along the outer margins of the basin, but most of the groundwater is below the BPO. While TDS concentrations are generally below 500 mg/L in many subregions, elevated TDS concentrations in some subregions are likely naturally-occurring poor quality groundwater as a result of mineralization. For example, dissolution of formation materials high in silts and clays is the likely cause of naturally high groundwater TDS concentrations in the northern portion of the Lucerne Valley subregion.

The Helendale Fault (see **Figure 3-6**) is a partial hydraulic barrier and is known to cause upwelling of deep groundwater with elevated TDS. This is the primary cause of elevated groundwater TDS concentrations observed in the Alto Transition Zone – Floodplain (Helendale) and southwestern portion of the Centro – Floodplain subregions.

In the Morongo Basin, groundwater TDS concentrations generally increase along groundwater flowpaths away from the southwestern margins of the basin where mountain-front recharge occurs. Groundwater quality is good in the Warren Valley and Joshua Tree subregions, central portion of the Ames-Means Valley subregion, and southern portion of the Copper Mountain-Giant Rock subregion. Elevated TDS concentrations in some subregions generally represent naturally-occurring, poor quality groundwater as a result of mineralization and geologic faulting. For example, dissolution of formation materials high in silts and clays is the likely cause of naturally high groundwater TDS concentrations in the Lucerne Valley (north) subregion and contributes to naturally elevated TDS concentrations in the Johnson Valley and northern portion of the Ames-Means Valley.

Figure 4-3
2008-2013 Well Median TDS Concentrations

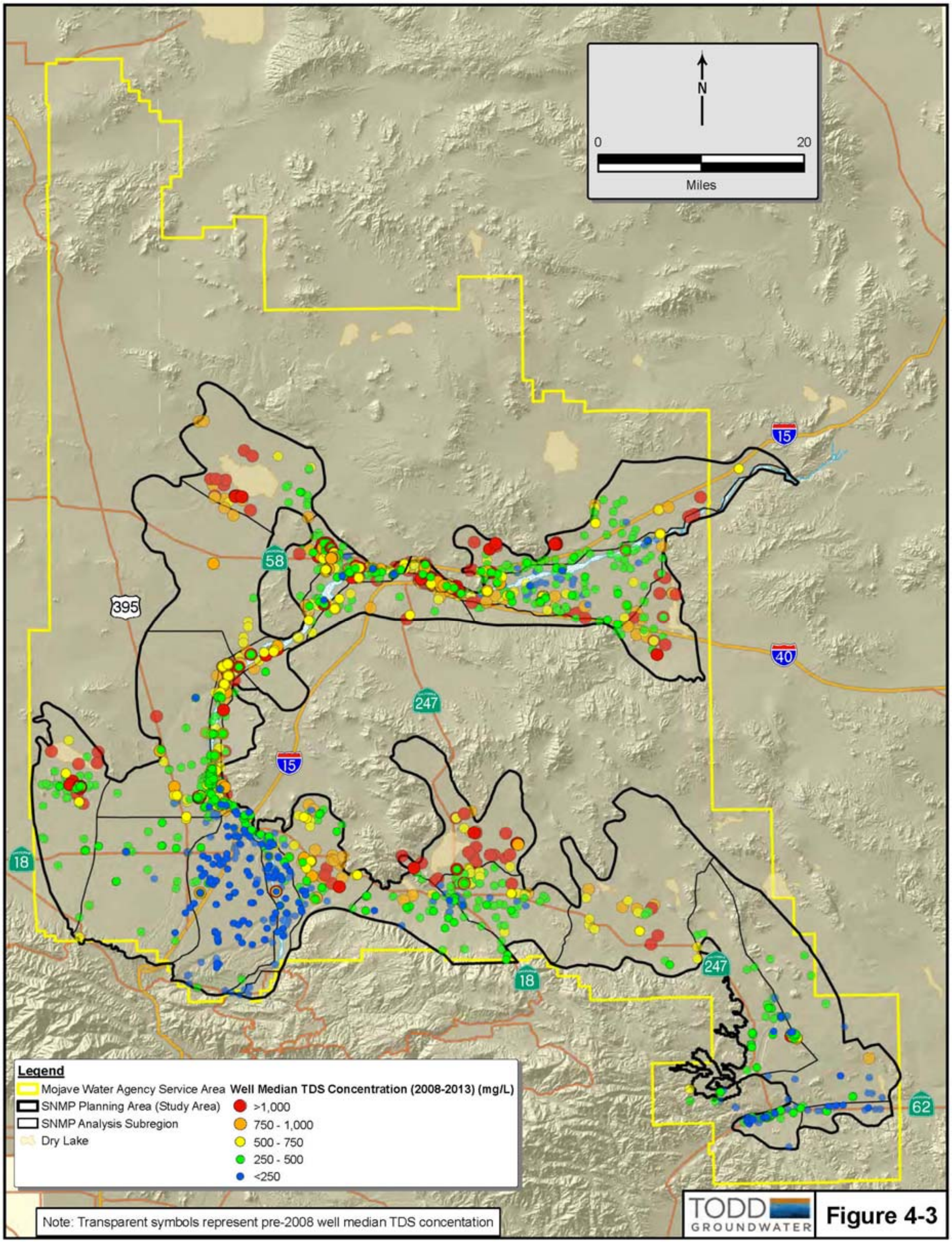
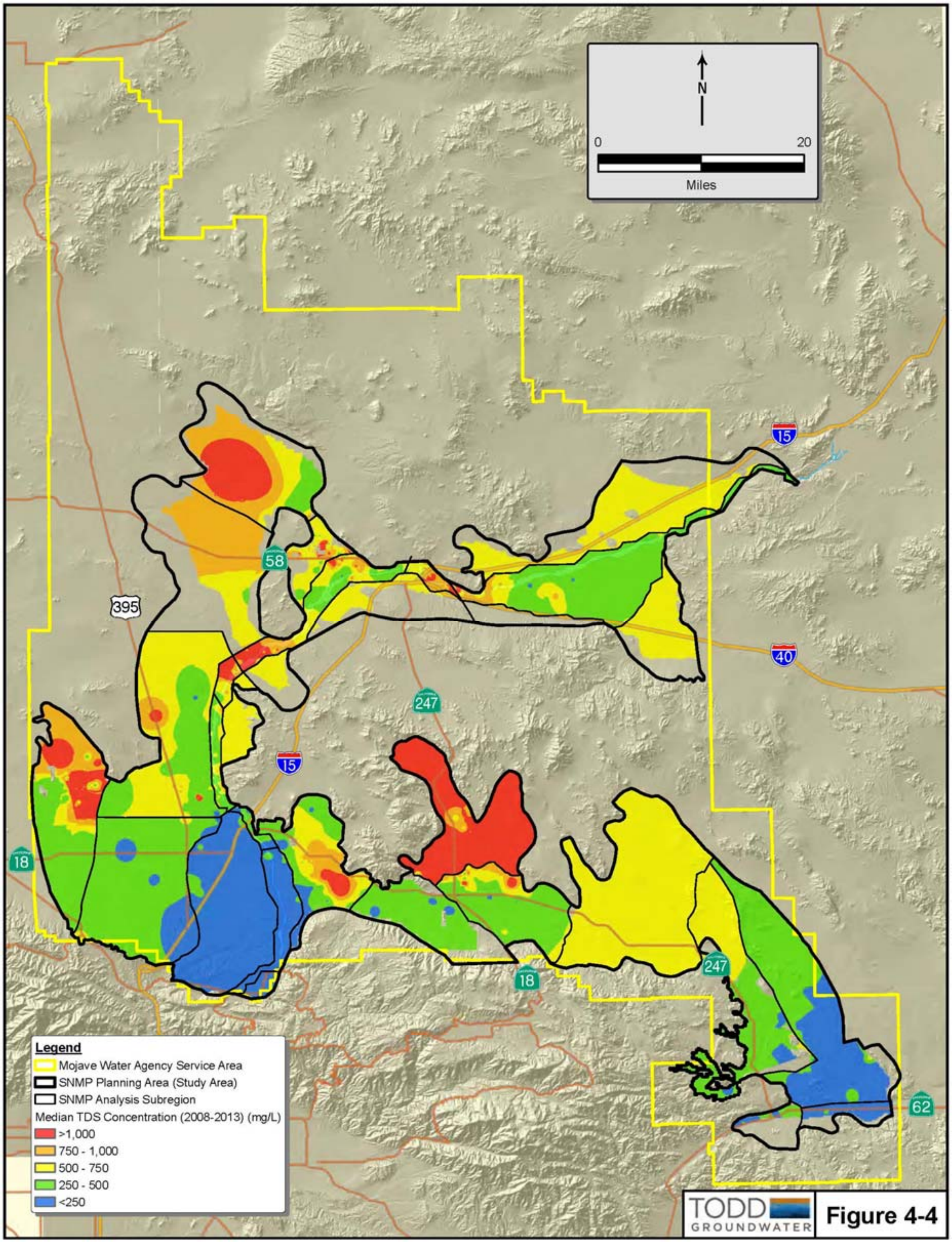


Figure 4-4
2008-2013 TDS Concentration Contours



4.6.2 Existing Nitrate Concentrations

Figure 4-5 shows median nitrate concentrations for monitoring and production wells for the recent 5-year water quality averaging period. **Figure 4-6** shows the nitrate concentration contour map of the Study Area. As shown on these figures, nitrate concentrations are typically low (less than 10 mg/L as NO_3) in most areas.

In the Mojave River Basin, a few areas have nitrate concentrations near or above the BPO of 45 mg/L. Areas include the Centro – Floodplain and Centro – Regional subregions in the vicinity of Hinkley and northeast of the Helendale Fault. Elevated concentrations in each of these areas are associated with either legacy and/or existing dairy operations and agricultural fields. It also appears that deep groundwater upwelling at the Helendale Fault contributes partially to elevated concentrations along the boundary of the Alto Transition Zone – Floodplain (Helendale) and Centro - Floodplain subregions. Elevated nitrate concentrations above 45 mg/L are also observed in the central portion of the Oeste subregion in the vicinity of an active dairy and industrial facility. Elevated nitrate concentrations (between 10 to 22.5 mg/L as NO_3) in the Alto – Mid Regional subregion are likely associated with septic tanks return flows.

In the Morongo Basin, elevated nitrate concentrations in Warren Valley are associated with the entrainment of septage residing in the vadose zone by rising groundwater following enhanced recharge of SWP water from the mid-1990s to early-2000s. Current groundwater nitrate concentrations are significantly below their historical peak in the early-2000s as a result of recent groundwater management. Elevated nitrate in the Joshua Tree subregion and southern portion of the Copper Mountain-Giant Rock subregion is associated with higher-density septic tank use.

Localized elevated nitrate concentrations are also observed in the vicinity of wastewater effluent discharge locations. This includes effluent discharge facilities associated with the Victor Valley Wastewater Reclamation Authority (Alto Transition Zone – Floodplain), Helendale CSD (Alto Transition Zone – Floodplain (Helendale)), City of Barstow WWTP (Centro – Floodplain and Baja – Floodplain), City of Adelanto (Alto Transition Zone – Regional). With the exception of the Barstow WWTP area, groundwater nitrate-NO_3 concentrations in these areas are well below the BPO of 45 mg/L.

Figure 4-5
2008-2013 Well Median Nitrate Concentrations

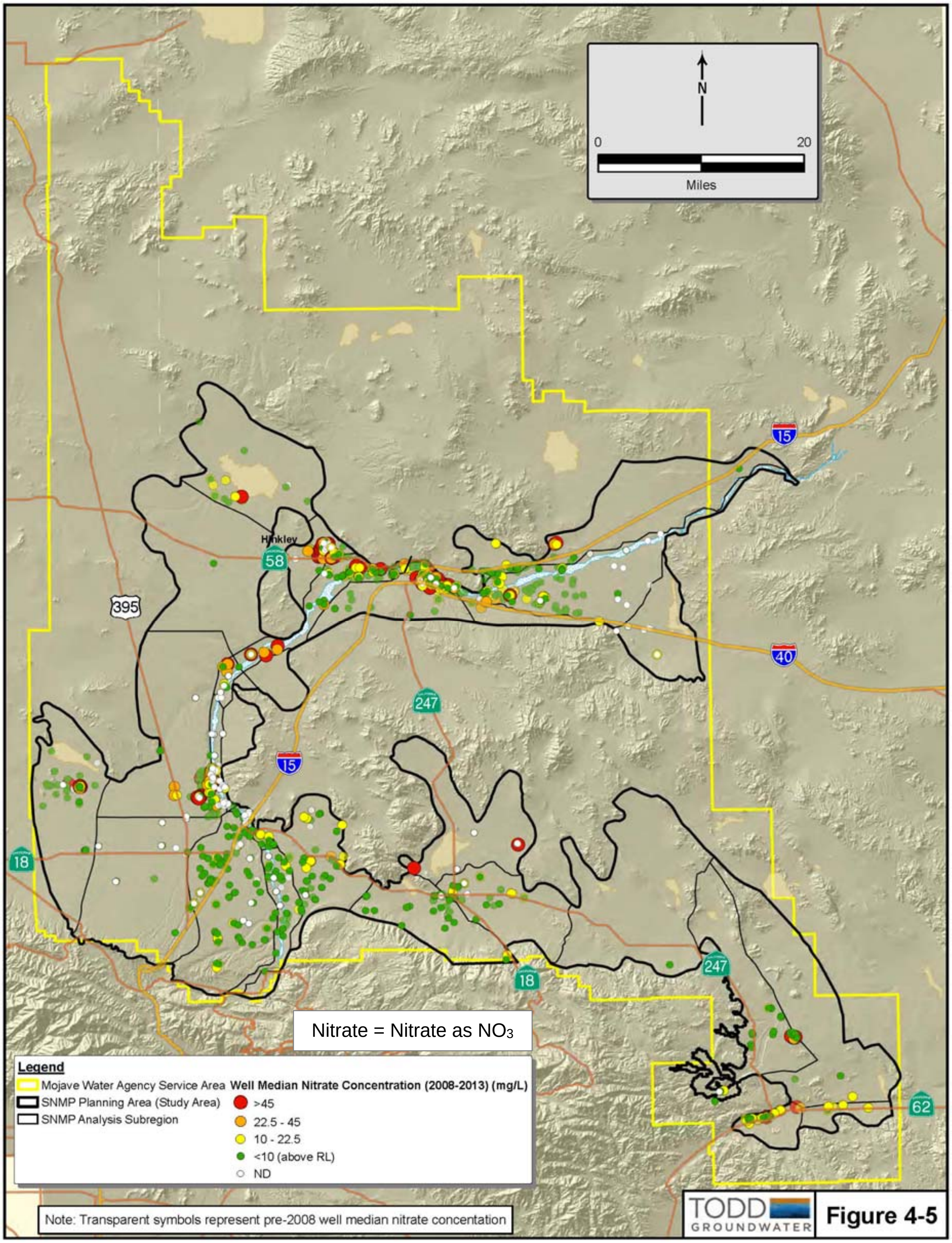
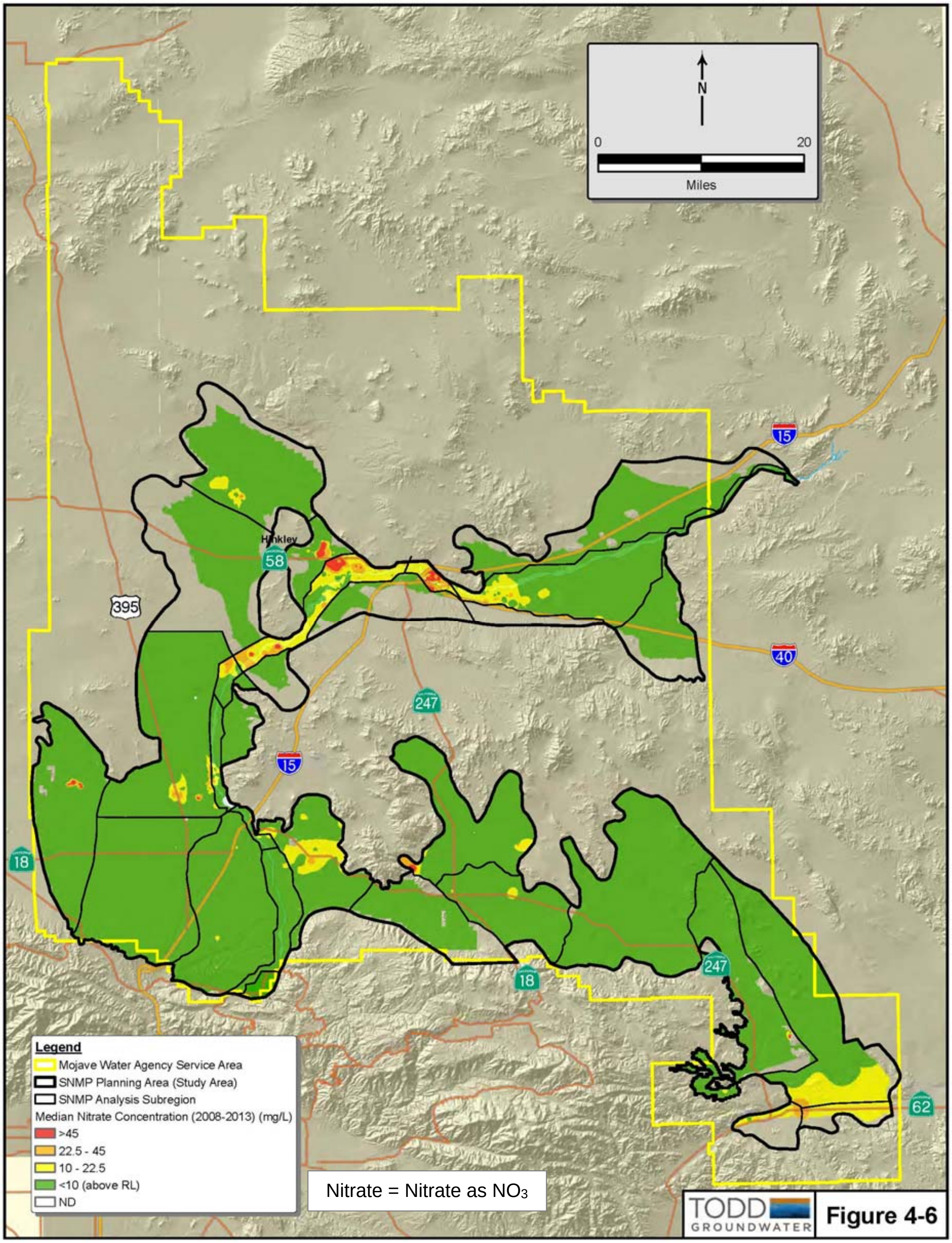


Figure 4-6
2008-2013 Nitrate Concentration Contours



4.6.3 Average Existing TDS and Nitrate Concentrations and Assimilative Capacity by Subregion

Based on the concentration contour maps, the volume-weighted average existing TDS and nitrate-NO_3 concentrations were calculated for each analysis subregion. Results are summarized in **Table 4-3** and depicted on **Figure 4-7**.

Average subregional TDS concentrations vary considerably ranging from 153 mg/L to 1,716 mg/L across the Study Area. Average TDS concentrations are very low in the upgradient portions of the Mojave River Basin (less than 300 mg/L) and increase along the pathways along and away from the Mojave River due to natural processes (e.g., mineralization) and impacts from anthropogenic loading. As shown in the upper chart on **Figure 4-7**, 8 of the 9 downgradient analysis subregions composing the Alto Transition Zone, Centro, and Baja subareas have average TDS concentrations at or above 500 mg/L (Baja - Floodplain is the lone exception). Average TDS concentrations in Centro – Regional (Harper Dry Lake) (1,028 mg/L) are primarily influenced by a high degree of mineralization and evaporation beneath the dry lake bed.

In the Morongo Basin, average TDS concentrations are generally below the recommended SMCL for TDS of 500 mg/L. Exceptions include Lucerne Valley (north) (1,716 mg/L) and Johnson Valley (678 mg/L), where elevated TDS concentrations primarily reflect a high degree of mineralization and dry lake bed evaporation.

Nitrate-NO_3 concentrations are generally low across the Study Area. Average subregional concentrations range from 0.9 to 20.7 mg/L. Average nitrate-NO_3 concentrations are at or above 15 mg/L in Centro – Floodplain, Warren Valley, and Joshua Tree. Additionally, nitrate-NO_3 concentrations are slightly elevated (between 7.5 and 10 mg/L) in Centro – Regional (west), Alto Transition Zone – Floodplain (Helendale), and Alto – Right Regional. As discussed previously, in the Centro Subarea, elevated nitrate concentrations are associated with historical and existing agricultural operations (crop field and dairies) and naturally-occurring processes (upwelling of deep groundwater at the Helendale Fault). In Alto – Right Regional and Joshua Tree, septic tank return flows are the most significant contributing factor to slightly elevated groundwater nitrate concentrations. In the Warren Valley, elevated nitrate concentrations are associated with a high density of septic tank usage and historical entrainment of septage stored in the vadose zone following managed aquifer recharge operations.

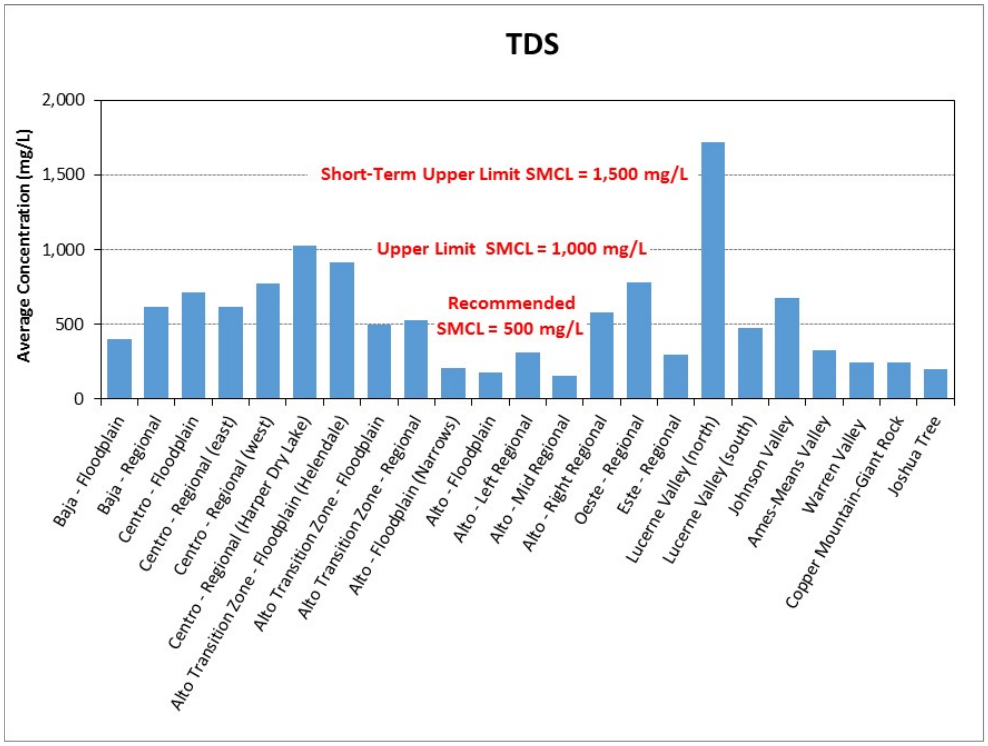
In accordance with the SWRCB Recycled Water Policy, the available assimilative capacity is calculated by comparing the pertinent BPOs with the average concentration of the basin/subbasin. The definition of assimilative capacity is illustrated by an example as shown on **Figure 4-8**.

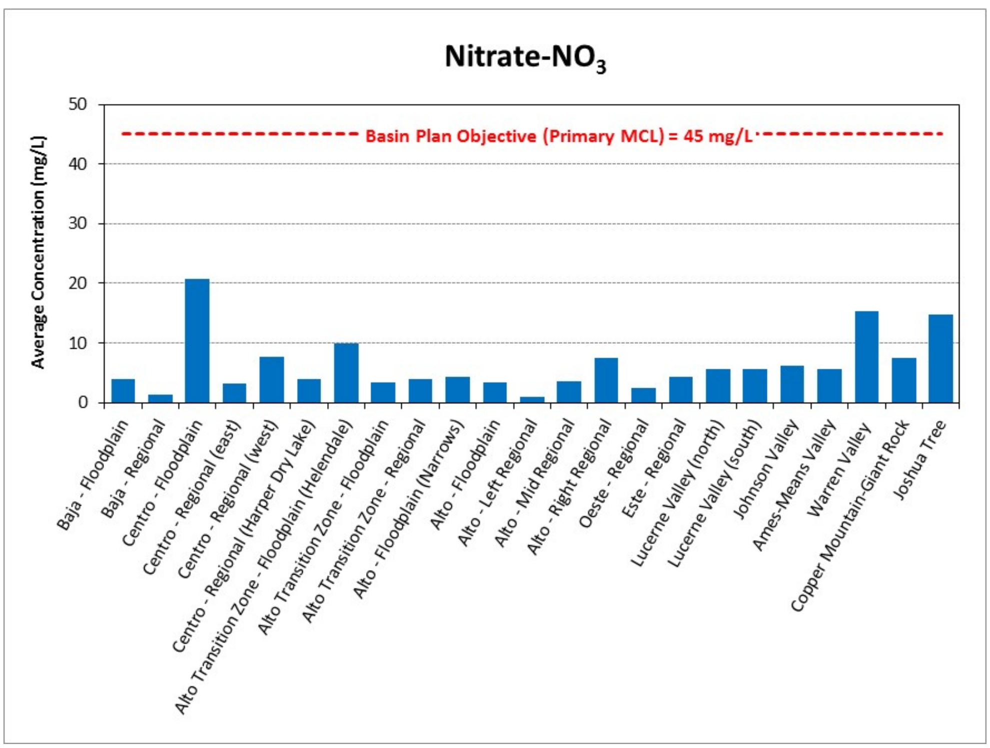
Table 4-3
Average Existing TDS and Nitrate Concentrations by Subregion

SNMP Analysis Subregion	Estimated Groundwater in Operational Storage[a] (acre-feet)	Volume-Weighted Average Existing TDS Concentration (mg/L)	Volume-Weighted Average Existing Nitrate-NO_3 Concentration (mg/L)
MOJAVE RIVER BASIN			
Baja - Floodplain	4,886,000	401	3.9
Baja - Regional	2,014,000	617	1.4
Centro - Floodplain	1,405,000	711	20.7
Centro - Regional (east)	301,000	618	3.2
Centro - Regional (west)	1,580,000	771	7.7
Centro - Regional (Harper Dry Lake)	2,128,000	1,028	4.0
Alto Transition Zone - Floodplain (Helendale)	269,000	915	10.0
Alto Transition Zone - Floodplain	431,000	500	3.4
Alto Transition Zone - Regional	5,067,000	529	3.9
Alto - Floodplain (Narrows)	264,000	205	4.3
Alto - Floodplain	801,000	177	3.3
Alto - Left Regional	1,812,000	310	0.9
Alto - Mid Regional	1,893,000	153	3.5
Alto - Right Regional	1,052,000	579	7.5
Oeste - Regional	807,000	781	2.5
Este - Regional	840,000	299	4.3
Mojave River Basin Total	**25,550,000**		
MORONGO BASIN			
Lucerne Valley (north)	869,000	1,716	5.6
Lucerne Valley (south)	996,000	472	5.7
Johnson Valley	2,273,000	678	6.2
Ames-Means Valley	692,000	330	5.7
Warren Valley	330,033	243	15.4
Copper Mountain-Giant Rock	3,827,410	247	7.5
Joshua Tree	376,748	202	14.7
Morongo Basin Total	**9,364,190**		
MOJAVE RIVER BASIN AND MORONGO BASIN TOTAL	**34,914,190**		

Notes:
mg/L = milligrams per liter
(a) Volume of groundwater above estimated base of groundwater production zone

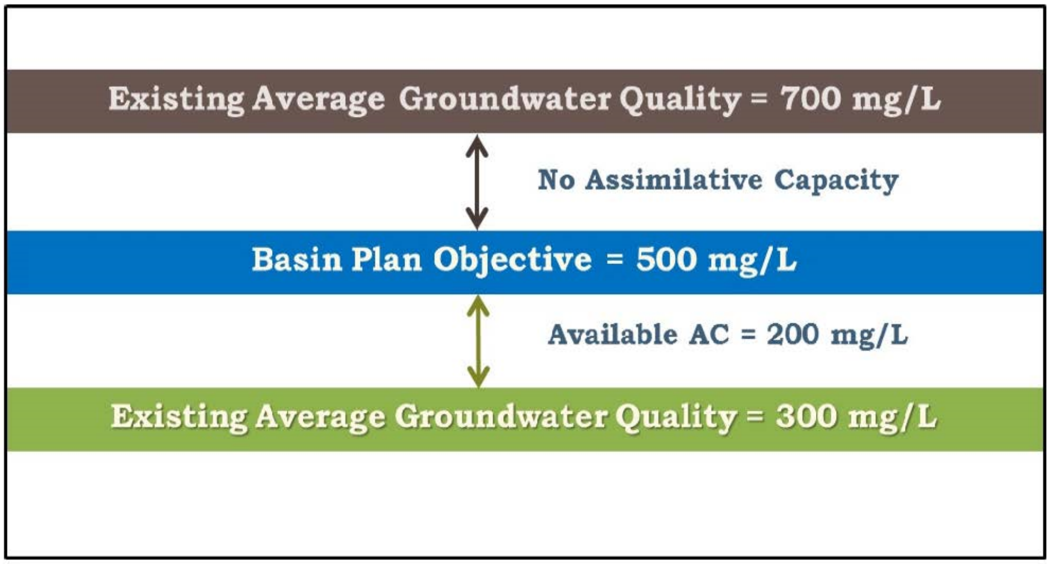
Figure 4-7
Average TDS and Nitrate Concentrations by Subregion





Notes:
SMCL = Secondary Maximum Contaminant Level; MCL = Maximum Contaminant Level

Figure 4-8
Assimilative Capacity Example



A BPO for TDS of 500 mg/L (the recommended SMCL) is assumed in the illustration above. If existing average groundwater quality is 700 mg/L, then the BPO is exceeded by 200 mg/L, and there is no available assimilative capacity. Conversely, if existing average groundwater quality is 300 mg/L, there is 200 mg/L of existing available assimilative capacity.

Assimilative capacity calculations for TDS and nitrate for each subregion are shown in **Table 4-4**. Assimilative capacity calculations are provided for TDS based on the recommended upper limit and short-term upper limit SMCLs of 500, 1,000, and 1,500 mg/L. Assimilative capacities for nitrate are based on the primary MCL of 45 mg/L for nitrate-NO_3. Positive values indicate that there is available assimilative capacity; negative values indicate the lack of available assimilative capacity.

4.6.3.1 Existing TDS Assimilative Capacity Calculation

As shown in the **Table 4-4**, average groundwater TDS concentrations are below all three BPO concentrations in four out of five Alto (Floodplain, Floodplain (Narrows), Left Regional, and Mid Regional) subregions, Baja – Floodplain, and Este – Regional in the Mojave River Basin. Existing assimilative capacity exists for all subregions based on a BPO of 1,000 mg/L, with the exception of Centro – Regional (Harper Dry Lake), which historically high TDS concentrations due to natural dry lake evaporation. At a BPO of 1,500 mg/L, assimilative capacities exist for all subregions.

In the Morongo Basin, average groundwater TDS concentrations are below all three BPO concentrations (and thus there is available assimilative capacity) in three of the five subregions (Ames-Means Valley, Warren Valley, and Copper Mountain-Giant Rock-Joshua Tree).

Average concentrations in two subregions, Centro – Regional (Harper Dry Lake) and Lucerne Valley, are above 1,000 mg/L due to the presence of dry lake bed and highly mineralized regions. These subregions would have no assimilative capacity if a BPO of 1,000 mg/L is applied.

Table 4-4
Existing TDS and Nitrate Assimilative Capacity

Subregion	TDS				Nitrate-NO_3	
	Average TDS Groundwater Concentration	Assimilative Capacity[a]			Average Nitrate-NO_3 Groundwater Concentration	Assimilative Capacity[a]
		BPO = 500 mg/L	BPO = 1,000 mg/L	BPO = 1,500 mg/L		BPO = 45 mg/L
MOJAVE RIVER BASIN						
Baja - Floodplain	401	99	599	1,099	3.9	41.1
Baja - Regional	617	-117	383	883	1.4	43.6
Centro - Floodplain	711	-211	289	789	20.7	24.3
Centro - Regional (east)	618	-118	382	882	3.2	41.8
Centro - Regional (west)	771	-271	229	729	7.7	37.3
Centro - Regional (Harper Dry Lake)	1,028	-528	-28	472	4.0	41.0
Alto Transition Zone - Floodplain (Helendale)	915	-415	85	585	10.0	35.0
Alto Transition Zone - Floodplain	500	0	500	1,000	3.4	41.6
Alto Transition Zone - Regional	529	-29	471	971	3.9	41.1
Alto - Floodplain (Narrows)	205	295	795	1,295	4.3	40.7
Alto - Floodplain	177	323	823	1,323	3.3	41.7
Alto - Left Regional	310	190	690	1,190	0.9	44.1
Alto - Mid Regional	153	347	847	1,347	3.5	41.5
Alto - Right Regional	579	-79	421	921	7.5	37.5
Oeste - Regional	781	-281	219	719	2.5	42.5
Este - Regional	299	201	701	1,201	4.3	40.7
MORONGO BASIN						
Lucerne Valley (north)	1,716	-1,216	-716	-216	5.6	39.4
Lucerne Valley (south)	472	28	528	1,028	5.7	39.3
Johnson Valley	678	-178	322	822	6.2	38.8
Ames-Means Valley	330	170	670	1,170	5.7	39.3
Warren Valley	243	257	757	1,257	15.4	29.6
Copper Mountain-Giant Rock	247	253	753	1,253	7.5	37.5
Joshua Tree	202	298	798	1,298	14.7	30.3

Notes:
Red highlighted cell indicates that average concentration exceeds respective BPO, and there is no available assimilative capacity.
(b) Assimilative capacity equals BPO minus average concentration (in mg/L); positive value indicates available assimilative capacity; a negative value indicates no available assimilative capacity.

4.6.3.2 Existing Nitrate Assimilative Capacity Calculation

As shown in the **Table 4-4**, average groundwater nitrate-NO_3 concentrations are generally well below the BPO concentration in all subregions. The average assimilative capacity is about 39 mg/L across the Study Area. Subregions with below-average nitrate-NO_3 assimilative capacities include the following:

- Centro – Floodplain
- Centro – Regional (west)
- Alto Transition Zone – Floodplain (Helendale)
- Alto – Right Regional
- Warren Valley
- Copper Mountain- Giant Rock
- Joshua Tree

Section 5: Salt and Nutrient Loading Analysis

A S/N loading analysis was conducted to estimate the impact of planned future land uses and associated water use on groundwater quality in the Study Area. The S/N loading analysis considers the existing S/N mass in groundwater storage and the source water volumes of key inflows and outflows and their associated TDS and nitrate concentrations. The analysis also considers any added TDS and nitrate from use as well as other fate and transport processes that influence groundwater concentrations. This section describes the methodology and data used to estimate key S/N loading factors (considering projected growth and future projects) and to predict their individual and cumulative effects on groundwater quality in the Study Area.

The primary objectives of the S/N loading analysis are aligned with the goals set forth in the Recycled Water Policy and include the following:

1. Identify and estimate the key inflows and outflows for the basins

2. Identify the major contributors of salts and nutrients in the basins and estimate their impact on groundwater quality under projected future conditions

3. Quantify the impact of projected population growth (and associated increases in water use and imported water demand) on groundwater quality

4. Quantify the impact of planned future recycled water projects on groundwater quality

Section 5.1 summarizes the physical structure of and processes simulated in the water quality mixing model developed for the Mojave SNMP. Refinements made to the original MWA water quality mixing model are described along with advantages and limitations of the overall modeling approach.

Section 5.2 describes the general mixing model inputs and data sources and the approach used to characterize three future S/N loading conditions (or scenarios) for the Mojave SNMP.

Sections 5.3 and 5.4 present the S/N concentrations for individual source waters and key S/N inflows and outflows for the Study Area. The description of the groundwater quality mixing model and simulation results over the SNMP future period are presented in Sections 5.5 and 5.6.

5.1 Mojave SNMP Groundwater Quality Mixing Model

To satisfy the goals and objectives of the SNMP, a regional groundwater quality mixing model (SNMP mixing model) focusing on TDS and nitrate was developed to perform two primary functions:

3) Simulate regional groundwater quality within the Study Area over the 70-year future simulation period from water year (WY) 2012-13 through WY 2081-82 under various future S/N loading conditions (or scenarios), and

4) Quantify the effect of planned future recycled water projects and other land use/water use changes on regional groundwater quality.

The SNMP mixing model also serves a secondary, yet critical, function. Because of the inherent uncertainties associated with estimating S/N loading factors for numerous individual sources, verification of S/N loading estimates in some form is warranted. For the Mojave SNMP, the sensitivity of groundwater quality for each model subregion to individual S/N loading factors was assessed to ensure a reasonable agreement between simulated and historically observed regional groundwater quality trends (based on qualitative evaluation of time-concentration plot maps).

To satisfy the goals and objectives of the SNMP, the SNMP mixing model was developed to: 1) account for the current groundwater volume and S/N mass in operational storage within the Study Area subregions, and 2) track the loading/unloading of S/Ns through major groundwater sources and sinks under current and future S/N loading conditions.

The effect of S/N loading on groundwater quality is predicated on the following understanding that groundwater quality: 1) improves if the flow-weighted concentration of all inflows (or mass) is less than the flow-weighted concentration (or mass) of all outflows, 2) degrades if the flow-weighted concentration of all inflows (or mass) is greater than the flow-weighted concentration (or mass) of all outflows, or 3) remains unchanged, if the flow-weighted concentration (or mass) of all inflows equals the flow-weighted concentration (or mass) of all outflows. This concept is expressed by the three equations below.

If $[\Sigma I_k * C_k] / [\Sigma I_k] - [\Sigma O_j * C_j] / [\Sigma O_j] < 0$ water quality is improving

If $[\Sigma I_k * C_k] / [\Sigma I_k] - [\Sigma O_j * C_j] / [\Sigma O_j] > 0$ water quality is degrading

If $[\Sigma I_k * C_k] / [\Sigma I_k] - [\Sigma O_j * C_j] / [\Sigma O_j] = 0$ water quality not changing

where, I_k = volumetric inflow for component *k*

C_k = TDS, chloride, or nitrogen concentration associated with inflow component *k*

O_j = volumetric outflow for component *j*

C_j = TDS or nitrogen concentration associated with outflow component *j*

The Mojave SNMP mixing model simultaneously calculates volumetric and S/N fluxes for each subregion. The annual groundwater volume and S/N mass fluxes into and out of each subregion were mixed with the initial volume of groundwater and S/N mass in storage for each annual time step. Complete mixing of S/Ns in each subregion is assumed to occur over each annual time step. The key output of the mixing model is the estimated S/N concentration in each mixing cell, which was calculated as a volume-weighted average concentration at the end of each annual time step, in milligrams per liter (mg/L).

Consideration of the groundwater volume and S/N mass in storage is necessary for predicting future groundwater quality concentrations and comparing simulated concentrations with BPOs and any anti-degradation thresholds (assimilative capacity) defined in the Recycled Water Policy. Evaluation methods that quantify S/N mass changes without considering the current groundwater volume and S/N mass can only be used to evaluate qualitatively if S/N mass in groundwater is increasing or decreasing. For example, it is possible to compare an estimated change of +2.5 mg/L of TDS to the available assimilative capacity. However, an estimated change of +15,000 tons of TDS is not very meaningful and may be misinterpreted when the accompanying change in groundwater storage is not considered.

5.1.1 Refinements to the Original MWA Water Quality Mixing Model

The original MWA water quality mixing model developed using the Structural Thinking Experimental Learning Laboratory with Animation (STELLA) software package (MWA, 2007) served as the basis for development of the SNMP mixing model. The original MWA mixing model was developed to evaluate projects considered during development of the MWA 2004 RWMP and addressed only TDS. For the SNMP, a similar module for nitrate was developed, and the model was updated to incorporate the revised volumes of groundwater (see **Table 3-3** in Section 3.8) and associated volume-weighted average concentrations for TDS and nitrate in operational storage in each subregion (see **Table 4-3** in Section 4.6.3).

Verification of the hydraulic relationships in the SNMP mixing model was performed to ensure that the updated mixing model accurately simulates storage-head-flow relationships in the Mojave River Basin derived from the USGS MODFLOW model, given the refinements to the groundwater volume in operational storage and new definitions of subregional water budgets and flow processes. MODFLOW is the USGS's three-dimensional (3D) finite-difference groundwater model first published in 1984. The SNMP model further incorporates fluxes from MODFLOW models developed for areas in the Morongo Basin by the USGS (Nishikawa et. al., 2001 and 2004) covering Warren Valley, Copper Mountain Valley, and Joshua Tree) and Bighorn-Desert View Water Agency (2011) covering Ames Valley.

5.1.2 Model Advantages, General Assumptions, and Limitations

The water quality mixing model developed for the Mojave SNMP is consistent with many other SNMP groundwater quality models in development across the State. These include SNMPs that are currently being prepared by the Water Replenishment District of Southern California, San Benito County Water Agency, Santa Clara Valley Water District, Sonoma County Water Agency, and Upper Los Angeles River Area Watermaster, among others.

For most other basins, groundwater quality mixing models were developed using standard spreadsheet software and do not simulate the hydraulic response of the aquifer to predicted storage changes. For example, subsurface inflows and outflows between basin subareas are often assumed to be constant despite changes in groundwater storage and hydraulic heads between subareas. While the Mojave SNMP mixing model simplifies the hydraulic responses from the Mojave River Basin USGS MODFLOW groundwater flow model using regression analysis techniques, doing so allows for more realistic simulation of aquifer hydraulic response to estimated groundwater storage changes in the Mojave River Basin. For example, the effects of groundwater storage and hydraulic head changes on groundwater-surface water interactions beneath the Mojave River are captured in the Mojave SNMP mixing model. These factors distinguish the Mojave SNMP mixing model from “static” mixing models used for other SNMPs in California.

The primary assumption and limitation of the SNMP mixing model is that S/N mixing within a given subregion is complete during each annual time step. While the Study Area is divided into 22 subregions to account for variable loading and non-uniform concentrations across the basins, it is recognized that the assumption of complete mixing can result in two potential errors: 1) overestimation or underestimation of the S/N concentration assigned to subsurface flows between neighboring mixing cells, and 2) overestimation of the effect of S/N loading changes associated with point-source projects in one subregion on neighboring subregions. However, the Mojave SNMP mixing model allows for efficient and reliable simulation of S/N loading conditions on a regional scale without re-running of the Mojave River Basin USGS MODFLOW groundwater flow model. Accordingly, the mixing model is deemed compatible with analysis at the planning level and serves as an appropriate screening tool for managing of S/N sources on a basin-wide or watershed-wide scale, as encouraged by the Recycled Water Policy.

5.2 Mixing Model Inputs and Simulation of Future Scenarios

Inputs to the SNMP mixing model included the following:

- Initial Groundwater Volume in Operational Storage
- Initial S/N Mass (Volume-Weighted Average Concentration) in Storage
- Inflow and Outflow Rates
- Inflow and Outflow Concentrations

5.2.1 Initial Groundwater Volume in Operational Storage

One of the key inputs to the SNMP mixing model is the initial volume of groundwater in operational storage for each subregion. The procedures used to estimate the existing groundwater volumes in operational storage by subregion are described in Section 3.8; final volumes are shown in **Table 3-3**.

5.2.2 Initial S/N Mass (Volume-Weighted Average Concentrations) in Storage

Current average S/N groundwater quality was estimated using available monitoring and production well sampling results from 2008 through 2013, the most recent five-year period as required by the Recycled Water Policy (Please note that, at the time of the data collection process, the last sampling event for many wells occurred in late 2012/early 2013). Older water quality data were used to supplement the evaluation where recent data were sparse. The procedures used to calculate the volume-weighted average TDS and nitrate concentrations are described in Section 4.6.3; final average concentrations are shown in **Table 4-3**.

5.2.3 Data Sources and Approach to Estimating Inflow and Outflow Rates

The SNMP mixing model accounts for key stresses and natural volumetric flow rates within each Study Area subregion. The updated (February 26, 2014) MWA demand forecast model served as the primary basis for estimating key stresses on the groundwater system, including anthropogenic inflows (MWA 2014b). These include managed aquifer recharge with imported SWP water; return flow from municipal and agricultural irrigation, including crops and dairies; return flows (leakage) from recreational lakes; WWTP effluent discharge and septic tank discharge; and outflows represented by groundwater pumping for the various water demand sectors.

Water budgets were developed for each subregion and input into the SNMP water quality mixing model. For the Mojave River Basin, natural inflows (including stream recharge, mountain-front recharge, and subsurface inflows) and outflows (including subsurface outflows and evapotranspiration (ET) by phreatophytes along the Mojave River) were calculated by the SNMP mixing model based on the revised annual anthropogenic water budgets and hydraulic relationships from the Mojave River Basin USGS MODFLOW model, which were incorporated into the model (see Section 5.2.4 for additional discussion).

For Morongo Basin subregions, estimated long-term average recharge rates from natural sources were applied based on various data sources detailed as follows: Estimates were derived from a combination of basin conceptual model and numerical groundwater flow model documentation reports, including the Warren Valley and Copper Mountain Valley USGS MODFLOW groundwater flow models developed by the USGS (Nishikawa, et al., 2004), basin conceptual model reports for the Ames-Means Valley and Johnson Valley subregions (MWA, 2007) and Lucerne Valley (Malcolm Pirnie, 1990).

The following procedure was used to develop anthropogenic water budget components (pumping, return flows, imported SWP water) for each subregion:

1. The anthropogenic flow inputs to the SNMP STELLA model were derived primarily from the MWA 2010 UWMP demand model (updated through WY 2012 as detailed in the Mojave IRWM Plan (MWA, 2014c)). Population growth and associated water use and supply projections in the MWA UWMP demand model from WY 2013 through WY 2035 are calculated on the subarea level (e.g., Alto, Centro, Baja, Oeste, Este, and Morongo). For the SNMP, projected water production and demand derived using the MWA UWMP demand model was apportioned to each of the 22 subregions defined in the SNMP. As such, projections in the MWA UWMP demand model were broken down to the water purveyor level (as much as possible) and re-packaged to generate water budgets by subregion. Annual growth projections for subarea water demand were apportioned consistently across individual purveyors (in lieu of applying variable growth curves by individual water purveyor).

2. Future groundwater production for each water purveyor was apportioned by subregion based on 2012 pumping distribution. Similarly, groundwater production estimates to satisfy agriculture, golf course, and recreational demand were based on 2012 verified well production values from Mojave Basin Area Watermaster (MBAW), and future demands were apportioned based on 2012 pumping distribution. Minimal producer demand was apportioned based on the MWA 2012 GIS coverage of identified minimal producers.

3. Return flow calculations in the MWA 2010 UWMP water demand model were apportioned by subregion based on purveyor service area coverage, and estimated gross return flow percentages were refined using available information from preliminary refined consumptive use/wastewater generation analyses completed by MBAW. For the SNMP, 2012 normalized consumptive use and wastewater generation factors from the MBAW analysis were applied to water demand projections, resulting in projected annual return flow estimates for municipal residential (indoor sewer, indoor septic tank, and outdoor irrigation), industrial, and commercial uses. Return flows from agricultural, golf course, and recreation are based on MBAW return flow percentages estimated for 2012 land use conditions.

MBAW estimates that return flows from municipal (landscape) irrigation are negligible, based on preliminary evaluation of chloride profiles beneath selected golf courses and public parks conducted as part of MBAW's current work to refine municipal and agricultural irrigation return flow estimates (communication with Robert Wagner [MBAW Engineer] on April 10, 2014). However, application of 0 percent return flow would not provide an effective means for evaluating the impact of future planned recycled water irrigation projects. As such, municipal (landscape) irrigation return flows were assumed to be 5% of estimated outdoor water use for the Mojave SNMP (additional discussion of this assumption and its significance to S/N loading is provided in Section 5.3.7).

4. Managed aquifer recharge calculations in the MWA 2010 UWMP water demand model were apportioned to existing and projected future managed aquifer recharge facilities based on evaluation by MWA staff of the recharge capacity of existing and future facilities. Annual recharge volumes were then grouped by subregion for the SNMP loading analysis.

5.2.4 Data Sources and Approach to Estimating Concentrations for Flow Components

Various data sources, approaches, and assumptions were used to derive representative concentrations for key inflows for the water quality modeling.

Key data sources included the following:

1. SWP water quality at MWA CAAQUEDUCT01 from 2003 to 2013 (DWR, 2014). See Section 5.3.3 for further discussion.

2. Mojave River surface water quality (USGS National Water Information System, 2014). See Section 5.3.1 for further discussion.

3. Recent treated effluent quality for all key WWTP discharge facilities and identified WDR sites. See **Table 5-3** for list of concentrations applied and Section 5.3.5 for further discussion.

4. Literature references for estimating nitrogen loading from septic tank return flows (Lowe , 2009; Umari, et al. 1993; and Schroeder, et al., 1993), dairy operations and nitrogen-based fertilizers in agricultural irrigation return flows (UC Davis, 2012).

5. Irrigated land use coverage (crop and landscaping acreages) to which unit S/N loading factors from municipal and agricultural irrigation return flows were applied (MWA, 2012).

Careful consideration was given to ensure that estimated demands (within the MWA 2010 UWMP demand projection model) were apportioned correctly by subregion and associated TDS and nitrate mass values were conserved.

5.2.5 Model Scenario Definition

Three future scenarios were simulated to evaluate the impact of population growth and planned future recycled water projects. There are:

- Scenario 1 – 2012 Baseline
- Scenario 2 – Growth (with no recycled water projects)
- Scenario 3 – Growth (with recycled water projects)

Table 5-1 shows the model components applied for the three future scenarios.

Table 5-1
Summary of Future Scenarios Simulated for Mojave SNMP

	Mojave River Basin			Morongo Basin		
Model Component	**Scenario 1 (Baseline)**	**Scenario 2 (Growth with No Recycled Water Projects)**	**Scenario 3 (Growth with Recycled Water Projects)**	**Scenario 1 (Baseline)**	**Scenario 2 (Growth with No Recycled Water Projects)**	**Scenario 3 (Growth with Recycled Water Projects)**
Hydrologic Conditions	Variable (1931 to 1999 repeated)[a]			Fixed (Average)		
Stream Recharge	Variable (calculated by SNMP mixing model)[b]			Not applicable		
Subsurface Flows				Fixed (Average)		
Groundwater Production	2012	Annual Projection[c] (MWA demand model)		2012	Annual Projection[b] (MWA demand model)	
Return Flows						
Imported SWP water						
Wastewater Treatment	Existing Facilities		Existing and Planned Facilities	Existing Facilities		Existing and Planned Facilities

Notes:
(a) 1931 to 1999 hydrologic conditions repeated for 2013 to 2081 (e.g., 1931 applied to 2013, 1932 applied to 2014, etc.).
(b) Calculated based on regression equations (storage-head, head-subsurface flow, and head-stream recharge) based on Mojave River Basin USGS MODFLOW model (Stamos et al., 2001).
(c) February 2014 update the 2010 UWMP MWA demand projection model; subarea annual growth rate from 2034 to 2035 applied to future years (2036 to 2081) for production, return flows, and imported SWP water.

As shown in the table above, a base case scenario—Scenario 1 (Baseline)—was developed to simulate future groundwater quality under continued existing S/N loading conditions. For Scenario 1, current (2012) rates of groundwater production, return flows, and imported SWP water were applied to future years.

A second future scenario—Scenario 2 (Growth with No Recycled Water Projects)—was also modeled. For Scenario 2, the effects of population growth along with associated increased water demand, return flows, and imported SWP water demand were simulated based on projected growth rates with moderate conservation (as explained previously in Section 3.11). No planned future wastewater treatment or reclamation plants are simulated, and increased sewer flows are hypothetically treated by existing wastewater treatment facilities in this scenario.

A third future scenario—Scenario 3 (Growth with Recycled Water Projects)—was also modeled. For Scenario 3, the effects of population growth along with increased water demand were simulated with recycled water projects. Similar to Scenario 2, return flows, and imported SWP water demand were simulated based on projected growth rates with moderate conservation.

Planned future wastewater treatment or reclamation plants are simulated, and increased sewer flows are treated by existing and planned future wastewater treatment facilities in this scenario.

The Mojave River Basin portion of the SNMP mixing model incorporates components of the USGS MODFLOW model of the Mojave River Basin (Stamos, 2001), including the hydrologic conditions simulated over the groundwater flow model calibration period (1931 to 1999). The model calibration period includes historical wet and dry periods that compose the Base Period of the Mojave Basin Area Judgment (1931-1990), the accepted long-term average hydrologic conditions of the basin. Variable hydrologic conditions were simulated by repeating the hydrologic conditions from the MODFLOW model, and subsurface flows between adjacent subregions were calculated by the SNMP mixing model based on regression equations developed from the USGS MODFLOW model and incorporated into the SNMP mixing model. Additionally, subsurface inflows and outflows between adjacent subregions and stream recharge rates were calculated based on defined storage-hydraulic head and storage-stream recharge relationships, developed from regression analysis of original MODFLOW model results.

In the Morongo Basin, fixed long-term average hydrologic conditions (natural recharge and subsurface flows) were applied for each year in the future simulation period.

5.2.5.1 Planned Future Recycled Water Projects

Table 5-2 shows the recycled water projects simulated in Scenario 3.

Table 5-2
Recycled Water Projects Simulated in Mojave SNMP Future Scenario 3

Agency	Simulated Planned Future Recycled Water Projects	Subregion(s) directly affected	Recycled Water Use
VVWRA	SWRP (Apple Valley)	Alto - Right Regional Alto Transition Zone - Floodplain	Landscape Irrigation
	SWRP (Hesperia)	Alto - Mid Regional Alto Transition Zone - Floodplain	Landscape Irrigation
City of Victorville	IWWTP - Excess Recycled Water Recharge at VVWRA Pond 14	Alto Transition Zone - Floodplain	Excess Recycled Water Pond Discharge
Helendale CSD	Recycled Water Reclamation Plant	Alto Transition Zone - Floodplain (Helendale)	Landscape Irrigation
HDWD	Regional Water Reclamation Plant	Warren Valley	Pond Recharge

Notes:
Victor Valley Wastewater Reclamation Authority (VVWRA)
Helendale Community Services District (Helendale CSD)
Hi-Desert Water District (HDWD)
Subregional Water Reclamation Plant (SWRP)
Industrial Wastewater Treatment Plant (IWWTP)

Recycled water projects shown in **Table 5-2** were all identified and selected during the development of the recently completed Mojave IRWM Plan (MWA, 2014c). The selected projects were required to meet certain planning requirements such as having completed permits, satisfied project-level environmental review requirements, and finalized future flows and water quality concentrations associated with each project. Projects included in the Mojave IRWM Plan that were not well-defined or far enough along in the planning process were not considered for evaluation within the Mojave SNMP; however these projects may be evaluated in the future as their future flows and project water quality are decided and finalized. Additional details of the selected future recycled water projects and assumptions used to simulate each project in the Mojave SNMP mixing model are described as follows:

1. **VVWRA Subregional Water Reclamation Plants – Apple Valley and Hesperia**
   Two 1.0 MGD subregional water reclamation plants (SWRPs) are proposed in the Alto Subarea. The two SWRPs will be located in Apple Valley (Alto - Right Regional) and Hesperia (Alto - Mid Regional). Both SWRPs are projected to be online and generating recycled water for landscape irrigation starting in 2017. The SWRPs represent scalping plants that will remove and treat a portion of the total sewer flows that are currently conveyed to VVWRA's Regional WWTP. Scalped flows will be treated to non-potable recycled water quality and used for landscape irrigation. Recycled water for irrigation will replace groundwater demand by respective purveyors commensurate with the volume of delivered recycled water.

   To simulate the effect of new SWRPs on groundwater quality, the following assumptions were applied:

   i. Sewer flows to the SWRPs are assumed to start at 1.0 MGD in 2017; an equal reduction in sewer flows to the VVWRA Regional WWTP is thus assumed starting in 2017.

   ii. Once projected sewer flows to the SWRPs reach the 1.0 MGD plant capacities, additional flows are apportioned equally to the Regional WWTP and two SWRPs, based on guidance provided by VVWRA (personal communication with Logan Olds, General Manager of VVWRA, March 2014).

   iii. It is assumed that all recycled water generated from the reclamation plants is used for municipal landscape irrigation. A recycled water return flow to groundwater of 5 percent (the percentage applied to all outdoor landscape irrigation) is assumed. The return flow is applied in the same subregion as the SWRPs (e.g., for the Apple Valley SWRP, return flows are assigned to Alto - Right Regional).

   iv. In lieu of apportioning the replacement in individual purveyor's groundwater demand by recycled water, a reduction in the total subregional pumping (within which the SWRP is located) is applied equivalent to the annual volume of recycled water generated.

2. **City of Victorville Industrial WWTP - Recycled Water Pond Recharge**
   Recycled water from the City of Victorville Industrial Wastewater Treatment Plant (IWWTP) is used to augment irrigation and industrial water supply at the Southern California Logistics Airport (SCLA) complex. Planned recycled water uses include dust control at SCLA runways, irrigation of parks and green belts, cooling at the High Desert Power Project (HDPP), irrigation at the Westwinds Golf Course, and construction water within the SCLA complex area only. The SCLA complex is under the control of the Southern California Logistics Airport Authority, including the recycled water use areas. According to a 2014 Lahontan Regional Board Order (R6V-2014-0002 WDID NO. 6B360911001), TDS concentrations will need to be reduced further before recycled water can be used to augment water supply for the HDPP.

Recycled water in excess of recycled demand will be piped and discharged to VVWRA's Pond 14 (Alto Transition Zone – Floodplain). The effect of excess recycled water recharge at VVWRA Pond 14 is simulated in Scenario 3 by applying the projected net increase in discharge at the pond (56 afy from 2016 to 2020 and 482 afy from 2021 to 2081). Return flows from recycled water used for dust control and runway washing are assumed to be negligible (and the benefit from replacing groundwater with recycled water is assumed to be insignificant). Some of the additional recycled water flow provides an offset for Federal Bureau of Prison (Prison) domestic wastewater effluent. Future effluent flows at the Prison are incorporated in the effluent projections for the VVWRA Regional Treatment Plant.

3. **<u>Helendale CSD Water Reclamation Plant</u>**

   A wastewater reclamation project is being proposed by the Helendale CSD. The project will have the capacity to produce up to 600 afy of recycled water starting in 2017. All recycled water will be used for municipal landscape irrigation. Conceptual water budgets developed for the Mojave SNMP (based on the MWA water demand model) predicts that sewer flows to Helendale CSD will be 556 afy in 2017 and reach 600 afy by 2024. Accordingly, for the mixing model simulation, all sewered flows from 2017 to 2024 are assumed to be treated to recycled water quality and applied as municipal landscape irrigation. For subsequent years, projected effluent flows above 600 afy are assumed to recharge groundwater as wastewater effluent. Municipal irrigation return flow of recycled water is assumed to be 5 percent.

4. **<u>Hi-Desert Water District Regional Water Reclamation Plant</u>**
   A regional water reclamation plant (WRP) is proposed in the Warren Valley subregion by the Hi-Desert Water District (HDWD). The new plant will replace the current wastewater treatment practices in Warren Valley by septic tank leach fields. Effluent from the regional WRP will be treated to recycled water quality; however, there are currently no plans for recycled water delivery. The expansion of the regional WRP and sewer collection area will occur in three phases (phases are scheduled for completion in 2016, 2019, and 2022). Collected sewer flow rates estimated by HDWD were incorporated in the SNMP water budgets (HDWD, 2014). Recycled water discharges will increase from about 0 afy in 2016 to 2,100 afy in 2022; septic tank return flows will decline from about 1,900 afy in 2015 to 0 afy in 2022.

5.2.5.2 Stormwater Capture Projects

The Adjudication of the Mojave Basin Area (Judgment) includes an injunction against diverting stormwater flow away from downstream users of the Mojave River; therefore, no major stormwater capture projects are proposed in the area. The other relevant prohibition of the Adjudication is any project that alters the bed of the Mojave River and reduces the surface area over which stormwater currently flows. Although some stormwater related projects were identified in the Mojave River Basin in the IRWM Plan, all projects are in conceptual pre-design phase and, therefore, were not modeled.

In the Morongo Basin, stormwater naturally percolates through ephemeral stream channels to recharge groundwater. Only during occasionally large storm events does stormwater flow reach the dry lake beds; otherwise the stormwater either percolates into the ground or evaporates. At this time, there are no immediate plans to capture the stormwater runoff in the Morongo Basin for groundwater recharge.

While the Adjudication of the Mojave River Basin prohibits diversions of stormwater flow away from downstream users, the Phase 2 municipal separate storm sewer system (MS4) General Permit Order No. 2013-0001-DWQ requires implementation of post construction best management practices (BMPs) such as low impact development (LID) measures that infiltrate runoff for new and redevelopment projects. LID measures treat and infiltrate rainfall from small, frequent storms that typically do not generate flows in the Mojave River. The Phase 2 MS4 permit applies to projects that create or replace impervious area of 5,000 square feet or more and requires implementation of post construction BMPs for those projects.

The Mojave River Watershed Group (MRWG) prepares annual reports in compliance with the Phase 2 Municipal Separate Storm Sewer System (MS4) permit, which document implementation of post-construction BMPs for the permittees: the Town of Apple Valley, the Cities of Hesperia and Victorville, and the County of San Bernardino. The Mojave SNMP will consider incorporating review of the MRWG Phase 2 MS4 annual reports for post-construction BMPs.

In addition, Senate Bill (SB) 985 authorizes public agencies to develop stormwater resources plans, to be incorporated into IRWM Plans as a condition of receiving stormwater funds under Proposition 1. A stormwater resources plan evaluates opportunities to encourage the use of storm water and dry weather runoff as a resource to improve water quality, reduce localized flooding, and increase water supplies for beneficial uses and the environment in accordance with SB 985. The Mojave IRWM Plan has general objectives that align with SB 985; the Mojave IRWM Regional Water Management Group (RWMG) will consider whether a stormwater resources plan is relevant for the Mojave watershed. The goals and recommendations of this SNMP will also be considered by the RWMG during review of the IRWM Plan's objectives and its project prioritization process.

5.2.6 Planning Horizon and Future Simulation Period and Hydrologic Conditions

The workplan developed for the Mojave SNMP defines a planning horizon through 2035, matching that of the 2010 update of the MWA UWMP, from which SNMP subregional water budgets were developed. However, because changes in regional groundwater quality and quasi-equilibration to changing land use (loading) conditions may take several decades, a simulation period beyond 2035 is warranted to determine the long-term effect of individual and collective S/N loading factors on groundwater quality (recognizing that uncertainties in prediction of future water demand and associated S/N loading conditions increase beyond the 2035 planning horizon).

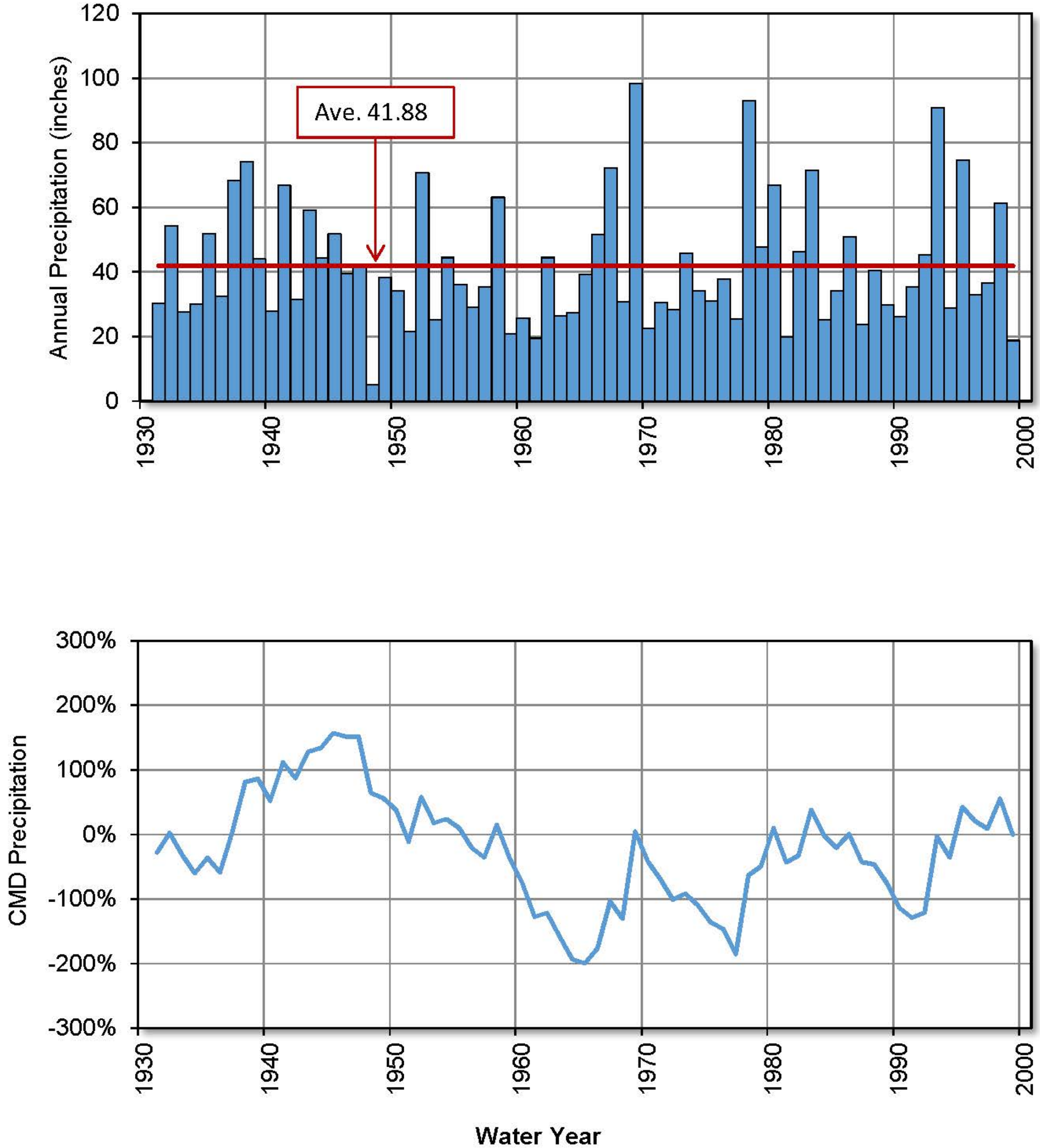
The Mojave River Basin portion of the SNMP mixing model incorporates components of the USGS MODFLOW model of the Mojave River Basin (Stamos, 2001), including the hydrologic conditions simulated over the groundwater flow model calibration period (1931 to 1999). The model calibration period includes historical wet and dry periods that compose the Base Period of the Mojave Basin Area Judgment (1931-1990), the accepted long-term average hydrologic conditions of the basin. For future water quality simulations, the hydrologic conditions from 1931 to 1999 were repeated over a future simulation period from 2013 through 2081.

Figure 5-1 shows the annual WY precipitation record for the San Bernardino Mountains from WY 1931 to WY 1999. As shown on the figure, average annual precipitation from 1931 to 1999 was 41.88 inches. The highest total annual rainfall on record is 98.24 inches (WY 1968-69). Other notable wet years include WYs 1977-78 (93.03 inches), 1979-80 (66.72 inches) 1982-83 (71.41 inches), 1992-93 (90.88 inches), and 1994-95 (74.51 inches).

In order to illustrate the varying climatic records over time, a cumulative mean departure (CMD) curve of the annual rainfall record in the San Bernardino Mountains was developed (lower graph on **Figure 5-1**). The CMD curve represents the cumulative annual departures relative to the average annual precipitation. As a result, positive (increasing) slopes represent relatively wet years, while negative (decreasing) slopes represent relatively dry years. The CMD curve is useful for identifying an appropriate study period with average climatic conditions as well as for understanding the relationships between rainfall, stream discharge, and groundwater system response.

As shown by the CMD curve on **Figure 5-1**, most of the slopes are increasing from 1930 to 1946, indicating overall above-average rainfall conditions (with the exception of the drought cycle in the late 1920s/early 1930s). The early wet period was followed by an extended dry period from 1946 through 1964. More recently, moderately dry time periods spanning eight to nine years (e.g., WYs 1969-70 to 1976-77, WYs 1983-84 to 1991-92, and WYs 1995-96 to 2002-03) have been separated by some of the wettest years on record (e.g., WYs 1977-88, 1982-83, 1992-33, 1994-95, 2004-05). For the Judgment, the 60-year period from WY 1930-31 to WY 1989-90 was selected to represent long-term water supply conditions in the Basin. Over this period, average annual rainfall was 41.09 inches.

Figure 5-1
Annual Precipitation and Cumulative Mean Departure Curve
San Bernardino Mountains (1931 to 1999)



To estimate water demand beyond 2035, the annual population growth rate from 2034 through 2035 for each subarea was applied as a constant growth rate to individual purveyor single-family residential (SFR) and multi-family residential (MFR) for all future years in the simulation beyond the 2035 UWMP planning horizon (i.e., from 2036 to 2081). Estimated annual growth rates from 2034 to 2035 are 1.7 percent in the Alto (Subarea), 1.5 percent in Baja, 1.3 percent in Centro, and 1.4 percent in Este, 1.1 percent in Oeste, and 0.6 percent in the Morongo Basin. These growth rates were also used to simulate imported SWP water recharge volumes from 2036 to 2081.

5.3 TDS and Nitrate Concentrations of Key Inflows

Various data sources, approaches, and assumptions were used to derive representative concentrations for key inflows for the water quality modeling.

Table 5-3 summarizes the concentrations of key inflows or equations used to calculate concentrations assuming variable source concentrations. For example, return flows from septic tanks are based on source water (groundwater) quality, which changes over time.

Discussion of concentrations applied in the SNMP mixing model for key inflows and outflows are discussed below.

Table 5-3
Summary of TDS and Nitrate Concentrations used in SNMP Mixing Model

Inflow		TDS Concentration (mg/L)	Nitrate-NO_3 Concentration (mg/L)	Notes
Stream (Mojave River) recharge		110	0.6	1
Mountain-front recharge		210	0.6	2
State Water Project water		250	2.5	3
Agricultural return flow (including dairies)		background [ ] / (1 - C.U.)	background [ ] + fertilizer/organic	4
Outdoor irrigation return	groundwater source	5x background [ ]	background [ ] + fertilizer	5
	recycled water source (VVWRA)	1,650	45.5	
	recycled water source (Helendale)	2,500	54.4	
Indoor septic return	DTW = <100 feet-bgs	Regression analysis (see footnote)	170 mg/L + background	6
	DTW = 100 to 200 feet-bgs		100 mg/L + background	
	DTW = >200 feet-bgs		40 mg/L + background	
WWTP Effluent Discharge and Recycled Water	**Pertinent Subregion**			
Crestline Sanitation District	Alto Floodplain (imported)	520	95.0	7
Lake Arrowhead Community Services District	Alto Floodplain (imported)	265	21.0	
Big Bear Area Regional Wastewater Agency	Lucerne Valley (south) (imported)	445	13.4	8
City of Adelanto WWTP	Transition Zone - Regional	631	36.7	9
VVWRA Regional WWTP	Transition Zone - Floodplain	375	30.9	10
VVWRA Subregional WWTP (Recycled Water)	Alto - Mid and Right Regional	330	35.4	11
Victorville Industrial WWTP (Recycled Water)	Transition Zone - Floodplain	763	6.2	7
City of Helendale WWTP	Transition Zone - Floodplain (Helendale)	830	54.9	7
City of Helendale WWTP (Recycled Water)	Transition Zone - Floodplain (Helendale)	500	44.3	12
MCLB Nebo WWTP	Centro - Floodplain	760	119.5	8
MCLB Yermo WWTP	Baja - Floodplain	530	22.3	
HDWD Regional WWTP (Recycled Water)	Warren Valley	500	35.4	13

Notes: (see next page)

Table 5-3 (continued)
Summary of TDS and Nitrate Concentrations used in SNMP Mixing Model

Notes (for Table 5-3):
[ ] = concentration
DTW = depth to water (in feet below ground surface [feet-bgs])
Background = background groundwater concentration = subregional average concentration at start of respective annual time step in SNMP mixing model.
C.U. = consumptive use (in percent)
VVWRA - Victor Valley Water Reclamation Authority
MCLB - Marine Corp Logistics Base
HDWD - Hi-Desert Water District
WWTP - Wastewater Treatment Plant
Recycled water from Victorville Industrial WWTP and HDWD Regional WRP are simulated as direct discharge to groundwater via percolation ponds.

(1) Based on evaluation of water quality data through 2014; weighted towards high stream discharge events.
(2) Estimated TDS concentration based on Mojave River recharge (110 mg/L) plus 100 mg/L to account for additional mineralization in desert alluvial washes. Nitrate concentration assumed equal to Mojave River recharge.
(3) Average TDS concentration based on biweekly grab sample data from 2001 to 2013 from CAAQUEDCT01 station (downstream of Check 41 in Victorville). Average Nitrate concentration based on monthly grab sample data from 2003 to 2013 from CAAQUEDCT01 station (downstream of Check 41 in Victorville).
(4) For TDS, equation applies maximum evapo-concentration of 5 times background concentration. Nitrate addition based on analysis of MWA 2012 irrigated lands coverage and published fertilizer leaching rates by crop type and dairy return flow rates and concentrations (UC Davis, 2012).
(5) TDS concentration equals 5 times background groundwater concentration to account for evapo-concentration. Groundwater source: Nitrate concentration equals background groundwater concentration plus leaching fraction of nitrogen-based fertilizer application. Recycled water source: Nitrate concentration equals recycled water source's (e.g., VVWRA or Helendale) total N concentration converted to nitrate plus average added leaching concentration from nitrogen-based fertilizer (10.1 mg/L).
(6) TDS concentration calculated based on regression analysis of measured tap water and septic effluent at nine local sites (Umari et al., 1993); average groundwater TDS in subregion applied as source water in model. Nitrate concentration assumes initial 199 mg/L concentration (based on conversion of effluent ammonium-N [53 mg/L] to nitrate and 15% loss to organic sludge [USEPA, 2002]). 15% vadose zone attenuation through denitrification for subregions where average depth to water (DTW) is less than 100 feet-bgs. 50% vadose zone attenuation through denitrification for subregions where average DTW is 100 to 200 feet-bgs. 80% vadose zone attenuation through denitrification for subregions where average DTW is greater than 200 feet-bgs.
(7) Average 2012; nitrate concentration based on total nitrogen (TKN + nitrate) converted to nitrate.
(8) Average 2012; nitrate concentration based on nitrate only (no other species reported).
(9) Average 2010-2011; nitrate concentration based on total nitrogen (TKN + nitrate) converted to nitrate.
(10) Flow-weighted average 2012 concentration to effluent ponds and Mojave river discharge; nitrate concentration based on total nitrogen (TKN + nitrate) converted to nitrate.
(11) Average annual effluent concentration limit; nitrate based on irrigation water quality objective for total nitrogen (TKN + nitrate = 8.0 mg/L as N) converted to nitrate.
(12) Assumed average annual effluent concentration of 500 mg/L TDS and 10 mg/L total nitrogen converted to nitrate.
(13) TDS effluent concentration limits pending - TDS concentration assumed. Nitrate concentration based on permit effluent total nitrogen (TKN + nitrate) concentration (8 mg/L as N) converted to nitrate.

5.3.1 Concentrations for Stream Recharge

The primary source of recharge in the Mojave River Basin is streamflow infiltration through the bottom of the Mojave River. The Mojave River is formed by the confluence of two tributary streams at The Forks (**Figure 3-1**). From The Forks, the Mojave River flows north through Victorville, then north-northeast to Barstow, and finally east towards Afton Canyon, where it exits the Basin approximately 100 miles from its origin.

Streamflows are fed by storm runoff from rainfall in the San Bernardino Mountains. The USGS has historically operated eight stream gaging stations on the Mojave River and its two main tributaries above the Mojave River (The Forks) Dam. A summary of the USGS stream gage stations is provided in **Table 5-4** (locations of active gages are shown on **Figure 3-1**).

Table 5-4
Mojave River Stream Gage Summary

Station Name	USGS Station No.	Period of Record		Major Record Gaps	Status
		Start	End		
Deep Creek near Hesperia, CA	10260500	1904	current	1922-29	Active
West Fork Mojave River near Hesperia, CA[a]	10261000	1930	1971		Inactive
West Fork Mojave River above Forks Reservoir near Hesperia, CA[a]	10260950	1974	current		Active
Mojave River at Lower Narrows near Victorville, CA	10261500	1900	current	1901-02; 1905-30	Active
Mojave River at Wild Crossing near Helendale, CA	10261900	1966	1970		Inactive
Mojave River near Hodge, CA	10262000	1930	1993	1932-1970	Inactive
Mojave River at Barstow, CA	10262500	1930	current		Active
Mojave River at Afton, CA	10263000	1929	current	1932-52; 1978-80	Active

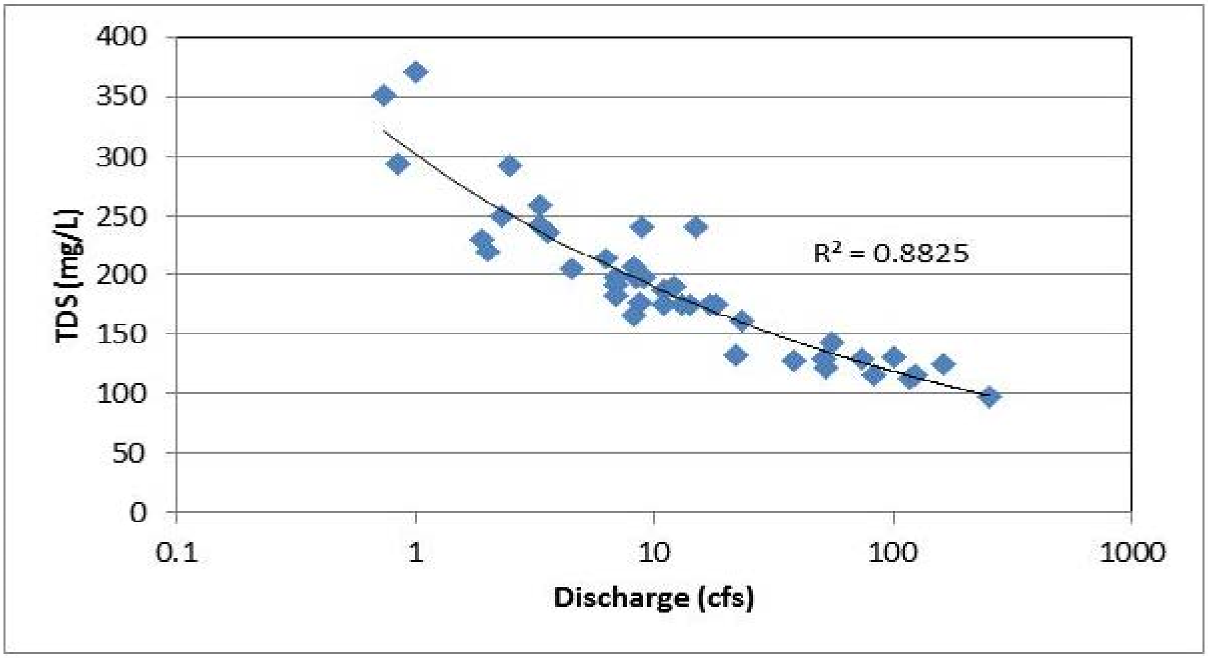
Notes:
(a) Combined flows at West Fork Mojave River and Deep Creek represent flows into Mojave River.

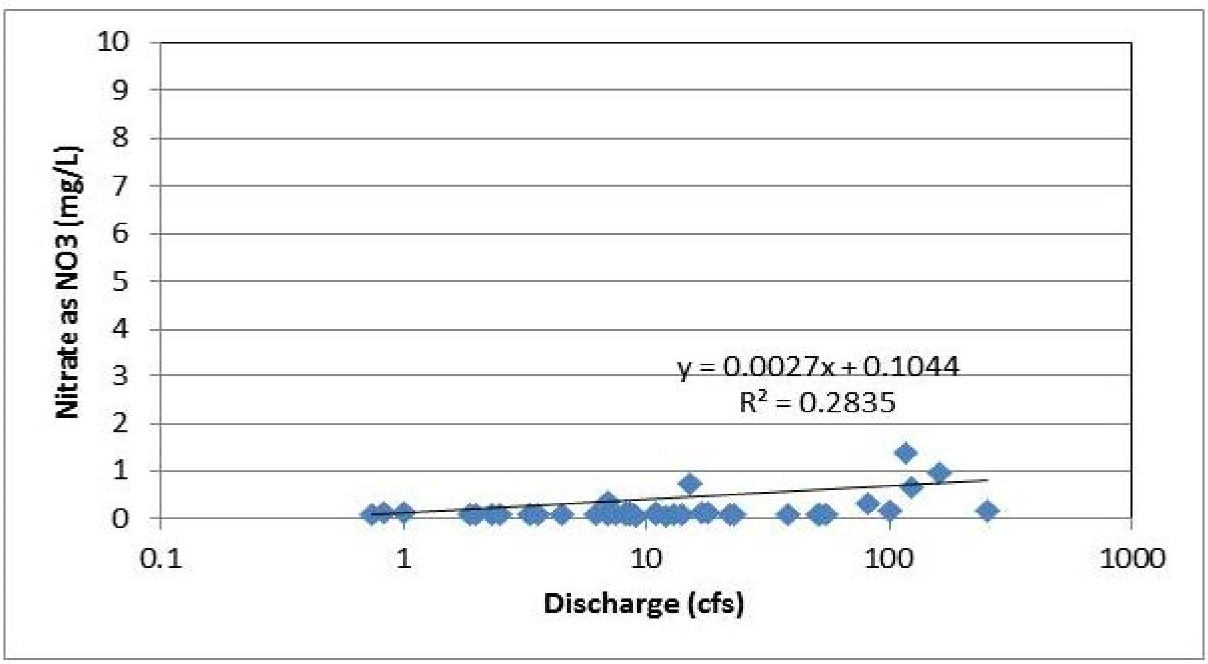
As shown in the table above, five stream gages have collectively provided a near-continuous record of Mojave River discharge since 1930. The West Fork and Deep Creek gages together represent the total inflows to the Basin, while the Lower Narrows, Barstow, and Afton gages provide a record of downstream discharges.

The USGS routinely collects surface water quality grab samples at the three upper active stream gage stations – Deep Creek, West Fork Mojave River (above Forks Reservoir), and Mojave River at Lower Narrows during relatively low flow conditions. Grab samples are not routinely collected at lower gage stations, because flows at the downstream stations occur only following large storm events that produce large flood flows.

Figure 5-2 shows the TDS and nitrate concentrations of surface water in the Mojave River for Deep Creek over a range of discharge rates recorded. As shown on the figure, TDS concentrations

Figure 5-2
TDS and Nitrate Concentrations vs. Discharge
Deep Creek at Hesperia





decrease with increasing discharge rates as expected. This inverse relationship between concentration and discharge rates is observed for all Mojave River stream gages in the Study Area.

Conversely, nitrate-NO_3 concentrations are relatively insensitive to stream discharge and are generally low (less than 1.0 mg/L) (the slight positive correlation between stream nitrate-NO_3 concentrations and discharge rates in the lower chart on **Figure 5-2** is not considered statistically significant). Average nitrate-NO_3 concentration is 0.6 mg/L from available grab samples for the three upper stream gages.

It is important to recognize that **Figure 5-2** does not include sampling events for larger stream discharge events, which correspond to the periods of significant stream recharge in the Mojave River Basin. For example, average discharge rates observed at the Deep Creek gage have historically exceeded 14,000 cubic feet per second (cfs). It is only during these large discharge events that stream recharge occurs in downstream portions of the basin. During these larger storm recharge events, TDS concentrations are expected to be lower (on the order of 90-100 mg/L or less).

Based on the evaluation of available surface water quality data for the Mojave River, a constant TDS concentration of 110 mg/L and nitrate-NO_3 concentration of 0.6 mg/L was applied to stream recharge for the SNMP model. Given the lack of grab samples collected over full range of flow conditions in the Mojave River (particularly the upper range), these concentrations should not be considered absolute values but reasonable estimates. Existing data are insufficient to calculate potential statistical error (e.g., standard deviation) of the assigned flow-weighted average TDS and nitrate concentrations for stream recharge. However, examination of the relationship between TDS concentrations and discharge rate suggests that flow-weighted average TDS concentrations could be as low as 90-100 mg/L at higher discharge rates. Flow-weighted average nitrate concentrations could also be lower than 0.6 mg/L, given that concentrations are expected to decrease at higher discharge rates.

5.3.2 Mountain-Front Recharge

There are no reliable water quality data for mountain-front recharge. However, assessment of groundwater quality data along the southern margins of the Mojave River Basin and southwestern margins of the Morongo Basin indicates that mountain-front recharge likely has relatively similar quality to (Mojave River) stream recharge. Given that the mountain-front recharge occurs more intermittently, the residence time of mountain-front recharge with alluvial sediments in the vadose zone allows for some mineral dissolution along recharge pathways.

For the SNMP, a constant TDS concentration of 210 mg/L (100 mg/L more than Mojave River stream recharge) and nitrate-NO_3 concentration of 0.6 mg/L (same as Mojave River stream recharge) was applied to mountain-front recharge in the SNMP mixing model.

5.3.3 SWP Water Recharge

Imported water in the MWA service area consists of SWP supplies. The source of SWP water is rain and snow from the Sierra Nevada, Cascade, and Coastal mountain ranges. This water travels to the Sacramento-San Joaquin Delta, which is a network of natural and artificial channels and reclaimed islands at the confluence of the Sacramento and San Joaquin rivers. The Delta forms the eastern portion of the San Francisco Bay estuary, receiving runoff from more than 40 percent of the State's land area. It is a low-lying region interlaced with hundreds of miles of waterways. From the Delta, the water is pumped into a series of canals and reservoirs, which provides water to urban and agricultural users throughout the San Francisco Bay Area and Central and Southern California. As discussed in MWA's 2010 UWMP, SWP supplies are received at four MWA turnouts off the East Branch of the SWP, located in the southwestern corner of the MWA service area.

An important property of SWP water is the chemical make-up, which fluctuates and is influenced by its passage through the Delta. The Delta is basically a very large marsh (or estuary) with large masses of plants and peat soils. These contribute organic materials to the water. Salt water can also move into the Delta from San Francisco Bay and the Pacific Ocean.

Figure 5-3 shows the TDS and nitrate-NO_3 concentrations from 2003 to 2012 for SWP water grab samples collected just upstream of the turnout to the MWA's Mojave River and Morongo Basin pipelines (the station is referred to internally as CAAQUEDCT01 by MWA). The figure shows that the quality of SWP water used for recharge within the Study Area fluctuates seasonally and annually, but is overall very good.

The average TDS concentration over this 10-year period (250 mg/L) and the average nitrate-NO_3 concentration (2.5 mg/L) were applied to SWP water recharge in the SNMP mixing model.

5.3.4 Concentrations of Subsurface Inflows from Adjacent Subregions

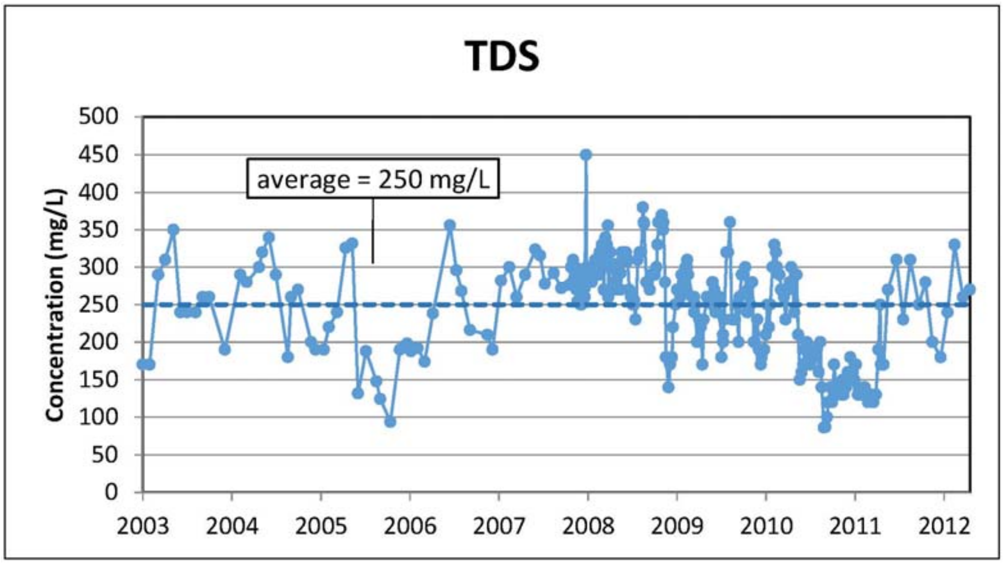
The volume-weighted average TDS and nitrate concentrations for subsurface inflows from upgradient adjacent subregions into a given subregion are calculated within the SNMP mixing model for each annual time step. Subsurface outflows from each subregion are assigned the average concentration at the start of each year of the simulation. Simulated concentrations for subsurface inflows are thus variable over the future simulation period.

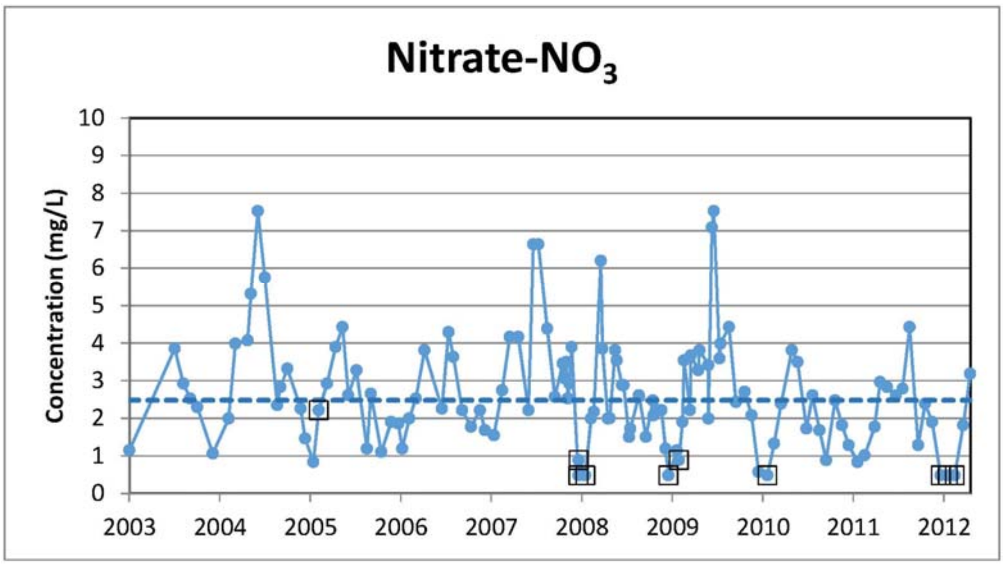
5.3.5 Concentrations for Municipal Wastewater Treatment Plant Effluent Discharge

Available TDS and nitrate concentrations for all WWTP effluent facilities were obtained and evaluated. A representative constant concentration for TDS and nitrate was applied for all years of each simulation, as shown in **Table 5-3**. To account for potential transformation of nitrogen species in the subsurface, 100 percent of total nitrogen (including nitrate and total kjeldahl nitrogen [TKN]) concentrations in treated effluent are converted to nitrate-NO_3 and recharge the groundwater system in the SNMP model.

It is noted that no vadose zone attenuation or subsurface attenuation is applied to municipal wastewater treatment plant effluent discharges in the SNMP model. While recent studies have demonstrated the effectiveness of denitrification processes in reducing nitrate concentrations downgradient of selected WWTPs (e.g., Barstow WWTP [DPRA, 2010]), denitrification rates are highly site-specific and can vary considerably over time depending on geochemical conditions. Because of the uncertainty and the limitations of the regional S/N mixing model to verify whether a selected local-scale nitrate attenuation rate for WWTP effluent is reasonable, a conservative approach is applied whereby no attenuation of nitrate mass from WWTP effluent is applied. Accordingly, projected nitrate impacts from WWTP effluent discharges on groundwater quality in the SNMP should be considered a worst-case scenario.

Figure 5-3
TDS and Nitrate Concentrations of SWP Water (2003 to 2013)





Notes:
Box values in nitrate chart represent non-detect values (i.e., concentration is less than laboratory reporting limit). The value shown on chart is the laboratory reporting limit.

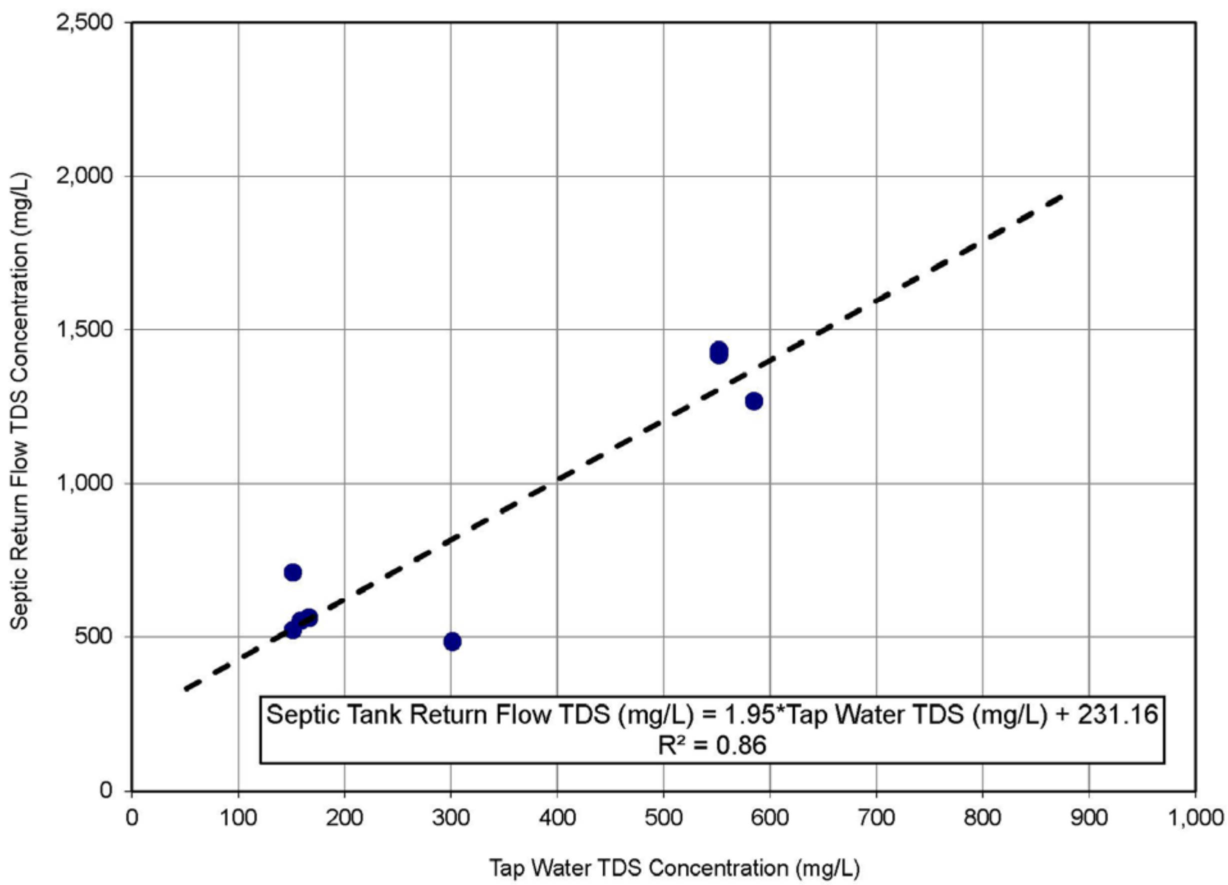
5.3.6 Concentrations for Septic Tank Return Flows

Groundwater is the sole source of water supply for users relying on septic tank systems. For TDS, concentrations were calculated based on a regression analysis of tap water and septic return flow TDS measurements reported in a historical USGS study in the Mojave River Basin (Umari et al., 1993). For this study, nine sites with septic systems were evaluated. **Figure 5-4** shows a chart of the data and regression equation for estimating TDS concentration of septic system return flows from source water TDS concentrations that was used in the SNMP mixing model.

For the SNMP mixing model, average groundwater TDS concentration in the subregion is used in lieu of tap water TDS concentration in the regression equation to estimate septic tank return flow TDS concentrations.

Fate and transport studies from onsite wastewater systems have yielded a range of values for the amount of total nitrogen in effluent that ultimately recharges groundwater as nitrate-NO_3. Variables include the initial concentration of total nitrogen in the leachate, the fraction of the total nitrogen that is in the form of ammonium, and the percent of ammonium transformed into nitrate.

Figure 5-4
Tap Water TDS vs. Septic Tank Return Flow TDS



Source: Umari et al, 1993 (modified from electrical conductivity to TDS)

In 1993, a field investigation on the fate and transport of nitrogen in septic tank return flow was conducted by the USGS (Umari et al., 1993). For the study, nine septic tank sites in the Victorville, Apple Valley and Hesperia area were investigated. The study found that nitrate concentrations in septic tank return flows were attenuated significantly through denitrification in the vadose zone. The study found a direct correlation between attenuation rates and depth to groundwater. The range in depth to water for sites tested was from 87 to 220 feet-bgs.

Figure 5-5 depicts the nitrate-NO_3 concentrations of unsaturated zone soil samples beneath evaluated septic tank systems from the USGS study against sample depth. The generally decreasing nitrate concentrations with depth at each site indicate that the thickness of the vadose zone beneath septic tank leach fields is a significant factor for estimating nitrate attenuation rates. While results do not offer a strong statistical regression correlation, the polynomial trend line (for all data points shown combined) shown on the figure provides some pertinent insights. Based on the trend line, it is observed that the septic tank nitrate-NO_3 concentration of all evaluated sites point to an initial nitrate-NO_3 concentration in the range of 200 mg/L, similar to estimates based on the range of assumed nitrogen loading and loss factors reported by Lowe, et al. (2009) and USEPA (2002).[3]

It is recognized that subsurface lithology also plays a role in the degree of nitrate attenuation beneath septic tank leach fields. Nonetheless for the Mojave SNMP, the estimated average depth to water in each subregion (see Section 3.6 and **Table 3-2**) is used as the sole factor to estimate nitrate attenuation for septic tank return flows. **Table 5-5** shows the attenuation rates and estimated nitrate-NO_3 concentration for septic tank return flows that recharge groundwater. Three attenuation factors are applied corresponding to three intervals of groundwater depth as follows:

- For subregions where the average depth to water is between 0 and 100 feet-bgs, a nitrate-NO_3 concentration of 170 mg/L is added to the background groundwater concentration and assigned to septic tank return flows. This corresponds to a vadose zone nitrate attenuation factor of 15 percent (200 mg/L x 85 percent).

- For subregions where the average depth to water is between 100 and 200 feet-bgs, a nitrate-NO_3 concentration of 100 mg/L is added to the background groundwater concentration. This corresponds to a vadose zone nitrate attenuation factor of 50 percent (200 mg/L x 50 percent).

- Finally, for subregions where the average depth to water is greater than 200 feet-bgs, a nitrate-NO_3 concentration of 40 mg/L is added to the background groundwater concentration. This corresponds to a vadose zone nitrate attenuation factor of 80 percent (200 mg/L x 20 percent).

[3] Mass loads can be estimated by assuming an average effluent concentration of 63 mg/L total nitrogen, of which 53 mg/L is present as ammonium (Lowe, et al. 2009). The percentage of total nitrogen as ammonium closely matches the value reported by USEPA (2002). The remaining 10 mg/L of nitrogen in the effluent is assumed to be organic nitrogen, which accumulates with sludge that remains in the septic tank until it is cleaned out. In fine-textured soils, between 10 and 20 percent of ammonium undergoes denitrification (USEPA, 2002). Applying these assumptions, the net loss of nitrogen is 30 percent (15 percent loss to organic nitrogen and 15 percent loss of ammonium by denitrification). A preliminary estimate of 199 mg/L nitrate-NO_3 for septic tank return flows is assumed. This concentration may be subject to further denitrification processes depending on various site specific factors, including soil characteristics and depth to water.

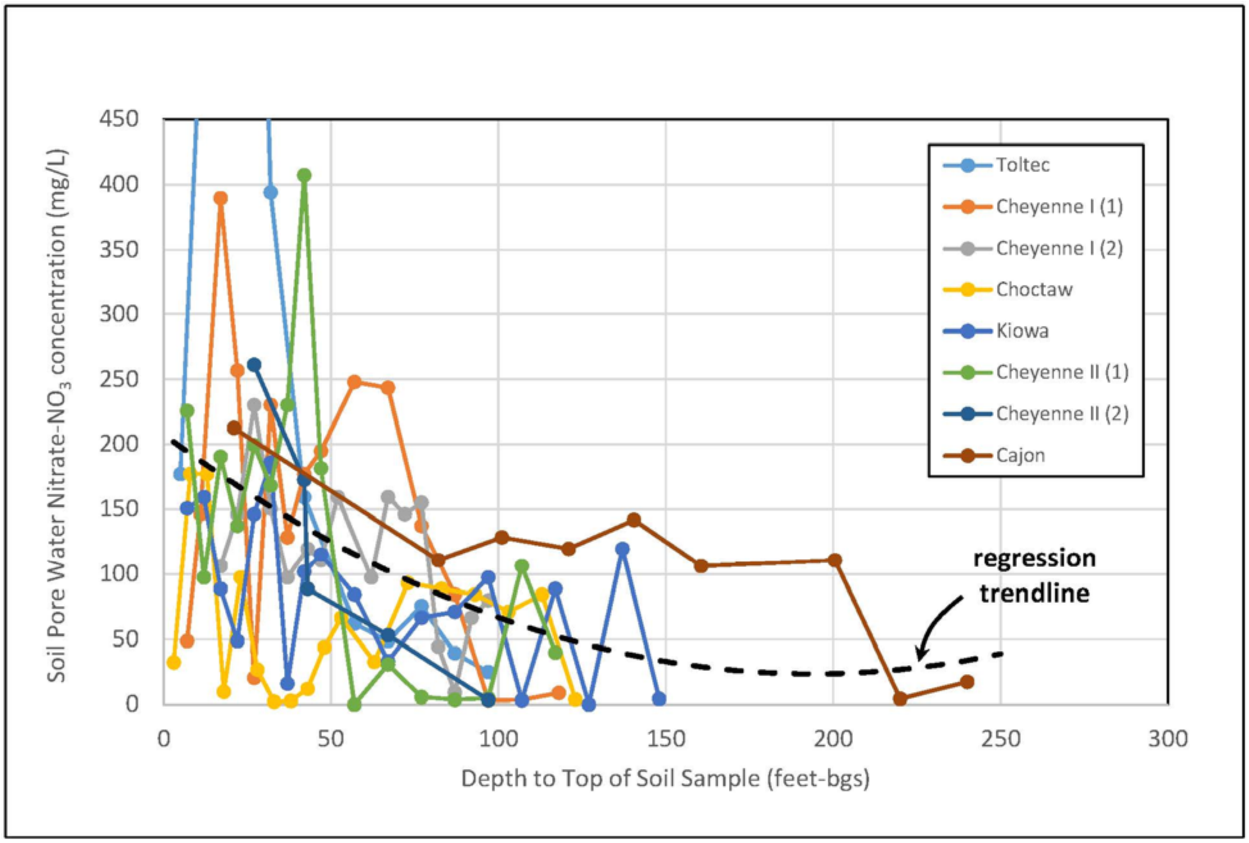
The nitrate concentrations for septic tank return flows applied in the SNMP mixing model are within the upper range of nitrate concentrations observed in soil pore water from corresponding depths in the USGS study (see **Figure 5-5** for comparison).

Table 5-5
Vadose Zone Nitrate Attenuation Rates for
Septic Tank Return Flows for Mojave SNMP Mixing Model

Subregion	Average Depth to Water[a] (feet-bgs)	Vadose Zone Nitrogen loss to Denitrification (%)	Septic Nitrate-Nitrate-NO_3 Concentration[b] (mg/L)
Transition Zone Floodplain (Helendale)	20	15%	170 mg/L + groundwater nitrate-NO_3 concentration
Transition Zone Floodplain	20		
Centro Floodplain	30		
Alto - Floodplain (Narrows)	40		
Alto Floodplain	40		
Harper Lake Regional	60		
Baja Floodplain	70		
Este Regional	70		
Johnson Valley	90		
Centro Regional (east)	110	50%	100 mg/L + groundwater nitrate-NO_3 concentration
Transition Zone Regional	110		
Oeste Regional	110		
Baja Regional	120		
Lucerne Valley (north)	140		
Alto Right Regional	150		
Lucerne Valley (south)	160		
Centro Regional (west)	160		
Warren Valley	200		
Ames-Means Valley	220	80%	40 mg/L + groundwater nitrate-NO_3 concentration
Copper Mountain-Giant Rock	250		
Alto Mid Regional	280		
Alto Left Regional	290		
Joshua Tree	360		

Notes:
feet-bgs = feet below ground surface.
(a) Average depth to water in production zone aquifer.
(b) Based on initial septic tank effluent concentration of 200 mg/L.

Figure 5-5
Nitrate-NO_3 Concentrations beneath Mojave River Basin
Septic Tank Sites (Umari et al., 1993)



Source: Umari et al., 1993

5.3.7 Municipal (Landscape) Irrigation Return Flow Concentrations

MBA Watermaster is currently conducting field investigations to better understand the fate of applied irrigation water beneath urban parks, golf courses, and selected agricultural lands. The investigation has involved the collection and laboratory analysis of soil cores for soil water content and chloride content to estimate the percentage of municipal and agricultural irrigation water that returns to groundwater.

Based on preliminary MBA Watermaster results, it is estimated that a small percentage (0 to 5 percent) of applied municipal irrigation water may return to groundwater (communication with Robert Wagner [MBAW Engineer] on April 10, 2014). For the SNMP, the upper estimate of 5 percent return flow is assumed for municipal irrigation water. In other words, for every 100 afy of applied municipal irrigation water, 5 afy returns to groundwater.

Given the small percentage of estimated municipal irrigation return flow, minerals in applied irrigation water can be reasonably expected to precipitate in the vadose zone beneath irrigated urban land and not return with the return flow to groundwater.

For municipal (landscape) irrigation return flow TDS concentrations, a fixed evapo-concentration factor of five (5) is applied to source water concentrations for TDS to account for some mineral precipitation (i.e., if the TDS concentration for irrigation water is 500 mg/L, then the return flow TDS concentration is 2,500 mg/L). An evapo-concentration factor of 5 implies that on average 75 percent of the TDS mass in applied irrigation water precipitates in the vadose zone beneath irrigated urban land and does not return to groundwater.

There are no available site-specific data to derive nitrate loading from urban fertilizer use on golf courses and parks in the Study Area. To estimate the nitrate concentration of municipal irrigation return flows, a leaching rate of nitrogen-based fertilizer application for turf of 8.9 pounds of nitrogen per acre was applied. This rate represents the upper limit of leaching from fertilizer applications on golf courses and turf (UC Davis, 2012), assuming an application rate of 45 pounds of nitrogen per acre per year, of which 36 pounds is lost to plant uptake and denitrification in the root zone. All nitrogen species are conservatively assumed to convert to nitrate, and the nitrate mass is added to the background source water (groundwater or recycled water) concentration. No additional nitrate attenuation was applied to municipal irrigation return flows (e.g., no additional vadose zone denitrification/attenuation below the root zone was applied). For calculation of landscaped acreage subject to fertilizer application, a 2012 MWA geographic information system (GIS) coverage of irrigated lands (including acreages of golf courses, parks, and grass – see **Table 5-6**) was obtained, and fertilizer application rates were applied to those acreages.

For recycled water, permitted TDS and nitrate concentrations from future planned reclamation plants and associated concentrations of municipal irrigation return flows are applied (see **Table 5-3**).

5.3.8 Agricultural Return Flow Concentrations

For the S/N balances, minerals and nitrate-NO_3 dissolved in irrigation source water and applied as soil amendments or fertilizer—minus losses due to applicable attenuation factors—were assigned to the deep percolation fraction of applied agricultural irrigation water.

Groundwater is the sole source of water supply for agricultural use (including dairies). Average groundwater concentrations were used to represent the concentration of source waters. Evapo-concentration factors for crops were calculated based on aggregate 2012 return flow percentages estimated by the MBAW. Aggregate 2012 crop return flow rates by subregion are: 10 percent for Alto Subarea, 36.6 percent for Centro Subarea, 21 percent for Baja, 41.8 percent for Este, and 42.5 percent for Oeste (personal communication with MBAW Engineer, 2014).

Agricultural return flow TDS and nitrate concentrations were estimated based on the 2012 MWA GIS shapefile of irrigated lands, including dairies. **Table 5-6** summarizes the acreages of irrigated vegetation and dairy lands.

Estimated fertilizer application, crop loss, and net nitrogen input (leaching) rates to groundwater by crop were estimated in the UC Davis nitrate study (2012). Calculated fertilizer leaching rates are shown in **Table 5-7** and were applied to respective crop acreages in **Table 5-6**.

The UC Davis study evaluated dairy operations across the Central Valley and concluded that return flow rates and nitrogen inputs from corrals and lagoons were consistent. The study estimated a net

Table 5-6
Acreages of Irrigated Crops, Dairies, and Turf by Subregion

Subregion	Alfalfa	Grain	Orchard	Pasture	Pistachios	Row Crop	Sorghum	Sudan	Mixed	Dairy[(a)]	Turf[(b)]
	all values in acres										
Baja - Floodplain	2,245	1,049	16	4	174		232		601	18.7	41
Baja - Regional	246	44	0	0	217						13
Centro - Floodplain	938	75	11	115	35		281	305	86	205.2	62
Centro - Regional	205	0		7	2					29.5	58
Centro - Regional (Harper Dry Lake)			3			23					0
Alto Transition Zone - Floodplain (Helendale)				15							193
Alto Transition Zone - Floodplain		10	7	61		1				3.5	32
Alto Transition Zone - Regional											112
Alto - Narrows Floodplain				90							25
Alto - Floodplain	53	80	0	39		10					321
Alto - Left Regional											34
Alto - Mid Regional	0			117							413
Alto - Right Regional											235
Oeste - Regional		618	2			1				121.1	5
Este - Regional				2							0
Lucerne Valley (north)	139	77							150		
Lucerne Valley (south)	496	71	33	17	27	40			64		10

Notes:
Source: MWA 2012 irrigated lands GIS coverage (crops and dairies shown; not included are irrigated turf area).
(a) Includes acreage of corrals and lagoons.
(b) Includes irrigated area for golf courses and parks.

Table 5-7
Fertilizer Application Rates and Crop Loss Rates

Vegetation Type	Applied Nitrogen (lbs/ac)	Crop Uptake Rate (%)	Net Nitrogen after uptake (lbs/ac)	Gaseous Losses (%)	Net Nitrogen Input (lbs/ac)
Alfalfa[(a)]					27.0
Grain	172.7	81%	32.8	10%	29.5
Orchard[(b)]	108.3	24%	82.3	10%	74.1
Pasture[(c)]	31.0	50%	15.5	10%	14.0
Pistachios	154.9	75%	38.7	10%	34.9
Row Crop	179.4	51%	87.9	10%	79.1
Sorghum	137.1	65%	48.0	10%	43.2
Sudan[(d)]					27.0
Mixed[(e)]					41.1
Turf[(f)]					8.9

Notes:
Applied N, Crop Uptake Rate, and Gaseous Losses from UC Davis (2012) unless otherwise noted.
(a) Net N input to groundwater estimated for alfalfa by UC Davis (2012).
(b) Average values for non-pistachio deciduous.
(c) Estimated from Yates (2003).
(d) Alfalfa net N input to groundwater assumed.
(e) Arithmetic mean of Net N input all other crop types assumed.
(f) Net N input to groundwater estimated for turf by UC Davis (2012).

nitrogen input rate to groundwater of 163 pounds per acre per year for both corral and lagoon areas and an average recharge rate of 1 afy/acre from these areas. Assuming complete transformation of nitrogen to nitrate-NO_3, this nitrogen leaching rate corresponds to a nitrate concentration of 261 mg/L as nitrate-NO_3. This estimate matches well with localized groundwater nitrate concentration hotspots in the vicinity of historical and existing dairy operations. For the SNMP mixing model, the loading rates were applied to dairy acreages shown in **Table 5-6**.

5.4 TDS and Nitrate Concentrations for Subsurface Outflows

5.4.1 Groundwater Production, Subsurface Outflow to Adjacent Sub-Regions, and Evapotranspiration

The average S/N concentration in a subregion at the start of each year is assigned within the SNMP mixing model to all groundwater outflow components (e.g., groundwater production, subsurface outflows, and groundwater discharge to surface water) with the exception of ET. For ET, a TDS concentration of 0 mg/L is assumed, and a fixed nitrate-NO_3 concentration of 3 mg/L is assumed to account for nutrient uptake by riparian vegetation (less than the minimum average nitrate concentration in any floodplain subregion with riparian vegetation).

5.5 SNMP Mixing Model Results and Simulated Future Groundwater Quality

Results of the SNMP mixing model simulations are presented in this section. Mixing model results allow for the identification (by subregion) of 1) key inflows and outflows, 2) major contributors of salts and nutrients, and 3) the individual and collective impact of S/N loading contributors on future groundwater quality. Additionally, comparison of future groundwater quality for the three simulations reveals the impact of projected population growth (and associated increases in water use and imported water demand) with and without planned future recycled water projects on groundwater quality.

To assist with the distillation of SNMP mixing model results of the 22 subregions for TDS and nitrate, Section 5.5.1 presents a discussion of the future water budget for Scenario 3. Charts and tables showing the projected future groundwater quality trends and changes for all three scenarios are presented in calculated future assimilative capacity for all 22 subregions. A synopsis for each subregion is presented in **Appendix C.**

5.5.1 Summary of Future Inflow and Outflows – Scenario 3

Table 5-8 summarizes the average inflows and outflows for Scenario 3, which includes projected growth and future planned recycled water projects. For each subregion, the normalized average annual flow of each inflow term is shown as a percentage of total flows such that the sum of all inflows equals 100. Likewise, the sum of all outflows equals 100. Normalizing the flows allows for quick identification of the distribution of inflows and outflows in each subregion and across subregions in Scenario 3.

In addition to normalizing the flows, inflow cells are color-coded based on the average flows estimated over the 70-year future simulation period. For example, gray colored cells indicate a small flow component that contributes less than 200 afy, while purple highlighted cells indicate a large flow component of greater than 10,000 afy. Colors for inflow cells provide insight into the relative contribution of individual inflows in a given subregion and across subregions. For example, the largest flow in the Morongo Basin is treated wastewater (treated to recycled water quality) in the Warren Valley subregion that will recharge groundwater via percolation ponds at the planned future regional water reclamation plant. This inflow represents the largest single flow in the entire Morongo Basin.

The color for groundwater production cells depicts the distribution of groundwater demands in the Study Area. As indicated by the purple cells, groundwater demand is highest within the Baja, Centro, and Alto floodplains and Alto – Mid Regional subregions. Conversely, groundwater demand is minimal (less than 200 afy) in Alto Transitional Zone – Regional and Johnson Valley.

5.5.2 Summary of Future TDS and Nitrate Mass Loading – Scenario 3

To determine the contribution of TDS and nitrate loading by each term, the mass (flow x concentration) of each term must be considered. **Table 5-9** and **Table 5-10** summarize the relative contribution of TDS and nitrate mass loading by inflow and outflow term within each subregion for Scenario 3. For each subregion, the relative mass contribution of each inflow term (as a percentage of total mass inflows) is shown, such that the sum of all inflows equals 100. Likewise, the sum of all

Table 5-8
Summary of Volumetric Flow Contribution by Subregion – Scenario 3

	MOJAVE RIVER BASIN															MORONGO BASIN						
	Baja - Floodplain	Baja - Regional	Centro - Floodplain	Centro - Regional	Centro - Regional (Harper Dry Lake)	Alto Transition Zone - Floodplain (Helendale)	Alto Transition Zone - Floodplain	Alto Transition Zone - Regional	Alto - Floodplain (Narrows)	Alto - Floodplain	Alto - Left Regional	Alto - Mid Regional	Altro Right Regional	Oeste - Regional	Este - Regional	Lucerne Valley (north)	Lucerne Valley (south)	Johnson Valley	Ames-Means Valley	Warren Valley	Copper Mountain-Giant Rock	Joshua Tree
	*values equal to percent contribution of **volumetric flows** in subregion*																					
Inflows																						
Stream Recharge	43		66			19	14		21	38												
Mountain-Front Recharge		32									51	6		30	64	64	19	97	39	2	4	5
Subsurface Inflows	13	3	5	67	95	67	1	22	76	1	13	76	12	2					13		96	5
SWP Water Recharge	25									49		3		46					31	31		45
Return Flow																						
WWTP Effluent Discharge	1		14			7	83	68		6							44					
Septic Tank	6	46	2	17	4	1	<1	6	2	3	29	13	77	4	31	10	7	3	17	3	<1	45
Recycled Water Percolation Pond							2													61		
Municipal Irrigation (groundwater)	1	4	1	5	<1	4	<1	4	1	1	7	2	7	<1	3	<1	1			3		
Municipal Irrigation (recycled water)						<1						<1	4									
Agriculture Irrigation (irrigated crops)	8	6	11	10	1	<1	<1		<1	<1		<1		14	2	26	29					
Agriculture (dairies)	<1		1	1			<1							4								
Recreation (lakes)	3	9								3												
Outflows																						
Subsurface Outflow		38	12	41		17	27	92	2	54	81	1	36		25			27	26	2	99	8
Groundwater Production	93	62	84	59	100	69	52	8	72	44	19	99	64	100	75	100	100	7	73	98	<1	92
Evapotranspiration	6		4			14	21		26	2												
Dry Lake Evaporation																		66	1			
Stream Discharge	1																					

Notes:
Magnitude of average annual inflows over simulation period indicated by highlighted cell color based on legend below:

purple highlighting = greater than 10,000 AFY
orange highlighting = 5,000 to 10,000 AFY
green highlighting = 2,500 to 5,000 AFY
blue highlighting = 200 to 2,500 AFY
gray highlighting = less than 200 AFY

Table 5-9
Summary of TDS Mass Loading Contribution by Subregion – Scenario 3

	MOJAVE RIVER BASIN															MORONGO BASIN						
	Baja - Floodplain	Baja - Regional	Centro - Floodplain	Centro - Regional	Centro - Regional (Harper Dry Lake)	Alto Transition Zone - Floodplain (Helendale)	Alto Transition Zone - Floodplain	Alto Transition Zone - Regional	Alto - Floodplain (Narrows)	Alto - Floodplain	Alto - Left Regional	Alto - Mid Regional	Altro Right Regional	Oeste - Regional	Este - Regional	Lucerne Valley (north)	Lucerne Valley (south)	Johnson Valley	Ames-Means Valley	Warren Valley	Copper Mountain-Giant Rock	Joshua Tree
	*values equal to percent contribution of **TDS mass** in subregion*																					
Inflows																						
Stream Recharge	10		16			3	4		8	17												
Mountain-Front Recharge		5									17	4		11	30	8	6	81	20	1	2	2
Subsurface Inflows	17	2	10	38	86	47	1	18	81	4	15	56	2	2					23		96	4
SWP Water Recharge	13									49		2		20					20	17		25
Return Flow																						
WWTP Effluent Discharge	<1		16			19	88	58		8							28					
Septic Tank	13	52	7	25	11	2	1	9	7	6	40	26	77	10	55	22	13	19	37	5	1	69
Recycled Water Percolation Pond							4													68		
Municipal Irrigation (groundwater)	3	11	4	16	2	28	1	16	4	6	28	10	16	2	14	4	3			9		
Municipal Irrigation (recycled water)						2						2	4									
Agriculture Irrigation (irrigated crops)	33	15	43	20	2	<1	1		<1	<1		<1		27	2	66	50					
Agriculture (dairies)	<1		3	1			<1							29								
Recreation (lakes)	10	15								9												
Outflows																						
Subsurface Outflow		38	13	41		15	34	92	3	55	81	1	36		25			78	26	2	99	7
Groundwater Production	100	62	87	59	100	71	66	8	97	45	19	99	64	100	75	100	100	22	74	98	1	93
Evapotranspiration	0		0			0	0		0	0												
Dry Lake Evaporation																		0	0			
Stream Discharge	<1																					

Notes:
TDS mass contribution by individual flow term indicated by highlighted cell color based on legend below:

purple highlighting = 80 to 100%
orange highlighting = 60 to 80%
green highlighting = 40 to 60%
blue highlighting = 20 to 40%
gray highlighting = 0 to 20%

Table 5-10
Summary of Nitrate Mass Loading Contribution

	MOJAVE RIVER BASIN															MORONGO BASIN						
	Baja - Floodplain	Baja - Regional	Centro - Floodplain	Centro - Regional	Centro - Regional (Harper Dry Lake)	Alto Transition Zone - Floodplain (Helendale)	Alto Transition Zone - Floodplain	Alto Transition Zone - Regional	Alto - Floodplain (Narrows)	Alto - Floodplain	Alto - Left Regional	Alto - Mid Regional	Altro Right Regional	Oeste - Regional	Este - Regional	Lucerne Valley (north)	Lucerne Valley (south)	Johnson Valley	Ames-Means Valley	Warren Valley	Copper Mountain-Giant Rock	Joshua Tree
	*values equal to percent contribution of **nitrate mass** in subregion*																					
Inflows																						
Stream Recharge	1		1			<1	<1		1	2												
Mountain-Front Recharge		<1									2	<1		1	1	2	<1	9	2	<1	<1	<1
Subsurface Inflows	6	1	2	38	49	58	<1	8	63	4	4	45	1	1					8		95	6
SWP Water Recharge	4		<1							12		0.5		10					7	3		1
Return Flow																						
WWTP Effluent Discharge	<1		12			32	97	73		29							22					
Septic Tank	62	88	13	52	39	4	<1	17	33	46	91	49	95	31	99	47	30	91	83	13	4	93
Recycled Water Percolation Pond							<1													81		
Municipal Irrigation (groundwater)	1	1	1	2	<1	4	2	2	1	2	3	3	2	<1	1	1	2			3		
Municipal Irrigation (recycled water)						1						1	2									
Agriculture Irrigation (irrigated crops)	24	10	44	9	12	<1	<1		2	1		<1		44	<1	50	47					
Agriculture Irrigation (dairies)	<1		27	<1			<1							13								
Recreation (lakes)	1	1					1			3												
Outflows																						
Subsurface Outflow		38	12	41		18	30	92	3	54	81	1	36		25			78	26	2	99	8
Groundwater Production	96	62	86	59	100	79	67	8	82	45	19	99	64	100	75	100	100	22	74	98	1	92
Evapotranspiration	3		2			3	3		15	1												
Dry Lake Evaporation																		0	0			
Stream Discharge	<1																					

Notes:
Nitrate mass contribution by individual flow term indicated by highlighted cell color based on legend below:

purple highlighting = 80 to 100%
orange highlighting = 60 to 80%
green highlighting = 40 to 60%
blue highlighting = 20 to 40%
gray highlighting = 0 to 20%

outflows equals 100. Normalizing the mass contributions allows for quick identification of the major loading factors in each subregion and across the Study Area in Scenario 3. For example, **Table 5-10** shows that septic tank return flow is the primary nitrate loading factor in half of the subregions (11 of 22 subregions). The major contributing TDS and nitrate loading factors in each subregion are identified in **Table 5-9** and **Table 5-10**.

It is important to reiterate that the values in the tables (and used in pie charts of subregional synopses in **Appendix C**) are normalized (shown as percentage of total mass inflows, such that the sum of all inflows equal 100) and cannot be used to show the influence of individual and collective loading factors on groundwater quality. For example, while septic tank return flows represent 91 percent of the total mass that recharges the groundwater system in Johnson Valley, the total nitrate mass in the subregion is relatively small. Thus, the effect of nitrate loading on groundwater quality in Johnson Valley is small. The effect of TDS and nitrate mass budgets on groundwater quality changes by subregion are further explained in the following sections.

5.5.3 Future Groundwater TDS Concentrations (WY 2081) and Net Concentration Change (WY 2013 to WY 2081)

The key output of the mixing model is the estimated S/N concentration in each subregion, which was calculated as a volume-weighted average concentration at the end of each annual time step, in mg/L. Expressing the groundwater volume and S/N mass in storage over time as a volume-weighted average concentration is necessary to compare with BPOs and assimilative capacity thresholds. For example, it is possible to compare a change of +2.5 mg/L of TDS to the available assimilative capacity. However, an estimated change of +15,000 tons of TDS is not very meaningful. Depending on the change in groundwater storage associated with the mass change, +15,000 tons of TDS may result in an increasing, stable, or decreasing groundwater TDS concentration.

Figure 5-6 shows the simulated average groundwater TDS concentration trends (from WY 2013 through WY 2081) by subregion for all three future scenarios. TDS concentration trend lines for Scenario 1 (blue), Scenario 2 (gold), and Scenario 3 (purple) are shown; BPOs for TDS are also shown (dotted lines) for reference; these correspond to the recommended (500 mg/L), upper-limit (1,000 mg/L), and short-term limit (1,500 mg/L) secondary MCLs. The net change in average TDS concentration by subregion (from WY 2013 through WY 2081) for the three future scenarios is provided in **Table 5-11**.

As shown in the figure and table, changes in TDS concentrations from WY 2013 to WY 2081 in Scenario 3 vary significantly between subregions. Increasing TDS concentrations are projected in 17 of the 22 subregions, with the largest increase projected in Alto – Right Regional (317 mg/L). TDS concentration declines are projected in 5 subregions, with the largest decline projected in Centro – Floodplain (-113 mg/L).

The concentration difference between Scenario 2 versus Scenario 1 shows the effect of projected growth and associated increased water demand and imported water with no recycled water projects. As shown in the table, projected growth is responsible for increased TDS concentrations in 15 subregions, with declines projected in 4 subregions, and no change in concentration in 1 subregion. For the Mojave River Basin, the largest projected increases in groundwater TDS concentrations in Scenario 2 occur in Alto – Right Regional and Alto – Mid Regional (+391 and +197 mg/L, respectively). In Scenario 2, increased return flows from indoor water use in these two subregions are treated hypothetically by existing treatment facilities (i.e., septic systems and the VVWRA Regional WWTP). Because septic returns are a relatively significant inflow component in the water budgets for Alto – Right Regional and Alto – Mid Regional, groundwater TDS concentrations increase over the future simulation period. For Baja – Floodplain, groundwater TDS concentrations increase more gradually in Scenario 2 versus Scenario 1 as a result of projected decreases in agricultural land use and associated irrigation return flow. The largest projected TDS increases in the Morongo Basin is in the Warren Valley. In Scenario 2, increased return flows from indoor water use is treated hypothetically by existing treatment facilities (i.e., septic systems).

The concentration difference between Scenario 3 versus Scenario 2 shows the effect of recycled water projects alone. Key observations are presented below:

- The effect of recycled water projects on TDS concentrations is generally limited to those subregions that include new regional or subregional wastewater treatment or reclamation facilities and/or future irrigation demand satisfied partially by recycled water. With the exception of the Alto Transition Zone – Floodplain, changes to groundwater TDS concentrations as a result of irrigation with recycled water are relatively small.

- The largest projected increase in groundwater TDS concentration as a result of recycled water projects is in the Alto Transition Zone – Floodplain (+73 mg/L). The increase is caused by overall declining effluent discharges projected for the VVWRA Regional WWTP. Effluent discharge is simulated at a constant TDS concentration of 375 mg/L (based on average 2012 effluent concentrations) and thus benefits groundwater TDS concentrations in the subregion (initial average TDS concentration in Alto Transition Zone – Floodplain is 500 mg/L). Additionally, excess recycled water flows from the Victorville IWWTP (average TDS concentration of 763 mg/L) to VVWRA Pond 14 are projected to increase in the future (with a net increase of 56 afy from 2016 to 2020 and 482 afy from 2021 to 2081). Together, these two factors cause groundwater TDS concentrations to increase slightly in Scenario 3 relative to Scenario 2 throughout the simulation.

- Impacts to groundwater TDS concentrations in subregions with recycled water irrigation projects range from relatively neutral (Alto – Mid Regional, Alto Transition Zone – Floodplain – Helendale) to beneficial (Alto – Right Regional). In general, the effect of additional TDS loading associated with recycled water use for irrigation is overshadowed by changes to other water budget components resulting from the corresponding reduction in groundwater pumping (assumed to be commensurate with the recycled water demand). Specifically, changes to subsurface flows between the subregion with the recycled water project and neighboring subregions directly and indirectly affect the water and TDS mass balance. A more detailed discussion of groundwater quality changes caused by recycled water application is presented in pertinent subregional synopses in **Appendix C**.

- In the Warren Valley, the construction and operation of the future HDWD Regional WRP and phasing out of septic systems in the subregion will result in a significant improvement in groundwater TDS concentrations (-173 mg/L). While groundwater TDS concentrations will still gradually increase over time, a comparison of TDS concentration trend lines for Scenario 3 versus Scenario 1 shows that even with projected population growth, future TDS loading with the HDWD Regional WRP is less than current (2012) TDS loading in the Warren Valley.

Figure 5-6
Simulated Future TDS Concentrations (WY 2013 through WY 2081)

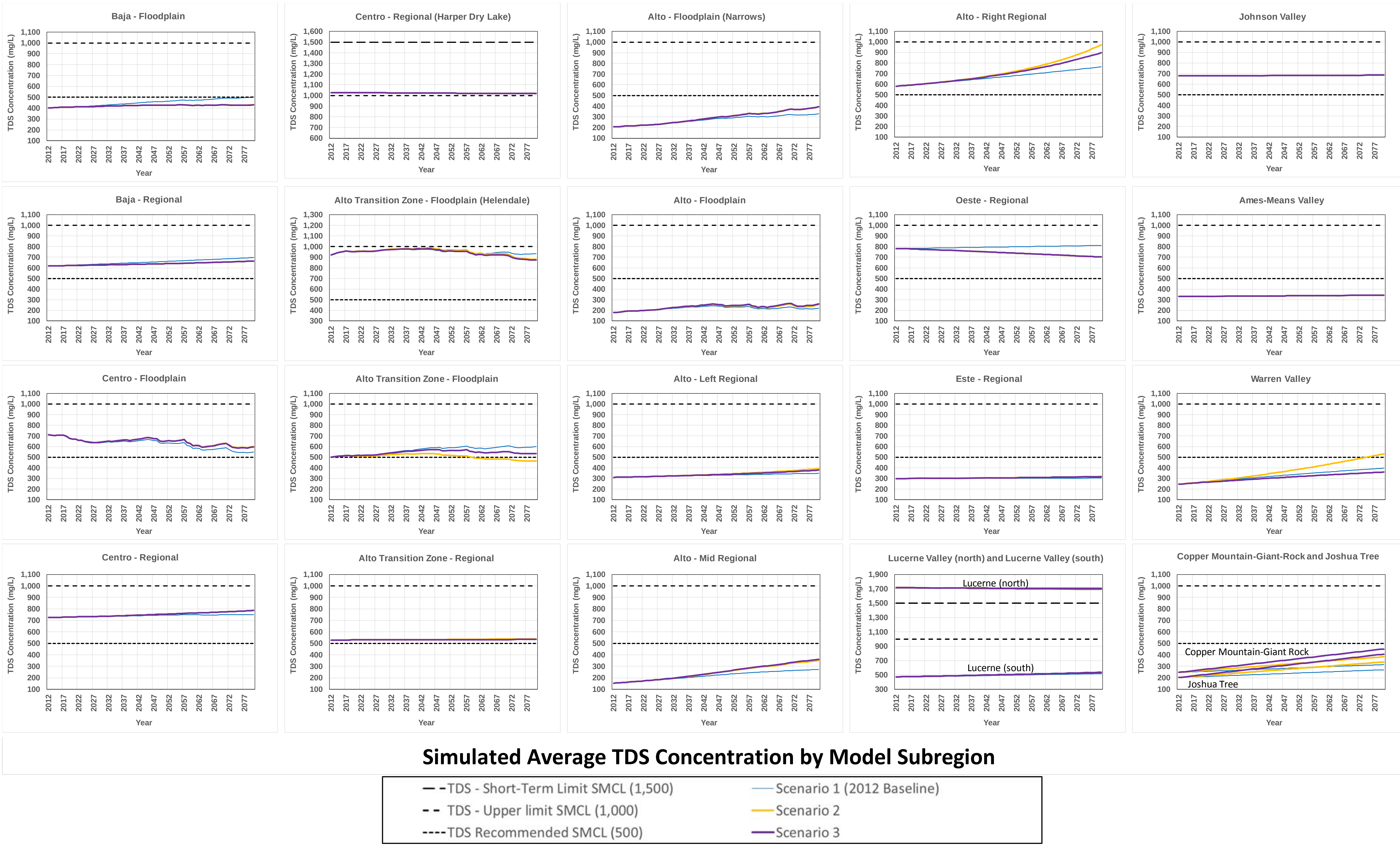


Table 5-11
Simulated Future Groundwater TDS Concentration (WY 2081) and Net Change (WY 2013 through WY 2081)

Subregion	TDS								
	Current (2012) Average Groundwater TDS Concentration (mg/L)	Scenario 1 (Baseline)		Scenario 2 (Growth with No Recycled Water Projects)			Scenario 3 (Growth with Recycled Water Projects)		
		Simulated Future (2081) Groundwater TDS Concentration (mg/L)	Simulated Future (2013 to 2081) Groundwater TDS Concentration Change (mg/L)	Simulated Future (2081) Groundwater TDS Concentration (mg/L)	Simulated Future (2013 to 2081) Groundwater TDS Concentration Change (mg/L)	Effect of Projected Growth (mg/L)	Simulated Future (2081) Groundwater TDS Concentration (mg/L)	Simulated Future (2013 to 2081) Groundwater TDS Concentration Change (mg/L)	Effect of Recycled Water Projects (mg/L)
	(a)	(b)	(b - a)	(c)	(c - a)	(c - b)	(d)	(d - a)	(d - c)
Baja - Floodplain	401	503	102	430	29	-73	429	28	-1
Baja - Regional	617	697	80	664	47	-33	664	47	0
Centro - Floodplain	711	548	-163	601	-110	54	598	-113	-4
Centro - Regional	747	748	2	785	39	37	786	39	0
Centro - Regional (Harper Dry Lake)	1,028	1016	-12	1018	-10	2	1018	-10	0
Alto Transition Zone - Floodplain (Helendale)	915	935	20	879	-36	-55	874	-41	-6
Alto Transition Zone - Floodplain	500	601	101	462	-38	-138	535	35	73
Alto Transition Zone - Regional	529	537	8	540	11	3	534	5	-6
Alto - Floodplain (Narrows)	205	326	121	394	189	68	395	190	2
Alto - Floodplain	177	220	43	254	77	34	262	85	8
Alto - Left Regional	310	348	38	392	82	44	378	68	-14
Alto - Mid Regional	153	273	120	350	197	77	355	202	5
Alto - Right Regional	579	763	184	970	391	207	896	317	-74
Oeste - Regional	781	811	30	702	-79	-109	702	-79	0
Este - Regional	299	303	4	318	19	15	318	19	0
Lucerne Valley (north)	1,716	1693	-23	1705	-11	12	1705	-11	0
Lucerne Valley (south)	472	522	50	535	63	13	535	63	0
Johnson Valley	678	685	7	686	8	1	686	8	0
Ames-Means Valley	330	345	15	343	13	-2	343	13	0
Warren Valley	243	397	154	532	289	134	359	116	-173
Copper Mountain-Giant Rock	247	248	1	248	1	0	248	1	0
Joshua Tree	202	264	62	279	77	15	279	77	0

red color indicates net increase in concentration
blue color indicates no change in concentration
green color indicates net decrease in concentration

5.5.4 Future Groundwater Nitrate Concentrations (WY 2081) and Net Concentration Change (WY 2013 to WY 2081)

Figure 5-7 shows the projected future average groundwater nitrate-NO_3 concentration trends (from WY 2013 through WY 2081) by subregion for all three future scenarios. Nitrate-NO_3 concentration trend lines for Scenario 1 (blue), Scenario 2 (gold), and Scenario 3 (purple) are shown; the BPO for nitrate-NO_3 corresponding to the primary MCL (45 mg/L) is also shown (dotted line) for reference. The net change in average nitrate-NO_3 concentration by subregion (from WY 2013 through WY 2081) for the three future scenarios is provided in **Table 5-12**.

As shown on the figure and table, while changes in future groundwater nitrate concentrations vary significantly between subregions, increasing concentrations are projected in all 22 subregions, with increases ranging from less than 1 mg/L up to 33 mg/L in Scenario 3. Groundwater nitrate concentration changes above +34 mg/L are projected in Scenario 1 for Alto Transition Zone – Floodplain and in Scenario 2 for Warren Valley. These are discussed in more detail below.

It is noted that projected increases in groundwater nitrate concentrations are considered conservative, as 1) no vadose zone attenuation is applied to nitrogen loading from municipal and agricultural irrigation return flows and 2) no attenuation in groundwater is simulated. Despite these conservative assumptions, results of the mixing model simulations indicate that the BPO of 45 mg/L as nitrate-NO_3 will be protected over the 70-year future simulation period in all subregions.

The concentration difference between Scenario 2 versus Scenario 1 shows the effect of projected population growth and associated increased water demand and imported SWP water with no recycled water projects. As shown in **Table 5-12** and **Figure 5-7**, projected population growth with no recycled water projects is responsible for increased nitrate concentrations in 16 of the 22 subregions, with declines projected in the other four subregions. Additional key observations are presented below:

- The largest projected increase in groundwater nitrate concentrations occurs in the Warren Valley in Scenario 2 (+43.9 mg/L). In Scenario 2, increased return flows from indoor water use are treated hypothetically by existing treatment facilities (i.e., septic systems), for which nitrate-NO_3 concentrations exceed 140 mg/L. Accordingly, groundwater nitrate concentrations increase significantly over the simulation period.

- The projected small improvement in groundwater nitrate concentration in Alto Transition Zone – Floodplain (in Scenario 2 versus Scenario 1) is the direct result of increased effluent discharges from the VVWRA Regional WWTP associated with projected population growth. Effluent discharge is simulated at a constant nitrate-NO3 concentration of 30.9 mg/L (based on average 2012 effluent concentrations). While the additional effluent increases groundwater nitrate concentrations at a slightly faster rate (compared to Scenario 1) in the beginning of the simulation, once groundwater quality concentrations exceed 30.9 mg/L, effluent discharges maintain the nitrate concentration. As described above, the overall increase is considered conservative, as no nitrate attenuation was applied to effluent discharges in the vadose zone or in groundwater. The small decrease in Centro – Regional (-0.3 mg/L) in Scenario 2 versus Scenario 1 is the result of a small net decrease in subsurface inflow from Centro – Floodplain (in Scenario 2 versus Scenario 1). Because the nitrate concentration in Centro – Floodplain groundwater is higher than in Centro – Regional, the reduction in subsurface inflow results in a small improvement in nitrate concentrations in Centro – Regional.

The concentration difference between Scenario 3 versus Scenario 2 shows the effect of recycled water projects alone. Key observations are presented below.

- As shown in **Table 5-12**, projected increases in groundwater nitrate-NO_3 concentration as a result of recycled water projects are small, with the largest increase projected in the Alto Transition Zone – Floodplain (+1.3 mg/L as nitrate-NO_3). The small projected increase in groundwater nitrate concentrations in Alto Transition Zone – Floodplain (in Scenario 3 versus Scenario 2) is attributable to decreased effluent discharges projected for the VVWRA Regional WWTP as associated impacts including reduction in subsurface outflows (in Scenario 3 versus Scenario 2).

  To clarify, effluent discharge is simulated at a constant nitrate-NO_3 concentration of 30.9 mg/L (based on average 2012 effluent concentrations). The average groundwater nitrate concentration in all scenarios rises above 30.9 mg/L over the final 20 years of the simulation. Groundwater concentrations exceed the WWTP effluent concentration, because the simulated riparian ET increases the concentration of the groundwater nitrate in the subregion. In Scenario 3, there is less WWTP effluent to "stabilize" groundwater nitrate concentrations at 30.9 mg/L. Thus, concentrations rise higher in Scenario 3 versus Scenario 2. Because WWTP effluent flows are lowest in Scenario 1, nitrate concentration rise is highest in Scenario 1. The differences in groundwater nitrate concentration between the 3 scenarios are small as a result of subsurface flow changes in each scenario.

  Additional detailed discussion on the effect of recycled water projects is provided in the Alto Transition Zone – Floodplain subregional synopsis presented in **Appendix C**. The overall groundwater nitrate increases are considered highly conservative, as no nitrate attenuation was applied in the vadose zone beneath effluent ponds or along groundwater flowpaths away from effluent ponds. See Section 5.3.5 for additional discussion.

- Changes to groundwater nitrate concentrations in subregions with recycled water irrigation projects (Alto – Mid Regional, Alto – Right Regional, and Alto Transition Zone – Floodplain (Helendale) indicate that impacts from recycled water irrigation on groundwater nitrate concentrations are neutral to beneficial. Generally, the small effect of additional nitrate loading associated with recycled water use for irrigation is overshadowed by changes to other water budget components resulting from the corresponding reduction in groundwater pumping (assumed to be commensurate with the recycled water demand). Specifically, changes to subsurface flows between the subregion with the recycled water project and neighboring subregions directly and indirectly affect the water and nitrate mass balance. A more detailed discussion of groundwater quality changes caused by recycled water application is presented in pertinent subregional synopses in Section 5.6.

- In the Warren Valley, the construction and operation of the future HDWD Regional WRP and phasing out of septic systems in the subregion will result in a significant improvement in groundwater nitrate-NO_3 concentrations (-37.9 mg/L improvement in Scenario 3 relative to Scenario 2). While groundwater nitrate concentrations will still increase slightly, a comparison of nitrate concentration trend lines for Scenario 3 versus Scenario 1 shows that even with projected population growth, future nitrate loading with the HDWD Regional WRP is less than current (2012) nitrate loading in the Warren Valley.

Figure 5-7
Simulated Future Nitrate-NO_3 Concentrations (WY 2013 through WY 2081)

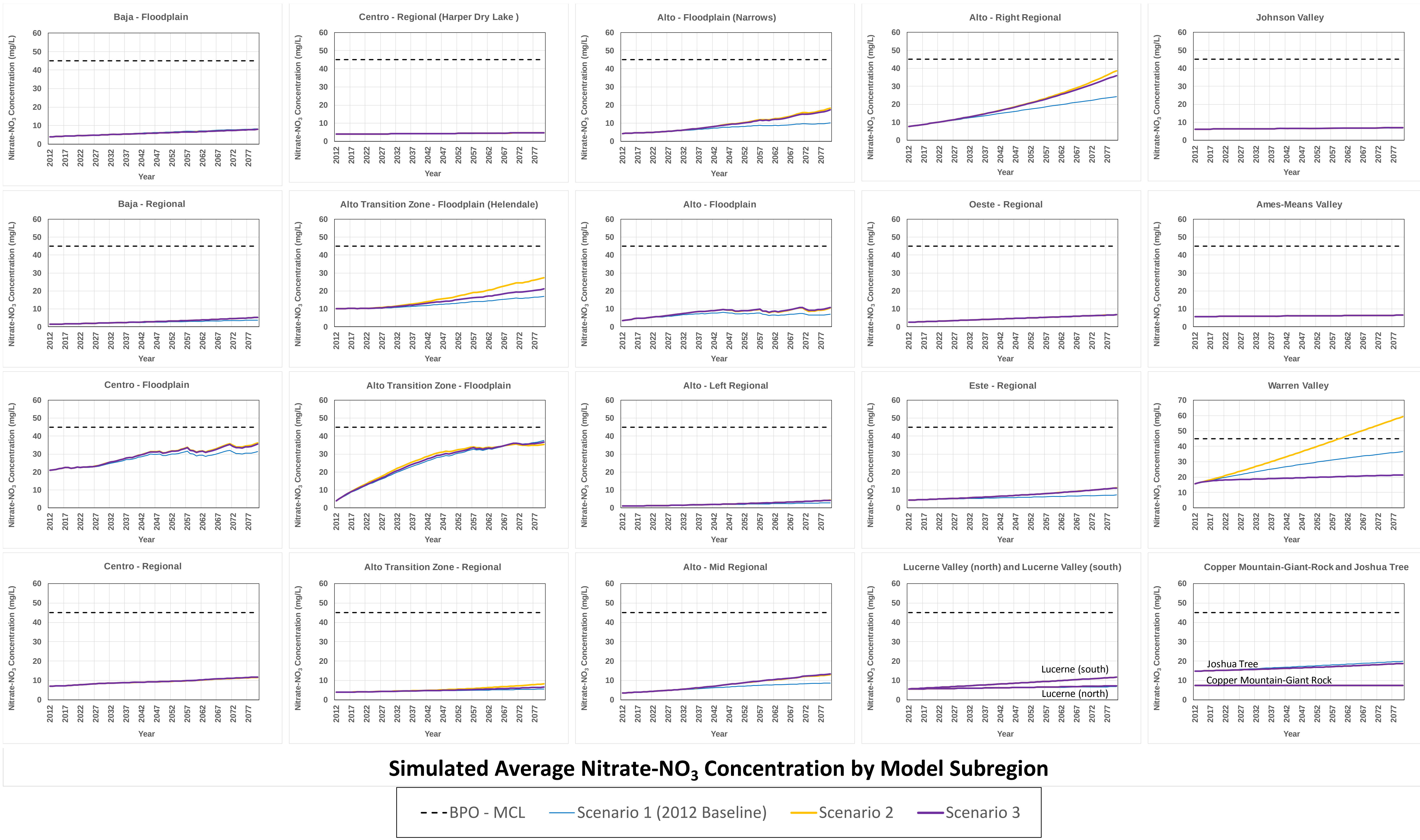


Table 5-12
Simulated Future Groundwater Nitrate–NO_3 Concentration (WY 2081) and Net Change (WY 2013 through WY 2081)

Subregion	Nitrate-NO_3								
		Scenario 1 (Baseline)		Scenario 2 (Growth with No Recycled Water Projects)			Scenario 3 (Growth with Recycled Water Projects)		
	Current (2012) Average Groundwater Nitrate-NO_3 Concentration (mg/L)	Simulated Future (2081) Groundwater Nitrate-NO_3 Concentration (mg/L)	Simulated Future (2013 to 2081) Groundwater Nitrate-NO_3 Concentration Change (mg/L)	Simulated Future (2081) Groundwater Nitrate-NO_3 Concentration (mg/L)	Simulated Future (2013 to 2081) Groundwater Nitrate-NO_3 Concentration Change (mg/L)	Effect of Projected Growth (mg/L)	Simulated Future (2081) Groundwater Nitrate-NO_3 Concentration (mg/L)	Simulated Future (2013 to 2081) Groundwater Nitrate-NO_3 Concentration Change (mg/L)	Effect of Recycled Water Projects (mg/L)
	(a)	(b)	(b - a)	(c)	(c - a)	(c - b)	(d)	(d - a)	(d - c)
Baja - Floodplain	3.9	8.2	4.3	7.9	4.0	-0.3	7.9	4.0	0.0
Baja - Regional	1.4	3.7	2.3	5.2	3.8	1.5	5.2	3.8	0.0
Centro - Floodplain	20.7	31.4	10.7	36.2	15.5	4.8	35.5	14.8	-0.6
Centro - Regional	7.0	11.9	4.9	11.6	4.6	-0.3	11.8	4.8	0.2
Centro - Regional (Harper Dry Lake)	4.0	4.6	0.6	4.7	0.7	0.2	4.7	0.7	0.0
Alto Transition Zone - Floodplain (Helendale)	10.0	17.0	7.0	27.4	17.4	10.5	21.0	11.0	-6.4
Alto Transition Zone - Floodplain	3.4	37.5	34.1	35.3	31.9	-2.2	36.6	33.2	1.3
Alto Transition Zone - Regional	3.9	5.5	1.6	8.3	4.4	2.7	6.6	2.7	-1.7
Alto - Floodplain (Narrows)	4.3	10.1	5.8	18.3	14.0	8.2	17.3	13.0	-1.0
Alto - Floodplain	3.3	6.9	3.6	10.5	7.2	3.5	10.7	7.4	0.3
Alto - Left Regional	0.9	2.8	1.9	4.2	3.3	1.5	4.2	3.3	0.0
Alto - Mid Regional	3.5	8.7	5.2	13.0	9.5	4.4	13.3	9.8	0.3
Alto - Right Regional	7.5	24.3	16.8	38.7	31.2	14.3	36.0	28.5	-2.6
Oeste - Regional	2.5	6.9	4.4	6.7	4.2	-0.2	6.7	4.2	0.0
Este - Regional	4.3	7.1	2.8	11.1	6.8	4.0	11.1	6.8	0.0
Lucerne Valley (north)	5.6	6.8	1.2	7.3	1.7	0.5	7.3	1.7	0.0
Lucerne Valley (south)	5.7	7.8	2.1	11.7	6.0	4.0	11.7	6.0	0.0
Johnson Valley	6.2	6.9	0.7	7.0	0.8	0.1	7.0	0.8	0.0
Ames-Means Valley	5.7	6.4	0.7	6.5	0.8	0.0	6.5	0.8	0.0
Warren Valley	15.4	36.5	21.1	59.3	43.9	22.7	21.4	6.0	-37.9
Copper Mountain-Giant Rock	7.5	7.5	0.0	7.5	0.0	0.0	7.5	0.0	0.0
Joshua Tree	14.7	19.9	5.2	18.8	4.1	-1.1	18.8	4.1	0.0

red color indicates net increase in concentration
blue color indicates no change in concentration
green color indicates net decrease in concentration

5.5.5 Future Assimilative Capacity Calculation

Based on the mixing model results, future assimilative capacities for TDS and nitrate are estimated.

5.5.5.1 TDS

Table 5-13 shows the calculated future TDS assimilative capacity for each subregion based on simulated WY 2081 groundwater concentrations. Similar to the calculations shown for current conditions (see **Table 4-4** in Section 4.6.3), assimilative capacity calculations are provided for TDS based on the recommended, upper limit, and short-term upper limit SMCLs of 500, 1,000, and 1,500 mg/L. Positive values indicate that there is available assimilative capacity; negative values indicate the lack of available assimilative capacity.

As shown in the table and figure, and similar to existing conditions shown in **Table 4-4**, average groundwater TDS concentrations in the Mojave River Basin are below all three BPO concentrations in 4 out of 5 Alto subregions (Floodplain, Floodplain (Narrows), Left Regional, and Mid Regional), Baja – Floodplain, and Este – Regional. Assimilative capacity exists for all subregions based on a BPO of 1,000 mg/L, with the exception of Centro – Regional (Harper Dry Lake), which has historically high TDS concentrations due to dry lake evaporation and natural mineralization processes. At a BPO of 1,500 mg/L, assimilative capacity exists for all Mojave River Basin subregions.

In the Morongo Basin, average groundwater TDS concentrations are below all three BPO concentrations (and thus there is available assimilative capacity) in 4 of the 7 subregions (Ames-Means Valley, Warren Valley, Copper Mountain-Giant Rock, and Joshua Tree). Average TDS concentrations are above 500 mg/L in Lucerne Valley (south) and Johnson Valley. Average TDS concentrations in Lucerne Valley (north) are above 1,500 mg/L due to dry lake bed evaporation and natural mineralization. Therefore, no assimilative capacity exists in Lucerne Valley (north).

5.5.5.2 Nitrate

Table 5-13 shows the calculated future nitrate-NO_3 assimilative capacity for each subregion based on simulated WY 2081 groundwater concentrations. Assimilative capacities for nitrate are based on the primary MCL of 45 mg/L for nitrate-NO_3. As shown in **Table 5-13** despite some projected increases in nitrate concentrations in selected subregions, groundwater nitrate-NO_3 concentrations are generally well below the BPO concentration in all subregions. The average assimilative capacity is 30.9 mg/L across the Study Area, equating to about 8 mg/L use of current assimilative capacities by subregion on average (see **Table 4-4** in Section 4.6.3). Subregions with below-average nitrate-NO_3 assimilative capacities (less than 30.9 mg/L) include the following:

- Centro – Floodplain
- Alto Transition Zone – Floodplain (Helendale)
- Alto Transition Zone – Floodplain
- Alto - Floodplain (Narrows)
- Alto – Right Regional
- Warren Valley
- Joshua Tree

Table 5-13
Future TDS and Nitrate Assimilative Capacity (WY 2081)

Subregion	TDS				Nitrate-NO_3	
	Simulated Future (2081) Groundwater TDS Concentration (mg/L)	Assimilative Capacity[a]			Simulated Future (2081) Groundwater Nitrate-NO_3 Concentration (mg/L)	Assimilative Capacity[a]
		BPO = 500 mg/L	BPO = 1,000 mg/L	BPO = 1,500 mg/L		BPO = 45 mg/L
MOJAVE RIVER BASIN						
Baja - Floodplain	429	71	571	1,071	7.9	37.1
Baja - Regional	664	-164	336	836	5.2	39.8
Centro - Floodplain	598	-98	402	902	35.5	9.5
Centro - Regional	786	-286	214	714	11.8	33.2
Centro - Regional (Harper Dry Lake)	1,018	-518	-18	482	4.7	40.3
Alto Transition Zone - Floodplain (Helendale)	874	-374	126	626	21.0	24.0
Alto Transition Zone - Floodplain	535	-35	465	965	36.6	8.4
Alto Transition Zone - Regional	534	-34	466	966	6.6	38.4
Alto - Floodplain (Narrows)	395	105	605	1,105	17.3	27.7
Alto - Floodplain	262	238	738	1,238	10.7	34.3
Alto - Left Regional	378	122	622	1,122	4.2	40.8
Alto - Mid Regional	362	138	638	1,138	13.4	31.6
Alto - Right Regional	896	-396	104	604	36.0	9.0
Oeste - Regional	702	-202	298	798	6.7	38.3
Este - Regional	318	182	682	1,182	11.1	33.9
MORONGO BASIN						
Lucerne Valley (north)	1,705	-1,205	-705	-205	7.3	37.7
Lucerne Valley (south)	535	-35	465	965	11.7	33.3
Johnson Valley	686	-186	314	814	7.0	38.0
Ames-Means Valley	343	157	657	1,157	6.5	38.5
Warren Valley	359	141	641	1,141	22.5	22.5
Copper Mountain-Giant Rock	248	252	752	1,252	7.5	37.5
Joshua Tree	279	221	721	1,221	18.8	26.2

Notes:
Red highlighted cell indicates that average concentration exceeds respective BPO and there is no available assimilative capacity.
(a) Assimilative capacity equals BPO minus average concentration (in mg/L); positive value indicates available assimilative capacity; a negative value indicates no available assimilative capacity.

5.6 Subregional Synopses of SNMP Mixing Model Results

This section presents the components of individual summaries (or synopses) for each of the 20 Mojave SNMP subregions, which are presented in **Appendix C**. Each synopsis includes detailed information from mixing model results that helps to identify key individual loading factors and explain their individual and collective influence on future groundwater quality. Additionally, TDS and nitrate time-concentration plot maps are also included for reference.

While the emphasis of each synopsis is on Scenario 3 results, differences in future groundwater quality trends between Scenario 3 and Scenarios 1 and 2 are also examined and discussed.

5.6.1 Synopsis Components

5.6.1.1 Summary Table of Scenario 3 Results

At the beginning of each synopsis (**Appendix C**), a table summarizing key inflows and simulated future groundwater quality changes for Scenario 3 is provided. An example from the Oeste – Regional subregion is provided as **Table 5-14**.

Table 5-14
Example Summary of Scenario 3 Mixing Model Results
Oeste – Regional

Inflow	Average Annual Rate		TDS		Nitrate-NO_3	
	(AFY)	(% of Total)	Concentration (mg/L)	Mass Loading (%)	Concentration (mg/L)	Mass Loading (%)
Mountain-Front Recharge	1,941	30%	210	11%	0.6	1%
Subsurface Inflow	128	2%	525	2%	5.4	1%
SWP Recharge	3,007	46%	250	20%	2.5	9%
Septic Tank Return	229	4%	1,619	10%	107.3	30%
Municipal Irrigation Return	19	0%	3,688	2%	14.3	0.3%
Agriculture Irrigation Return	1,190	18%	1,787	56%	40.0	58%
Flow-Weighted Average Concentration of Total Inflows			583		12.6	
Flow-Weighted Average Concentration of Total Inflows (with no SWP Recharge)[a]			868		21.2	
Initial (2012) Groundwater Concentration			781		2.5	
Simulated Final (2081) Groundwater Concentration			702		8.6	

Notes:
TDS and nitrate concentration for individual inflows represents flow-weighted average over 70-year simulation.

Concentration is above simulated concentration range
Concentration is within simulated concentration range
Concentration is below simulated concentration range

For each individual inflow, the table shows the average annual volumetric flow rate, the (flow-weighted) average TDS and nitrate concentrations, and the relative contribution of TDS and nitrate mass over the 70-year simulation period. Below the information shown for individual inflows in the table, the (flow-weighted) average TDS and nitrate concentrations for all inflows (collectively) over the 70-year simulation period is provided. For subregions projected to receive SWP water for recharge, the (flow-weighted) average TDS and nitrate concentrations for all inflows (collectively) excluding SWP water recharge over the 70-year simulation period is provided. In the two bottom rows of **Table 5-14**, the initial (2012) and simulated final (2081) average groundwater concentrations in the subregion are provided.

As shown in the example **Table 5-14**, for each individual inflow, the cell containing the (flow-weighted) average concentration is highlighted with one of three colors, according to whether the average concentration of an individual inflow is above (red), below (green), or within (yellow) the range of simulated future groundwater concentrations in the subregion (between the initial and final simulated groundwater concentrations). The color of the cell indicates whether the inflow term improves (green) or degrades (red) future groundwater quality in the subregion or is a relatively neutral inflow (yellow). In the example above, three inflows are highlighted green for TDS, because the average concentration for all three terms (mountain-front recharge, subsurface inflow, and SWP recharge) are below the simulated range of future groundwater concentrations in the Oeste – Regional subregion (from 781 to 702 mg/L).

The information presented in each subregional synopsis table helps to explain the relationships between loading factors (inflows) and the future groundwater concentration trends observed in Scenario 3. This is based on the fundamental concept that future groundwater quality generally approaches the (flow-weighted) average concentration of total subregional inflows over time. To be specific:

1. *Groundwater concentrations will decrease over the simulation period, if the (flow-weighted) average concentration of all inflows is below the range of simulated groundwater concentrations in a subregion over the 70-year simulation period*
2. *Groundwater concentrations will increase over the simulation period, if the (flow-weighted) average concentration of all inflows in a subregion is above the range of simulated groundwater concentrations over the 70-year simulation period.*

Refer to Sections 5.5.2 and 5.5.3 for further explanation as to why mass alone cannot be used to explain groundwater quality changes.

While future groundwater concentrations will either decrease or increase towards the (flow-weighted) average concentration of all inflows, the rate at which groundwater concentrations converge towards the average inflow concentration over time is dependent on the groundwater volume in storage. For example, a subregion with a relatively large groundwater storage volume has a large capacity to buffer annual TDS and nitrate loads without changing significantly. In the example table for Oeste – Regional, the (flow-weighted) average TDS concentration of total inflows is 583 mg/L, lower than the initial (2012) groundwater TDS concentration of 781 mg/L. Thus, future groundwater TDS concentrations decrease over time, reaching 702 mg/L in 2081. In contrast, the (flow-weighted) average nitrate-$\underline{NO_3}$ concentration of total inflows is 12.6 mg/L, higher than the initial (2012) groundwater nitrate-$\underline{NO_3}$ concentration of 2.5 mg/L. Thus, future groundwater nitrate-$\underline{NO_3}$ concentrations increase over time, reaching 8.6 mg/L in 2081.

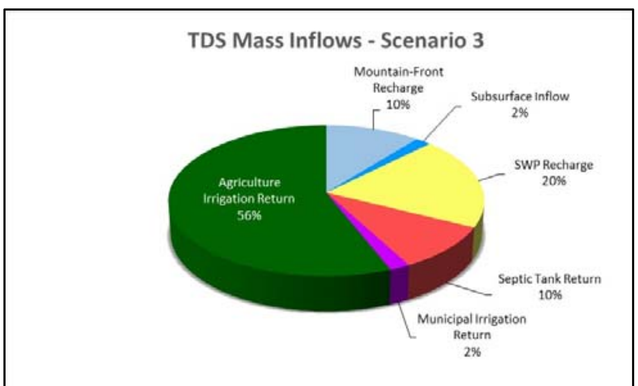
In some subregions, the final simulated future groundwater concentration increases above the (flow-weighted) average concentration of total inflows. This occurs in subregions where ET by riparian vegetation or dry lake evaporation is a significant portion of groundwater outflows. Because it is assumed that TDS mass is not removed by either ET or dry lake evaporation (0 mg/L TDS is assigned to both terms) and nitrate uptake by plants by ET is minimal (3 mg/L nitrate-NO_3 is assigned), both ET and dry lake evaporation serve to increase concentrations of the remaining groundwater in storage.

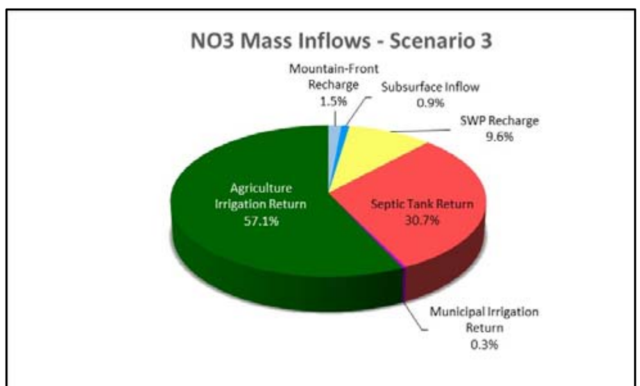
As discussed above, future groundwater quality generally approaches the (flow-weighted) average concentration of total inflows over time. Accordingly, if the average concentration of total inflows with SWP water is less than or equal to the average concentration of total inflows without SWP water, then it can be concluded that SWP water maintains or improves groundwater quality over time. The example table from Oeste – Regional (**Table 5-14**) shows that the average concentration of total inflows is 583 mg/L with SWP water and 868 mg/L without SWP water, demonstrating the conceptual benefit of SWP water to groundwater quality.

5.6.1.2 Summary Charts of Relative Mass Contribution by Inflow

In each synopsis (**Appendix C**), the relative contribution of TDS and nitrate mass of each inflow term (in percentage) over the 70-year simulation period is both provided in the summary table for Scenario 3 results and depicted in pie charts. As an example, **Figure 5-8** presents the modeling results in pie chart format from the Oeste – Regional subregion.

Figure 5-8
Scenario 3 Mixing Model Results
Pie Charts of Relative TDS and Nitrate Mass Contribution by Inflow
Oeste – Regional



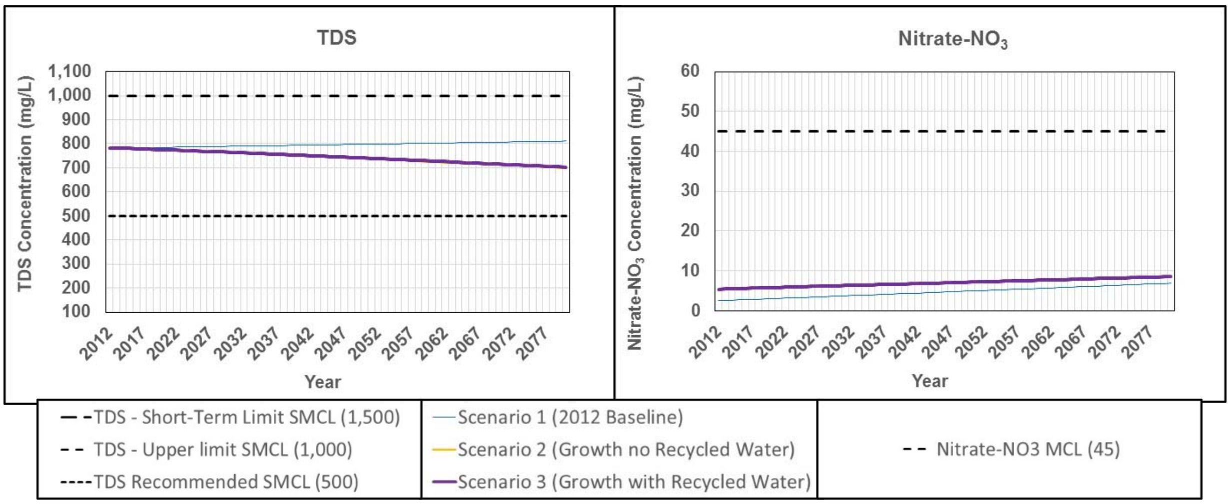


These pie charts illustrate the relative loading factors in the subregion because values are normalized (shown as percentage of total mass inflows, such that the sum of all inflows equal 100). However, the pie charts cannot be used to show the influence of individual and collective inflows on groundwater quality (see Sections 5.5.2 and 5.5.3 for additional explanation); the color of the individual and collective loading factors in the synopsis summary table (green, yellow, and red) is provided for that purpose.

5.6.1.3 Simulated Groundwater Concentration Trends over Time

Lastly, the simulated future groundwater TDS and nitrate concentration trends for all three scenarios over the 70-year simulation period (2013 to 2081) are presented and discussed in each synopsis (**Appendix C**). The example for Oeste – Regional is shown on **Figure 5-9.**

Figure 5-9
Scenario 3 Mixing Model Results
Simulated Groundwater TDS and Nitrate Concentrations
Oeste – Regional



5.6.1.4 Impacts from Recycled Water Projects

The direct impact of recycled water projects on groundwater TDS and nitrate concentrations are discussed in the synopses of subregions (**Appendix C**), which include the following:

- Alto – Mid Regional
- Alto – Right Regional
- Alto Transition Zone – Floodplain
- Alto Transition Zone – Floodplain (Helendale)
- Warren Valley

For these subregions, the synopses demonstrate that planned future recycled water projects have minimal impact on future groundwater TDS and nitrate concentrations in their respective subregions, and in some cases incrementally improve groundwater quality.

It should be recognized that the scale and purpose of the S/N loading analysis and S/N mixing model used to evaluate regional impacts from recycled water projects for the SNMP differ from similar analyses conducted to satisfy individual recycled water project permit requirements. Projected population growth (and associated effluent flows) and TDS and nitrate concentrations applied in the SNMP are based on the most current information available during the development of S/N loading analysis.

5.6.1.5 Supplemental Evaluation of Imported SWP Water Impacts (Benefits) on Groundwater TDS and Nitrate Concentrations:

Mixing model results are evaluated to isolate the impact (benefit) of imported SWP water recharge on groundwater TDS and nitrate concentrations. While not simulated explicitly using the mixing model (e.g., by removing SWP water in a separate scenario), the conceptual benefit of SWP water on future groundwater quality is identified by comparing the flow-weighted average TDS and nitrate concentration of total inflows for a given subregion with and without SWP water.

As shown in **Table 5-15**, the flow-weighted average TDS and nitrate concentrations of total inflows for subregions projected to receive SWP recharge water are lower with SWP water than without SWP water, clearly demonstrating the benefit of SWP recharge water on future groundwater quality. The one exception is the Alto – Floodplain, where the average TDS concentration of total inflows with SWP water (249 mg/L) and without SWP water (248 mg/L) are similar. However, as discussed in further detail below, comparison of average inflow concentrations alone does not consider other potential groundwater quality benefits from imported SWP water for recharge, including 1) reductions in pumped groundwater and associated S/N loading from return flows, and 2) increased S/N loading buffering capacity and reduction in high-TDS subsurface inflows due to increased hydraulic heads from SWP water recharge. Consideration of these factors suggests that imported SWP water recharge would benefit groundwater TDS concentrations in the Alto – Floodplain as well.

Table 5-15
Summary of Flow-Weighted Average TDS and Nitrate Concentrations with and without SWP Recharge Water

Subregion with Projected SWP Recharge	TDS			Nitrate-NO_3		
	Initial Flow-Weighted Average Groundwater Concentration	Flow-Weighted Average Concentration of Total Inflows <u>with SWP water</u>	Flow-Weighted Average Concentration of Total Inflows <u>without SWP water</u>	Initial Flow-Weighted Average Groundwater Concentration	Flow-Weighted Average Concentration of Total Inflows <u>with SWP water</u>	Flow-Weighted Average Concentration of Total Inflows <u>without SWP water</u>
Baja - Floodplain	401	487	567	3.9	18.0	23.2
Alto - Floodplain	177	249	248	3.3	9.7	16.5
Alto - Mid Regional	153	349	351	3.5	12.7	13.0
Oeste - Regional	781	583	868	2.5	12.0	20.2
Ames-Means Valley	330	394	459	5.7	11.3	15.3
Warren Valley	243	449	539	15.4	26.8	37.7
Joshua Tree	202	455	625	14.7	27.4	49.6

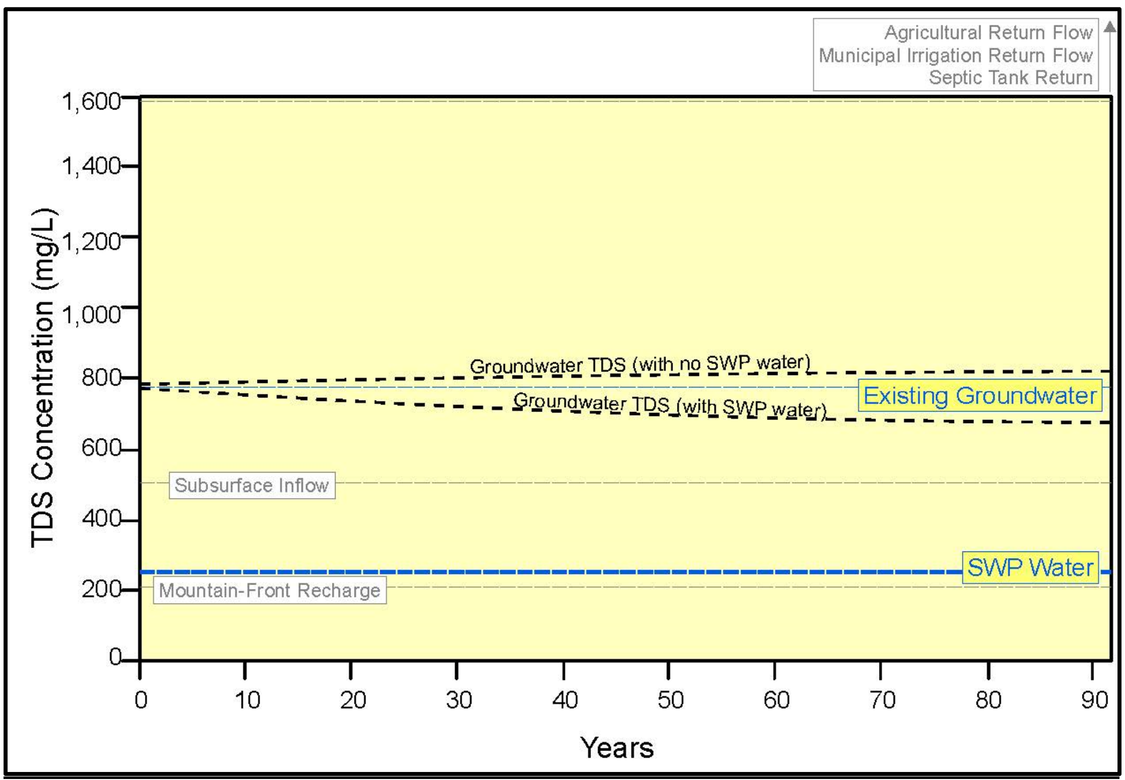
<u>Notes:</u>

While SWP water has historically been imported and recharged in the Centro – Floodplain via the Hodge and Lenwood recharge facilities, there is no projected future SWP water demand in Centro.

Table 5-15 demonstrates that SWP water improves future groundwater TDS and nitrate concentrations in subregions that 1) have better groundwater quality (i.e., subregions with lower existing groundwater TDS and nitrate concentrations compared to SWP water) and 2) worse average groundwater quality (i.e., subregions with higher existing groundwater TDS and nitrate concentrations compared to SWP water).

To further illustrate the effect of imported SWP water on groundwater quality, two figures are presented. In each figure, TDS concentrations of various inflows are shown along with the projected groundwater concentration trend with and without SWP water. **Figure 5-10** presents (flow-weighted) average TDS concentrations from the Oeste – Regional Scenario 3 simulation. **Figure 5-11** shows (flow-weighted) average TDS concentrations from the Alto - Floodplain 3 simulation.

Figure 5-10
Conceptual Benefit of Imported SWP Water Recharge on Groundwater Quality in Subregion with Poorer Groundwater Quality
Example: Oeste – Regional (TDS)

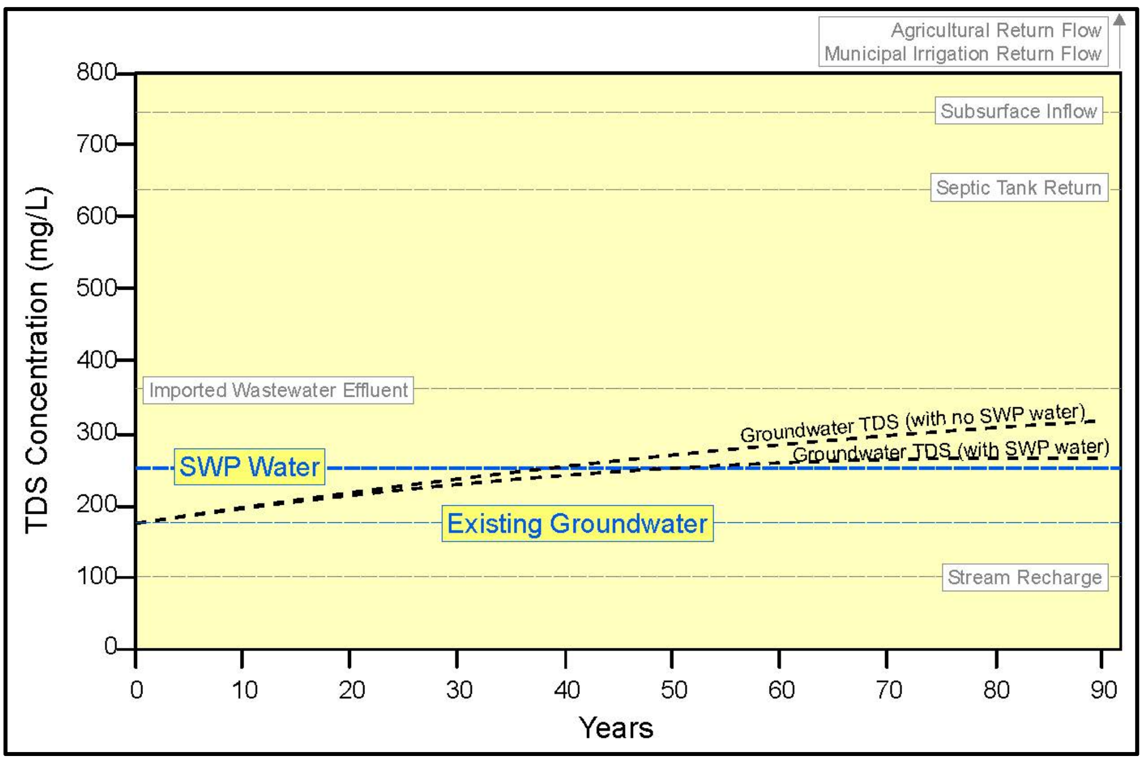


The average TDS concentration of imported SWP water (250 mg/L) is lower than the existing groundwater TDS concentration in four of the six subregions projected to receive SWP water recharge as shown in **Table 5-15** (the two exceptions are Alto – Floodplain and Alto – Mid Regional). Additionally, in each of these four subregions, the flow-weighted average TDS and nitrate concentrations of total inflows are lower with SWP water than without SWP water. In the example above shown on **Figure 5-10** for Oeste – Regional, the existing groundwater TDS concentration is

781 mg/L. Future groundwater TDS concentrations are expected to decrease towards the flow-weighted average concentration of total inflows with SWP water (583 mg/L). Without SWP water, the flow-weighted average TDS concentration of total inflows (based on fixed rate for other inflows) increases significantly (to 868 mg/L). Thus, without SWP water, subregional groundwater TDS concentrations are expected to increase over time.

The general loading conditions in Oeste – Regional, wherein 1) initial subregional groundwater concentrations are higher than SWP water concentrations and 2) the flow-weighted average TDS and nitrate concentrations of total inflows are lower with SWP water than without SWP water, apply to four of the six subregions shown in **Table 5-15** (Baja - Floodplain, Oeste – Regional, Ames-Means Valley, and Warren Valley).

Figure 5-11
Conceptual Benefit of Imported SWP Water Recharge on Groundwater Quality in Subregion with Better Groundwater Quality
Example: Alto – Floodplain (TDS)



The average TDS concentration of imported SWP water (250 mg/L) is higher than the existing groundwater TDS concentration in two of the six subregions projected to receive SWP water recharge as shown in **Table 5-15**. These are Alto – Floodplain and Alto – Mid Regional. With respect to Alto – Mid Regional, the flow-weighted average TDS and nitrate concentrations of total inflows are lower with SWP water than without SWP water – clearly demonstrating the benefit of SWP recharge water on groundwater quality in Alto – Mid Regional.

In the Alto Floodplain, the flow-weighted average TDS and nitrate concentrations of total inflows is similar but slightly higher with SWP water than without SWP water. As shown on **Figure 5-11** for Alto – Floodplain, the existing groundwater TDS concentration is 177 mg/L. Future groundwater TDS concentrations are expected to increase towards the flow-weighted average concentration of total inflows (249 mg/L). Future TDS concentrations in Alto- Floodplain increase slightly above SWP water concentrations (due to the effect of evapotranspiration in the subregion). Without SWP water, the flow-weighted average TDS concentration of total inflows (based on fixed rate for other inflows) does not change significantly (248 mg/L). However, comparison of the average concentration of total inflows alone does not consider other related benefits from imported SWP water, including 1) reduction in pumping and associated loading from return flows, and 2) increased S/N loading buffering capacity and reduction in high-TDS subsurface inflows due to increased storage volume from SWP water recharge. Consideration of these factors suggests that while groundwater TDS concentrations are expected to increase in the Alto - Floodplain, the rate of increase with imported SWP water recharge is lower than without SWP water. This condition also applies to Alto Mid – Regional.

Section 6: Project Review, Prioritization, and Implementation Measures

This section presents the objectives for using recycled water and stormwater in the MWA service area that were developed based on stakeholder input and on the information contained in the recently published Mojave IRWM Plan and other planning documents.

Also, this section includes and recommends methods and regional Best Management Practices (BMPs) to manage salt and nutrient loadings on a sustainable basis, using the modeling results from the previous section to develop appropriate implementation measures that can be recommended for the MWA service area. Activities have been identified that can be phased in a reasonable timeframe for successful implementation.

Within the MWA service area, there are currently two sources of recycled water, Victor Valley Wastewater Reclamation Authority (VVWRA) and the Victorville Water District; however there are several other sources (all wastewater flows) of potential recycled water within MWA's service area that may be treated to become recycled water as detailed in MWA's 2010 UWMP and summarized below by agency:

- City of Adelanto
- City of Barstow
- Victorville Water District
- VVWRA
- Helendale CSD
- MCLB
- Hi-Desert Water District

The VVWRA provides wastewater collection and treatment services within the MWA boundary. VVWRA was originally formed by the Mojave Water Agency to help meet the requirements of the federal Clean Water Act and provide wastewater treatment for the growing area. The VVWRA is now a joint powers authority and public agency of the state of California. The VVWRA serves portions of Victorville, Hesperia, Apple Valley, and San Bernardino County Service Areas 42 and 64.

In 2010, the Victorville Water District began to use recycled water for the High Desert Power Project (HDPP) power plant cooling system. Before this, recycled water was being used at VVWRA's treatment facility for landscape irrigation at its on-site composting facility for processing, dust control and fire protection and for irrigation at the Westwinds Golf Course. Most of the treated wastewater effluent is recharged to the groundwater basin. Because the Mojave Groundwater Basin is essentially a closed basin, these supplies contribute to the overall water supply of the area.

6.1 Managing Salt and Nutrient Loadings on a Sustainable Basis

Future TDS and nitrate concentrations are not expected to increase significantly as a result of planned future recycled water projects (projects). Average existing and future TDS and nitrate concentrations in the MWA groundwater basins do not currently exceed SNMP water quality management goals and are not predicted to exceed these goals within the SNMP planning horizon (through 2035). These goals are consistent with the Regional Boards' Basin Plans to protect beneficial uses of the water.

Therefore, no new implementation measures as part of the SNMP process are recommended at this time. Nevertheless, existing measures and practices are already in place to manage water quality, and frequent monitoring, should also be implemented to assess trends in water quality.

6.2 Goals/Objectives

This section presents the goals and objectives for using recycled water and stormwater in the MWA service area. These objectives were crafted by stakeholders over many meetings and are based on planning documents (including the recently updated and adopted Mojave IRWM Plan) and applicable Regional Board documents for the MWA service area. Additionally, water conservation programs provide a useful basis for understanding and assessing recycling activities. The agencies within the MWA service area implement extensive water conservation programs, ranging from residential, commercial, industrial and municipal to agricultural programs.

For the stormwater objectives, the use of existing and proposed local stormwater detention and/or detention basins for their potential dual use as recharge facilities was considered.

6.2.1 Recycled Water and Stormwater Objectives

During the Mojave IRWM Plan update process, 14 objectives were developed that reflect the broad range of current challenges and opportunities related to integrated water management in the Mojave Region (an expanded version of the MWA service area). Two of the 14 objectives are related to recycled water and stormwater as shown in **Table 6-1**. The objectives were designed to allow stakeholders to measure and track progress toward improving integrated water management within the Mojave Region over time.

Early in the planning process, the stakeholders agreed the Mojave IRWM Plan would only have measureable objectives and not include any higher-level "Goals" because objectives would be sufficient to align stakeholders and focus implementation efforts.

Table 6-1
Recycled Water and Stormwater Objectives for the SNMP

Summary of Objective	Quantitative Measurement	Target	Approach
10. Preserve water quality as it relates to local beneficial uses of water supplied by each source, including groundwater, stormwater, surface water, imported water, and recycled water.	Regular summaries of key water quality constituents for various water supplies as they relate to the local beneficial uses.	Maintain the water quality objectives in the Lahontan and the Colorado River Regional Board Basin Plans.	
14. Increase the use of recycled water in the Region (an expanded version of the MWA service area) while maintaining compliance with the Mojave Basin Area Judgment as applicable.	Measured by changes in the volume of recycled water being used in the Region.	Double recycled water use (purple pipe; not total discharges from wastewater treatment plants) over next 10 years.	Compare annual recycled water volumes to 2010 volume.

Notes:
Source is 2014 Mojave IRWM Plan.

6.3 Ongoing Management Programs

Several ongoing programs are already being implemented that include measures for the management of water quality including salts and nutrients. A summary of these programs is provided below. Implementation of these programs is currently underway and will continue in conjunction with the SNMP.

6.3.1 Mojave Basin Area Adjudication

MWA is the current Court-appointed Watermaster for the Mojave Basin Area Judgment. The Watermaster's main responsibilities are to monitor and verify water production, collect required assessment, conduct studies and prepare an annual report. The adjudication is primarily concerned with maintaining groundwater levels to help maintain a specified level of groundwater pumping in the area. The Watermaster does not have a specific obligation towards maintaining water quality; however, it is noted that continued pumping in depleted areas may result in long-term local negative impacts such as water quality problems due to migration of lesser quality water.

Monitoring requirements are described in the Judgment After Trial (1996) and in the Mojave Basin Area Watermaster Annual Reports. Some components of the water budget called for in the Judgment, such as flows across subarea boundaries, must be estimated from collected data. The Watermaster is currently responsible for reporting the following types of data in the Mojave Basin Area:

- Verification of reported groundwater production
- Mojave River Flows
- Precipitation

- Wastewater Discharges
- Subsurface Inflow
- State Water Project and wastewater imports
- Groundwater levels
- Ungauged surface water inflows
- Consumptive Use

MWA and the Watermaster will continue to perform monitoring activities prescribed by the Judgment, and will endeavor to improve methodologies to quantify components of the water budget and to facilitate integration of collected information with the MWA data set.

6.3.2 Warren Valley Basin Adjudication

The Warren Valley Basin adjudicated area is located within the Morongo Basin/Johnson Valley Area (Morongo). Groundwater from the Warren Valley Basin is used to supply the Town of Yucca Valley and its environs. Extractions from the Warren Valley Basin began exceeding supply in the 1950s and its progressively increasing overdraft led to adjudication of the Warren Valley Basin in 1977. In its Warren Valley Judgment (see **Figure 1-2**), the court appointed the Hi-Desert Water District (HDWD) as Watermaster and ordered it to develop a physical solution for halting overdraft. Objectives identified by the Watermaster Board include managing extraction, importing water supplies, conserving stormwater, encouragement of conservation and reclamation, and protecting groundwater quality. A Basin Management Plan was adopted that called for importing SWP water from MWA through the then-proposed Morongo Basin Pipeline to balance demand and replenish past overdraft.

6.3.3 2004 Regional Water Management Plan

MWA prepared a 2004 Regional Water Management Plan (also known as the 2004 IRWM Plan and Groundwater Management Plan) (2004 RWMP) (MWA, 2004) to plan necessary water supplies for the Agency and its purveyors through 2020. The management actions consisted of 60 specific actions that can be grouped into the following seven elements:

- Monitoring
- Improve characterization of the basin
- Continue long-term planning
- Groundwater protection
- Construction and implementation
- Financing
- Public participation

As part of the 2004 RWMP, MWA has several programs for monitoring groundwater levels and quality from monitoring wells within the Mojave Basin Area. This work is supplemented by efforts of the USGS as part of a cooperative water services program with MWA. In the 2004 Plan, the following actions are noted:

- MWA will ensure that sufficient monitoring wells are installed around each recharge site to provide information needed to determine vertical and horizontal groundwater flow conditions and potential groundwater mounding in the vicinity.

- Existing monitoring wells will be maintained and gaps in data identified. The need for additional monitoring wells will be assessed and a plan developed for construction of additional wells if necessary. This assessment could lead to the identification and elimination of some superfluous measurement points.

- For probable recharge locations, MWA will perform an inventory and map potential sources of contamination including toxic investigation sites, industrial sites, gas stations, dairies, and sites investigated by the Regional Boards, and use this information in selecting recharge sites and in planning recharge site operation in order to minimize the potential for water supply contamination. MWA will compile existing SWRCB Division of Drinking Water, formerly CDPH reports developed for existing wells to aid in mapping potentially contaminating activities.

- MWA will coordinate with regional water quality agencies, including the USEPA, Lahontan and Colorado River Basin Regional Boards, the CDPH, and San Bernardino County Health Services to identify potential water quality threats to candidate recharge sites, and compile this information into a data management system for use in selection of recharge sites.

- Maintain in-house staff efforts for collection, compilation, and archiving an increasing quantity of collected data.

6.3.4 Groundwater Storage Program

MWA is one of 29 State Water Project (SWP) contractors that deliver water via the California Aqueduct, and MWA imports water from this source as needed. MWA's Regional Recharge and Recovery Project, known as "R-Cubed", is part of a comprehensive solution developed by MWA and applicable stakeholders to ensure a sustainable water supply for the service area. To accomplish this, R-Cubed is a conjunctive use project that stores SWP water in the local aquifer for later recovery for distribution to local water purveyors. The Project provides an option for retail water purveyors to offset their need to pump within the regional aquifer system.

6.3.5 Mojave IRWM Plan

As previously discussed, the Mojave IRWM Plan (MWA, 2014c) was completed concurrently with this SNMP and adopted by MWA and other participants in June 2014. Within the Mojave Region (an expanded version of the MWA service area) there are existing systems in place for collecting data on groundwater and surface water supplies and water quality. Collection of data can be used to help quickly identify data gaps, assess project and program performance, support statewide data needs, and integrate with other regional and statewide programs. Table 10-2 from the Mojave IRWM Plan describes the entities responsible for maintaining data:

- Resource agencies providing water supplies, sanitary services, or regulating land use have the responsibility to maintain these data consistent with the laws described above (Water Code, California Government Code, Clean Water Act).

- The governing IRWM Regional Water Management Group will require project proponents implementing projects as part of the IRWM Program to collect and maintain data generated as part of their projects (such as ambient groundwater quality, treated water quality, amount of invasive species removal, volume of water treated, amount of pipeline improved or replaced, and more) during project implementation.

Data are vitally important to agencies trying to maximize operating efficiency and design projects with limited budgets. The types of data available, current relevance and trends, and knowledgeable personnel that can interpret these data are all important. Equally important is the opportunity for federal and state agencies to view local data for their own monitoring needs and to better understand local conditions.

6.4 Implementation Measures

The Mojave IRWM development process provided a mechanism for: 1) coordinating, refining and integrating existing planning efforts within a comprehensive, regional context; 2) identifying specific regional and watershed-based priorities for implementation projects; and 3) providing funding support for the plans, programs, projects and priorities of existing agencies and stakeholders. The process also included public outreach and groundwater management strategies and objectives for the Mojave Region (an expanded version of the MWA service area), including this SNMP, as well as a list of implemented and proposed projects to meet the management objectives.

As mentioned, projected future groundwater quality concentrations are not expected to exceed the SNMP water quality management goals and implementation of the identified projects will not unreasonably affect the MWA service area groundwater basins' designated beneficial uses. Therefore, no new or additional implementation measures are recommended to manage salts and nutrients within the basins. Several programs that help manage groundwater supplies and quality are underway in the basin; these programs fall under six categories, as follows:

- Groundwater Management
- Municipal Wastewater Management
- Recycled Water Irrigation
- Onsite Wastewater Treatment System Management
- Stormwater
- Agricultural

6.4.1 SWP Groundwater Recharge Implementation Measures

Data in Section 5 shows that the water quality of SWP water used for recharge within the Study Area fluctuates seasonally, but is overall very good. The average TDS concentration over a 10-year period was 250 mg/L and the average nitrate-NO3 concentration was 2.5 mg/L.

Subregions projected to receive imported SWP water for groundwater recharge include the following:

- Baja – Floodplain
- Alto - Floodplain
- Alto – Mid Regional
- Oeste - Regional
- Ames-Means Valley
- Warren Valley
- Joshua Tree

While SWP water has historically been imported and recharged in the Centro – Floodplain via the Hodge and Lenwood recharge facilities, there is no projected future SWP water demand in Centro and therefore, that subregion is not listed above.

As discussed in detail in Section 5.6.1.3, modeling results demonstrate that imported SWP water recharge would benefit groundwater TDS concentrations in all of the above-listed subregions. The flow-weighted average TDS and nitrate concentrations of total inflows for subregions projected to receive SWP recharge water are lower with SWP water than without SWP water, clearly demonstrating the benefit of SWP recharge water on future groundwater quality. The one exception is the Alto – Floodplain, where the average TDS concentration of total inflows with SWP water (249 mg/L) and without SWP water (248 mg/L) are similar. However, consideration of other potential groundwater quality benefits from imported SWP water for recharge, including 1) reductions in pumped groundwater and associated S/N loading from return flows, and 2) increased S/N loading buffering capacity due to increased hydraulic heads from SWP water recharge, suggests that imported SWP water recharge would benefit groundwater TDS concentrations in the Alto – Floodplain as well.

To be conservative, MWA has evaluated potentially treating the SWP water for high TDS concentrations used in the MWA R-Cubed project and found it to be much more expensive than anticipated (RBF, 2008).

The MWA R-Cubed project is intended to be operated within a range of water levels that prevent unwanted consequences such as failing wells that may induce the migration of poor water quality.

Monitoring points have been established around each recharge site, depending upon local conditions. Sites with complex geology may require multiple completion wells to monitor water levels in all affected strata. Movement of recharged water will be tracked to monitor recharge effectiveness.

6.4.2 Municipal Wastewater Implementation Measures

VVWRA currently owns and operates the only large-scale wastewater treatment plant within the MWA service area. VVWRA treats nearly 13 MGD of wastewater at its Regional WWTP. Wastewater is collected through supporting pipelines and infrastructure from Victorville, Apple Valley, Hesperia and parts of San Bernardino County including Spring Valley Lake. The wastewater that comes to the VVWRA Regional WWTP is treated before being returned to the Mojave River or used in a cooling tower at the HDPP.

VVWRA implements source control programs as required by the SWRCB for the Regional WWTP National Pollutant Discharge Elimination System (NPDES) permit to operate and discharge. The municipal wastewater treatment includes source control programs for industrial waste management measures such as pre-treatment programs. Pre-treatment is the reduction of the amount of pollutants, the elimination of pollutants, or the alteration of the nature of pollutants in wastewater to a less harmful state prior to discharge to the treatment plant. In addition, source control measures include educational outreach and coordination with customers to help control salinity and nutrients in influent waters. VVWRA will continue to implement these source control measures, which ultimately improve the quality of discharged wastewater and therefore, recycled water.

6.4.3 Recycled Water Implementation Measures

The recycled water projects described in Section 5.2 were all identified and selected during the development of the recently completed Mojave IRWM Plan (MWA, 2014c). The selected projects were required to meet certain planning requirements such as having completed permits, satisfied project-level environmental review requirements, and finalized future flows and water quality concentrations associated each project. Projects selected from the Mojave IRWM Plan to be included in this SNMP are:

- VVWRA Subregional Water Reclamation Plants – Apple Valley and Hesperia
- City of Victorville Industrial WWTP - Recycled Water Pond Recharge
- Helendale CSD Water Reclamation Project
- Hi-Desert Water District Regional WRP

The implementation of recycled water is regulated by the Title 22 California Code of Regulations (Title 22). Numerous Best Management Practices (BMPs) and operating procedures must be followed when using recycled water for irrigation to ensure safety. The following BMPs, among others, are implemented in recycled water operations, per permitting by the Regional Board:

- Water quality monitoring at the treatment plant to ensure regulatory compliance with Title 22 and meet monitoring requirements as part of the Recycled Water Policy.

- Irrigation at agronomic rates – irrigation water is applied at a rate that does not exceed the demand of the plants, with respect to water and nutrients (typically monitored as nitrogen), and does not exceed the field capacity of the soil.

- Site Supervisor – a site supervisor who is responsible for the recycled water system and for providing surveillance to ensure compliance at all times with regulations and permit requirements is designated for each site. A site supervisor is trained to understand recycled water and supervision duties. In addition to monitoring the recycled water system, a site supervisor must also conduct an annual self-inspection of the system.

- Minimize runoff of recycled water from irrigation – Irrigation is not allowed to occur at any time when unauthorized runoff may occur, such as during times of rainfall or very low evapotranspiration, and any excessive overspray must be controlled.

6.4.4 Septic System Implementation Measures

A large percentage of the MWA service area includes groundwater basins which are overlain by rural areas that manage waste through individual onsite wastewater treatment systems (OWTS), also known as septic systems. Individual property owners are responsible for managing their own systems and employ a variety of BMPs such as monitoring and frequent pumping to manage the operation of the systems. In 2012, the SWRCB adopted the Water Quality Control Policy for Siting, Design, Operation, and Maintenance of OWTS. The intent of the Policy is "to allow the continued use of OWTS, while protecting water quality and public health".

BMPs required in the Policy include site evaluations, setbacks, and percolation tests for new systems. Properly maintaining septic systems is one of the most important aspects for reducing the water quality effects from septic tanks, but is commonly overlooked. Since septic systems are primarily privately owned, public outreach programs should emphasize how these measures help reduce salt and nutrient loading at the source before entering groundwater. Public outreach should target septic tanks owners and provide information on what measures can be performed. These measures could include:

- Implement a public outreach program to promote waste reduction to septic systems.
- Provide information to help local septic users to understand the importance of regular inspection, maintenance and septic waste hauling for maintaining a properly functioning septic system.
- Provide information for financial assistance to low income households to upgrade or replace failing septic systems.
- Identify potential high-volume or high-density locations, such as commercial property or mobile home parks, that would be good candidates to implement advanced treatment.

6.4.5 Stormwater Implementation Measures

Currently, stormwater recharge occurs naturally through the infiltration of precipitation into the soil; however, additional projects to enhance stormwater recharge in the Mojave Basin area are not planned. The Adjudication of the Mojave Basin Area (Judgment) included an injunction against diverting stormwater flow away from downstream users of the Mojave River; therefore, no major stormwater capture projects are proposed at this time. Although some stormwater related projects were identified in the Mojave River Basin in the IRWM Plan, all projects are in conceptual pre-design phase and, therefore, were not considered. The other relevant prohibition of the Adjudication is any project that alters the bed of the Mojave River and reduces the surface area over which stormwater currently flows.

In the Morongo Basin, stormwater naturally percolates through ephemeral stream channels to recharge groundwater. Only during occasionally large storm events does stormwater flow reach the dry lake beds; otherwise the stormwater either percolates into the ground or evaporates. At this time, there are no immediate plans to capture the stormwater runoff in the Morongo Basin for groundwater recharge.

Review of the MRWG Phase 2 MS4 annual reports for post-construction BMPs and development of a stormwater resources plan by the Mojave IRWM Regional Water Management Group will be considered during the next SNMP update (see Section 5.2.5.2 for additional discussion). Future implementation measures associated with these activities may be developed along with these activities.

6.4.6 Agriculture Implementation Measures

Groundwater is the sole source of water supply for agricultural use, including dairies, within the MWA service area. Agricultural return flow contains TDS and nitrate concentrations from fertilizer, soil leaching and other sources. Agricultural areas include various ongoing BMPs that may include:

- Drip irrigation – water application is minimized by focusing the amount and area applied.
- Focused application of fertilizer and soil amendments – application of salts and nutrients is limited to the area at the point of the irrigation drip emitter, rather than broadcast across a large area.

Land management practices at dairy operations include various ongoing BMPs. To be effective, BMPs need to be consistently implemented and operations reviewed to identify areas for improvement. Implementation for the SNMP is to emphasize that these BMPs need to be continually employed and upgraded at dairy operations. Several commonly used BMPs used for dairy operations are listed below:

- Pavement and cover (roofing) in intensive manure areas to control runoff.
- Spreading liquid manure at agronomic rates.
- Manure application (solids) on vegetated fields – spreading on vegetated areas allows for greater uptake of nutrients by plants.
- Organic dairies utilize larger land base for grazing area, allowing for greater uptake of nutrients.

As discussed earlier, development and implementation of new BMPs is not recommended at this time due to a combination of only modest estimated increases in TDS and nitrate concentrations in the future. This Plan anticipates continued implementation of BMPs that are already in place. Development and implementation of new BMPs should be considered during future updates, utilizing the results of future technical work and the results of monitoring developed through this Plan.

6.5 Program Implementation

For the Mojave SNMP, implementation strategies should integrate water quantity and quality, groundwater and surface water, and recharge area protection in order to maintain a sustainable long-term supply for multiple beneficial uses. These strategies will be dictated to a large degree by basin-specific characteristics and conditions. Depending on conditions within each basin/sub-basin, strategies may generally be geared towards:

- Pollution prevention to maintain and protect groundwater quality at levels consistent with Basin Plan Objectives;
- Source load reductions to groundwater basins;
- Treatment and management of areas of impaired water quality; and
- Increasing recycled water use.

As lead agency for development of this Plan, MWA commits to maintaining their current monitoring program and working with the Regional Boards and other stakeholders to make data readily available. However, due to budget concerns, it still is to be decided who will act as lead agency for SNMP implementation and Plan updates. Coordination will need to include overseeing the monitoring program, collecting monitoring data, data assembly and reporting, and updating the Plan on a regular basis.

6.6 Groundwater Monitoring

As detailed in Section 8, SNMP Groundwater Monitoring Program, groundwater quality data collected through 2013 were compiled to assess groundwater quality for the Mojave SNMP. The existing groundwater quality data are deemed adequate to support SNMP basin characterization. Existing groundwater quality monitoring programs are deemed adequate for determining whether the concentrations of salts, nutrients, and other constituents of concern as identified in this SNMP are consistent with applicable water quality objectives on a subregional scale.

Section 7: Anti-Degradation Assessment

7.1 Recycled Water Irrigation Projects

Recycled water project(s) in the MWA service area include planned future use of recycled water through the end of the future planning period (WY 2081).

7.2 SWRCB Recycled Water Policy Criteria

Resolution 68-16, the Statement of Policy with Respect to Maintaining High Quality Waters in California, was adopted by the SWRCB in 1968. The policy is the driving force behind the analysis and planning required for SNMPs. This policy has two primary parts:

Section 9 of the SWRCB's Recycled Water Policy (Anti-Degradation) states:

a. The State Water Board adopted Resolution No. 68-16 as a policy statement to implement the Legislature's intent that waters of the state shall be regulated to achieve the highest water quality consistent with the maximum benefit to the people of the state.

b. Activities involving the disposal of waste that could impact high quality waters are required to implement best practicable treatment or control of the discharge necessary to ensure that pollution or nuisance will not occur, and the highest water quality consistent with the maximum benefit to the people of the state will be maintained…

d. Landscape irrigation with recycled water in accordance with this Policy is to the benefit of the people of the State of California. Nonetheless, the State Water Board finds that the use of water for irrigation may, regardless of its source, collectively affect groundwater quality over time. The State Water Board intends to address these impacts in part through the development of salt/nutrient management plans described in paragraph 6.

(1) A project that meets the criteria for a streamlined irrigation permit and is within a basin where a salt/nutrient management plan satisfying the provisions of paragraph 6(b) is in place may be approved without further anti-degradation analysis, provided that the project is consistent with that plan.

(2) A project that meets the criteria for a streamlined irrigation permit and is within a basin where a salt/nutrient management plan satisfying the provisions of paragraph 6(b) is being prepared may be approved by the Regional Water Board by demonstrating through a salt/nutrient mass balance or similar analysis that the project uses less than 10 percent of the available assimilative capacity as estimated by the project proponent in a basin/sub-basin (or multiple projects using less than 20 percent of the available assimilative capacity as estimated by the project proponent in a basin/sub-basin).

7.3 Assessment

The existing average TDS and nitrate concentrations for each of the 22 SNMP analysis subregions were estimated and available assimilative capacities are summarized in **Table 4-4** in Section 4.6.3. **Table 5-9** and **Table 5-10** present the predicted change in groundwater quality for TDS and nitrate for scenarios with (Scenario 3) and without (Scenario 2) recycled water projects for each subregion through the future simulation period (to WY 2081). As shown in the tables, impacts from recycled water projects to groundwater TDS and nitrate concentrations (concentration differences between Scenario 3 and Scenario 2) are small, and in some subregions, result in a small incremental benefit to groundwater quality. The one exception is in the Warren Subbasin, where the new HDWD Regional WRP (which will treat wastewater to recycled water quality) will significantly improve TDS and nitrate groundwater concentrations.

Mixing model results indicate the following:

1. No individual recycled water project uses more than 10% of the available assimilative capacity, and combined effects of simulated recycled water projects do not use more than 20% of the assimilative capacity.

2. The water quality changes will not result in groundwater quality less than prescribed in the Basin Plan(s).

3. The water quality changes will not unreasonably affect existing and anticipated beneficial uses.

4. The water quality changes are consistent with the maximum benefit to the people of the state of California.

Accordingly, planned future recycled water projects evaluated under this SNMP are in compliance with SWRCB Resolution No. 68-16.

Section 8: Groundwater Monitoring Program

This section describes the Mojave SNMP Groundwater Quality Monitoring Program, and includes descriptions of the groundwater sampling locations, sampling frequency, constituents monitored, sampling protocols and associated quality assurance and quality control (QA/QC) procedures, data analysis and evaluation criteria, and reporting procedures. The entities responsible for monitoring and reporting are also described.

8.1 Background and Monitoring Program Goals

With respect to groundwater monitoring, the Recycled Water Policy states that the SNMP should include a monitoring program that consists of a network of monitoring locations "… adequate to provide a reasonable, cost-effective means of determining whether the concentrations of salts, nutrients, and other constituents of concern as identified in the salt and nutrient plans are consistent with applicable water quality objectives." Additionally, the SNMP "… must focus on basin water quality near water supply wells and areas proximate to large water recycling projects, particularly groundwater recharge projects. Also, monitoring locations shall, where appropriate, target groundwater and surface waters where groundwater has connectivity with the adjacent surface waters." The preferred approach is to "… collect samples from existing wells if feasible as long as the existing wells are located appropriately to determine water quality throughout the most critical areas of the basin. The monitoring plan shall identify those stakeholders responsible for conducting, sampling, and reporting the monitoring data. The data shall be reported to the RWQCBs at least every three years."

With regard to constituents of emerging concern (CECs), for basins with recycled water recharge projects, the Recycled Water Policy requires that the SNMP include "….a provision for annual monitoring of Constituents/Constituents of Emerging Concern (e.g., endocrine disruptors, personal care products or pharmaceuticals) consistent with recommendations by CDPH and consistent with any actions by the State Water Board…." However, Attachment A of the Policy also states that "Monitoring of health-based CECs or performance indicator CECs is not required for recycled water used for landscape irrigation due to the low risk for ingestion of the water." The policy does not discuss CEC monitoring for agricultural irrigation application uses. Because the only recycled water projects in the Study Area are for landscape irrigation, monitoring for CECs in groundwater is not required under the Recycled Water Policy or other state regulations.

MWA proposes to satisfy the monitoring requirements set forth in the Recycled Water Policy through the existing groundwater quality monitoring programs implemented across the Study Area, documented below.

8.2 Monitored Parameters

TDS and nitrate are the indicator salts and nutrients (S/Ns) selected for the Mojave SNMP. Total salinity is commonly expressed in terms of TDS in mg/L. TDS data are available for source waters (both inflows and outflows) in the Study Area. While TDS can be an indicator of anthropogenic impacts such as infiltration of runoff, soil leaching, and land use, there is also a natural background TDS concentration in groundwater. The background TDS concentration in groundwater can vary considerably based on purity and crystal size of the formation minerals, rock texture and porosity, the regional structure, origin of sediments, the age of the groundwater, and many other factors (Hem, 1989).

Nitrate is a widespread contaminant in California groundwater. High levels of nitrate in groundwater are associated with agricultural activities, septic systems, confined animal facilities, landscape fertilization, and wastewater treatment facility discharges. Nitrate is the primary form of nitrogen detected in groundwater. Nitrate data are available for source waters (both inflows and outflows) in the Study Area. Natural nitrate levels in groundwater are generally very low (typically less than 10 mg/L for nitrate as nitrate (nitrate-$\underline{NO_3}$). Nitrate is commonly reported as either nitrate-$\underline{NO_3}$ or nitrate as nitrogen (nitrate-N); and one can be converted to the other. Nitrate-$\underline{NO_3}$ is the form of nitrate selected for assessment for this SNMP.

Additional parameters associated with salts and nutrients are also monitored in groundwater.

8.3 Groundwater Quality Monitoring Programs

The current MWA groundwater monitoring program includes groundwater quality data collected by MWA and the USGS through their cooperative water resources program and through the Drinking Water Program directed by the SWRCB Division of Drinking Water (formerly CDPH). The SNMP Groundwater Quality Monitoring Program will include data from these ongoing programs. The SNMP monitoring program will also collect and consider data from other special/technical studies conducted in the Study Area pertinent to S/Ns. Key monitoring programs and well types are described below.

8.3.1 MWA and USGS Cooperative Water Resources Program (CWRP)

Groundwater quality investigations in the Study Area date back to the 1930s. To further understanding of basin-wide groundwater quality and to optimize groundwater quality monitoring efforts in the basin, MWA has developed a regional groundwater quality monitoring program in collaboration with interested stakeholders and cooperative agencies.

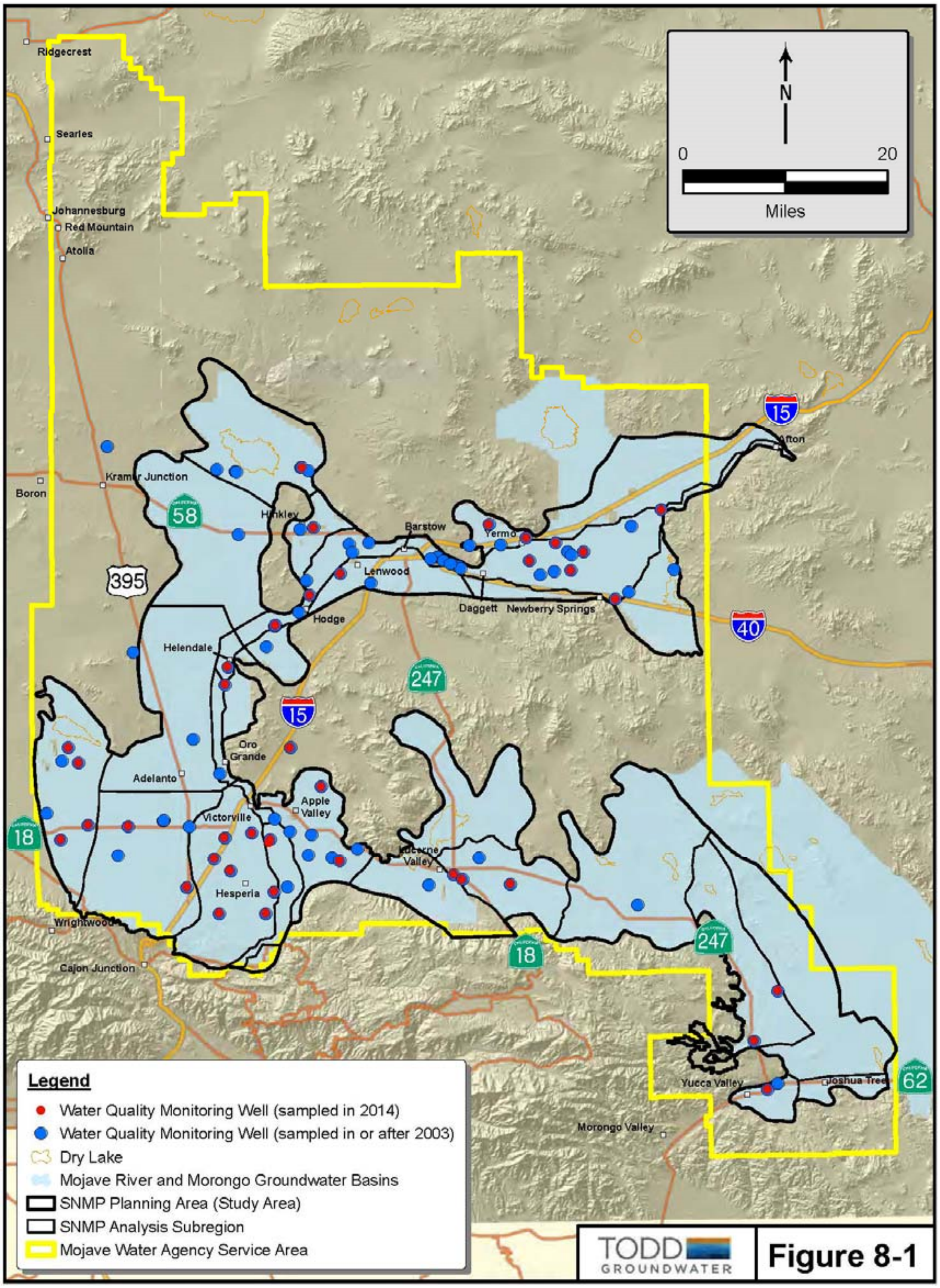
In 1990, MWA entered into a joint agreement with the USGS to develop and fund the Cooperative Water Resources Program (CWRP). The CWRP provides funding for a) groundwater level measurement and groundwater quality sampling activities across the Mojave River and Morongo groundwater basins; b) stream gage maintenance and continuous flow monitoring of the Mojave River; c) continuous and discrete sampling of Mojave River water quality; and d) review and uploading of data collected under the CWRP and other MWA groundwater monitoring programs to the publicly available USGS National Water Information System (NWIS) website. Under the CWRP program, MWA technical field staff participate in annual workshops led by members of the USGS California Water Science Center Quality Assurance Team to review and audit field techniques and QA/QC protocols related to equipment maintenance, instrument calibration, groundwater level measurement, and groundwater quality sampling.

Wells selected for inclusion in the CWRP are chosen from a network of “key wells” and carefully screened by MWA technical staff to optimize groundwater quality characterization across the MWA service area while concentrating monitoring efforts in areas of active groundwater use and management to address impacts from potentially contaminating land use activities. The list of wells is reviewed annually and updated in consideration of current water development and management activities, site/well ownership, and access. The number of dedicated monitoring wells sampled for groundwater quality annually under the CWRP has increased from 35 wells in 1990 up to 42 wells in 2014. **Figure 8-1** shows the well locations for wells sampled from 2003 through 2014. As shown on the figure, several wells are located in the subregions comprising the Floodplain Aquifer to monitor surface water-groundwater interactions along the Mojave River, which aligns with groundwater quality monitoring objectives of the Recycled Water Policy. As shown in **Table 8-1**, 19 of the 20 SNMP subregions are monitored by one or more wells under the CWRP. Monitoring wells are sampled and measured annually (in May) and analyzed by the USGS National Water Quality Laboratory for a comprehensive list of analytes, including TDS and nitrate, as shown in **Table 8-2**. The number of analytes has grown significantly since the inception of the CWRP to address current and future groundwater quality issues and associated constituents of concern.

Table 8-1
Summary of 2003-2014 MWA-USGS CWRP Groundwater Quality Monitoring Wells by Subregion

SNMP Subregion	Number of CWRP Wells
1. Baja – Floodplain	17
2. Baja – Regional	5
3. Centro – Floodplain	12
4. Centro – Regional	6
5. Centro – Regional (Harper Dry Lake)	6
6. Alto Transition Zone - Floodplain (Helendale)	1
7. Alto Transition Zone - Floodplain	1
8. Alto Transition Zone – Regional	2
9. Alto - Floodplain (Narrows)	2
10. Alto – Floodplain	5
11. Alto - Left Regional	8
12. Alto - Mid Regional	7
13. Alto - Right Regional	12
14. Oeste – Regional	7
15. Este – Regional	1
16. Lucerne Valley	6
17. Johnson Valley	1
18. Ames-Means Valley	2
19. Warren Valley	2
20. Copper Mountain-Giant Rock-Joshua Tree	0
TOTAL	103

Figure 8-1
MWA-USGS Cooperative Water Resources Program
Groundwater Quality Monitoring Wells (2014)



All water quality data collected under the CWRP are subject to rigorous QA/QC protocols by MWA and USGS staff, and only data that satisfy data reliability criteria are archived and published on the NWIS database. All data are accessible at http://nwis.waterdata.usgs.gov/nwis/qwdata. Groundwater quality data on the NWIS site can also be queried by geographical township, range, and section through a map-based user interface provided on the MWA online data portal at http://www.mojavewater.org/regional-water-quality.html. The data are also archived separately by MWA in their in-house water quality database.

Table 8-2
MWA-USGS CWRP
Groundwater Quality Analyte and Field Parameter List (2014)

Analytes		Field Parameters
TDS (sum of constituents)	Nitrate + Nitrite (as N)	Temperature
TDS (ROE at 180°C)	Nitrite	pH
Calcium	Sodium Absorption Ratio	Specific Conductance
Sodium	Ammonia	Dissolved Oxygen
Magnesium	Orthophosphate	Turbidity
Potassium	Fluoride	
Chloride	Boron	
Sulfate	Iron	
Bicarbonate	Manganese	
Hardness	Arsenic	
Non-Carbonate Hardness	Chromium (Total)	
Alkalinity as CaCO3	Chromium (Hexavalent)	
Silica	Vanadium	

Notes:
Analyses conducted by the USGS National Water Quality Laboratory.

8.3.2 Title 22 Drinking Water Well Program

The SWRCB Division of Drinking Water (formerly CDPH) regulates public drinking water systems in the State to ensure the delivery of safe drinking water to the public. A public drinking water system is defined as a system for the provision of water for human consumption through pipes or other constructed conveyances that has 15 or more service connections or regularly serves at least 25 individuals daily at least 60 days out of the year. Private domestic wells and irrigation wells are not regulated by the SWRCB Division of Drinking Water.

The SWRCB Division of Drinking Water enforces the monitoring requirements established in Title 22 of the CCRs for drinking water wells and all the data collected must be reported to the Division of Drinking Water, as summarized in **Table 8-3** below. Local compliance also is summarized. Title 22 also designates the regulatory limits (e.g., MCLs for various water contaminants, including volatile organic compounds, non-volatile synthetic organic compounds, inorganic chemicals, radionuclides, disinfection byproducts, general physical constituents, and other parameters).

As shown in **Table 8-3**, groundwater quality data are submitted electronically and are available for download at the water quality analyses data and download page: http://www.cdph.ca.gov/certlic/drinkingwater/Pages/EDTlibrary.aspx. MWA downloads the

CDPH water quality database on a semi-annual to annual basis. Data are screened by MWA technical staff, and data satisfying reliability criteria are archived in the MWA water quality database.

Groundwater quality monitoring schedules are well-specific and dependent on groundwater quality results relative to drinking water standards. CDPH tracks monitoring requirements by water system through their drinking water quality monitoring notification documents, which are posted online to assist public water systems in planning for upcoming sampling events.

Table 8-3
California Code of Regulations, Title 22 Drinking Water Well Monitoring

Program Origin	Title 22 of the California Code of Regulations: http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Lawbook.aspx
Responsible Agency	Drinking water well owners meeting the regulation connection definitions.
Monitoring Locations	Active drinking water wells permitted by the SWRCB, Division of Drinking Water (formerly CDPH) that are located throughout the Mojave River and Morongo basins (see **Figure 8-2**).
Constituents and Frequency	Drinking water wells are sampled for many parameters, including coliform bacteria/E-coli, volatile organic compounds, non-volatile synthetic organic compounds, inorganic chemicals, radionuclides, disinfection byproducts, and other general physical constituents. The constituents monitored and the frequency of monitoring varies based on the well location, size of the water system, and history of water quality results. These programs include the two indicators of salts and nutrients (TDS and nitrate) designated in the SNMP. Drinking water wells must be sampled in accordance with monitoring schedules (http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Monitoring.aspx) enforced by the SWRCB Division of Drinking Water.
Other Media Monitored/ Monitoring Locations	Water samples are collected at various locations throughout the distribution system, including: • Raw water at the well, • Service connections to other systems or imported water service connections, • Designated sampling points along the distribution piping, • Effluent of water storage tanks and blending tanks, and • Effluent of treatment plants.
Reporting/ Databases	• Analytical results are submitted directly to the SWRCB Division of Drinking Water database as Electronic Database Files: http://www.cdph.ca.gov/certlic/drinkingwater/Pages/EDT.aspx • Title 22 monitoring data can be downloaded from the SWRCB Division of Drinking Water website: http://www.cdph.ca.gov/certlic/drinkingwater/Pages/EDTlibrary.aspx • Title 22 monitoring data as well as other water quality data are available at the Groundwater Ambient Monitoring and Assessment (GAMA) Program website: http://geotracker.waterboards.ca.gov/gama/
QA/QC Program	• Provided by certified laboratories and their established QA/QC programs. • Laboratories utilize US Environmental Protection Agency method acceptance criteria and laboratory internal controls for QC parameters, including preparation blanks, surrogates, spikes, duplicates and laboratory control samples.
Compliance Oversight	Data are reviewed for compliance and any necessary corrective actions by groundwater purveyors and the SWRCB Division of Drinking Water.

Table 8-4 lists the public water supply systems regulated under the SWRCB Drinking Water Program by subregion. As shown in the table, there are 130 public water supply systems with production wells in the Study Area; 107 systems are located in the Mojave River Basin, and 23 systems are located in the Morongo Basin.

Figure 8-2 shows the wells that currently report groundwater quality data to the SWRCB Division of Drinking Water under the Title 22 Drinking Water program within MWA's service area. While the number of active wells changes year to year, there are currently 448 wells in the database, of which 426 wells are located within the Study Area. **Table 8-5** provides an inventory of wells by subregion. On average, there are 20 wells in each subregion. Every subregion includes at least one well, with the exception of Centro – Regional (Harper Dry Lake).

Table 8-4
Public Water Supply Systems by Subregion

MOJAVE RIVER BASIN			
Alto Floodplain	**Alto Left Regional**	**Alto Mid Regional**	**Alto Right Regional**
Apple Valley Ranchos WC	Burger King #9310	Hesperia Water District	Apple Valley Foothill CWD
Hesperia Water District	City of Adelanto	Hollandburger Cafe	Apple Valley Heights CWD
Joshua Inn	Phelan Pinon Hills CSD	Mojave River Forks Reg. Park	Apple Valley Horseman Center
Mariana Ranchose CWD	SBC Service Area 70J	SBC Service Area 64	Apple Valley Ranchos WC
Ponderosa Guest Ranch	Victorville Water District	SBC Service Area 70J	Apple Valley View MWC
Rancheritos MWC	Woody s Cocky Bull	Victorville Water District	Bear Valley MHP (Westland MHP)
SBC Service Area 64			Bum Steer Restaurant , The
Valley Christian Fellowship			Golden State WC - Apple Valley North
			Golden State WC - Apple Valley South
			Green Acres Est Imp Association
			Lone Wolf Colony
			Mendel Park (Apple Valley Parks)
			Navajo MWC
			Paradise Mobile Estates
			Rancheritos MWC
			Vali-Hi Mobile Home Park
Narrows Floodplain	**Este Regional**	**Oeste Regional**	**Transition Zone Floodplain**
Apple Valley Ranchos WC	Ace Motel	Chamisal MWC	City of Adelanto
Cemex/Southdown River Plnt	Behind the Chute Saloon (aka: DJ s)	El Mirage Market	CSA 42 Oro Grande
River Ranch MHP	Burger Depot	Murphy s Cafe	Helendale CSD
Stoddard Valley MWC	Desert Dawn MWC	Phelan Pinon Hills CSD	Iron Hog Saloon
Victorville Water District	Golden State WC - Lucerne		Oro Grande Apartments
	Golden State WC - Desert View		Riverside Cement/Plnt Eng
	Junpier Riviera CWD		
	Lettys Restaurant		**Helendale Floodplain**
	Lucerne Valley MWC		Helendale CSD
	Mitsubishi Cement Corp		Riverview Middle / Helendale School
	Moose Lodge		
	R W Ranch		**Transition Zone Regional**
	VFW Post 5551		Federal Correctional Institution
	West End Mutual (Willow Wells)		Victor Valley WRA
Centro Floodplain	**Centro Regional**	**Baja Floodplain**	**Baja Regional**
Desert View Mobile Park	Bar-Len MWC	Barstow Dagget Airport	American Legion - NS #751
Golden State WC - Barstow	Del Taco #201	Calico Lakes Homeowners	Bagdad Cafe, Andrea Pruitt
Hacienda Mobile Home Park	Hi Desert MWC	Crystal Lake Property Owners	Calico Ghost Town
PG & E Pipeline Operation	Hinkley Elementary School	Daggett Comm Svcs Dist	Ironwood Campground
Shady Lane RV Park	Hinkley Market	Ironwood Campground	Kelly s Market Video
	Hinkley Senior Center	Lake Jodie Water System	Minneola Mini Mart
	Our Place (Lost & Found Tavern)	Lake Wainani Owner s Assoc	Newberry Community Svc Dist
	Sunrise Mobile Home Park	Newberry Elementary School	Newberry Mini Market
		Newberry Springs Senior Center	Newberry Mountain RV & Motel Park
		Twin Lakes RV Resort	Oasis Palms
		US Marine Corp - Yermo Annex	Peggy Sue s Diner
			US Marine Corp - Yermo Annex
			Wesco Fuel & Food
			Yermo Water Company
MORONGO BASIN			
Lucerne Valley (south)	**Johnson Valley**	**Copper Mountain-Giant Rock**	**Joshua Tree**
Bar H MWC	Bighorn-Desert View Water Agency	Bighorn-Desert View Water Agency	Joshua Basin Water District
Center Water Company		Joshua Basin Water District	
Desert Springs MWC		SBC Service Area 70 W-1	
Gordon Acres (Stewart WC)			
Hitchin Lucerne Inc	**Means-Ames Valley**	**Warren Valley**	
Jubilee MWC	Bighorn-Desert View Water Agency	Hi-Desert Water District	
Lucerne Valley Elem School	SBC Service Area 70 W-4		
Lucerne Valley High School	Hi-Desert Water District		
Lucerne Vista MWC			
Moss Mobile Manor			
Mt. View Continuation School			
New Beginnings			
Rancho Pino Verde - Casa Colina			
SS Hert Trucking , Inc			
Yermo Water Company			

Notes:
Systems with wells in multiple subregions listed in each subregion
SBC = San Bernardino County
MWC = Mutual Water Company
WC = Water Company
WD = Water District
CSD = Community Services District

Figure 8-2
Division of Drinking Water Public Water Supply Wells

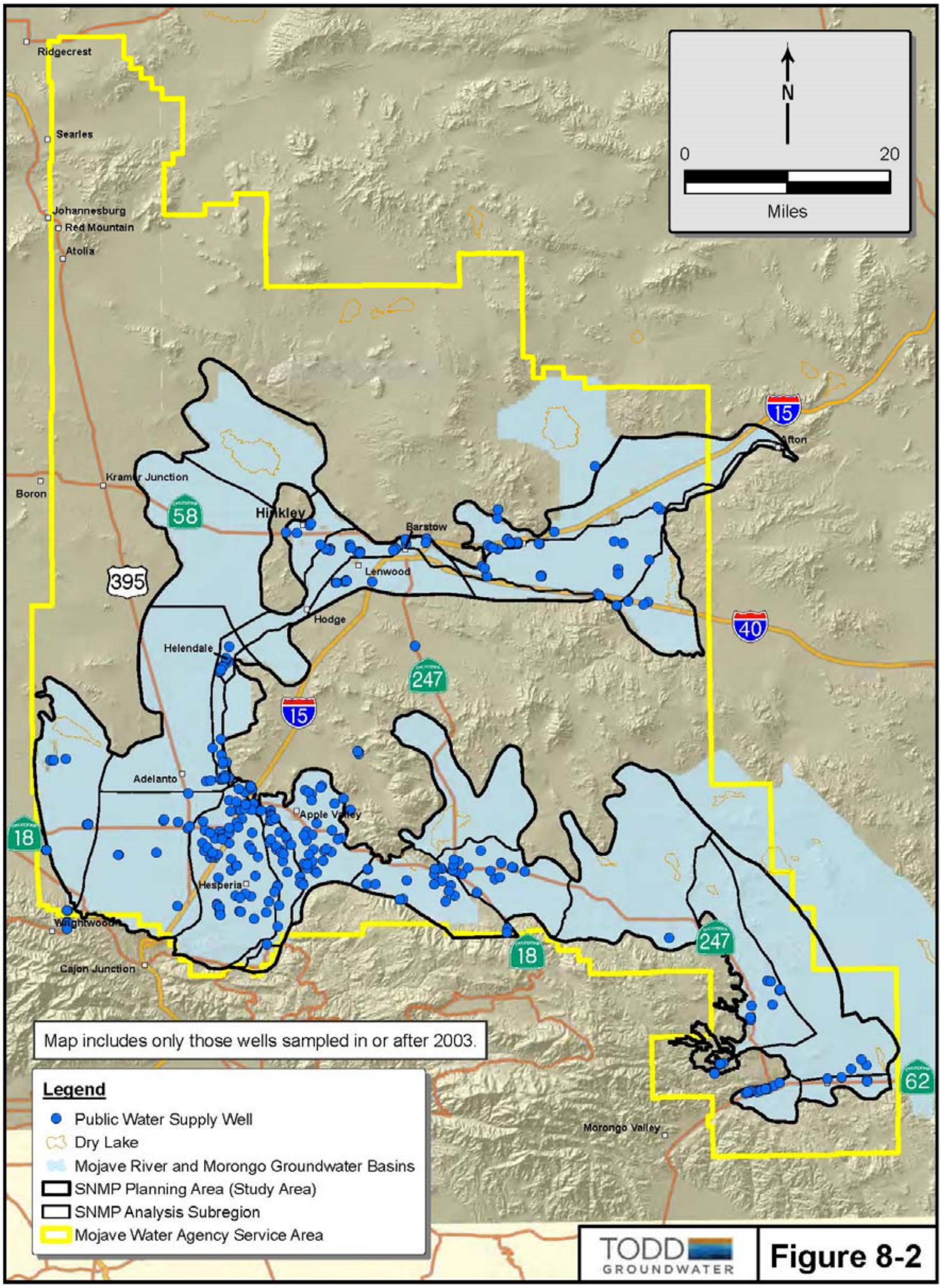


Table 8-5
Inventory of Public Water Supply Wells by Subregion

SNMP Subregion	Number of Public Water Supply Wells
1. Baja - Floodplain	24
2. Baja – Regional	21
3. Centro – Floodplain	41
4. Centro – Regional (east)	18
5. Centro – Regional (Harper Dry Lake)	0
6. Alto Transition Zone - Floodplain (Helendale)	11
7. Alto Transition Zone – Floodplain	31
8. Alto Transition Zone – Regional	4
9. Alto - Floodplain (Narrows)	18
10. Alto – Floodplain	20
11. Alto - Left Regional	11
12. Alto - Mid Regional	78
13. Alto - Right Regional	44
14. Oeste – Regional	8
15. Este – Regional	22
16. Lucerne Valley (north)	0
17. Lucerne Valley (south)	24
18. Johnson Valley	1
19. Ames-Means Valley	13
20. Warren Valley	20
21. Copper Mountain-Giant Rock	3
22. Joshua Tree	14
TOTAL	426

Notes:
Based on SWRCB Drinking Water program database (2014).

8.3.3 MWA Regional Groundwater Quality Monitoring (Key Well) Program

Since the early 1990s, MWA has developed and actively maintained a Key Well program to support ongoing groundwater management activities, including monitoring of groundwater levels and water quality within the MWA service area. Wells in the Key Well program include a combination of dedicated monitoring wells, scientific investigation wells, domestic water supply wells, and agricultural irrigation wells. Public water supply wells are not included. Important wells identified or installed during scientific studies are continually added to the Key Well program.

In support of upcoming studies/projects, such as the recent Basin Conceptual Model and Assessment of Water Supply and Demand for the Baja and Centro Subareas (MWA, 2014a), MWA periodically conducts "groundwater quality sampling sweeps" across a given subarea or region. To prepare, MWA technical staff examine the wells in the Key Well program and develop a regional sampling program to optimize the collection of water quality data to support the pertinent study or project.

Over the past ten years, MWA has conducted groundwater quality sweeps in each of the five management subareas comprising the Mojave River Basin (including the Lucerne subregion in Morongo Basin). **Figure 8-3** shows the current wells in the MWA Key Well program, which currently comprises about 330 wells. While not all of the wells in the figure will be sampled for groundwater quality in the future, the wells shown on the figure illustrate the distribution of monitoring wells available to support future groundwater management activities. **Figure 8-3** highlights those wells sampled by MWA for groundwater quality in the Oeste Subarea in 2006 (20 wells), Alto Subarea in 2007 (34 wells), Baja and Centro subareas in 2009 (79 wells), and Este Subarea (24 wells) and Alto (Transition Zone) Subarea (37 wells) in 2010/2011.

Groundwater quality samples are sent to MWA's contracted state-certified analytical laboratory (Test America) for analysis of constituents provided in **Table 8-6** (current through 2014). MWA anticipates that groundwater quality sweeps for a given region will be conducted every 6 to 8 years in the future, depending on the degree of groundwater management activity in a region.

As shown on **Figure 8-3**, key wells in the eastern portion of the Morongo Basin have not been sampled by MWA within the past 10 years as part of a regional sweep. While MWA will plan to monitor these areas in the near future, this apparent data gap has been filled to date by groundwater quality data for public water supply wells and for monitoring wells in USGS-MWA CWRP. Additionally, in the Ames-Means subregion, MWA member water agencies (Bighorn-Desert View Water Agency (BDVWA), Hi-Desert Water District (HDWD), and County Service Area (CSA) 70 W-1 and 70 W-4) are actively collecting groundwater quality data to support the recently implemented Ames-Reche Groundwater Storage and Recovery Plan, which will be incorporated into the MWA water quality database.

Figure 8-3
MWA Key Wells and Recent Groundwater Quality Sampling Events

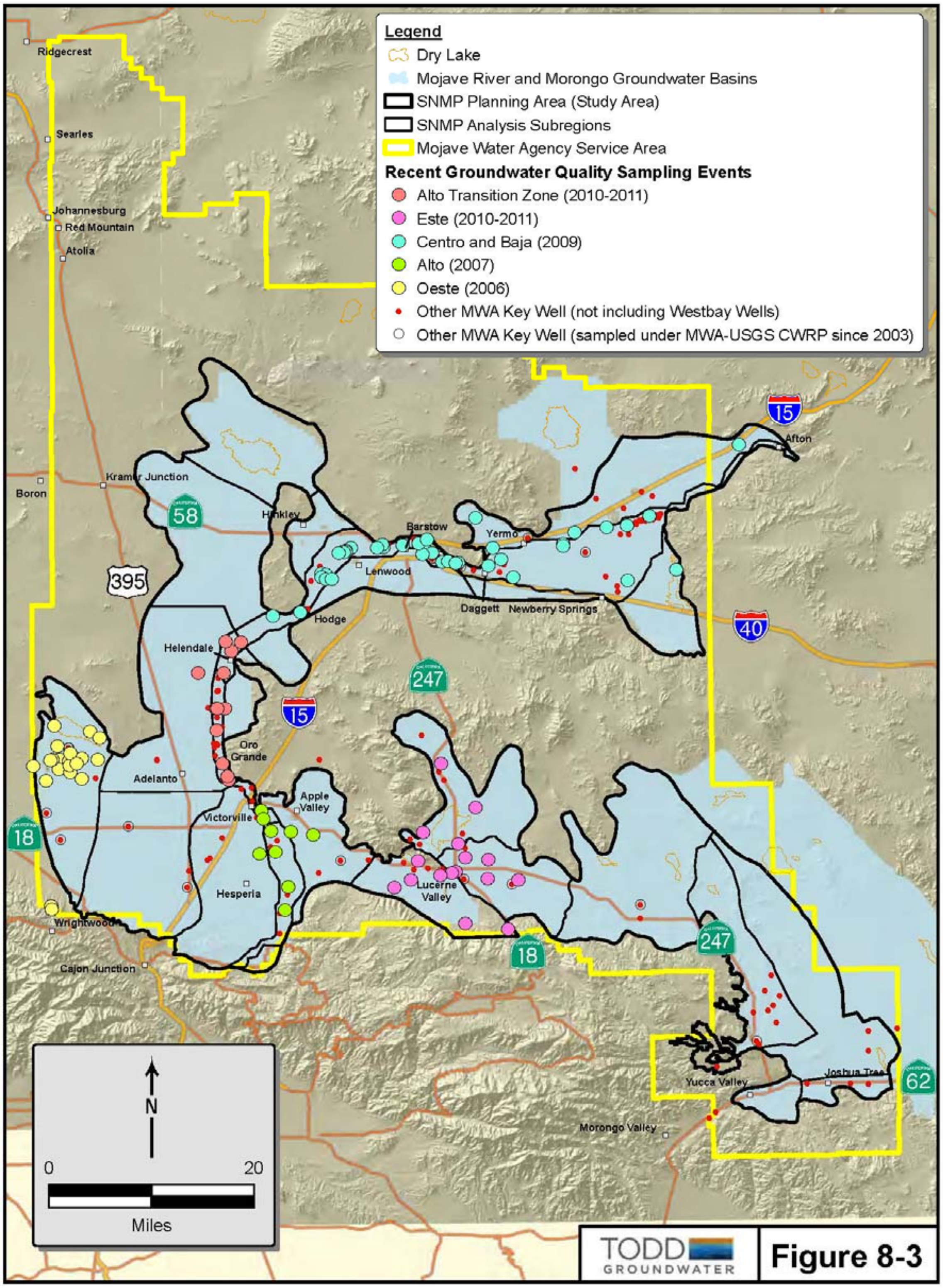


Table 8-6
MWA Groundwater Quality Monitoring Programs Analyte List (2014)

Analytes		
TDS	Nitrate (as N)	Aluminum
Calcium	Nitrate (as NO_3)	Antimony
Sodium	Nitrite (as N)	Arsenic
Magnesium	Nitrite (as NO_2)	Barium
Potassium	Nitrate-Nitrite (as N)	Beryllium
Chloride	Fluoride	Cadmium
Sulfate	Orthophosphate-dissolved	Chromium
Bicarbonate	SiO2, Silica dissolved	Chromium VI
Carbonate	Turbidity	Copper
Hydroxide Alkalinity	pH	Lead
Alkalinity (as $CaCO_3$)	Specific Conductance	Mercury
Hardness (as $CaCO_3$)	Color	Nickel
Iron (dissolved)	Redox Potential (Eh)	Selenium
Iron (total)	Cations, Total	Thallium
Ferrous Iron (Fe2+)	Anions, Total	Vanadium
Ferric Iron (Fe3+)	Cation/Anion Balance	Zinc
Manganese	Langlier Index	Boron

Notes:
Analyses conducted by TestAmerica, a California certified laboratory.

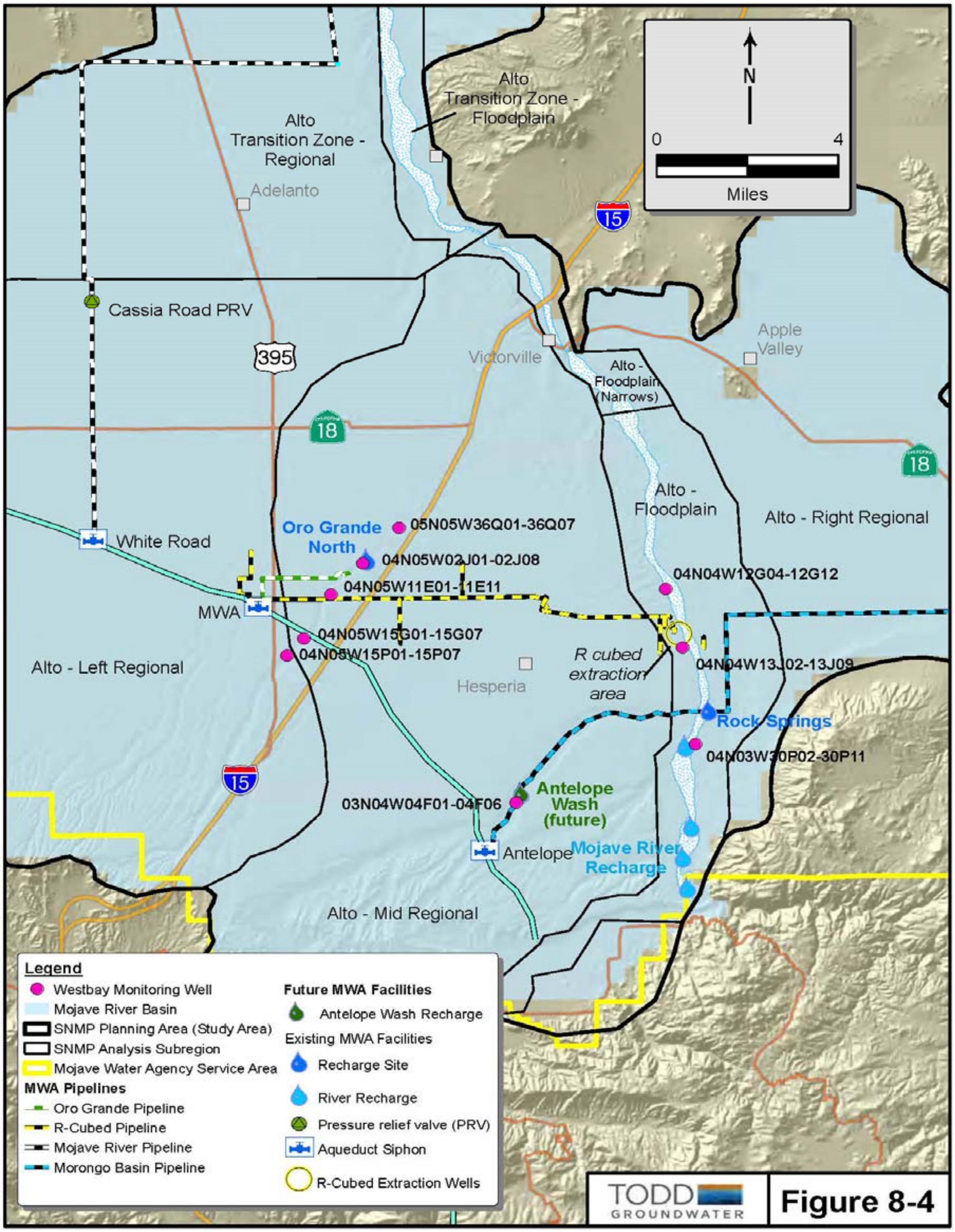
8.3.4 MWA Westbay Multi-Completion Wells

From 2003 to 2009, MWA installed nine Westbay System (Westbay) multilevel groundwater monitoring wells in the Alto Subarea (see **Figure 8-4**). The Westbay wells were installed to provide detailed hydrogeologic information in the vicinity of key MWA managed aquifer recharge facilities in the Alto Subarea (Alto-Floodplain, Alto-Mid Regional, and Alto-Left Regional subregions). Managed aquifer recharge sites are located in the vicinity of the Mojave River, Oro Grande Wash and Antelope Wash, and extraction wells associated with MWA's Regional Recharge and Recovery Project (R-Cubed Project) ("R-Cubed extraction area" on **Figure 8-4**).

Each Westbay well allows for collection of discrete groundwater quality samples from multiple depths. There are six to eleven sampling ports in each of the MWA Westbay wells, with shallow sampling ports ranging from 100 to 400 feet-bgs and deeper sampling ports ranging from 1,000 feet-bgs to greater than 1,500 feet-bgs. Wells are sampled annually for water quality. Samples are sent to MWA's contracted state-certified analytical laboratory (Test America) and analyzed for the same parameters as for the Key Well program regional sweeps (**Table 8-6**).

All water quality data are reviewed by MWA staff, and only data that satisfy data reliability criteria are forwarded to USGS for archiving and publishing on the NWIS site. As is the case for all water quality data collected by MWA or the USGS, data are archived in the MWA water quality database.

Figure 8-4
MWA Westbay Multilevel Wells



8.3.5 Other Groundwater Quality Monitoring Programs

8.3.5.1 RWQCB Waste Discharge Requirement (WDR) Site Monitoring

Groundwater quality data from regulated WDR sites (reported to the RWQCBs) were incorporated into the SNMP groundwater quality analysis (see **Figure 4-1** for active WDR sites). Data included electronic data from WDR sites downloaded from the RWQCB Geotracker site as well as data obtained from onsite review of hardcopy reports at the Lahontan and Colorado River Basin Regional Board offices. Currently, MWA does not routinely incorporate groundwater quality data from WDR sites into its groundwater quality database due to the lack of an efficient process by which to do so (i.e., not requiring onsite file review and manual digitization of data). Future incorporation of RWQCB WDR data into the MWA water quality database is possible, if data can be made available digitally.

8.3.5.2 GAMA and USGS Monitoring

In 2000, the SWRCB established the GAMA Program, California's comprehensive groundwater quality monitoring program (http://www.swrcb.ca.gov/water_issues/programs/gama/). The main goals of GAMA are to improve statewide groundwater monitoring, increase the availability of groundwater quality information to the public, and better understand and identify risks to groundwater resources.

There are currently four components to the GAMA Program:

a. Priority Basin Project – To assess California's drinking water aquifers, the USGS collects groundwater samples from public supply wells throughout the State and analyzes the samples for regulated and unregulated chemicals, including emerging contaminants such as pharmaceuticals and personal care products, isotopes, and age-dating tracers. Monitoring and assessments are on a 10-year cycle, with trend monitoring more frequent.

b. Domestic Well Project – Private wells in the State are sampled by volunteer well owners and samples are analyzed for nitrate, trace metals, volatile organic compounds, pesticides, and radionuclides.

c. Special Studies Project – With the Lawrence Livermore National Laboratory as the project lead, specific groundwater quality studies have been conducted using state of the art scientific techniques and methods that help researchers and public policy planners better understand how groundwater contamination occurs and behaves. Studies have included sources of nitrate, wastewater mixing, groundwater recharge, trace detection of pharmaceutical compounds and personal care products, use of low-level anthropogenic compounds as tracers, and isotopic composition as a contamination source tool.

d. GeoTracker GAMA – A publicly-accessible, on-line groundwater information system that integrates and displays water quality data on an interactive, searchable map (http://geotracker.waterboards.ca.gov/gama/). Its analytical tools and reporting features help users assess groundwater quality and identify potential groundwater issues. GeoTracker GAMA contains over 125 million data records from different sources such as cleanup sites, well logs, SWRCB Division of Drinking Water quality data from public supply wells (discussed in the previous section), water levels from the DWR, California Department of Pesticide Regulation, GAMA Priority Basin Project, GAMA Domestic Well Project, and the GAMA Special Studies Project.

In 2005, as part of the GAMA Priority Basin Project, the USGS sampled 72 wells in the MWA service area (65 wells are located within the SNMP analysis subregions) for inorganic constituents including TDS and nitrate, volatile organic compounds and pesticides, and special interest constituents (perchlorate and N-Nitrosodimethylamine) (Dawson and Belitz, 2012). The location of GAMA wells are shown on **Figure 8-5.** Future groundwater quality data collected under the GAMA program will be incorporated in the MWA water quality database.

8.4 Field and Laboratory Quality Assurance/Quality Control (QA/QC)

8.4.1 MWA-USGS

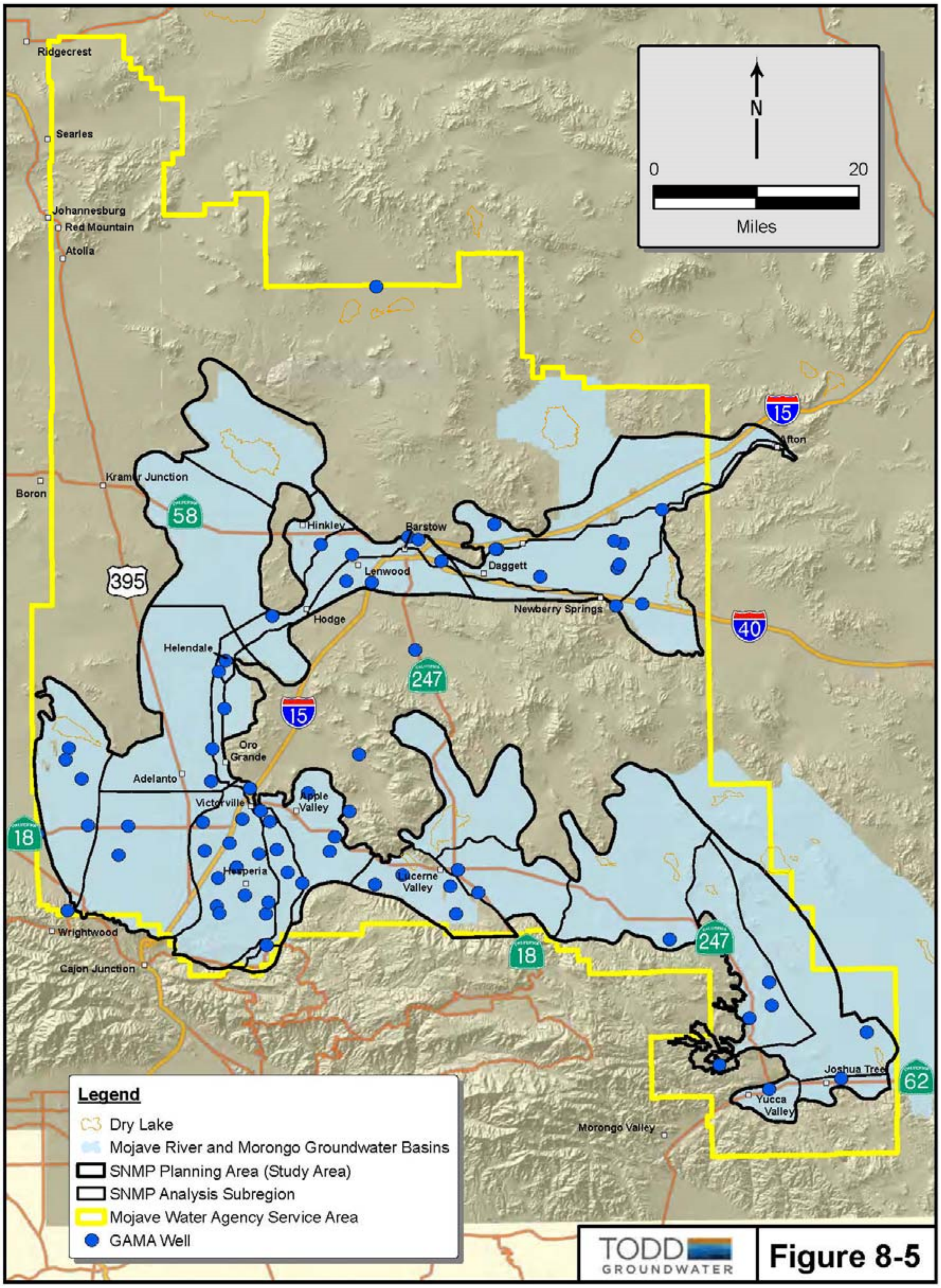
As described in the groundwater monitoring programs led or co-led by MWA, groundwater sampling is conducted by technical field staff from MWA and USGS. Sampling of wells in MWA follows monitoring well sampling guidelines presented in the National Field Manual for the Collection of Water-Quality Data (USGS, 2012).

Generally, the wells have been pumped prior to sample collection, or are purged. Purging is conducted until field instruments indicate that water quality parameters (pH, oxidation-reduction potential, specific conductance, and temperature) have stabilized and turbidity measurements are below five Nephelometric Turbidity Unit (NTUs). The pumping or purging demonstrate that the sample collected is representative of formation water and not stagnant water in the well casing or well filter pack.

All groundwater samples are collected in laboratory-supplied, pre-labeled containers and include prescribed preservatives. All field measurements are recorded in a field logbook or worksheets and the sample containers are labeled correctly and recorded on the chain-of-custody form. The applicable chain-of-custody sections are completed and forwarded with the samples to the laboratory. Upon receipt of the samples at the laboratory, laboratory personnel complete the chain-of-custody.

QA/QC assessment of field sampling includes use of field blanks. Field blanks identify sample contamination that is associated with the field environment and sample handling. These samples are prepared in the field by filling the appropriate sample containers with the distilled water used for cleaning and decontamination of all field equipment. One field blank per sampling event is collected. In addition to the field blanks, MWA also does QA/QC assessment using duplicates, replicates and equipment blanks.

Figure 8-5
USGS GAMA Wells



Samples are sent to a State-certified laboratory that has in place a documented analytical QA/QC program that includes procedures to reduce variability and errors, identify and correct measurement problems, and provide a statistical measure of data quality. The laboratory conducts all QA/QC procedures in accordance with its QA/QC program. All QA/QC data are reported in the laboratory analytical report, including: the method, equipment, and analytical detection limits, the recovery rates, an explanation for any recovery rate that is less than 80 percent, the results of equipment and method blanks, the results of spiked and surrogate samples, the frequency of quality control analysis, and the name of the person(s) performing the analyses. Sample results are reported unadjusted for blank results or spike recovery.

8.4.2 SWRCB Division of Drinking Water Title 22

Data collected under the SWRCB Division of Drinking Water Title 22 Drinking Water program are analyzed by certified laboratories and their established QA/QC programs. Laboratories utilize US Environmental Protection Agency method acceptance criteria and laboratory internal controls for QC parameters, including preparation blanks, surrogates, spikes, duplicates and laboratory control samples.

8.5 Database QA/QC

8.5.1 MWA-USGS

Because the data compiled and entered into the database may come from numerous external sources, methods to ensure data quality are limited. The data entry process has focused on obtaining electronic data wherever available to limit transcription errors. Data are checked against the original source (electronic or paper) after entry into the database.

The database also has certain built-in controls to maintain the integrity of the data. The chemical table contains the identification of the agency responsible for collecting/storing the data, allowing each record to be traced to its original source. The location table has fields that document the original source of sampling location information and well construction data. Every record in both the chemical table and the location table has a primary key that was developed to require data in certain fields and prevent repetition in a table. This primary key does not allow a repeating entry with the same agency, the same sampling event, and the same chemical as an existing entry in the database. Sampling events must also be unique. If a water sample is analyzed as a duplicate sample for field and laboratory quality control, data entered into the database must reflect the fact that it is a duplicate sample in the sampling event (Sample ID). In addition to these protections, regular evaluation of the data in the context of a basin-wide characterization also allows for data outliers to be identified. The chemical table contains a QA/QC field that allows notes to be tied to questionable records.

8.5.2 SWRCB Division of Drinking Water Title 22

Analytical results are submitted directly to the SWRCB Division of Drinking Water database as Electronic Database Files (see **Table 8-3**). Data are reviewed for compliance and any necessary corrective actions by groundwater purveyors and the SWRCB Division of Drinking Water. Title 22 monitoring data can be downloaded from the SWRCB Division of Drinking Water website. Title 22 monitoring data as well as other water quality data are available at the Groundwater Ambient Monitoring and Assessment (GAMA) Program website (see **Table 8-3**).

8.6 Data Analysis and Reporting

8.6.1 MWA-USGS

All groundwater quality data collected under the MWA-USGS CWRP and through MWA's various groundwater quality monitoring programs are subject to rigorous QA/QC protocols by MWA and USGS staff, and only data that satisfy data reliability criteria are archived and published on the NWIS database. Additionally, the USGS perform annual audits of the MWA database. Data are accessible at http://nwis.waterdata.usgs.gov/nwis/qwdata.

Groundwater quality data on the NWIS site can also be queried by geographical township, range, and section through a map-based user interface provided on the MWA online data portal at http://www.mojavewater.org/regional-water-quality.html. The data are also archived separately by MWA in their in-house water quality database.

8.6.2 SWRCB Division of Drinking Water Title 22

Groundwater quality data for Division of Drinking Water public supply wells are uploaded by the responsible water purveyors to the SWRCB Division of Drinking Water water quality portal and data are available on the Division of Drinking Water website and via the GAMA GeoTracker site. Responsible parties in the Basin include water companies, water districts, municipalities/ water departments, other government agencies, community services districts, water associations, schools, private companies and businesses, residential developments, camp grounds, golf courses, prisons, and hospitals.

8.7 Conclusions and Recommendations

Groundwater quality data collected through 2013 were compiled to assess groundwater quality for the Mojave SNMP. The existing groundwater quality data are deemed adequate to support SNMP basin characterization. Existing groundwater quality monitoring programs are deemed adequate for determining whether the concentrations of salts, nutrients, and other constituents of concern as identified in this SNMP are consistent with applicable water quality objectives.

Data from the Title 22 Drinking Water Well Program, MWA-USGS CWRP, and MWA groundwater quality monitoring programs (collectively comprising the bulk of proposed SNMP Groundwater Quality Monitoring Program wells) are uploaded to the SWRCB Division of Drinking Water (DDW) water quality portal and USGS NWIS website on a regular basis. Data are publicly available and can be downloaded to evaluate future basin water quality changes and for comparison with model predictions. While no additional reporting is proposed, MWA is committed in supporting the Regional Boards to protect groundwater quality objectives through its participation in both groundwater monitoring and management. As discussed above, MWA maintains active GIS databases that can aid in the development of future regional policies as well as address localized groundwater quality issues.

Section 9: CEQA Analysis

The adopted State Recycled Water Policy generally states (on page 5) that the local water and wastewater entities, together with local salt/nutrient contributing stakeholders, will fund locally driven and controlled, collaborative processes open to all stakeholders that will prepare salt and nutrient management plans for each basin/sub-basin in California, including compliance with California Environmental Quality Act (CEQA) and participation by Regional Water Board staff.

In discussions with the Lahontan and Colorado River Basin Regional Board staff, it was determined that if a Regional Board is going to do a basin plan amendment to incorporate the SNMP Implementation Plan, then a Substitute Environmental Document (SED) is required and the Regional Board will be the lead agency for the SED. The SED is the SWRCB's document akin to a programmatic environmental impact report (EIR) under CEQA.

For the Mojave SNMP, modeling results completed to date indicate that there will be no Regional Board Basin Plan (for the Lahontan and the Colorado River Basin) amendment necessary for the MWA service area – if anything, the SNMP modeling indicates that future S/N loading conditions may actually improve groundwater TDS concentrations in 4 subregions (see Scenario 3 results in Table 5-11; second column from the right). No improvement is expected in any subregion with respect to groundwater nitrate concentrations (based on Scenario 3 results shown in Table 5-12).

When summarizing the effects of recycled water projects alone, there would be 7 subregions where future S/N loading with recycled water projects would improve groundwater TDS concentrations relative to concentrations under future loading without recycled water projects (based on right-most column in Table 5-11). Recycled water projects would improve groundwater nitrate concentrations for 6 subregions relative to concentrations under future loading without recycled water projects (based on right-most column on Table 5-12).

Since the SNMP modeling indicates that the water quality of the groundwater basins are not being degraded using the future S/N loading conditions, then no basin plan amendment is needed and therefore, no CEQA or SED would be required for the Regional Boards. Correspondence confirming this was completed with each of the Regional Boards and both responses were the same and shown below:

> **Lahontan Regional Board Response**: *The Lahontan Regional Board does not require MWA to produce a CEQA or SED document with its SNMP because the current draft SNMP makes no request of Lahontan to amend our Basin Plan or change established water quality objectives (letter from Mike Plaziak [Lahontan RWQCB] to Kirby Brill [MWA], April 8, 2015).*
>
> **Colorado River Basin Regional Board Response:** *The Mojave SNMP does not propose to change water quality objectives, beneficial uses, or implementation programs. Therefore, it is our understanding that the SNMP does not require a formal approval from the Lahontan Regional Water Board or an amendment to the Water Quality Control Plan for the Colorado River Basin Region (letter from Robert Perdue [Colorado RWQCB] to Patty Kouyoumdjian [Lahontan RWQCB] October 9, 2015).*

Section 10: Conclusions

Based on the requirements of the SWRCB Recycled Water Policy, groundwater quality characterization and salt and nutrient loading analyses, and assessment of S/N implementation measures and groundwater monitoring programs, the following conclusions can be made with respect to the Mojave SNMP:

- The extent and scale of existing groundwater monitoring programs is sufficient to characterize existing groundwater quality and evaluate groundwater quality trends with respect to S/Ns on a subbasin/subregion scale.

- Technical information used to develop regional water management planning documents, including the MWA UWMP, MWA IRWM Plan, and MBA Watermaster consumptive use evaluations provide sufficient resolution to reliably estimate contributions from major S/N loading sources on a subbasin/subregional scale.

- Three future scenarios were simulated using the SNMP groundwater quality mixing model to evaluate the individual effects of background population growth (and associated water demand and imported water use) and recycled water projects on future groundwater quality on a subbasin/subregional scale.

- Results of the modeling indicate that while increasing TDS and nitrate concentrations are anticipated in some subregions, planned recycled water projects do not contribute significantly to assimilative capacity use and in some subregions improve groundwater quality with respect to TDS and nitrate.

- The Mojave SNMP is in compliance with SWRCB Resolution 68-16 and Section 9.C.(1) of the Recycled Water Policy with respect to anti-degradation. No individual recycled water project uses more than 10% of the available assimilative capacity, and combined effects of simulated recycled water projects do not use more than 20% of the assimilative capacity. The water quality changes will not result in groundwater quality less than prescribed in the Basin Plans. The water quality changes will not unreasonably affect existing and anticipated beneficial uses, and the water quality changes are consistent with the maximum benefit to the people of the state of California.

- Modeling results demonstrate that imported SWP water recharge improves groundwater quality with respect to salts and nutrients. TDS and nitrate concentrations of total inflows for subregions projected to receive SWP recharge water are lower with SWP water than without SWP water, clearly demonstrating the benefit of SWP recharge water.

- Existing groundwater monitoring programs implemented across the Study Area comprise the proposed SNMP groundwater monitoring program. Existing groundwater quality monitoring programs are deemed adequate for determining whether the concentrations of salts, nutrients, and other constituents of concern as identified in this SNMP are consistent with applicable water quality objectives on a subregional scale. Water quality data from the Title 22 Drinking Water Well Program, MWA-USGS CWRP, and MWA groundwater quality monitoring programs are uploaded to the SWRCB DDW water quality portal and USGS NWIS website on a regular basis. Data are publicly available and can be downloaded to evaluate future basin water quality changes and for comparison with model predictions. While no additional reporting is proposed, MWA is committed in supporting the Regional Boards to protect groundwater quality objectives through its participation in both groundwater monitoring and management.

- Because the SNMP does not propose to change water quality objectives, beneficial uses, or implementation programs, preparation of a SED was not required for the Mojave SNMP.

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